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THE EFFECTS OF A SEASON OF BASKETBALL PRACTICE ON MALE COLLEGE FRESHMEN AS INDICATED BY SELECTED TESTS OF FATIGUE

by
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A dissertation submitted in partial fulfillment
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The purpose of this study was to determine the effects of practice sessions of basketball on a freshmen squad by the use of the following selected tests of fatigue; patellar reflex, reaction time, pulse rate before and after a step test and grip strength. In addition data were collected on height, weight, and such subjective information as hours of sleep, eating habits, incidences of illness, academic examinations and previous exercise.

The experimental group was composed of twenty-two members of the freshman basketball squad at Iowa State College. The control group consisted of eleven volunteer freshmen physical education majors. Throughout the basketball season, there were twenty-six testing sessions from which data were collected on the experimental group before and immediately after basketball practice. The control group was given a single test battery at approximately the same time of day as the experimental group.

A graphical analysis of the data was presented on the weekly mean values of the selected tests for both groups. A statistical analysis was presented by the calculation of *t*-tests on the pre- and post-practice mean scores of the experimental group. The *t*-values obtained revealed that

there were significant changes in the patellar reflex and grip strength which indicated the presence of fatigue. Reaction time significantly decreased indicating that the practice was not fatiguing enough to be detected by the reaction time test.

Three periods of time were selected as the basis for further t-tests to reveal the significance of the changes that might occur. They were as follows: (1) first seven test periods which were used as base line figures, (2) first week in January which would reflect a month's vacation and (3) last week of testing which were used as end of the season figures. The results of the t-tests calculated on the means between the first seven test periods and the first week in January and between the first week in January and the last week of testing on all the selected tests indicated that both groups did not progress in the direction of fatigue except in one instance. The threshold of the patellar reflex increased for both groups between January and the end of the season. The results of t-tests calculated on the first seven test periods and the last week of testing for the control group did not reveal a fatigue state at the end of the season except in the case of the patellar reflex.

The hypothesis was postulated that the experimental subjects (basketball players) will make a complete recovery from fatigue between practice sessions and this state will be

evident in the pre-practice test results from the beginning to the end of the season. This hypothesis is accepted because:

1. The patellar reflex test results did not change significantly.
2. The reaction time test results decreased significantly indicating a faster reaction time.
3. The pulse rate before and after the step test lowered significantly indicating a better condition at the end of the season.
4. The grip strength test results improved significantly resulting in a stronger grip at the end of the season.

Dedicated To

My Mother and Father

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Appreciation is extended to the men on the Iowa State College freshman basketball squad of 1954 and the volunteer physical education majors whose loyalty and cooperation never ceased.

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CHAPTER I

INTRODUCTION

In recent years competitive athletics have become a major concern to educators. One of the major issues has been the extending of the competitive program downward into the junior high schools and grade schools. Since competition *per se* has not been the crux of the issue but rather the age at which inter-school competition should begin, many organizations have taken a stand on this matter. Four organizations representing the American Association for Health, Physical Education and Recreation; Society of State Directors of Health, Physical Education and Recreation; National Council of State Consultants in Elementary Education; and Department of Elementary School Principals of the National Education Association formed a Joint Committee to study the problem of competition of elementary and junior high school children. After a three year study ending in 1952 the committee concluded, "Interschool competition of a varsity pattern and similarly organized competition under auspices of other community agencies are definitely disapproved for children below the ninth grade."[1] The Joint Committee based its recommendation

[1] *Desirable Athletic Competition for Children*, p. 4. Joint Committee on Athletic Competition for Children of Elementary and Junior High School Age. Washington: American Association for Health, Physical Education and Recreation, November, 1952.

on the opinions given by 220 medical men. They represented a random sampling of pediatricians, cardiologists, orthopedic surgeons, physiologists and general practitioners. The physicians were asked which factor they considered most important in selecting the kind and extent of athletic activities. The only one which a majority (61 per cent) agreed upon was the factor of the carry-over of the activity past the stage of healthful fatigue to that of harmful exhaustion. Forty-five per cent of the physicians agreed that the greater vulnerability of joints to injury should be considered and 47 per cent agreed that fractures of the long bones were important factors. The other factors of disproportion of heart size to body mass, greater susceptibility to rheumatic fever and greater difficulty determining the healthy heart as a prerequisite to activity had less than one-third agreement among the respondents.

The second question asked of the physicians was formulated to ascertain which team sports they would disapprove under any circumstances and which type of administration they would approve for the various sports. This question was answered with the factors selected in the first question as a basis. In response to the first part, tackle football was the only sport which was disapproved of by any number (47 per cent). The type of administration approved by a majority of physicians was intramural and combination intramural and invitational. A minority, ranging from 29 to 40 per cent of respondents, approved such sports as baseball,

softball, volleyball, swimming and gymnastics for interschool competition. It seemed apparent, however, that there is a definite lack of agreement among medical men on this problem. Thus, in evaluating this recommendation it appeared that the conclusions were based on personal opinions of the medical men rather than opinions based on valid scientific research.

The Educational Policies Commission endorsed this recommendation of the Joint Committee and further stated that "highly organized programs . . . often create social pressures that cause children to continue to exert themselves beyond the point of healthful fatigue to harmful exhaustion."[1] In addition to the acceptance of the opinions of the medical men, this Commission supported the policy of no interschool competition below high school age because of malpractice in administration. Again this apparently was based on opinion rather than factual evidence as there was no indication in the report that any type of inquiry had been made to support their viewpoint.

Other national committees took action on this problem. They were committees on Health Policies of the National Conference for Cooperation in Health Education[2] and the

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[1] School Athletics, p. 29. Educational Policies Commission, A Report Prepared by the National Education Association of the United States and The American Association of School Administrators. Washington: National Education Association, 1954.

[2] Suggested School Health Policies, p. 34. Health Education Council, A Report by the National Committee on School Health Policies of the National Conference for Cooperation in Health Education. Washington: National Education Association, 1946 (2d. ed.).

American Association of School Administrators.[1] They also stated that interscholastic sports should be confined to the senior high schools. The school administrators went further in defining their reactions by emphasizing the physiological inadequacy of pre-pubescent boys in withstanding the physical and emotional strain of interscholastic competition.

It is conceded that the opinions presented are those of experts in their fields of specialization. However, it has been shown that opinion alone is not sufficient to guide athletic programs. The controversy over interscholastic athletics has become a heated one, but it has been recognized that research on the problem must be forthcoming to prove or disprove opinions. The National Council of the Research Section of the American Association for Health, Physical Education and Recreation has recognized this need and has as one of its projects the study of the effects of interscholastic competition. The mere fact that the members of the Research Section have agreed to study the problem is ample evidence that the subject is a moot one.

One of the apparent concerns of the associations in denouncing interscholastic competition for junior high school and grade school children was that such competition made undue physical demands upon the children. Thus, in the formulation

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[1] Health in Schools, p. 197. American Association of School Administrators, Twentieth Yearbook of the American Association of School Administrators. Washington: National Education Association, 1951 (2d ed. revised).

of evaluative criteria for studying the effects of various sports on the individual, investigators will be faced with the problem of measuring fatigue.

Although the main criticism of interscholastic athletics is aimed at the lower age levels, the writer was not in a position to use junior high school students as subjects. It is felt that this problem has implications for all age levels and that procedures and measurements used in this study will be of value for further research.

Purpose of the Study. -- The purposes of this study are as follows: (1) To determine the physical condition of the freshmen basketball players at Iowa State College by the use of the selected tests at the beginning of the season, (2) to measure the players twice weekly and to note any changes as they occur, and (3) to determine any changes in condition which might occur from the beginning of the basketball season to the end.

Hypothesis. -- It is postulated that the experimental subjects (basketball players) will make a complete recovery between basketball training sessions and this state will be evident in the pre-practice test results. Also as a consequence of the basketball season, the players' physical condition will not be impaired at the end of the season.

Limitations of the Study. -- Testing any group of college students in the actual physical set-up of the activity

involved carries with it certain practical limitations. The following limitations must be made for this study:

1. The test battery selected will be limited to test items which could be administered by a physical education teacher with a minimum amount of testing equipment.
2. It will be impossible to control the outside activities of the men on the basketball squad. It will be assumed that basketball practice, intra-squad games, studying and sleeping will consume the major portion of their free time.
3. The sample used in this study will be small and limited to one activity.
4. The length of time of experimentation will be limited to the basketball season.
5. The subjects in this study will be limited to men on the freshmen basketball squad and volunteer freshmen physical education majors at Iowa State College.

CHAPTER II

REVIEW OF LITERATURE

A search of the literature reveals that actual "tests of fatigue" are practically non-existent. One reason for that could be the lack of agreement on the term fatigue.

In this chapter the concept of fatigue will be reviewed. This will be followed by the physiological and psychological measures which have been attempted as a means for detecting fatigue. From this review the measures which have been used successfully or show promise will be selected as the test battery for this study.

Concept of Fatigue. -- In the 1870's and 80's Mosso performed his classic experiments on the measurement of fatigue in men. Heretofore, almost all experimentation had been performed on isolated frog muscles. However, as Mosso said, "With frogs it is impossible to reproduce the normal function of muscles and to imitate the action of a man who is doing mechanical work."[1] Thus the ergograph came into being as an instrument which would measure the work-output of man. As a result of the ergograph's construction,

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[1] Angelo Mosso, Fatigue, p. 83. Trans. by Margaret Drummond and W. B. Drummond. London: Swan Sonnenschein and Co., Ltd., 1906.

Mosso[1] felt that only the flexor muscles of the middle finger would come into play. However, Offner[2] pointed out at a later date that the ergograph is not as reliable as had been expected. The main criticism was that the number of muscles involved increases as fatigue increases so that the original presupposition of permanent isolation of a few muscles is never attained.

The concept of fatigue advanced from fatigue of an isolated muscle to the realization that fatigue was a psychophysical phenomenon, that is, concerned not only the physical aspects of our body but that fatigue was also a feeling, an introspective experience. Physiologists and psychologists have continued the study of fatigue of the various systems and tissues of the body.

The first quarter of the twentieth century gave rise to intensive work in industrial fatigue with emphasis on environmental factors. It was at this point that Muscio[3] recognized that an adequate definition of fatigue was lacking. He suggested that the word fatigue not be used and also that any attempts to obtain a fatigue test be abandoned.

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[1] Angelo Mosso, "Ueber die Gesetze der Ermüdung Untersuchungen an Muskeln des Menschen," Archiv für Anatomie und Physiologie, Jahrgang, 1890, pp. 90-99.

[2] Max Offner, Mental Fatigue, pp. 25-26. Trans. by Guy Montrose Whipple. Baltimore: Warwick and York, Ind., 1911.

[3] B. Muscio, "Is a Fatigue Test Possible?" A Report to the Industrial Fatigue Research Board, British Journal of Psychology, XII (1921, 1922), 45.

However, research went on searching for physical and mental evidence of fatigue.

Research workers at the Harvard Fatigue Laboratory made extensive physiological investigations on man in the resting state, during exercise and after exercise. Of the results of this, Forbes at a Symposium on Fatigue in 1942 said, "Nothing that we could measure was changed significantly even though the man was tired."[1] In this same article Forbes attacked the point of view held by the majority of the medical profession that "fatigue is an entity consisting of 'that tired feeling' that it is best regarded as a subjective symptom."[2] He counteracted by stating that this view "distorts the picture by neglecting and obscuring the relationship of this one manifestation of fatigue to the normal and universal phenomenon, but worse than this it is absolutely sterile."[3] Forbes then proposed a three-way classification of fatigue consisting of physical fatigue caused by the extensive use of one or more muscles; mental fatigue due to prolonged mental work and similar to boredom; and nervous fatigue caused by hurry, worry and emotional strains. The latter he stated constitutes the great bulk of all fatigue.

Davis in his introductory remarks at the same symposium said,

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[1] W. H. Forbes, "Problems Arising in the Study of Fatigue," Psychosomatic Medicine, V (April, 1943), 156.

[2] Ibid.

[3] Ibid.

> Fatigue to the physiologist means an impairment of performance as a result of previous activity . . . recovery, as a result of rest and the operation of normal anabolic processes, is possible within a reasonable length of time.[1]

Davis further elaborated that there were three concepts to impairment which should be distinguished from each other. They are accuracy, speed and efficiency. To an athlete one of the earliest manifestations of fatigue comes in the loss of fine coordination. Thus there is a change in the neuromuscular system caused by fatigue and impairment of the more delicate operations of adjustment. Davis stated that "if the variable opponent can be eliminated and the game made a solitaire, the score attained becomes a valid measure of performance and may be used to measure fatigue."[2]

The second concept of impairment, speed, is fundamental in the process of fitness. However, in spite of all efforts to attain the peak of physical condition it is impossible to work at top speed for an indefinite time. Thus, speed may yield a measure of fatigue either alone or in combination with accuracy.

Efficiency, the third concept of impairment, is the ratio of work accomplished to the expense of the organism. For measurement of efficiency Davis suggested measuring "the effect of continued activity or of some environmental stress, such as cold or noise, on the ability to perform certain

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[1] Hallowell Davis, "Symposium on Fatigue, Introductory Remarks," Psychosomatic Medicine, V (April, 1943), 152.

[2] Ibid., p. 153.

standardized tasks."[1]

One of the most comprehensive reports on fatigue was written by Bartley and Chute.[2] Their claim was that fatigue has not been viewed as an over-all picture but rather studied as the individual branch of science dictated so that the end products become kinds of fatigue. It was this lack that prompted the authors to make such a study. Briefly, they list fourteen points which they intended as a means of defining fatigue.

1. Fatigue and impairment are not identical when both exist at once, they can be separated.
2. Fatigue is not to be measured by measuring impairment.
3. Unlike impairment, fatigue is always directly experienced, i.e., it is an experience.
4. Fatigue is a part of the individual's stance with reference to activity, whether the activity is vigorous exertion, the assumption of an attitude toward a proposition, the maintenance of posture, or merely the need for staying awake, etc.
5. Fatigue is a manifestation of personal continuity.
6. Fatigue is personal.
7. Fatigue is an outcome of conflict.
8. Fatigue is not to be confused with boredom.
9. Fatigue is cumulative.
10. Fatigue's onset and recovery may be sudden.
11. The concept of fatigue pertains to organization.
12. Fatigue does not crucially depend upon energy expenditure.
13. Fatigue is never specific to a given body member.
14. Fatigue is not to be defined or analyzed in terms of its supposed origins, nor on the basis of function involved.[3]

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[1] Ibid.

[2] S. Howard Bartley and Eloise Chute, Fatigue and Impairment in Man. New York: McGraw-Hill Book Company, Inc., 1947.

[3] Ibid., pp. 53-56.

As to the nature of impairment, Bartley and Chute defined this term as follows:

> Impairment is a physiological change in tissue which reduces its ability to participate in the larger aspects of organic functioning. Impairment is identifiable only through the methods of physiology and biochemistry. Reduction in the ability of the organism as a whole to perform is no criterion for the presence of impairment.[1]

Thus the concepts of fatigue and impairment took on new meanings in antithesis to all that has gone before.

