THE EFFECTS OF SPEED AND PACE
CERTAIN PHYSIOLOGICAL MEASURES

Thesis for the Degree of M. A.

MICHIGAN STATE UNIVERSITY

Douglas Gordon Stuart

1956

THE EFFECTS OF SPEED AND PACE TRAINING ON CERTAIN PHYSIOLOGICAL MEASURES

By

Douglas Gordon Stuart

A THESIS

Submitted to the School of Graduate Studies of Michigan
State University of Agriculture and Applied Science
in partial fulfillment of the requirements
for the degree of

MASTER OF ARTS

Department of Health, Physical Education
and Recreation

1956

ACKNOWLEDGMENTS

I wish to express my sincere gratitude to Dr. Henry J. Montoye of the Department of Health, Physical Education and Recreation for his supervision and guidance throughout the study and preparation of this paper.

Dr. Wayne D. Van Huss of the same Department and Dr. W. D. Collings of the Physiology Department displayed an interest in the study that was always a source of encouragement.

Dr. Wilma Brewer, Dr. Dena Cederquist and Mr. Richard Slocum of the Department of Foods and Nutrition conducted the blood analyses, and have my full gratitude.

Mr. William Pierson drafted Figure 3 as well as criticising the text of this paper. Such generous help is deeply appreciated.

Mr. John P. Walter deserves mention for helping design the training systems and collecting the data.

Mr. Karl A. Schlademan, head track coach at Michigan State University and his able assistant Mr. Francis C. Dittrich gave permission for the four subjects to participate in this study. For this cooperation they are more than thanked.

D.G.S.

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AN ABSTRACT

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ABSTRACT

Statement of the Problem

The problem stated was: "What are the effects of speed and pace training on the electrocardiogram, basal metabolism, basal oxygen pulse, arterial blood pressure, blood hemoglobin level and five minute step test score of trained college freshmen?"

Speed and pace training are empirically considered essential components of middle distance (mile and half-mile) race training. Little is known of the relative physiological effects of either and it was felt that such study would contribute information of practical as well as theoretical value.

The physiological measures were selected on the basis of the interest they have aroused in the field of physical fitness research. As a subordinate investigation the inter-relation of certain of these measures was examined.

Experimental Procedure

Four members of the freshmen track team were prepared for the study by undergoing a season of cross-country running. This preliminary training was considered necessary to condition the subjects for the intensity of the nine week speed training and the nine week pace training programs. Before, during and after each of the programs a determination was made of each athlete's electrocardiogram, basal

metabolic rate, basal oxygen pulse, change in arterial systolic pressure from lying to standing, blood hemoglobin level and five minute step test score.

The raw physiological and training data were analyzed graphically to detect physiological changes and improved athletic performance. Statistical treatment was applied wherever considered necessary and necessitated computation of analyses of variance, student "t"s and coefficients of correlation.

Results and Discussion

There was no statistical or graphic evidence of any physiological changes or improved athletic performance throughout the study. The relative effects of speed and pace training could not be assessed as each had no effect on any of the subjects. It was not possible to determine whether this failure to produce any athletic improvement or physiological changes was due to too short a total training time or to the actual program being too mild in the amount of running undergone each day. Such a result illustrated the duration and intensity of training needed to elevate a freshman from one level of athletic achievement to the next is at least beyond that attempted in this study. It further illustrates that freshmen can cope with far more intensive running programs than usually attempted, for both the speed and pace training program were the most rigorous ever attempted by any of the subjects, but the over-all effect was maintenance of the "Status quo."

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Some statistically significant correlations were observed for the subjects between certain of the measures. Mostly these significant relationships were between measures that contained common factors. However, the relationship between basal O_2 pulse and step test score, a comparison of two relatively "isolated" physiological mechanisms, was close enough to justify a further study of basal oxygen pulse as an indicator of physical fitness.

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CHAPTER I

INTRODUCTION

A fundamental aspect of physiological research is the study of the body's reaction to disease and of the diseased state. Similarly, study of the body's reaction to the stress of athletic training and of the trained state augments physiological knowledge.

Such study of the effects of athletic training on various physiological measures has two-fold value: it leads to a concept of the duration and intensity of training needed to promote improvement in physical function and knowledge of the measures themselves is further developed by noting their reactions to such stress.