After reviewing the major works on the subject of fatigue, it would appear that the concept of fatigue is varied according to the author. However, there is agreement that fatigue does have many facets. Riedman listed three aspects of fatigue which appeared comprehensive.

> (1) The feeling of tiredness, bodily weariness, or disinclination to continue with the task because of bodily discomfort or a sense of boredom--in any case, an unpleasant subjective experience; (2) reduced capacity for work, a falling off of efficiency as measured in work output which can be determined objectively; (3) temporary physiological changes in the organism, presumably caused by the accumulation of the products of work, tending to upset chemical equilibrium.[2]

The author also makes the observation that the three aspects need not occur simultaneously. However, if they should they are not always correlated.

One of the most recent contributions to the study of fatigue has been the outcome of a Symposium on Fatigue[3] held

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[1] Ibid., p. 48.

[2] Sarah R. Riedman, The Physiology of Work and Play, p. 144. New York: The Dryden Press, 1950.

[3] Fatigue, edited by W. F. Floyd and A. T. Welford. London: H. K. Lewis and Co., Ltd., 1953.

by the Ergonomics Research Society in March, 1952, at the College of Aeronautics, Cranfield, England. Although the purpose of this Symposium was to bring together anatomists, physiologists, psychologists and others who were interested in the design of machinery and equipment for human use, it has many implications for those interested in the study of human fatigue of any kind. In reviewing this book, it was found that all contributors but one who ventured a definition of fatigue clung to the standard conceptions of the term defining fatigue in terms of work decrement, feeling of tiredness, or reduction in efficiency. Schwab[1] was the one contributor who apparently supported Bartley and Chute in their concept of fatigue. It appeared that Schwab used the term fatigue to cover the objective term impairment and also the subjective term fatigue, but stated that they were very different. It is not clear from his article, however, which so-called type of fatigue he was measuring.

Tests of Fatigue

The one criterion which seems to stand out is that a person is more tired after a session of work than when he started. This tiredness or fatigue may or may not be significant dependent upon the amount and type of work involved. Since this study is concerned with basketball practice as the

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[1] Robert S. Schwab, "Motivation in Measurements of Fatigue," Fatigue, pp. 143-148. Edited by W. F. Floyd and A. T. Welford. London: H. K. Lewis and Co., Ltd., 1953.

work session, the following sections were selected for review after an intensive study of the literature to determine what tests may have been used to reveal the fatigue state in athletes.

One of the most comprehensive reports to come out in recent years on the measurement of psychological performance was prepared by Finan, Finan and Hartson.[1] Although a great deal of the report has no bearing on this study, fatigue is one of the conditions brought out in the bibliography as representative of the efforts to quantify performance. The purpose of this review was to summarize, correlate and evaluate the quantitative tests. Investigating a variety of conditions similar to those encountered in flying, the authors categorized the tests in a meaningful and useable manner.

Flicker Fusion Frequency (FFF). -- A flicker fusion frequency test has been considered as a possible index for fatigue. In reviewing the work on the FFF, Simonson and Brozek[2] stated that the use of the FFF as an index for central nervous system fatigue is a complex and difficult subject. The authors reported a study by Brozek and Keys using the FFF

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[1] John L. Finan, Sarah C. Finnan and Louis D. Hartson, A Review of Representative Tests Used for the Quantitative Measurements of Behavior--Decrement Under Conditions Related to Aircraft Flight. Wright-Patterson Air Force Base, Dayton, Ohio: United States Air Force Air Material Command, July 1949.

[2] Ernst Simonson and Josef Brozek, "Flicker Fusion Frequency Background and Application," Physiological Reviews, XXXII (July, 1952), 349-378.

to detect fatigue after walking on a treadmill from one to three hours. They could find no consistent changes of the FFF.

Carrying the stress conditions further, Brozek, Simonson and Taylor[1] subjected an experimental and control group to hard physical exercises almost to the tolerance level. Their results agreed with Brozek and Keys, who found no statistically significant changes in the FFF.

Perpetual Fluctuation. -- An early experiment by Ash[2] revealed that there is an increase in perpetual fluctuation as fatigue increases. Hollingworth[3] later corroborated this belief. He ran six subjects through a series of physical tasks repeating the series eight times in a day. This was continued for six consecutive days.

Number checking and simple addition work curves did not show any considerable work decrement. However, the third test of a two minute observation of familiar illusions of reversible perspective (one a staircase, the other a nest of cubes) revealed that the fluctuations of figures increased

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[1] Josef Brozek, Ernst Simonson and Henry L. Taylor, "Changes in Flicker Fusion Frequency Under Stress," Journal of Applied Physiology, V (January, 1953), 330-334.

[2] Isaac Ash, "Fatigue and Its Effect Upon Control," Archives of Psychology, XXXI (June, 1914), 51-52.

[3] H. L. Hollingworth, "Perpetual Fluctuation as a Fatigue Index," Journal of Experimental Psychology, XXIV (April, 1939), 511-519.

as subjective feelings moved toward strain. The author believed the perpetual fluctuations to be an index of fatigue.

Electrocardiograph. -- All medical authorities are not in complete agreement as to the value of the electrocardiograph as an instrument for measuring the functional efficiency of the heart. Since this subject has not been fully explored, Wolf[1] attempted to determine whether or not the electrocardiograph may be used as an instrument to record and differentiate variations in the physical condition of undiseased subjects. He took tracings before and after mild, fairly active and vigorous exercise on 102 untrained subjects and twelve members of the University of Illinois cross-country track team. His results of the amplitude of the waves measured justified his conclusions that the electrocardiograph may be used to record the effects of exercise and differentiate between good and poor cardiovascular condition.

Basal Metabolic Rate. -- The studies on the effect of exercise on the basal metabolic rate has given rise to much uncertainty. The general consensus seemed to be that there is a slight decrease in the basal metabolic rate as a result of training. Steinhaus[2] conducted an experiment with

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[1] J. G. Wolf, "Effects of Posture and Muscular Exercise on the Electrocardiogram," Research Quarterly, XXIV (December, 1953), 475-490.

[2] Arthur Steinhaus, "Exercise and Basal Metabolism in Dogs," American Journal of Physiology, LXXXIII (January, 1928), 658-677.

dogs labeled exercised or non-exercised dogs. The exercised dogs after a conditioning program were given a measured amount of running on a treadmill. The author observed a slight decrease in the basal metabolic rate of his exercised dogs. This experiment was conducted over a period of two years and every phase of the dogs' lives was carefully controlled. Therefore, the results of this study tend to be acceptable.

Other studies using human subjects had conflicting results. Gemmill, Booth and Pocock[1] observed no significant changes in the basal values of metabolism of three subjects. The exercise for this study consisted of a repetition of a definite amount of work on a stationary bicycle every day for six weeks. Schneider and Foster,[2] on the other hand, found a majority of their subjects to experience a drop in their basal metabolic rate. However, one subject was found to increase the rate and one to undergo no change at all.

Steinhaus[3] in his review of this subject criticized many of the experimental designs used in investigating this problem. He pointed out many of the factors which tend to change the basal metabolic rate. He believed it was these

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[1] C. Gemmill, W. Booth, and B. Pocock, "Muscular Training, I. The Physiological Effect of Daily Repetition on the Same Amount of Light Muscular Work," American Journal of Physiology, XCII (February, 1930), 253-270.

[2] E. C. Schneider and A. O. Foster, "The Influence of Physical Training on the Basal Metabolic Rate of Man," American Journal of Physiology, XCVIII (November, 1931), 595-601.

[3] Arthur Steinhaus, "Chronic Effects of Exercise," Physiological Reviews, XIII (January, 1933), 126-128.

same factors which must be controlled before any evidence could be convincing.

Blood Lactate. -- The effect of exercise on the lactic acid accumulation in the blood has been suggested as having a relationship to the degree of physical fitness.

Testing the lactic acid concentration after strenuous activity, Margaria, Edwards and Diel[1] subjected trained and untrained individuals to strenuous exercises of running, varying the time, speed and intensity. The authors found the lactic acid concentration high in a trained subject and it remained so for six to eight minutes. In the untrained individual the lag of concentration may be two or three times as long as in the trained individual.

Robinson and Harmon[2] submitted nine non-athletes to a training program of six months. Their study revealed that the ability to accumulate lactic acid during anerobic work increased with training. During grade walking the lactic acid declined slightly with training and in submaximal running, the blood lactate declined significantly with training.

By increasing the number and types of experimental

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[1] R. Margaria, H. T. Edwards and D. B. Diel, "The Possible Mechanism of Contracting and Paying the Oxygen Debt and the Role of Lactic Acid in Muscular Contraction," American Journal of Physiology, CVI (December, 1933), 689-715.

[2] S. Robinson and P. M. Harmon, "The Lactic Acid Mechanism and Certain Properties of the Blood in Relation to Training," American Journal of Physiology, CXXXII (April, 1941), 757-769.

subjects, Crescitelli and Taylor[1] substantiated the results of Robinson and Harmon. They used forty-seven subjects ranging from ones who participated in vigorous exercise regularly to laboratory workers who took little or no exercise. The authors concluded that the men in the best physical condition had the lowest amount of lactate in the blood.

Montoye[2] produced further evidence that trained endurance athletes after a standard exercise exhibit lower blood lactate than do subjects in a poor state of training.

These experiments suggested that men in the best physical condition have the lowest amount of lactate in the blood after strenuous activity. Although it was found that the concentration of lactic acid was high in a trained subject, it was also concluded that the lactic acid concentration lasted two or three times longer in an untrained person.

Alkaline Reserve. -- Regulation of the acid-base balance in the blood is dependent upon the presence of sodium bicarbonate. This salt is known as the alkaline reserve. Many experimenters have expected this reserve to be increased as a result of a regular regime of training. However, the literature revealed that there are contradictory results.

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[1] F. Crescitelli and C. Taylor, "The Lactate Response to Exercise and Its Relationship to Physical Fitness," American Journal of Physiology, CXLI (July, 1944), 630-640.

[2] H. J. Montoye, "Inter-relation of Maximum Pulse Ratio During Moderate Exercise, Recovery Pulse Rate and Post Exercise Blood Lactate," Research Quarterly, XXIV (December, 1953), 453-458.

Using dogs as the subjects, Steinhaus[1] found no change in the alkaline reserve during training. On the other hand, Davis and Brewer[2] subjected dogs to a training regime of seven to nine weeks and found a steady rise in the alkaline reserve.

Robinson, Edwards and Diel[3] experimenting on five internationally known distance runners found that their alkaline reserve came well within the limits of untrained men. Likewise, Robinson and Harmon[4] found no change in the alkaline reserve of nine non-athletes during a six month training program.

According to Schneider[5] and Karpovich,[6] the only conclusion that can be drawn at this time is that the same adaptations to muscular activity are not always of the same pattern in all individuals.

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[1] Steinhaus, "Chronic Effects of Exercise," op. cit., 121-122.

[2] J. E. Davis and N. Brewer, "Effect of Physical Training on Blood Volume, Hemoglobin, Alkali Reserve and Osmotic Resistance of Erythrocytes," American Journal of Physiology, CXIII (November, 1935), 586-591.

[3] S. Robinson, H. T. Edwards, and D. B. Diel, "New Records in Human Power," Science, LXXXV (April, 1937), 409-410.

[4] Robinson and Harmon, "The Lactic Acid Mechanism and Certain Properties of the Blood in Relation to Training," op. cit., pp. 757-769.

[5] Edward Schneider, Physiology of Muscular Activity, p. 269. Philadelphia: W. B. Saunders Company, 1940.

[6] Peter Karpovich, Physiology of Muscular Activity, p. 138. Philadelphia: W. B. Saunders Company, 1953.

Leucocyte Count. -- A total leucocyte count has been suggested as a possible means of rating the strenuosity of intercollegiate sports and detecting the physical condition of athletes. A very early study by Schneider and Havens[1] revealed the immediate influence of exercise on nine subjects during spring training. He said the leucocyte count increased from approximately 14 to 130 per cent with the leucocytes returning to the pre-exercise level after a short time.

Farris[2] made a comprehensive study on more than sixty healthy, well-trained athletes. He carried the experiment throughout a complete season in several sports. In breaking down the leucocyte count, Farris' study revealed that counts which average below 25 per cent lymphocytes and are above 75 to 80 per cent neutrophiles are due to oncoming fatigue. He also stated that some indication of the physical condition of each player was furnished in football, basketball and baseball by a differential blood picture after the game. A fatigue to exhaustion range was evident in counts ranging from 80 to 91 per cent neutrophiles.

Meyer and Pella[3] confirmed the observations of

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[1] E. C. Schneider and L. C. Havens, "Changes in the Blood after Muscular Activity and During Training," American Journal of Physiology, XXXVI (February, 1915), 239-259.

[2] E. J. Farris, "The Blood Picture of Athletes as Affected by Inter-collegiate Sports," American Journal of Anatomy, LXXII (March, 1943), 223-257.

[3] Margaret H. Meyer and Germaine Pella, "The Effect of Hard Laboratory Exercise on the Total and Differential Leucocyte Count of Young Women," Research Quarterly, XVIII (December, 1947), 271-278.

previous authors using women subjects. In the differential count the authors found a slightly significant increase in lymphocytes and a significant decrease in neutrophiles in the immediate post-exercise count.

Hinrichs[1] disclosed in her study on eighty-seven athletes that there is a marked early lymphocytosis following a fatiguing exercise. She found this most marked in sports which are characterized by a long-sustained activity which requires individual physical and mental performance such as basketball or football. Also, the polymorphoneuclear leucocytes seemed to appear in fewer numbers immediately following fatiguing exercise.

It would appear that individuals in the best physical condition tend to develop less leucocytosis than do individuals in a poor physical condition. However, this conclusion can not be fully accepted until more experimentation confirms it.

Blood Pressure. -- Many observations have been made on the blood pressure of athletes and the effect a period of training may have. The general consensus seemed to be that the better physically trained individual tends to have a lower resting blood pressure. Because of the emotions, diurnal variations and individual differences reports have often been

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[1] Marie A. Hinrichs, "Further Studies on Some Effects of Physical Fatigue on the Peripheral Circulation of Athletes," Research Quarterly, XXI (October, 1950), 175-181.

conflicting. Dawson[1] and Gemmill, Booth and Pocock[2] have indicated that exercise over a period of time does not necessarily alter the blood pressure to any great extent. These studies were made on very few individuals and are not at all conclusive.

In an experiment with seven volunteers whose diet and activities were better controlled than in previous studies, Cogswell, Henderson and Berryman[3] found that the systolic resting blood pressure and the post-exercise blood pressure tended to decrease with training on a step-test.

Even though the latter study is a more recent one and better controlled, results of studies on blood pressure are still not conclusive. Karpovich[4] recently said that the statement by Dawson whereby the effects of training on the resting blood pressure were neither striking nor constant still holds true today.

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[1] Percy M. Dawson, "Effect of Physical Training and Practice on the Pulse Rate and Blood Pressure During Activity and During Rest, with a note on Certain Acute Infections and on the Distress Resulting from Exercise," American Journal of Physiology, L (December, 1919), 443-479.

[2] C. Gemmill, W. Booth, and B. Pocock, "Muscular Training, I. The Physiological Effect of Daily Repetition on the Same Amount of Light Muscular Work," op. cit., pp. 253-270.

[3] Robert C. Cogswell, Charles R. Henderson and George H. Berryman, "Some Observations of the Effects of Training on Pulse Rate, Blood Pressure and Endurance in Humans; Using the Step Test (Harvard), Treadmill and Electrodynamic Brake Bicycle Ergometer," American Journal of Physiology, CXLVI (June, 1946), 422-430.

[4] Karpovich, op. cit., p. 208.

Patellar Reflex. -- The patellar reflex or knee-jerk has been studied to find out the effect of fatigue and exercise on the height of the reflex. Brown[1] measured the height of the patellar reflex of thirty-four students in a School for Athletic Coaches. The apparatus used was specially constructed by W. W. Tuttle to deliver blows of uniform intensity at a constant rate of seven per minute to the patellar tendon. The author was well-acquainted with the men and subjectively rated them as to fitness. The men were measured before and after exercise of varying kinds. The height of the knee-jerk was found to increase in half the cases and decrease in the other half. Brown, in analyzing the type of exercise indulged in with the degree of fitness, summarized his experiment by saying that the knee-jerk is heightened by activity only when the activity does not cause fatigue. Whenever an activity caused fatigue the knee-jerk decreased. The author felt that the knee-jerk was an indication of muscular tonus.[2]

In a study similar to Brown's, Tuttle and Brown[3] using controlled exercises recorded the knee-jerk in terms of length of time necessary for the subject to react to a

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[1] L. T. Brown, "The Influence of Exercise on Muscle Tonus as Exhibited by the Knee Jerk," American Journal of Physiology, LXXII (April, 1925), 241-247.

[2] Ibid., p. 247.

[3] W. W. Tuttle and L. T. Brown, "Studies in Reaction Time," American Journal of Physiology, LXXVIII (September, 1926), 150-157.

stimulus and, also, the height of the reflex. The subjects were well trained in the experiment beforehand and had recorded the normal reactions. Two subjects did a series of climbing stairs, six subjects skipped rope and two subjects did full knee-bends.

The authors recorded both the reaction time and also the height of the knee-jerk following exercise. The authors concluded that "during periods of controlled exercise, the knee-jerk first gets higher and then lower thus following the physiological sequence of 'Treppe' and fatigue."[1] The authors also found that during the periods of decreased reaction time there was a corresponding increase in the height of the knee-jerk. Likewise, when the reaction time increased the knee-jerk correspondingly decreased.

The Tuttle and Brown study was a very well-controlled experiment. The findings would have presented a stronger case had the authors increased the number of subjects and treated the data statistically.

Dawson[2] made an observation that the knee-jerk diminishes as fatigue comes on and that there is a rise in the threshold with prolonged exercise. Studying the effect of exercise on the threshold of the knee-jerk,

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[1] Ibid., p. 156.

[2] Percy M. Dawson, The Physiology of Physical Education, p. 25. Baltimore: The Williams and Wilkins Company, 1935.

Burge et al.[1] used two wrestlers equated as to size and weight. By adding weights, 10 gr. at a time, the authors determined the weight necessary to elicit a minimal response after ten minutes of wrestling and the length of time required for the threshold of the response to return to the pre-exercise level. Other exercises such as running, basketball, football and floor dips were also studied to determine the effect of the exercise on the knee-jerk. All types of exercise produced a substantial rise in the threshold of the response. The evidence produced could not be termed conclusive due to the number of subjects used, but it could have implications for further study.

Quo,[2] in a study involving 305 subjects, measured the Achilles reflex and the patellar reflex to discover the effect of physical and mental work on daytime and nighttime laborers. Quo used a special hammering device, recording the falling-angle of the hammer. He concluded that the Achilles tendon reflex and the patellar reflex were excellent methods for study of physical and mental fatigue. After a ten hour day for the 145 men doing physical work, the fall of the hammer had to be increased 16 deg. to elicit the patellar reflex and 10 deg. for the Achilles reflex. The

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[1] W. E. Burge et al., "The Effect of Exercise, Fatigue, and Exhaustion on the Electrical Potential of the Brain Cortex and Threshold of the Knee Jerk," Research Quarterly, IX (October, 1938), 45-53.

[2] Sung-Ken Quo, "A New Method of Measuring Fatigue by the Threshold Stimulus of the Achilles Tendon Reflex," Journal of Applied Physiology, II-III (September, 1949), 148-154.

values on the Achilles reflex were found to be significant for both physical and mental fatigue. The patellar reflex raised almost in parallel with the Achilles reflex, but was not treated statistically. If the results of the patellar reflex tests had been treated statistically, this study would have been stronger. However, further study is necessary to determine significance and reliability.

Although many of the patellar reflex studies did not give conclusive evidence, it was, nevertheless, apparent that they all reached the same conclusion.

Reaction Time. -- The attention given to reaction time of athletes has been evident in many studies. However, few studies have been done measuring the reaction time of athletes before and after exercise. Fatigue as a result of exercise has been stated as a cause for an increase of reaction time. Among the physiologists who have made this claim were Dawson,[1] Zoethout and Tuttle[2] and Riedman.[3]

Fellows et al[4] conducted a study on the factors influencing reaction time. In summarizing the study, it was

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[1] Dawson, op. cit., p. 27.

[2] William D. Zoethout and W. W. Tuttle, Textbook of Physiology, p. 639. St. Louis: The C. V. Mosby Co., 1946.

[3] Riedman, op. cit., p. 150.

[4] Gladys Fellows, Grace Goldsmith, I. Lennzmann et al., "Effect of Physical Exercise Upon Complex Reaction Time and Auditory Acuity," American Journal of Physiology, LXXVII (July, 1926), 402-408.

stated that the reaction time of women students in physical education decreased after a day's work which might include a basketball match, a field hockey game or a swimming meet. It was further stated, however, that exercise which did not prove to be severe the first day might be so if repeated the next day.

The work of Fellows et al. was not quoted as to procedure or statistical analysis and used only a small group (nine). This could not be construed as being conclusive evidence, however, the implications for further study are apparent.

Indication that reaction time first decreases and then increases as exercise is prolonged was reported by Tuttle and Brown[1] who recorded the reaction time as indicated by the knee-jerk. They concluded that "during periods of controlled exercise, the reaction time first gets shorter than longer, following the physiological sequence of 'Treppe' and fatigue."[2]

Burpee and Stroll[3] constructed a chronoscope to measure reaction time employing the principle that "freely falling bodies have a uniform acceleration of thirty-two feet

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[1] Tuttle and Brown, "Studies in Reaction Time," op. cit., pp. 150-157.

[2] Ibid., p. 156.

[3] Royal H. Burpee and Wellington Stroll, "Measuring Reaction Time of Athletes," Research Quarterly, VII (March, 1936), 110-118.

per second; in two seconds, the range decided upon for the instrument, such a body would fall sixty-four feet."[1]

The subjects used were forty-six men who participated in various gymnasium activities in different degrees of participation. The results of the reaction time were correlated with the degree of participation. The correlation between participation and small-muscle reaction time was .401 and .654 between large-muscle reaction time and successful participation.

Although the Burpee and Stroll study did not measure reaction time before and after the exercise, the use of the device to measure the reaction was important.

McCurdy and Larson maintained in their book that "slower reaction time . . . may be used as clinical indications of over-work and fatigue."[2] Thus, Elbel[3] attempted to corroborate this belief by conducting a study in response time. He used a specially constructed device consisting of a stimulus unit, response units and a recording device. One hundred twenty-nine male students were divided into nine groups according to the type of exercise performed. One of the groups was composed of fifty members of the freshman

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[1] Ibid., p. 112.

[2] James Huff McCurdy and Leonard A. Larson, The Physiology of Exercise, p. 349. Philadelphia: Lea and Febriger, 1939 (3d ed.).

[3] E. R. Elbel, "A Study of Response Time Before and After Strenuous Exercise," Research Quarterly, XI (May, 1940), 86-95.

basketball squad. The exercise consisted of basketball scrimmages and practice fundamentals one and a half hours in length. Another group included fifty cases of intramural basketball players. Their exercise was a regular intramural game with eight minute periods, one minute rest between quarters and five minutes between halves. Both of the above mentioned groups were tested in hand and body response. The hand response required the subject to place either hand palm down on the stimulus-hand-response unit with the thumb outside a guide line 3 1/2 in. from the edge of the hand switch. To produce a proper response the subject was required to strike the hand-switch with the palm after the stimulus was given. The body response required the subject to stand on a line painted on the floor corresponding to his height. At the sound of a bell, the subject stepped forward, arms extended, striking the padded panel of the large switch. Elbel concluded that athletic competition significantly shortened the response time. In his discussion the author stated that although response time improved after exercise, if the activity had been carried on for a longer period of time, the response time would gradually become slower. Also, he commented that in individual cases where the response time did become slower that the fatigue factor was setting in causing a lessening of ability to respond.

Slater-Hammel[1] described a device for measuring

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[1] A. T. Slater-Hammel, "An Inexpensive Gravity Reaction Time Device," Research Quarterly, XXV (May, 1954), 218-221.

reaction time involving the same principle as the Burpee and Stroll study. The only difference was that instead of stopping a falling body, the subject moved away from the path of the falling body. The author experimented with the conventional reaction time device composed of an electric clock with a hundredth of a second hand, a light stimulus, a telegraph key and a gravity reaction-time device. The difference between the reaction time measured on the two devices was not significant and the correlation between the two measurements was .842.

The studies on reaction time of athletes indicate a possibility that reaction time increases with fatigue. However, more research is needed which would include reaction time taken before and after exercise. Another possibility for research in this area would be studies which would carry measurements throughout a training season.

Pulse Rate. -- Low resting pulse rates are generally considered indicative of a trained athlete.[1, 2] Riedman elaborated on the pulse rate making a comparison between the trained and the untrained individual.

> The trained individual responds better than the untrained to the same amount of severe work, as shown by the pulse rate. The pulse rate of the trained individual is lower

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[1] F. S. Cotton, "Relation of Athletic Status to Pulse Rate in Men and Women," Journal of Physiology, LXXVI (September, 1932), 39-51.

[2] Steinhaus, "Chronic Effects of Exercise," op. cit., p. 112.

> for every work load except the heaviest. With very heavy loads the heart rate of the untrained person does not rise in proportion to the requirements of the increased work but remains approximately at the level of adjustment for moderate work. The heart of the untrained person is unable to reach the rate required by the highest load of work, because it has used its reserve for the moderate loads.[1]

Since exercise is known as one factor which affects the heart rate immediately, it is possible to measure the heart rate over a period of time to determine any changes which may take place. Tuttle and Walker[2] took the following measurements in order to determine the effect of a season of training and competition on the hearts of high school boys: resting rate, heart rate after exercise, heart rate above the resting rate after exercise, primary recovery time, recovery time and recovery pulse. These measurements were given to fourteen track athletes before the season of training and competition started, mid-season and post-season. Only one change was regarded as significant by the authors. The recovery pulse was 355 pre-season, 349 mid-season and 288 post-season. The authors stated that the high school boys derived some good by participating in the training program as evidenced by the change in the recovery pulse, since fewer heart beats were required to establish the resting level.

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[1] Riedman, op. cit., p. 267.

[2] W. W. Tuttle and Frank H. Walker, "The Effect of a Season of Training and Competition on the Response of the Hearts of High School Boys," Research Quarterly, XI (December, 1940), 78-81.

Morehouse and Tuttle[1] studied the response of the normal and abnormal heart to exercises of different intensities. They studied the post-exercise pulse rate, the pulse ratio and the recovery time. A cardiotachometer was used for counting the heart rate. Stool-stepping and weight-lifting were the exercises employed in this study. Both exercises were graded as to intensity. The authors found that the reliability of the pulse rate for two minutes after exercise, the rate of the first few heart beats after exercise, the post-exercise increase above resting level and the rate of pulse deceleration following exercise are all directly related to the intensity of the exercise. Recovery time was apparently prolonged according to the intensity of the exercise and was not related to the resting pulse in this study.

Salit and Tuttle[2] studied the resting and post-exercise pulse rate and blood pressure scores on twenty college men and forty college women. Half the group participated regularly in vigorous exercise and the other half had little or no exercise. Each subject was measured four times at about weekly intervals. Pulse rates and blood pressure were taken

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[1] L. E. Morehouse and W. W. Tuttle, "A Study of the Post-Exercise Heart Rate," Research Quarterly, XIII (March, 1942), 3-9.

[2] Elizabeth Powell Salit and W. W. Tuttle, "The Validity of Heart Rate and Blood Pressure Determinations as Measures of Physical Fitness," Research Quarterly, XV (October, 1944), 252-257.

in a reclining position after five minutes of rest and also after a minute of standard exercise on a bicycle ergometer. Post exercise measurements were taken at one-half minute, two minutes and four minutes. Records of maximum work output for two minutes on the bicycle ergometer were also available. The authors concluded that the most valid measures of fitness for men were the increase in pulse and the pulse a half minute after the exercise. The authors also suggested that the cardio-vascular tests be validated in relation to a work output criterion in which allowances are made for differences in strength and body size.

Brouha, Fradd and Savage[1] working on the premise that the pulse curve is an accurate measurement of the physical state developed an index of physical efficiency.

$$\text{Index} = \frac{\text{Duration of Exercise in seconds x 100}}{\text{2 x Sum of pulse counts in recovery}}$$ [2]

The exercise was completed by eight thousand college students which consisted of a step test on a 20 in. bench thirty times a minute. The exercise is continued for five minutes or until the subject stops from exhaustion. Pulse is counted from one to one and one-half, two to two and one-half and three to three and one-half minutes after the exercise has ceased. The sum of the three pulse counts was used as the

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[1] Lucien Brouha, Norman W. Fradd and Beatrice M. Savage, "Studies in Physical Efficiency of College Students," Research Quarterly, XV (October, 1944), 211-224.

[2] Ibid., p. 212.

recovery score. The following interpretation of the Index scores was advanced:

Below 55 - Poor physical condition
From 55 to 64 - Low average
From 65 to 79 - Average
From 80 to 89 - Good
Above 90 - Excellent[1]

The authors tested various groups of Harvard students and then retested them after a training program. They found that the index "gives a suitable indication of the physical efficiency of young men because, among other reasons, it improves under regular training, and declines when training is insufficient or wanting."[2] They found a wide range of scores among men who are medically fit and a smaller range among those who engage regularly in muscular activity. The majority of freshmen improved their scores under training if they tested average or worse; those who tested higher showed a lower score which indicated that the training program was too easy for them.

Elbel and Holmer[3] studied the relationship between the pre-exercise pulse rate and the amount of time required for the pulse to return to the pre-exercise level following two minutes of exercise. The subjects were forty-five

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[1] Ibid.

[2] Ibid., p. 224.