Statement of the Problem

The problem stated is: "What are the effects of speed and pace training on the electrocardiogram, basal metabolism, basal oxygen pulse, arterial blood pressure, blood hemoglobin level, and five minute step test score of trained college freshmen?"

Justification for the Study

The physiological measures studied were selected on the basis of the interest they have aroused in physical fitness research. The step test score is the only selection universally accepted as a valid indicator of circulatory fitness and as being significantly affected by athletic training. It was felt that data on the other five measures, though collected on but four subjects, would contribute information to a field of conflicting opinion.

If the measures are affected by "middle distance" training, a valuable opportunity exists to observe two factors of such training. Speed and pace training are empirically considered to be essential components of training for the half-mile and mile races, the "middle distances." Nothing is known of the relative physiological effect of each and it was hoped that the study would contribute information to the problem.

Conventional studies of the effects of athletic training either consist of subjecting a sedentary group to a period of athletic training or testing athletes before, during and after a competitive season. With the former method the group have to become adapted to athletic activity by a graduated athletic program, meaning that a uniform system of training cannot be conducted. In the latter case there is doubt that athletes are in the "untrained" state before a competitive season, and a comparison to the mid-season state is not necessarily of the "untrained" to the "trained" state.

In an attempt to avoid such considerations the following experimental design was adopted. A group was conditioned to a highly trained state before the study was begun, then they were subjected to two standardized training programs of hitherto unattempted intensity. This was a deviation from the usual pattern that can only be validated by further experimentation.

Limitations

Due to the need for a carefully supervised training program only four subjects formed the experimental group. Conclusions which may be significant with a larger number of subjects are not necessarily significant with only four subjects.

Each training system was limited to approximately nine weeks--an unavoidably short period. Physiological effects that may not be seen in nine weeks could quite possibly be evidenced in a longer training period.

Uncontrollable variables such as "motivation," "emotionality," "fatigue" etc. were not considered measurable and as such were not discussed statistically.

No medical interpretations were attempted of the electrocardiograms. Rather, the amplitudes and intervals between the P, R and T waves of leads I, II, III, aVf, aVl and aVr were analyzed and the electrical axes of the QRS complexes calculated.

Definition of Terms

The Trained State: A state of improved physical performance the result of adaptation to regular athletic training.

Pace Training: A system of training based on repetitive efforts of running at a set speed until such speed can no longer be maintained.

Speed Training: A system of training based on repetitive maximal speed efforts at a set distance.

Electrocardiogram: a graphic record of the electrical activity of the heart.[1]

Standard Limb Leads: Positions from which electrodes lead off the electrical activity of the heart from the body surface in three combinations; lead I, right arm - left arm; lead II, right arm - left leg; lead III, left arm - left leg.

Augmented Unipolar Limb Leads: Placement of electrode in a direct lead to the central terminal of the electrocardiograph machine and the other on the right arm, left arm and left leg for leads aVr, aVl and aVf respectively.

P Wave: An indication of the spread of excitation over the auricles that precedes auricular contraction.

R Wave: An amplitude that depends on the direction of the electrical axis of the heart (see later) during the particular moment at which electrification of the main mass of the walls of the ventricles is beginning, an activity that precedes ventricular contraction.

T Wave: Possibly a representation of "the repolarization of the sinus node and action currents from the heart muscle"[2] based on the observation that the T wave and end of venticular contraction are co-incidental.

P-Q Interval: The interval between the beginning of P and the beginning of Q (R when Q is missing). This is thought to show the time relation between the auricular and ventricular contractions.[3]

Q-T Interval: The interval between the beginning of the Q (R when Q is missing) and the end of the T wave. This total duration is approximately the same as the mechanical systole but there is doubt that it can be used to determine the contraction time of the heart.

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[1] Houssay, Bernado A. Human Physiology, 2nd Ed., pp. 122-140, McGraw Hill Book Co., New York, 1955.

[2] Foerch, Richard L. A Comparison of Electrocardiographic Measurements of Athletes and Non-Athletes at Michigan State University, p. 4. (Unpub. Master's Thesis, Michigan State College, 1951).

[3] Houssay, op. cit., p. 124.