[3] Edwin R. Elbel and Robert M. Holmer, "The Relationship Between Pre-Exercise Pulse Rate and Recovery Following Exercise," Research Quarterly, XX (December, 1949), 367-377.

healthy male students engaging either in varsity athletics or physical education majors participating in activity classes. Data were collected on pre-exercise pulse rates and pulse rates following a two minute step-up exercise. As was shown previously by Morehouse and Tuttle, the authors also concluded that the pre-exercise pulse rate was not related to the recovery pulse. Other conclusions drawn were that body weight is not related to the amount of time required for the pulse to return to the pre-exercise level. The pre-exercise rate and the increase due to a two-minute period of exercise are not related and that there is an insignificant coefficient of correlation between the pulse rate taken for fifteen seconds immediately following exercise and recovery time.

Henry[1] studied the blood pressures, heart rates and pulse wave sphygmograms at rest on eighteen college athletes before and after a season of athletic training and competition. These results were compared with test-retest measurements of a control group of fifteen physically active men. In his conclusions on the pulse rate, the author said that the decrease in heart rate is a more effective test of changes in athletic condition and that the resting heart rate has significant validity as a test of the effect of athletic training.

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[1] Franklin M. Henry, "Influence of Athletic Training on the Resting Cardio-vascular System," Research Quarterly, XXV (March, 1954), 28-41.

The above studies revealed that heart rate seemed indicative of an individual's physical condition. They seemed to indicate that a pulse rate taken before and after a step test and before and after basketball practice might reveal any change in the physical condition of the athlete throughout the basketball season.

Grip Strength. -- Steinhaus[1] in discussing the lasting changes produced by exercise stated that "increase in muscle size, strength, and endurance are probably among the best recognized chronic effects of muscular exertion."[2] Therefore, it seemed logical that a test of grip strength would be included in a physical fitness battery. Clarke[3] commented on this in reviewing the use of the Physical Fitness Index battery. He said that "the PFI test has been carefully constructed and there is considerable evidence to justify its use as a basic test of physical condition."[4] Included in the six strength tests are the right and left grips.

Bookwalter[5] in determining grip strength norms for

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[1] Steinhaus, "Chronic Effects of Exercise," op. cit., pp. 103-147.

[2] Ibid., p. 104.

[3] H. Harrison Clarke, "Analysis of Physical Fitness Index Test Scores of Air Crew Students at the Close of a Physical Conditioning Program," Research Quarterly, XVI (October, 1945), 192-195.

[4] Ibid., p. 193.

[5] Karl W. Bookwalter et al., "Grip Strength Norms for Males," Research Quarterly, XXI (October, 1950), 249-273.

males stated that

> grip strength is one of the most reliable dynamometrical measures of human strength. It is a relatively economical measure, is easily administered and is a direct measure of applied force. Accordingly grip strength is a likely component of strength batteries, a strength item reasonably representative of total body strength.[1]

Since an increase in strength has been recognized as a chronic effect of muscular exertion and also one component of a reliable Physical Fitness Index, it appeared that prolonged exercise or over-exertion could produce changes in the hand grip.

Fisher and Birren[2] reported the effect of an eighteen hour fatigue run on the hand strength of 105 males. Using a hand dynamometer all the subjects were tested before the run started which consisted of continuous marching, calesthenics and active military exercises involving a minimum of hand work. Approximately half of the subjects dropped out before the end of the run because of fatigue. Thirty-two of this group were retested one to three hours afterward and before they had any sleep. A mean decrease in the score of this group was found to be 2.03 kg. with a standard error of .25 kg. The subjects who finished the run had a mean increase of .88 kg. with a standard error of .40 kg. from the first to the second test after the completed run. The difference

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[1] Ibid., p. 249.

[2] M. B. Fisher and J. E. Birren, "Standardization of a Test of Hand Strength," Journal of Applied Psychology, XXV (August, 1946), 380-387.

between the changes in mean score of the two groups was found to be highly significant statistically.

Thus, tests to measure the effect of exercise on the patellar reflex, reaction time, pulse rate and grip strength have been reviewed and selected for use in this study. Their selection was determined by the evidence presented that they had possibilities for revealing the fatigue state in an individual. Another pertinent factor was the ease of administration for a coach or physical educator's use at a later date.

The majority of the other areas reviewed are out of the realm of a physical educator or are not conducive to a set-up outside a laboratory. Their exclusion from this study was based, therefore, on the possibility of future practical application by the teachers and coaches in their respective schools.

Summary. -- The concept of fatigue has never been clearly defined and accepted. Fatigue has been thought of as work decrement or boredom. It has been distinguished from impairment by suggesting that fatigue is an over-all, subjective personal experience; whereas impairment is a physiological change in tissue which has nothing to do with work decrement. In spite of the fact that fatigue does not have a recognized definition, the three aspects of fatigue suggested by Riedman seemed comprehensive. They are: (1) a feeling of tiredness; (2) reduced capacity for work; (3) temporary physiological changes in the organism. These three

aspects may or may not occur at the same time. However, if they should they need not be correlated.

The search for possible tests indicating fatigue revealed some promise for a test battery comprised of a reaction time measurement, a post-exercise pulse count, the patellar reflex and grip strength.

CHAPTER III

METHOD OF PROCEDURE

This study was conducted in the men's gymnasium at Iowa State College with the freshmen basketball squad and volunteer freshmen physical education majors as subjects. The freshmen basketball coach explained the purpose and procedures for testing to his players. Since the data were collected immediately before and after practice sessions in basketball, the coach emphasized the importance of regularity of testing and the necessity for each man doing his best. Interest in the testing procedures was high among all members of the men's faculty. This reaction was also a helpful factor in maintaining a consistent atmosphere conducive to obtaining valid data.

Selection of Tests. -- In order to determine if changes occur as a result of a practice session in basketball, the literature was reviewed on various physiological tests which have been used or show some potentiality for revealing a fatigue state in the individual. Practicality and ease of administration were kept in mind for future use by coaches and physical education instructors.

The following tests were selected as measures of the various systems in the body as possibilities for revealing

the fatigue state:

1. Patellar reflex
2. Reaction time
3. Pulse rate before and after a step test
4. Grip strength

Additional information which might prove pertinent to the study was:

1. Weight
2. Hours of sleep preceding night
3. Record of eating habits
4. Record of previous exercise
5. Examinations scheduled

Also a record of the height of the individual was made at the beginning and end of the study.

Selection of Subjects. -- The experimental subjects, twenty-two in number, used in this study were the members of the entire freshmen basketball squad at Iowa State College. They were selected because of their regularity of practice, similarity of exercise, accessibility to testing procedures and the relative homogeneity of the group.

The control group was composed of volunteer freshmen enrolled in the physical education major curriculum at Iowa State College. The subjects in the control group were not in training for any sport at the time. The original number of volunteers was twelve. Three dropped out for various reasons and two were added after the Christmas holidays. The final number in the control group was eleven.

General Test Administration. -- A testing area was set up in a small room adjoining the main gymnasium. Four upper-class football players recommended by the department were hired to assist with the test administration. The assistants were given a training session and written standardized directions for administering the tests. They were instructed by the writer in the procedures of all the tests, but were specifically assigned to one in order to maintain standard conditions.

The experimental group was tested before and after basketball practice throughout the basketball season. The testing started approximately two weeks after the season started so that the personnel involved became experienced. It was decided to test on Monday and Thursday of each week to get the greatest number possible and to reflect any differences between first and last of the week figures. Thursday was decided upon instead of Friday because many of the men on the squad were unable to practice on Fridays. In order to determine base line figures, tests were taken every day the first and last weeks of the basketball season. Likewise, after a month long Christmas vacation, tests were taken every day the first week in January. Because of intra-squad games, practice with the varsity and other irregularities, it was not always possible to adhere to the above schedule as planned. However, it was followed whenever possible.

Practice sessions were scheduled from four to six o'clock every day. The pre-practice testing occurred between

three-thirty o'clock and four-thirty o'clock in the afternoon. The post-practice testing took place between five-thirty o'clock and six-thirty o'clock.

The control group was asked to report after their last class in the afternoon to the testing room. They were irregular in time, but it was confined between three-thirty o'clock and five-thirty o'clock in the afternoon. They were tested once at that time.

A short questionnaire* of subjective data was given to each man in the experimental and control groups as they reported to the testing room. This procedure was followed throughout the testing season.

The general order in which the tests were given was not specific except in one case. The step test was always given last in the pre-practice testing of the experimental group and in the control group. In the post-practice testing session, the step test was given first. This was adhered to throughout the season so that the one minute exercise would not affect other tests before practice and so that the pulse could be counted immediately from the basketball practice.

Testing started on November 22, 1954, and continued through February 24, 1955. There were twenty-six testing sessions for the experimental group and twenty-seven for the control group.

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* See Appendix A.

Administration of Individual Tests

Patellar Reflex. -- A specially constructed instrument (Figure 1) adapted from those used by Burge et al.[1] and Quo[2] was used to measure the threshold response of the patellar reflex. This instrument was designed to measure in degrees the lift of the hammer necessary to elicit the minimal response.

The subject sat on a table with the right thigh over the base of the instrument. The lower leg hung freely over the edge of the table. The instrument was adjusted for each individual so that the hammer would strike the patellar tendon as the needle indicated 90 deg. on the protractor. Likewise, allowances were made for the width of the thigh by moving the hammer arm closer or farther away from the vertical standard.

The measurements were all taken by the writer following standard procedures.* A needle attached to the end of the hammer indicated on a protractor the number of degrees the hammer was lifted. At rest against the patellar tendon, the needle registered 90 deg. As the hammer was lifted the needle registered between 90 deg. and 180 deg. The number

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[1] Burg et al., op. cit., pp. 45-53.

[2] Quo, op. cit., p. 150.

* See Appendix B.

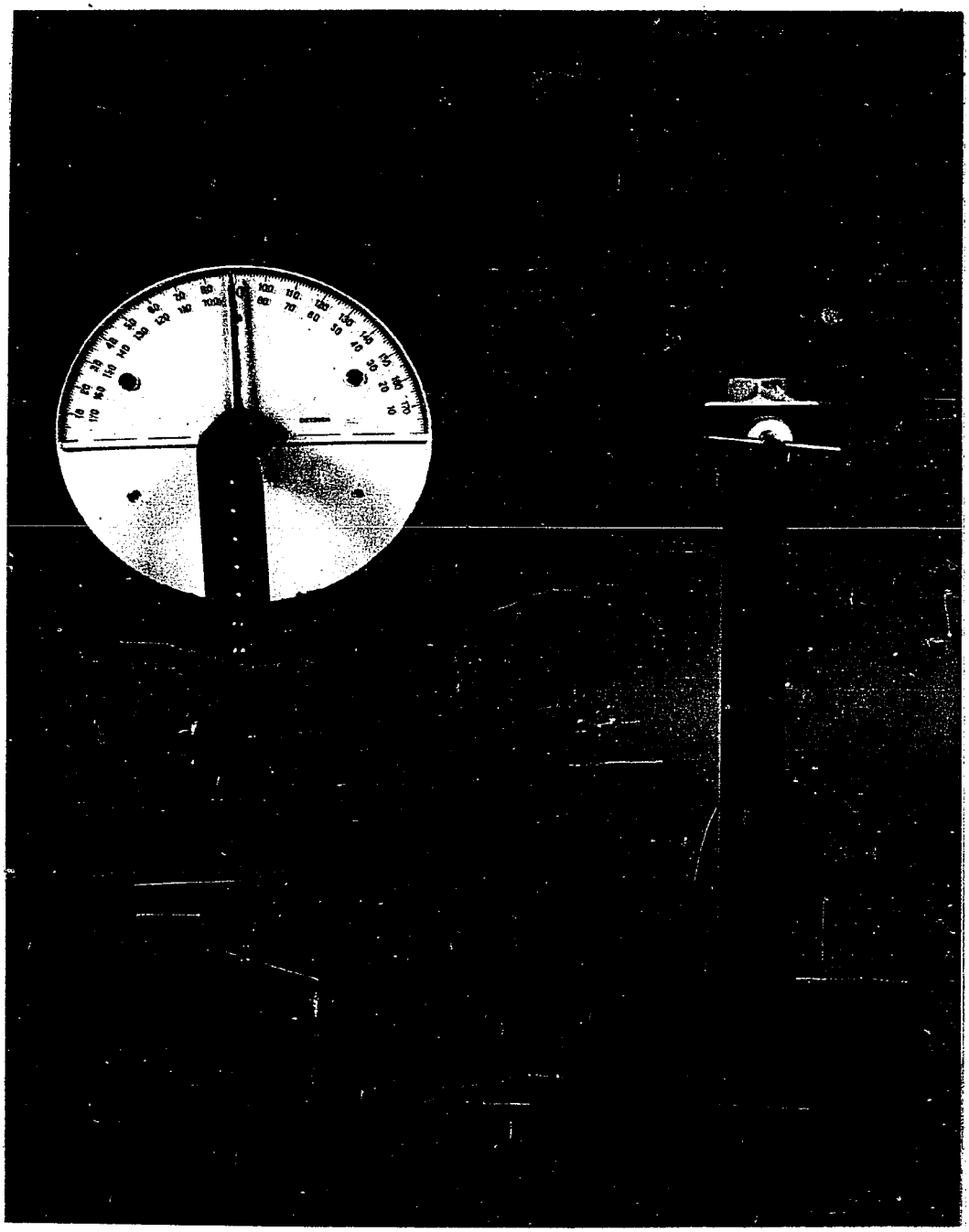


Fig. 1. Patellar Reflex Instrument

of degrees recorded was the smallest degree of lift minus 90 deg. which would still elicit a response.

The experimental group was tested on the patellar reflex instrument before and after a practice session of basketball. A measurement of the patellar reflex was taken once on the control group each testing session.

Reaction Time. -- A meterstick chronoscope (Figures 2 and 3) for measuring simple visual reaction time was constructed after the basic scheme presented by Woodworth and Schlosberg.[1]

The subject was asked after a given signal to stop the fall of the meterstick. The distance in inches the meterstick fell was converted into seconds using the formula $T = \sqrt{\frac{2S}{G}}$. T is the time in seconds, S is the distance in inches the meterstick falls, and G is the gravity pull of 384 in./sec. A reaction time conversion scale was used for interpretation.

Each subject was given five trials and an average was taken for the final score. The subjects in the experimental group were tested before and after a practice session of basketball. The control group was tested once in each testing period.

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[1] Robert H. Woodworth and Harold Schlosberg, Experimental Psychology, p. 15. New York: Henry Holt and Co., 1954 (2d ed.).