QRS Instantaneous Electrical Axis: A vector that gives an indication of the voltage resulting from the electromotive forces developed during the QRS complex and indicating the direction in which the current flows.[4]

Basal Metabolism: "The irreducible energy cost of maintenance during complete rest."[5] It is calculated as a rate of heat production based on reading post-absorptive oxygen consumption, i.e., basal metabolic rate = Calories per hour per square meter of body surface area.

Basal Oxygen Pulse: The quantity of oxygen utilized by the body, in the resting post absorptive state, per heart beat. It is usually expressed in ccs.O_2 per pulse and, for comparative purposes and due to its direct correlation with body weight,[6] per kilogram of body weight.

Arterial Blood Pressure: The force exerted by the blood on the walls of the arteries. The pressure is at its greatest during the contraction phase of the heart's action (systole) and at its least during the heart's relazation phase (diastole); hence the terms systolic and diastolic arterial blood pressure.

Blood Hemoglobin Level: The grammes of hemoglobin, a pigment in the red blood cells, per 100 ccs. of blood. Hemoglobin is termed the "respiratory" pigment by virtue of its role in taking up oxygen from the lungs, transporting it in the circulating blood, delivering it to the body tissues, and helping carry carbon dioxide back from the tissues to the lungs. But for hemoglobin, blood could only transport 1/6th the amount of oxygen.[7]

Five Minute Step Test Score: The number of pulses for thirty seconds, thirty seconds after a subject has completed 5 minutes' stepping up and down a 17" stool with each of the four steps of each cycle taking 0.5 seconds.

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[4] Ibid., p. 128.

[5] Brody, Samuel, Bioenergetics and Growth, p. 59, Reinhold Publ. Corp. New York, 1945.

[6] Ibid., p. 932.

[7] Houssay, op. cit., p. 27.

CHAPTER II

REVIEW OF THE LITERATURE

The Electrocardiogram

It is becoming increasingly difficult to deny that athletic training has an effect on the electrocardiogram. Many authorities have resisted such a belief. Katz[1] reflects this opposition, stating that "nothing in the ECG gives information regarding the power of the heart, vigor of contraction and tone, only the presence or absence of injury, the character and spread of excitation and its point of origin . . ."[2] The literature on training effects is not voluminous in English-speaking countries and Robertson[3] believes that too little attention has been given to continental views, a neglect due in the main to language difficulties.

Lepeschkin[4] reviewed electrocardiographic studies, mostly European, and, in a summary devoted to athletic training effects, stated that:

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[1] Katz, L. N. Electrocardiography, 2nd Edit., p. 80, Lea and Ferbiger, Philadelphia, 1947.

[2] Ibid.

[3] Robertson, Douglas, Translator's preface to Clinical Electrocardiography, M. Holzmann, Staples Press, London, 1952.

[4] Lepeschkin, E. Modern Electrocardiography, pp. 263-4, Williams & Williams, Baltimore, 1951.

1. The P wave is lowered.
2. The P-R interval is prolonged, beyond .019 seconds in 5-20% of all cases studied.
3. This prolongation is due to an increase in vagal tone, proven by its return to normal following atropine injection or exercise.
4. The QRS electrical axis in a large group of athletes averaged +50° (with normal subjects the axis tends to +60°).[5]
5. No relation has yet been discovered between the duration of QRS and its axis deviation.
6. The T wave is increased, especially in long distance track men and in champions.
7. In lead III, T is inverted in 10% of the cases.
8. The development of an inverted T in lead III and an inversion of T in leads II and III has been ascribed to excessive training.
9. A pathological ECG was found in only four of 850 champions even after exhaustive competition.
10. The Q-T interval is prolonged especially in outstanding athletes and in long distance men where it may reach +30%.

Lepeschkin's review is a valuable supplement to the more widely read American studies.

Tuttle and Korns[6] quote Kraus and Nicolai's[7] finding that athletes' T waves were higher than non-athletes', though no other differences were noted. Von Csinady[8] and Reindell,[9] both working with large groups

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[5] Houssay, Bernardo A. Human Physiology, 2nd Edit., p. 129, McGraw Hill Book Co., New York, 1955.

[6] Tuttle, W. W. and Korns, H. M. "Electrocardiographic Observations on Athletes Before and After a Season of Physical Training." American Heart Journal 21:104, 1941.

[7] Ibid., citing Kraus, E. and Nicolai, E. Das Elektrokardiogramm des gesunden und Franken Menschen, Liepzig, 1910.

[8] Cureton, Thomas K. Physical Fitness of Champion Athletes, p. 143, The University of Illinois Press, Urbana, 1951, citing Von Csinady, E., "Sportzartalische Untersuchen 111. Mitteilong: vergleichende elektrokardiographische Untersuchen an Sporttreibenden be besonderer Berucksichtigung des EKG-Zeitwerte." Arbeitphysiologie 3:579, 1930.

[9] Ibid., p. 141 citing Reindell, H. "Kymographische und Elektrokardiographische Befunde am Sportheizen 1. Untersuchungen in Ruhe." Deutsche Archiv fur Klinische Medizin 131:385, 1937.

of athletes, established a longer P-R interval with the latter finding that the length of systole (as assessed by the Q-T interval) varied with the ability to perform in certain sports.

Hougerwerf's[10] widely publicized 1928 Amsterdam study found lower P waves but higher R and T waves for 260 Olympic athletes. On the contrary, Broustet and Eggenberger[11] found 33 normal ECG's in a group of 35 professional boxers, scullers, soccer players and cyclists.

A reason for the lowered P wave in athletes has been offered in both an Australian[12] and German study.[13] They maintain that a low P wave is associated with increased vagal and arterial tone and increased blood flow.

To illustrate the differences between athletes and non-athletes, data from the University of Illinois Physical Fitness Laboratory compares mean scores of 56 champion athletes[14] to 81 normal young men.[15] (See Table II, page 36.)

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[10] Ibid., p. 140 citing Hougerwerf, S., "Elektrokardiographische Untersuchen der Amsterdame Olympiade" Arbeitphysiologie 2:61,1929.

[11] Ibid., p. 141 citing Broustet, P. and Eggenberger, H., "L'elektrekardiographische des Sportifs," Journel de Medicine de Bourdeaux et du Sud-Oest 113:126, 1926.

[12] Cooper, E. L., O'Sullivan, J. and Hughes, E. "Athletics and the Heart. An Electrocardiographic and Radiological Study of the Response of the Healthy and Diseased Heart to Exercise." Medical Journal of Australia, 1:569, 1937.

[13] Cureton, op. cit., p. 144 citing Purjesz, B. and Von Csinady, E., "Effects of Changes of Position on the Human ECG." Rivista de Medicina Aeronautica, 3:106, 1950.

[14] Ibid., pp. 148-49.

[15] Ibid., p. 159 citing Wolf, J. G. "Electrocardiogram Standards for Normal Young Men" (Unpublished Master's Thesis, the University of Illinois, 1948).

With the same 56 Olympians, Cureton[16] recorded QRS axis deviations from + 137° to -34.5°. He claims that the athletes with the least left side hypertrophy tended to have the greatest left axis deviation and those with the smallest right diameter heart the largest right axis deviation.

Tuttle and Korns[17] followed 45 athletes in varying sports through a pre- to a post-competitive season and found no significant ECG differences in 43 of the subjects throughout this period.

Stauffer[18] established increased carbiovascular fitness for 15 varsity basketballers as they moved from pre- to mid-season and decreased efficiency as they went out of competition, but there were no significant changes in the ECGs throughout this period.[19]

Sesenbach[20] has listed, though not validated, 47 factors other than disease that can affect the ECG. Such factors must be taken into account when appraising any ECG study.

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[16] Ibid., p. 164.

[17] Tuttle, W. W. and Korns, H. M., op. cit.

[18] Stauffer, G. "The Effects of Conditioning on the Ballistocardiograms of Varsity Basketball Players," p. 50. (Unpubl. Master's Thesis, Michigan State University, 1955).

[19] Unpublished data collected by H. J. Montoye, W. D. Collings and G. Stauffer, Michigan State University, 1955.

[20] Sesenbach, W. "Some Common Conditions Not Due to Primary Heart Disease, That May be Associated with Changes in the ECG." Annals of Internal Medicine, 25:632,1946.

The only conclusion that can be drawn is that athletes have ECGs that vary from those of sedentary people but the duration and intensity of training needed to elicit such changes and their exact physiological interpretation are still unknown.

Basal Metabolic Rate

It is normally anticipated that athletic training will to some degree both develop the musculature and increase cardiovascular fitness. Different forms of training may elicit diverse effects. For instance, weight lifting should develop the musculative without increasing cellular efficiency and the opposite is possible with long distance running.