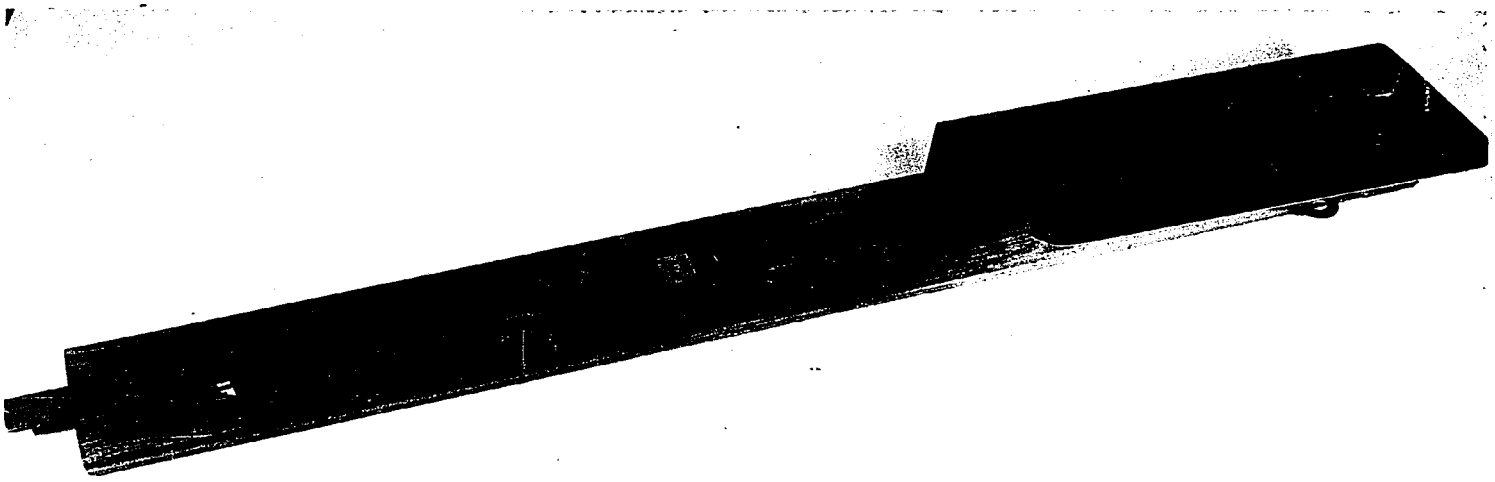


Fig. 2. Front View of Meterstick Chronoscope

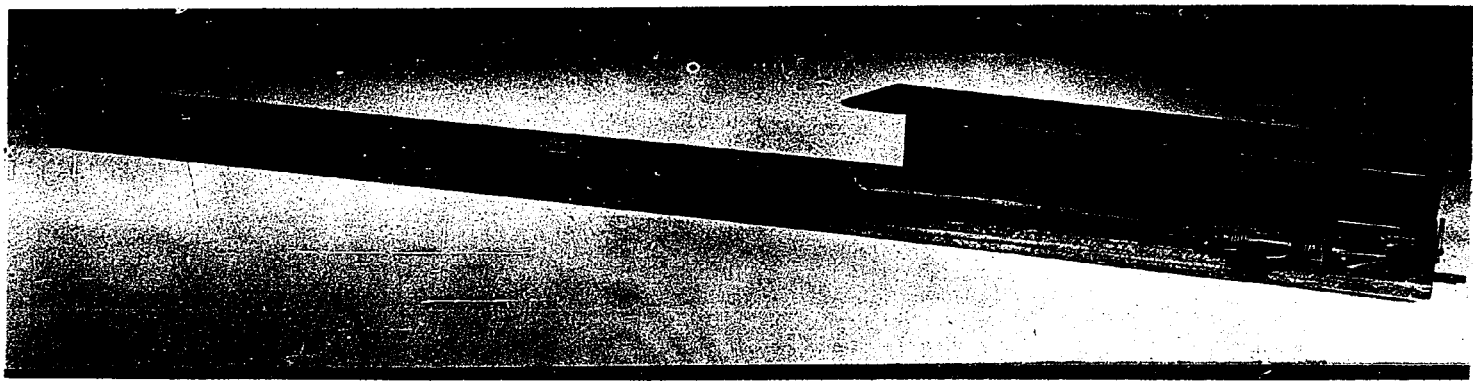


Fig. 3. Side View of Meterstick Chronoscope

The same assistant tested all the subjects in the reaction time experiment following standardized directions* set up by the writer.

Pulse Rate. -- Pulse rate for one minute was recorded on each subject before and after a step test. A resting pulse rate was obtained in a sitting position by counting the pulse for thirty seconds until two consecutive identical readings were obtained. This number was multiplied by two and recorded as the resting pulse.

A bench, 16 in. in height, was used for the exercise. The subjects were directed to follow the general procedure as prescribed by Tuttle.[1] The subjects stepped in cadence, thirty steps per minute, to a metronome for one minute. Immediately following the exercise, the subjects sat down on the bench. They were given five seconds to locate their pulse and a count was made by the individual for a full minute. This number was recorded as the post-exercise rate.

All subjects in the experimental group were tested in like manner before and after the practice session of basketball. Immediately following basketball practice, the subjects in the experimental group reported to the testing room, sat down, located their pulse and at a signal given by the assistant counted their pulse for one full minute.

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[1] W. W. Tuttle, "The Use of the Pulse-Ratio Test for Rating Physical Efficiency," Research Quarterly, II (May, 1931), 7-8.

* See Appendix B.

Following the step test they again counted their pulse for one minute and recorded it.

The control group was tested once in each session. Due to previous exercise, a full minute count of the pulse was made and recorded as the pre-exercise pulse. Following the step test, the pulse was counted for a full minute in a sitting position and recorded as the post-exercise pulse rate.

The assistants followed the standard procedures* set up by the writer. A stop watch was used to designate time limits. In order to expedite the testing of the pulse rate, all of the assistants aided in this test. This procedure was used so that the pulse rate could be taken immediately, especially in the post-practice session.

All the subjects were instructed and given practice in taking their own pulse. The writer spot checked the pulse count obtained by the subjects by counting the pulse simultaneously with a subject and comparing results.

Grip Strength. -- A C.H. Stoelting** hand dynamometer was used to measure grip strength. The instrument measured the grip strength in kilograms. The subjects were requested to stand, holding the dynamometer down at the side, away from the body. They were instructed to grip once with the right hand and once with the left. The two scores were added

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* See Appendix B.

** Loaned by the Driver Training Laboratory of the Psychology Department of Iowa State College.

together and the sum recorded for total grip strength.

The experimental group was tested before and after basketball practice. The control group was given one test during the testing session. One assistant assigned to this test encouraged each man to do his best and adhere to standard procedures.* Since motivation and effort are recognized to be necessary for the best possible test results on the dynamometer, encouragement by the assistant was a consistent procedure.

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* See Appendix B.

CHAPTER IV

FINDINGS

The data collected from the twenty-six testing sessions of the patellar reflex, reaction time, pulse rate and grip strength will be presented in separate sections. A summary of the subjective data, weight and the height will follow.

From the data collected on the experimental group, t-tests were calculated between the following group means: (1) total pre-practice means and total post-practice means, (2) first seven pre-practice means and first week in January pre-practice means, (3) first week in January pre-practice means and last week pre-practice means and (4) first seven pre-practice means and last week pre-practive means.

The control group was measured once each testing session. Therefore, t-tests were made on (2), (3) and (4) as in the experimental group.

Weekly group means for both the experimental and control group were determined in all four tests and will be presented in graph form.

Patellar Reflex. -- Reliability of the patellar reflex test was determined by the Pearson product - moment coefficient of correlation. Computing the r on two consecutive

days of testing, the patellar reflex test was found to have a reliability of .937.

Table 1 shows the means in degrees and the t-values for the experimental group before and after basketball practice.

TABLE 1

TOTAL PATELLAR REFLEX MEANS AND t-VALUE OF THE EXPERIMENTAL GROUP BEFORE AND AFTER BASKETBALL PRACTICE

Condition	Degrees of Freedom	Means in Degrees	Difference Between Means	t-Value
Pre-Practice	16	38.7	3.7	9.45*
Post-Practice	16	42.4		

* Significant at 5% level.

Using Fisher's table for t, it was found that the t-value of 9.45 was significant at the 5 per cent level of confidence. As Table 1 indicates, it took a stronger blow to elicit a minimal response after practice than was necessary on the pre-practice tests, thus revealing the presence of more fatigue.

Table 2 reveals the pre-practice means and t-values of the experimental group for the three test periods.

The average number of degrees necessary to elicit a minimal response before practice was found to decrease 5.7 deg. between the first seven testing sessions and the first week in January. The t-value of 2.69 was found to be significant at the 5 per cent level of confidence. This decrease in degrees marked the presence of less fatigue in January

TABLE 2

PRE-PRACTICE PATELLAR REFLEX MEANS AND t-VALUES OF THE EXPERIMENTAL GROUP FOR THREE TEST PERIODS

Pre-Practice Testing Periods	Degrees of Freedom	Means in Degrees	Difference Between Means	t-Values
First Seven	15	39.8	-5.7	2.69*
First Week in January	15	34.1		
First Week in January	16	34.3	8.9	3.7*
Last Week of Testing	16	43.2		
First Seven	15	39.8	3.4	1.53
Last Week of Testing	15	43.2		

* Significant at 5% level.

than was obvious at the beginning of testing. However, between the first week in January and the last week of testing was found a mean increase of 8.9 deg. This produced a t-value of 3.7 which was significant. Because of the increase in the number of degrees necessary to elicit a response, the significant difference denotes a more fatigued condition between these test periods. Again the difference between the first seven testing sessions and the last week of testing had a mean increase of 3.4 deg. However, the t-value of 1.53 revealed that the difference was not significant at the 5 per cent level of confidence.

The patellar reflex means and t-values for the three test periods are shown in Table 3.

TABLE 3

PATELLAR REFLEX MEANS AND *t*-VALUES OF THE CONTROL GROUP FOR THREE TEST PERIODS

Testing Periods	Degrees of Freedom	Mean in Degrees	Difference Between Means	*t*-Values
First Seven	7	45.6	-6.5	3.37*
First Week in January	7	39.1		
First Week in January	9	40.1	12.3	4.17*
Last Week of Testing	9	52.4		
First Seven	7	45.6	6.6	2.38*
Last Week of Testing	7	52.2		

* Significant at 5% level.

The mean difference between the first seven testing periods and the first week in January was a decrease of 6.5 deg. This furnished a *t*-value of 3.37 which was significant at the 5 per cent level of confidence. This significant difference revealed that the experimental and control group responded similarly for this test period by decreasing the number of degrees necessary to elicit a response. Again running parallel with the experimental group, the control group had a mean increase of 12.3 deg. between the first week in January and the last week testing sessions. The *t*-value of 4.17 was significant at the 5 per cent level of confidence. The response of the control group to the first seven testing periods and the last week of testing was contrary to the

experimental group. The mean increase of 6.6 deg. had a t-value of 2.38 which was significant at the 5 per cent level of confidence. It appeared that the control group ended the testing period in a more fatigued state than was evident at the beginning.

Figure 4 shows the weekly means for the patellar reflex of both the experimental group and the control group. The similarity of response is very obvious throughout the testing season. The arrow at the fourth week shows the point at which the groups returned from a Christmas vacation which amounted to approximately a month. This period included a week of final academic examinations previous to the vacation. The fact that the patellar reflex decreased appreciably at this point indicated that the vacation had afforded some rest. The experimental group then experienced a steady rise in the threshold of the patellar reflex while the response of the control group was more erratic until the seventh week when a rapid rise in the threshold occurred.

Reaction Time. -- The Pearson product-moment coefficient of correlation was used to determine the reliability of the reaction time test. Using two consecutive testing days, the reliability was found to be .64.

Total reaction time means and t-values for the experimental group are indicated in Table 4.

A decrease of .005 seconds was found between the pre-practice means and the post-practice means. This difference

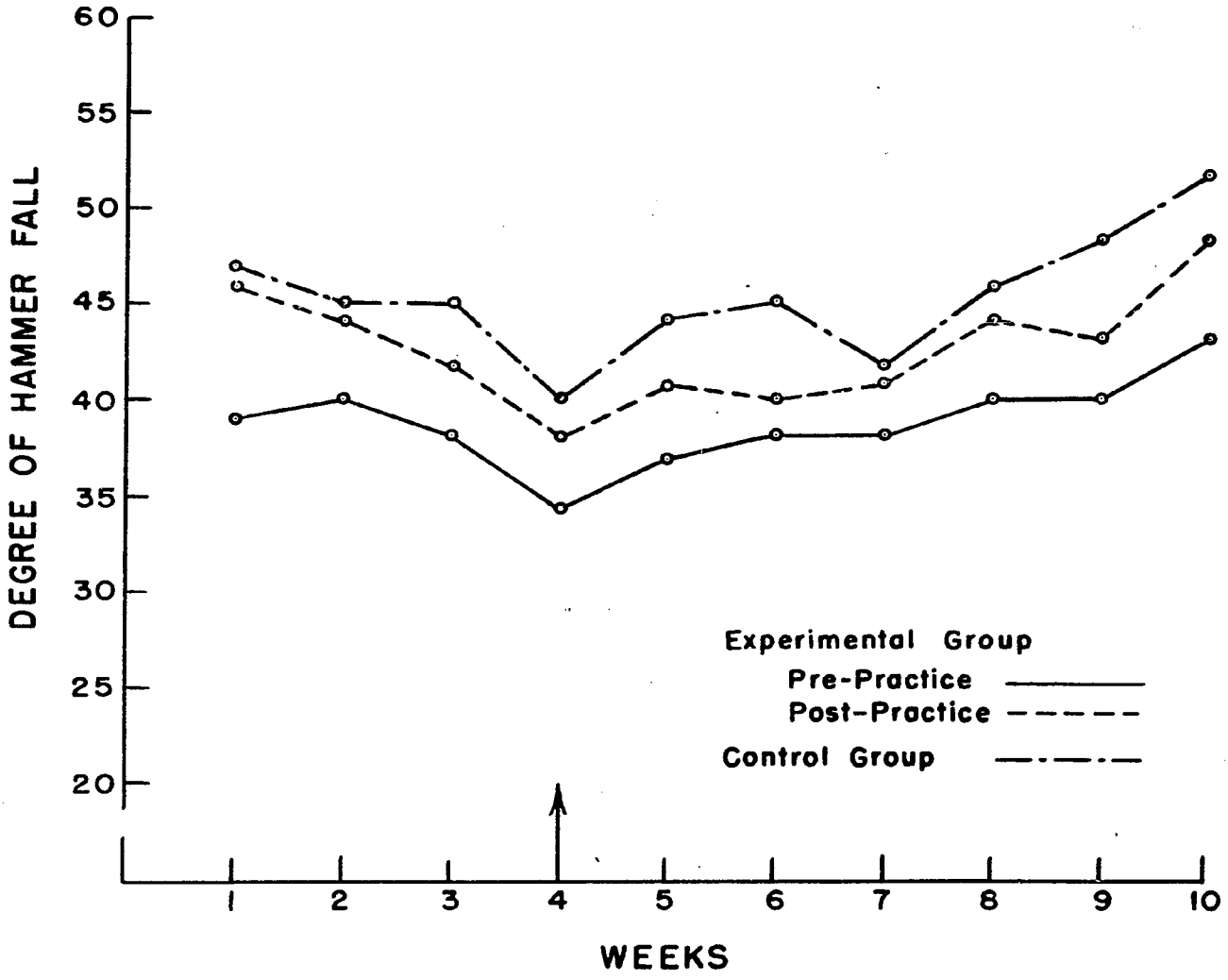


Fig. 4. Patellar Reflex Weekly Mean Values

TABLE 4

TOTAL REACTION TIME MEANS AND t-VALUE OF THE EXPERIMENTAL GROUP BEFORE AND AFTER BASKETBALL PRACTICE

Condition	Degrees of Freedom	Means in Seconds	Difference Between Means	t-Value
Pre-Practice	21	.148	-.005	5.9*
Post-Practice	21	.143		

* Significant at 5% level.

yielded a t-value of 5.9 which was significant at the 5 per cent level of confidence. Since a decrease in score means a faster reaction time after practice, the practice sessions apparently were not fatiguing enough to reflect in the reaction time test.

To determine the significance of the differences between three different test periods, t-tests were run between the pre-practice means. Table 5 shows the means and t-values of the experimental group.

As Table 5 indicates, there was a decrease of .016 seconds between the means of the first seven test periods and the first week in January on the reaction time test. This difference produced a t-value of 8.59 which was significant well beyond the 5 per cent level of confidence. Since there was an improvement in reaction time between the two periods, the significant difference favored the group. Although there was a slight increase (.001 seconds) in the difference of reaction time means between the first week in

January and the last week of testing, this difference was too small to warrant calculating a t-value. Consequently the difference was not significant. However, between the first seven test sessions and the last week, a difference of -.017 seconds was found. The t-value of 7.84 was significant and again indicated a bettering of reaction time between the two test periods.

TABLE 5

PRE-PRACTICE REACTION TIME MEANS AND t-VALUES OF THE EXPERIMENTAL GROUP FOR THREE TEST PERIODS

Pre-Practice Testing Periods	Degrees of Freedom	Means in Seconds	Difference Between Means	t-Values
First Seven	19	.164	-.016	8.59*
First Week in January	19	.148		
First Week in January	21	.149	-.001	0.00
Last Week	21	.148		
First Seven	19	.165	-.017	7.84*
Last Week	19	.148		

* Significant at 5% level.

The means and t-values on the reaction time tests of the control group for the three test periods are given in Table 6.

The responses of the control group to the reaction time test were very similar to those of the experimental

TABLE 6

REACTION TIME MEANS AND t-VALUES OF THE CONTROL GROUP FOR THREE TEST PERIODS

Testing Periods	Degrees of Freedom	Means in Seconds	Difference Between Means	t-Values
First Seven	8	.166	-.023	6.99*
First Week in January	8	.143		
First Week in January	10	.142	.001	0.00
Last Week	10	.143		
First Seven	8	.166	-.023	5.31*
Last Week	8	.143		

* Significant at 5% level.

group. As Table 6 reveals, the difference between the first seven testing sessions and the first week in January was a decrease of .023 seconds. Likewise between the first seven testing sessions and the last week there was a decrease of .023 seconds. The t-values of 6.99 and 5.31, respectively, were significant well beyond the 5 per cent level of confidence. The decreases in mean scores for these two periods both indicated an improvement in reaction time. The similarity between the first week in January and the last week was again apparent between the two groups. The mean increase of .001 seconds was too small to yield a significant difference.

Weekly mean values for the experimental and control groups in the reaction time test are seen in Figure 5. The two groups responded throughout the testing season in a

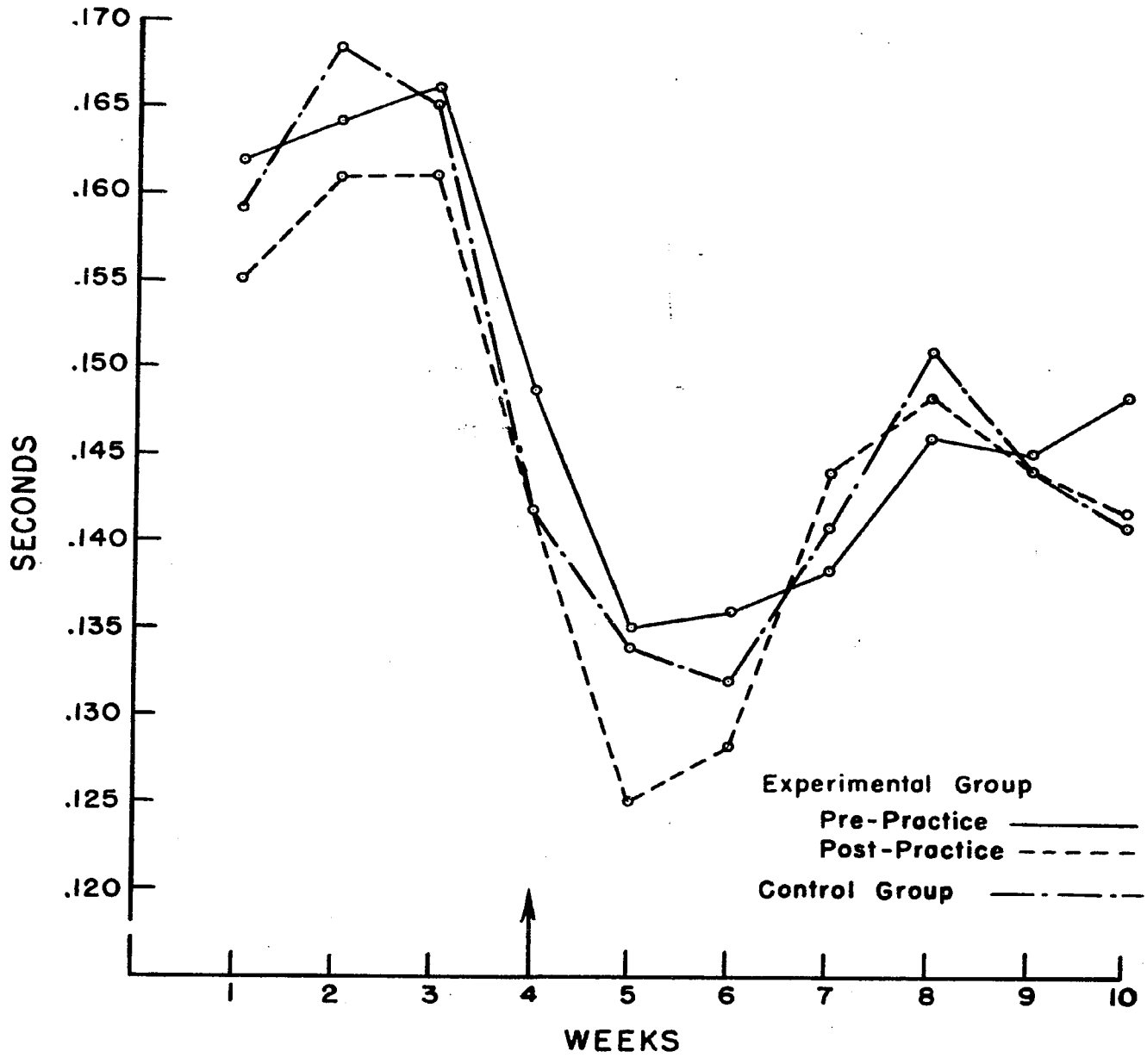


Fig. 5. Reaction Time Weekly Mean Values

similar fashion except in two instances. The fourth week which followed a month of vacation shows a large decrease in reaction time. Both groups continued to improve their time the fifth week. Starting with the sixth week the experimental group showed a steady increase in reaction time while the control group did not start to increase their time until the seventh week. The control group then continued to increase the eighth week and ended the season by bettering its time the last two weeks. The peculiarity lies within the experimental group at the seventh and eighth weeks. Heretofore practice has caused a decrease in reaction time. However, there is seen between the pre- and post-practice mean scores for the seventh and eighth weeks an increase in reaction time. There appeared to be no explanation for this in the data.

Pulse Rate. -- Reliability of the resting pulse rate was determined by the Pearson product-moment coefficient of correlation. Using two consecutive days of testing, the reliability was found to be .72.

Table 7 shows the mean pulse rates of the experimental group before and after basketball practice.

From Table 7 it can be seen that the pulse rate increased considerably after basketball practice and also after the step test. The pulse count taken after practice on the pre-step test and again after the step test shows the smallest difference of only 7.5 beats per minute. The step test in this instance was not much more strenuous than the

TABLE 7

TOTAL PULSE RATE MEANS OF THE EXPERIMENTAL GROUP BEFORE AND AFTER BASKETBALL PRACTICE

Condition	Number		Means of Pulse Per Minute	Difference Between Means
Pre-Practice	Pre-Step Test	22	67.7	25.5
	Post-Step Test	22	93.2	
Post-Practice	Pre-Step Test	22	107.7	7.5
	Post-Step Test	22	115.2	
Pre-Step Test	Pre-Practice	22	67.7	40.0
	Post-Practice	22	107.7	
Post-Step Test	Pre-Practice	22	93.2	22.0
	Post-Practice	22	115.2	

basketball practice in which they had just been engaging. The control group had a total pre-step test pulse rate mean of 83.5 beats per minute. After the step test the count raised to 106.5 beats per minute. In comparison to the experimental group, the pulse count of the control group was 15.8 beats more than the experimental group on the pre-step test and 13.3 beats more on the post-step test.

The resting pulse rate during three different testing periods of the experimental group is shown in Table 8. Subjecting the resting pulse rates of the experimental group to *t*-tests for three periods of time, it was found that between the first seven testing sessions and the first week in January there was only a difference of 1.1 beats per minute. The difference was too small to warrant calculating a *t*-value and, therefore, was not significant. However, between the

first week in January and the last week of testing, there was a decrease of 5.3 beats per minute. The t-value of 3.45 was significant at the 5 per cent level of confidence. Since a lower pulse indicates better physical condition, it appeared that the group was in better condition at the end of the testing season. Likewise, the difference between the first seven and the last week of testing produced a decrease of 3.7 beats per minute. This favorable decrease yielded a t-value of 2.77 which was significant at the 5 per cent level of confidence.

TABLE 8

PRE-PRACTICE, PRE-STEP TEST PULSE RATE MEANS AND t-VALUES OF THE EXPERIMENTAL GROUP FOR THREE TEST PERIODS

Testing Periods	Degrees of Freedom	Means of Pulse per Minute	Difference Between Means	t-Values
First Seven	19	68.0	1.1	0.00
First Week in January	19	69.1		
First Week in January	21	70.5	-5.3	3.45*
Last Week	21	65.2		
First Seven	19	68.0	-3.7	2.77*
Last Week	19	64.3		

* Significant at 5% level.

To indicate whether or not the increase in pulse rate before practice and after the step test increased significantly, t-tests were calculated on these sets of data. The post-step test pulse rates are shown in Table 9.

Between the first seven testing sessions and the

TABLE 9

PRE-PRACTICE, POST-STEP TEST PULSE RATE MEANS AND *t*-VALUES OF THE EXPERIMENTAL GROUP FOR THREE TEST PERIODS

Testing Periods	Degrees of Freedom	Means of Pulse per Minute	Difference Between Means	*t*-Values
First Seven	19	92.5	-0.1	0.00
First Week in January	19	92.4		
First Week in January	21	93.0	-3.0	1.86
Last Week	21	90.0		
First Seven	19	92.5	-3.5	2.11*
Last Week	19	89.0		

* Significant at 5% level.

first week in January and again between the first week in January and the last week, there was a small decrease in pulse rates after the step test as seen in Table 9. The *t*-values obtained from the differences were not significant at the 5 per cent level of confidence. However, between the first seven and the last week of testing there was a significant decrease of 3.5 beats per minute. This decrease appeared to indicate a better condition among the athletes since individuals increase the pulse rate after a step test if their physical condition diminishes.

The pulse rate of the control group presented a somewhat different picture from the experimental group. A basketball technique class was scheduled for the control group starting the first week in January and continued to

the end of the testing season. This class came just prior to the testing period. Therefore, the only resting pulse rates obtained on the control group were for the first seven testing periods. As a consequence t-values were unable to be calculated for the first seven testing periods and the first week in January or for the beginning of the season and the end of the season.

The resting pulse rate for the control group for the first seven periods averaged 70.3 beats per minute. This was only slightly higher than the 68.0 beats per minute obtained on the experimental group. Likewise, the pulse rate taken after a minute step test increased 21.0 beats per minute for the control group and 24.5 beats per minute for the experimental. The difference in the pulse rate between these two groups at the beginning of the season did not appear to be great.

Since the basketball technique class was a constant factor from January to the end of the testing season, t-values were obtained for the periods of first week in January and end of the season. Table 10 presents the pulse rate means and t-value of the control group before and after the step test for the one period of time.

The t-values of 4.33 on the pre-step test and 3.75 on the post-step test were both significant at the 5 per cent level of confidence. This decrease in pulse rates seemed to indicate that the control group ended the period of testing in better physical condition than was obvious in January.

TABLE 10

PRE- AND POST-STEP TEST MEANS AND t-VALUES OF THE CONTROL GROUP FOR THE FIRST WEEK IN JANUARY AND THE LAST WEEK OF TESTING

Condition	Testing Periods	Degrees of Freedom	Means of Pulse per Minute	Difference Between Means	t-Values
Pre-Step Test	First Week in January	10	91.5	-11.7	4.33*
	Last Week	10	79.8		
Post-Step Test	First Week in January	9	110.4	-12.2	3.75*
	Last Week	9	100.2		

* Significant at 5% level.

Figures 6 and 7 show the pulse rate weekly mean values for the experimental and control group. The experimental group had no exercise other than walking prior to the pulse rate taken before practice and before the step test. Therefore, their resting pulse showed a more constant rate throughout the season. The differences, as shown in Figure 6, between the three testing sessions (first seven, first week in January and last week) were not great, but they were significant. At the fourth week the pulse rate increased and then steadied for four weeks and declined significantly at the end of the season. It appeared that the men were in better physical condition. The pulse rate taken before practice and after the step test followed the same pattern fairly well, lowering as the season progressed.

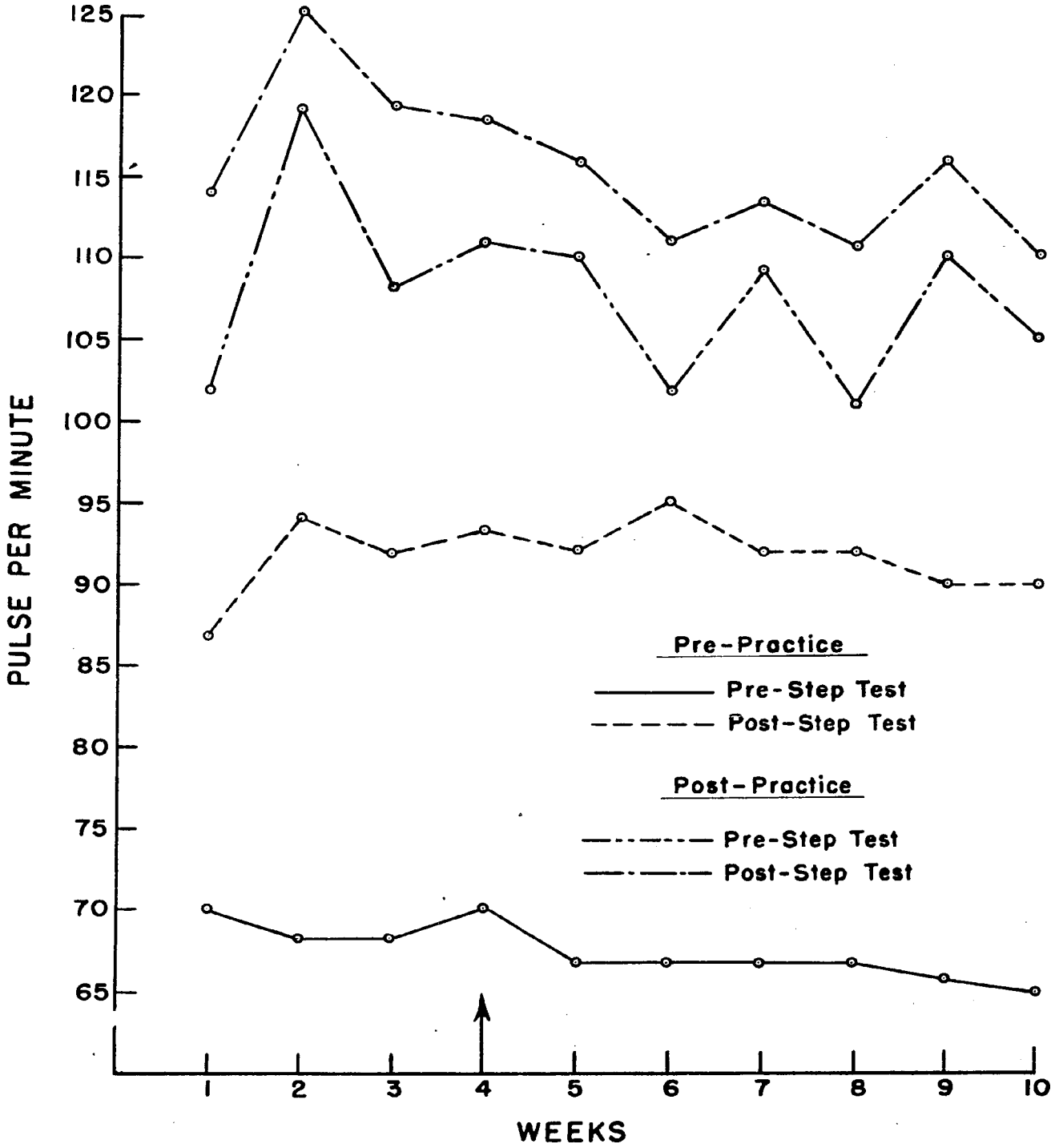


Fig. 6. Pulse Rate Weekly Mean Values of the Experimental Group

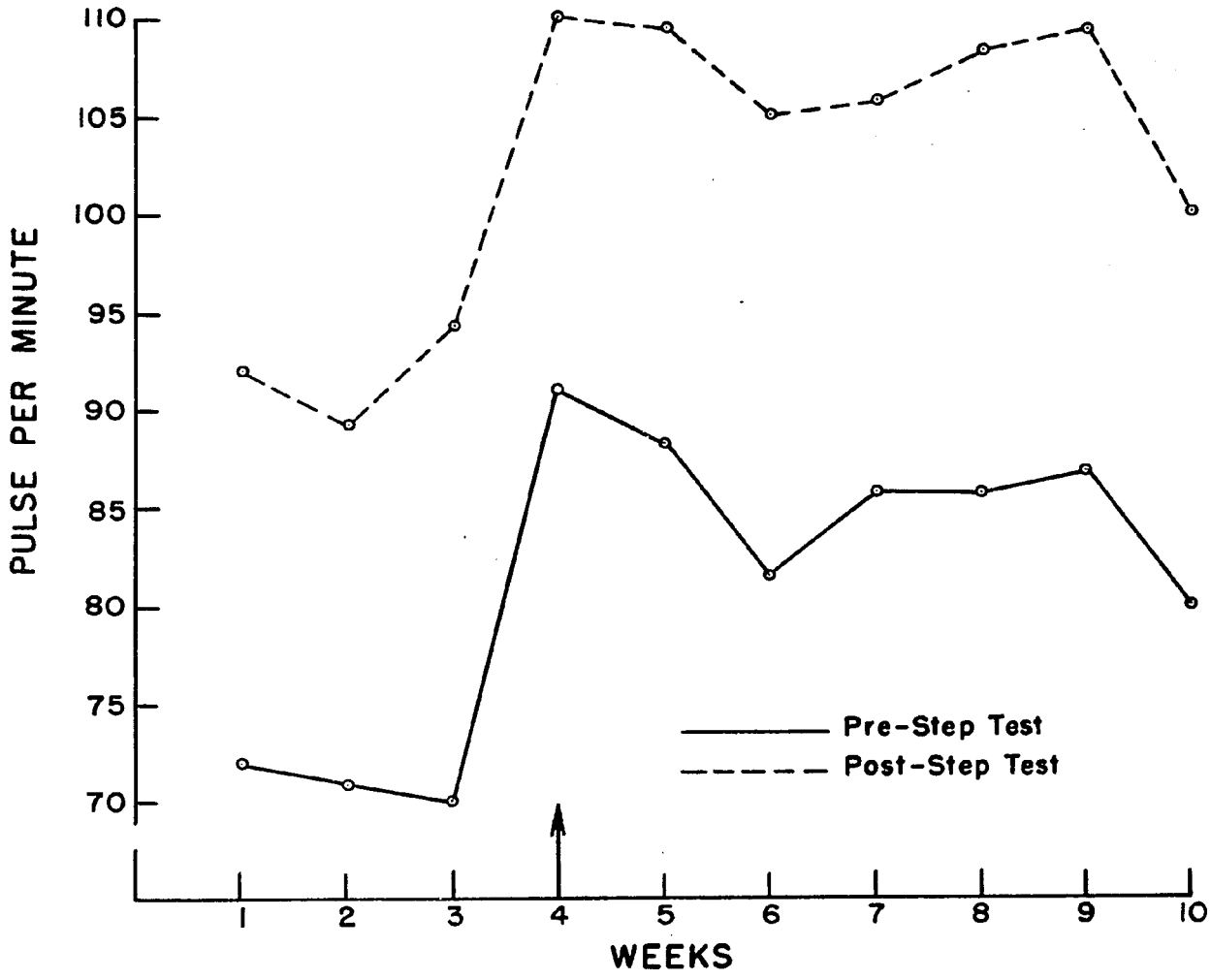


Fig. 7. Pulse Rate Weekly Mean Values of the Control Group

After practice the pulse rate became more erratic due to the strenuousness of the practice sessions. The fact that the difference between the pre-step test and post-step test pulse rate was not so great as the pulse rate taken before practice indicated that the step test was probably not much more vigorous than the scrimmage they had just been doing.

The fact that the control group had had immediate activity particularly after the fourth week is pointed up in the means in Figure 7. The resting pulse was not consistent as was the pulse of the experimental group. Again, at the fourth week, the pulse was as high as the pulse of the experimental group. The fact that the control group's pulse rate was not as high as the post-practice rate of the experimental group leads one to assume that the activity was not as vigorous, especially since the post-step test rate increased a great deal more than the experimental group.

Grip Strength. -- A reliability coefficient of .88 was obtained from two consecutive days of testing. This was determined by the Pearson product-moment coefficient of correlation.

In order to determine whether the difference between the pre-practice grip strength means and the post-practice means was significant, a *t*-test was made. Table 11 reveals the means and *t*-value for the experimental group.

TABLE 11

TOTAL GRIP STRENGTH MEANS AND t-VALUE OF THE EXPERIMENTAL GROUP BEFORE AND AFTER BASKETBALL PRACTICE

Condition	Degrees of Freedom	Means in Kilograms	Difference Between Means	t-Value
Pre-Practice	21	116.2	-4.2	5.43*
Post-Practice	21	112.0		

* Significant at 5% level.

From the means obtained, it can be seen that there was a decrease in grip strength of 4.2 kg. from the pre-practice to the post-practice testing. This difference had a t-value of 5.43 which was significant at the 5 per cent level of confidence. Since there was a loss in strength after practice, there was an indication of the presence of some fatigue.

Table 12 reveals the means and t-values of the experimental group's grip strength for three periods of time.

The test results of the first seven testing sessions and the first week in January demonstrated a decrease of 1.9 kg. in the means of the grip strength for the experimental group. The t-value obtained of 1.64 was not significant at the 5 per cent level of confidence. However, between the first week in January and the last week of testing and again between the first seven and the last week, there was found increases of 6.4 kg. and 5.0 kg., respectively. The t-values

of 4.75 and 3.10, respectively, were significant at the 5 per cent level of confidence. These significant increases revealed that the experimental group gained in strength from the beginning to the end of the season and also gained significantly from January to the end. The fact that a non-significant decrease occurred between the first seven and the first week in January demonstrated that the group neither lost nor gained significantly in grip strength.

TABLE 12

PRE-PRACTICE GRIP STRENGTH MEANS AND *t*-VALUES OF THE EXPERIMENTAL GROUP FOR THREE TEST PERIODS

Pre-Practice Test Periods	Degrees of Freedom	Means in Kilograms	Difference Between Means	*t*-Values
First Seven	19	115.8	-1.9	1.64
First Week in January	19	113.9		
First Week in January	21	112.4	6.4	4.75*
Last Week of Testing	21	118.8		
First Seven	19	115.8	5.0	3.10*
Last Week	19	120.8		

* Significant at 5% level.

Table 13 shows the grip strength means and *t*-values for the control group for the same periods of time as the experimental group.

As Table 13 reveals, there was a decrease in grip strength for the control group from the first seven to the

TABLE 13

GRIP STRENGTH MEANS AND *t*-VALUES OF THE CONTROL GROUP FOR THREE TESTING PERIODS

Test Periods	Degrees of Freedom	Means in Kilograms	Difference Between Means	*t*-Values
First Seven	8	117.8	-3.8	1.96
First Week in January	8	114.0		
First Week in January	10	112.8	2.8	1.33
Last Week	10	115.6		
First Seven	8	117.9	0.1	0.00
Last Week	8	118.0		

first week in January. This decrease of 3.8 kg. produced a *t*-value of 1.96 which was not significant at the 5 per cent level of confidence. Between the first week in January and the last week of testing, there was seen an increase of 2.8 kg. However, this increase which had a *t*-value of 1.33 was not significant at the 5 per cent level of confidence. Between the first seven and the last week there was an increase of only 0.1 kg. This was too small to warrant calculating a *t*-value and consequently was not significant. This indicated that the control group did not lose any grip strength over the period of time but neither did they gain any significant amount.

Figure 8 represents the weekly response of the experimental and control group to the grip strength test. After each practice session of basketball, the experimental group

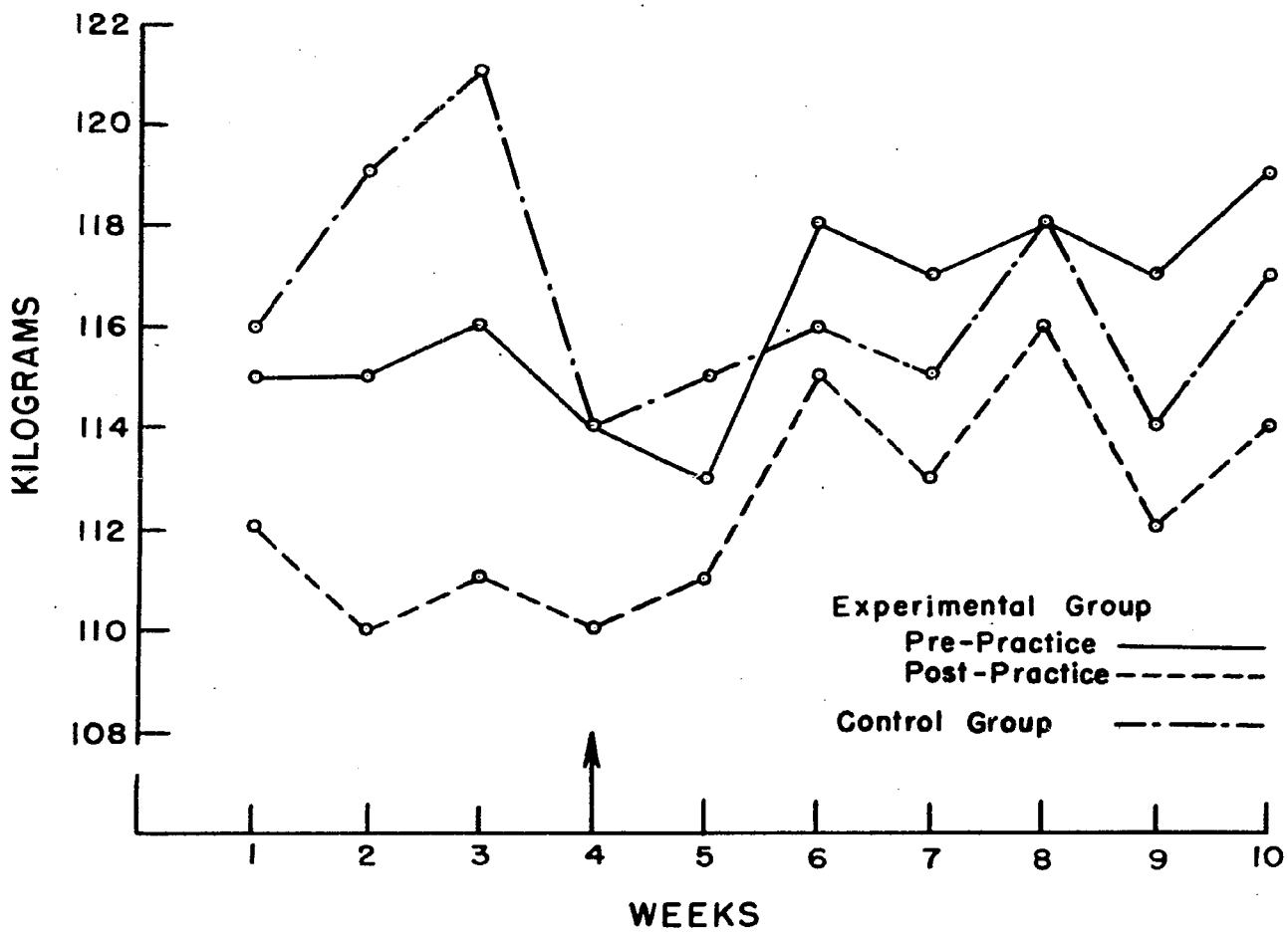


Fig. 8. Grip Strength Weekly Mean Values

experienced a decrease in strength yet increased their pre-practice grip strength as the season progressed. Again at the fourth week there was a decrease in grip strength from that of the pre-vacation period. However, in both the experimental and control group this decrease was not significant. The control group's response was not too dissimilar from the experimental group post-practice measurements particularly after the fourth week.

Subjective Data. -- A questionnaire was filled out by each member of the experimental and control group at each testing session. A record of their sleeping and eating habits was taken as well as any incidents of illness. In addition, the amount of exercise the groups had had previous to the testing and any academic examinations taken or scheduled were recorded. The height of each individual was taken at the beginning and end of the testing season.

Table 14 summarizes the hours of sleep, per cent eating breakfast and the per cent reporting colds in the experimental and control group.

From Table 14 it can be seen that the sleeping habits of both groups were fairly consistent throughout the testing season. Percentage-wise the experimental group consistently ate breakfast more often than the control group. There was one boy in each group who habitually did not eat breakfast. However, there was some irregularity in both groups. Lunches were eaten regularly by both groups. There were only four isolated cases reporting no lunch on any one day.

TABLE 14

SUMMARY OF WEEKLY MEANS OF SLEEPING AND EATING HABITS AND EVIDENCE OF COLDS OF THE EXPERIMENTAL AND CONTROL GROUP

Weeks	Hours Sleep		Per Cent Eating Breakfast		Per Cent With Colds	
	Experimental	Control	Experimental	Control	Experimental	Control
1	7.0	7.6	72	54	21	10
2	7.0	7.7	74	56	23	7
3	7.0	7.7	65	44	44	21
4	7.07	7.1	74	43	49	20
5	7.05	7.3	80	52	57	30
6	7.03	7.2	74	55	56	33
7	7.2	7.2	65	60	62	14
8	6.9	7.2	88	45	61	40
9	6.8	7.2	50	53	67	28
10	6.9	7.0	71	55	76	21

In reporting any evidences of illness, the vast majority reported colds. Table 14 shows the increased percentage of colds in the experimental group. There were less incidences of colds in the control group and apparently the number did not steadily increase. Among the experimental group, there were two cases of sore throat, three with stomach ache and four with flu. These were scattered throughout the testing season. Among the control group two members reported upset stomachs, one with a headache, one with flu and one with sinus infection.

In summarizing the exercise the groups had previous to the testing, it was found that the two groups had approximately the same amount. For the experimental group, only one member had had any previous exercise. The one boy had a wrestling class four hours earlier. In the control group the members had no previous exercise up until the fourth week. Starting with the fourth week, ten of the eleven had a basketball technique class just prior to the testing sessions. The one member who did not, had a swimming class four hours before the testing session.

The record of academic examinations taken and scheduled showed only scattered ones throughout the testing season.

A record of weight was taken each testing session. For the experimental group, weight was recorded before and after the practice session of basketball. The control group had a record of weight taken once each testing session. Table 15 summarizes the results of the weight records.

TABLE 15

SUMMARY OF PRE-PRACTICE WEIGHT RECORDS OF THE EXPERIMENTAL AND CONTROL GROUP

Group	Number in Group			Mean Number of Pounds	
	Gained	Lost	No Change	Gained	Lost
Experimental	14	5	3	4.3	3.2
Control	6	5	0	6.1	2.6

The experimental group had a relatively small gain and loss in weight as can be seen in Table 15. The control

group as a whole gained more weight and lost less than the experimental group. These changes were gradual throughout the testing season. For the experimental group an average of two pounds was lost between the pre-practice recording and the post-practice recording.

A recording of the height of each member of both groups was taken at the beginning and the end of the testing season. The experimental group had eleven members gain an average .5 in. The control group had six members gain an average of .7 in.

CHAPTER V

CONCLUSIONS, DISCUSSION AND RECOMMENDATIONS

The purpose of this study was to determine the effects of practice sessions of basketball on the freshman basketball squad by the use of selected tests for measuring fatigue. Tests were selected which had shown promise of detecting the fatigue state in individuals and which could be used effectively by coaches and physical education instructors. They were patellar reflex, reaction time, pulse rate before and after a step test and grip strength. In addition data were collected on weight, height, and such subjective information as hours of sleep, eating habits, incidences of illness, academic examinations and previous exercise.

The experimental group was composed of the entire freshman basketball squad at Iowa State College, numbering twenty-two. The control group consisted of eleven volunteer freshman men majoring in physical education but not in training for any sport at the time.

Testing started November 22, 1954, and continued through February 28, 1955. Within this period of time there were twenty-six testing sessions. The experimental group was measured in the selected tests before and immediately after a practice session in basketball in the late afternoon.

The control group was tested once at the same time as the experimental group.

In order to find out whether there was a significant difference between the pre- and post-practice means of the experimental group, t-tests were run on the group means of all four tests. This was done to find out the effect of the practice sessions on the scores of the various tests. In order to determine the effect of the practice season on the test scores, t-tests were run on sets of data for three different periods of time. They were: (1) first seven pre-practice mean scores and first week in January pre-practice mean scores, (2) first week in January pre-practice mean scores and last week of testing pre-practice mean scores, and (3) first seven pre-practice mean scores and last week of testing pre-practice mean scores. The t-tests were calculated on the same three periods of time on the mean scores of the control group.

Weekly mean scores on all four tests for the experimental and control group were calculated and presented in graphical form.

Results of the analysis of the data were as follows:

1. There was a significant mean increase in the threshold of the patellar reflex following the basketball practice sessions indicating that the squad was more fatigued than they were previous to the practice sessions.
2. The faster response of the squad to the reaction time

test showed that the practice sessions were not long enough nor fatiguing enough to cause a lessening of ability to respond.

3. There was a significant mean decrease in grip strength following the practice sessions in basketball which indicated the presence of some fatigue.
4. Whenever the data showed trends toward altered responses in pulse rate, reaction time and grip strength from the beginning to the end of the season, it was always in favor of more efficiency in the group.
5. The patellar reflex indicated a slight mean increase in the number of degrees necessary to elicit a response from the beginning of the season to the end, but the difference was not significant.
6. A vacation period had little or no effect on the mean scores of the reaction time, pulse rate and grip strength when compared with either the first seven test periods or the last week.
7. The patellar reflex had a significant decrease in the number of degrees necessary to elicit a response following the vacation period. This seemed to indicate that the vacation had afforded some rest.
8. There was a significant mean increase in the number of degrees necessary to elicit a response of the patellar reflex from the vacation period to the end of the season.

9. The control group responded similarly to the basketball squad except in two instances. The patellar reflex increased significantly in the number of degrees necessary to elicit a minimum response from the beginning to the end of the season. There was no significant increase in grip strength from the beginning of the season to the end for the control group.

Conclusions. -- The hypothesis that a complete recovery will be made between practice sessions of basketball and that this recovery will be reflected in the pre-practice test results from the beginning to the end of the season is accepted because:

1. The patellar reflex test results did not change significantly.
2. The reaction time test results decreased significantly indicating a faster reaction time.
3. The pulse rate before and after a step test lowered significantly indicating a better condition at the end of the season.
4. The grip strength test results improved significantly resulting in a stronger grip at the end of the season.

Discussion. -- By comparing the results of the four tests for the three periods of time of the experimental and control groups, it was possible to ascertain the difference or similarity between the groups. As has been noted

previously, the first week in January test results were used to determine whether a month of vacation which included a week of academic examinations would have any effect upon test results. For the experimental group, the results were all favorable to the group for the four tests between the first seven testing periods and the first week in January. However, for the control group there was one result which had not been anticipated. Ten of the eleven members of the control group had a basketball technique class scheduled just previous to the testing session. This class started in January. Therefore, the results of the first seven sessions and the first week in January cannot be compared since a resting pulse was impossible to attain.

From January to the end of the testing season (a period of approximately two months) a somewhat different picture was presented. The number of degrees necessary to elicit a minimal response in the patellar reflex test increased significantly for both groups. The increase assumed the presence of more fatigue at the end of testing than was obvious in January. Another assumption that could be made is that the vacation period had afforded some rest; hence, a lower patellar reflex was revealed upon returning to college. The other test results for both groups indicated changes which were in the direction of less fatigue. It should be noted here that the pulse rate for the control group decreased significantly between January and the end of

the testing season. A lowering of the pulse rate over a period of time usually denotes better physical condition. However, since the pulse rate for the control group after January was not a resting pulse, it was impossible to ascertain whether the lowered rate was due to better physical condition or less activity just previous to the testing.

From the beginning of the testing season to the end, all test results showed an improved condition in the experimental group. Again the control group showed a significant increase in the patellar reflex and significant increases in pulse rate. The same explanation of the added activity might be assumed to be the cause in this instance as in the other.

In the over-all picture of the experimental group and the control group, the similarity between them was very apparent. Since the control group was composed of physical education majors, it was logical that they would participate in an activity class of some kind during the day. However, it was not anticipated that such a class would be scheduled immediately preceding the testing session. Since the pulse is extremely sensitive to exercise, the differences between the experimental and control group were, in this case, understandable. The only other difference lay in the patellar reflex from the beginning of the season to the end. Both groups experienced an increased patellar reflex threshold, but the increase for the experimental group was not

significant. The added activity for the control group might be the explanation for this result. The reaction time and grip strength for the control group were apparently not affected by this activity. A partial explanation for the response and the reaction time test could be that exercise first decreases reaction time and then increases as fatigue sets in. The grip strength of the control group increased slightly but it was not a significant increase. It is the opinion of the writer that the patellar reflex test is too time consuming to be used efficiently by coaches and teachers of physical education where time is an important factor.

Recommendations. -- With the conclusions of this study in mind, the writer wishes to make the following recommendations for further study:

1. A similar study using varsity basketball players as subjects might indicate the stress of competition on the players by comparing the results with those of the practice sessions. Also a study of varsity players throughout a season with the element of competition included might reveal a different set of results from the beginning of the season to the end.
2. Similar studies on other varsity athletic teams such as football, swimming and tennis might reveal differences in fatigue conditions. Also a comparison of results as to the general outcome from the beginning of the season to the end might indicate the condition

of the team as revealed by the tests.

3. A study using junior or senior high school athletes as subjects should be made to corroborate the findings of this study.
4. Further exploration of the pulse rate might give a more complete picture of this response since the pulse rate is extremely sensitive to exercise and other variables. A regular check on the pulse count on individuals throughout a basketball season in the late afternoon and evening could add knowledge to the recovery pulse as well as to the stress of the activity concerned.
5. Further exploration of the patellar reflex test by working out intercorrelations with clinical tests of fatigue such as lactic acid concentration might improve the understanding of the patellar reflex test as a measure of fatigue.
6. Physical educators should be investigating the question of how much stress is put on individuals as a result of various activities. Subjecting any group of individuals to physical activity and carefully measuring physiologic and/or psychologic responses over a period of time should add knowledge to the general area of fatigue.

APPENDIX A

NAME_____AGE_____

Hours sleep last night_____

Did you eat breakfast this morning?_____

Did you eat lunch this noon?_____

Do you have a cold or any other symptoms of illness?_____

_____

Have you had any previous exercise today?_____

If so, when?_____

What kind?_____

Any scheduled exams?_____When?_____

Fig. 9A. Questionnaire of Subjective Data

APPENDIX B

STANDARDIZED DIRECTIONS FOR ADMINISTERING TESTS

Patellar Reflex Test:

Equipment:

1. Table
2. Patellar reflex instrument

Directions to subject:

1. Sit on table with right leg over base of instrument, lower leg hangs freely over edge of table
2. Sit in an upright position, relaxed

Directions to tester:

1. Adjust instrument so that the hammer at rest touches the patellar tendon. The needle attached to the end of the hammer should register 90 deg. in this position.
2. Adjust instrument to compensate for the width of the subject's thigh. Move the hammer arm closer or farther away from the standard. This will allow the hammer to strike the patellar tendon.
3. Pull the hammer back and allow it to swing freely hitting the patellar tendon. The weakest blow (least number of degrees) the hammer falls and still evoke a response will determine the threshold.
4. Record the least number of degrees as the threshold of the patellar reflex.

Reaction Time Test:

Equipment:

1. Free wall space at least 5 ft. in width
2. Meterstick chronoscope

Directions to subject:

1. Stand comfortably in front of meterstick chronoscope with left arm at side.
2. Place the forefinger of the right hand opposite the meterstick at approximately the 16 in. mark. Your finger may be as close as possible, but do not touch stick or board with finger or hand.
3. Keep your eyes on the red mark. As soon as the tester says "Ready" watch for the fall of the stick. Stop the fall of the stick as quickly as you can with your forefinger.

Directions to tester:

1. Give the subject a verbal signal of "Ready" before you release the meterstick.
2. After the "Ready" signal vary your release time from one to four seconds so that the subject cannot establish a definite rhythm to your release.
3. Try to avoid any overt movement prior to your release which may give the subject a clue.
4. Record the fall of the meterstick in one-eight inches reading from the 18 in. mark.
5. The subject will be allowed five trials and his score will be the average.

Pulse Rate:

Equipment:

1. Sixteen inch bench
2. Stop watch
3. Metronome

Directions to subject:

Pre-practice:

Pre-exercise:

1. Take radial pulse in a sitting position for fifteen seconds until two fifteen second readings are identical. Give your fifteen second score to tester.

Stool-stepping:

1. Stand facing the bench
2. On signal "Go" by tester, place your left foot on bench and step up, bring right foot up on bench beside left (knees are straight at this point), place left foot back on floor and then place right foot on floor.
3. The rhythm for the above four count cycle is set by the metronome--it will be started before your exercise begins.
4. Repeat the above exercise thirty times for one minute keeping in rhythm with the metronome (one hundred and twenty times per minute).
5. Body position for the exercise

a. Arms are bent at elbows at right angles
b. Elbows are held close to the body at all times
c. Step on the bench with the body weight over the feet

Post-exercise:

1. At signal of "Stop" by tester, turn immediately and sit down on bench.
2. You are given five seconds to locate radial pulse. At signal "Go" count pulse for one full minute and give count to tester.

Post-practice:

1. Report immediately to testing room, sit down and locate radial pulse. At signal "Go" by tester, count pulse for one full minute and give tester score.
2. Stool-stepping and post-exercise count same as given for pre-practice.

Directions to tester:

1. Give all starting signals as "Go."
2. Give all stopping signals as "Stop."
3. Start the metronome well in advance of step test and exercise so that subject can feel rhythm of exercise.
4. Watch body position during exercise so that all subjects are conforming. Caution subject not to lead with head or bend at waist for stool-stepping.

5. Allow subjects five seconds to locate pulse after step test and after practice before starting count and exercise.
6. Multiply the fifteen second count by four and record as full minute.
7. Watch subjects on using fingers over pulse and not the thumb.

Grip Strength:

Equipment:

1. A.T. Stoelting dynamometer

Directions to subject:

1. Stand holding dynamometer in right hand with the arm hanging naturally down to side but not touching the body.
2. Squeeze the dynamometer once to fullest extent
3. Repeat the above with the left hand

Directions to tester:

1. Watch subject for infringement of correct body position.
2. Do not allow a final thrust or a swinging of the dynamometer.
3. Record both readings (right and left hand) in kilograms.

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