Any increase in muscular development should increase the resting body's oxygen requirements while any increase in cellular efficiency should decrease this requirement. Perhaps this is the reason that studies of the effect of training on basal metabolism have often produced conflicting results. It is suggested that the type of training undergone is often neglected in the examination of the results of such experiments

> If during a period of training the gain in cellular efficiency overbalances the gain in the mass of body protoplasm then a fall in the B.M.R. will result. If, on the other hand, there occurs a considerable increase in the size of the muscles due to formation of active protoplasm, then this may overshadow the gain in cellular efficiency and result in an increase in metabolism. Lastly, if the increase in cellular efficiency should be just counterbalanced by the

production of protoplasm the B.M.R. of the individual will remain unchanged during a period of physical training.[21]

The Schneider and Foster study that provoked this discussion consisted of recording the B.M.R. of 9 varsity athletes in and out of training and 3 sedentary subjects throughout a six week exercise program. Seven of the athletes reduced their B.M.R.'s in training, one did not change, and one increased. Of the sedentary group, training increased pronouncedly the B.M.R. of one, moderately increased the B.M.R. of another, and moderately decreased the metabolism of the third.

An earlier study by Schneider with Clark and Ring[22] of one athlete in and out of competitive training and 4 sedentary subjects undergoing a 6-14 week program of tennis, handball, and swimming, produced diverse results. The athlete had a higher B.M.R. out of training while 3 of the sedentary group lowered their B.M.R. during training, the other raising this index. All the sedentary group returned to their pre-training levels after the program was completed. This trend toward a lower B.M.R. during athletic training prompted the statement that "one of the results of physical training is an increase in the efficiency with which the life processes are carried on."[23]

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[21] Schneider, E. C. and Foster, A. C. "Influence of Physical Training on the Basal Metabolic Rate in Man." American Journal of Physiology 98:595, 1931.

[22] Schneider, E. C., Clark, E. W. and Ring, E. C. "Influence of Physical Training on Basal Respiratory Exchange, Pulse Rate and Arterial Blood Pressures." American Journal of Physiology, 81:255, 1927.

[23] Ibid.

Knehr, Dill and Neufeld[24] trained 14 subjects for 6 months on cross-country running three times a week. Though they were able to demonstrate marked improvement in physical performance, there were no significant changes in the B.M.R.'s.

Morehouse[25] tested a group of trackmen throughout a track season and failed to show an increased metabolism due to track training.

Steinhaus[26] carefully controlled the environments of four dogs, interspersing periods of nearly total inactivity with periods of daily treadmill runs of 6-12 miles. He was unable to note basal metabolic variations due to such periods of activity.

In the above studies the type of training selected would tend to promote increased cellular efficiency rather than an increase in muscle development.

On the contrary, Nielsen[27] studied the basal metabolic rate of 19 college girls throughout a swimming course. The B.M.R. of 15 of the group rose and the 4 that did not elevate their index were on a low carbohydrate diet that tended to reduce their B.M.R.

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[24] Knehr, C. A., Dill, D. B. and Neufeld, W. "Training and its Effect on Man at Rest and at Work." Amer. Journal of Physiology 138:148, 1942.

[25] Cureton, op. cit. citing Morehouse, L. "Basal Metabolism of Athletes in Training," p. 67. (Unpubl. Master's Thesis, Springfield College, 1937).

[26] Steinhaus, A. H. "Exercise and Basal Metabolism in Dogs." Amer. Journal of Physiology, 83:658, 1928.

[27] Ibid., p. 292 citing Nielsen, L. "The Effect of Physical Education on the Basal Metabolism of College Women," p. 510. (Unpubl. Master's Thesis, Univ. of Illinois, 1950).

Cureton cites Leilich[28] who tested the B.M.R. of 70 students at the University of Illinois to find that 13 top athletes averaged 7.5% higher than 20 sedentary young men.

Nylin,[29] in a broad physiological examination of two outstanding Swedish milers, calculated both B.M.R.'s to be above normal, thus refuting an earlier statement in this review that track training would tend, by promoting cellular efficiency, to reduce the B.M.R. However, one of the subjects was of endomorphic structure (5'10", 164 lbs.) and according to Nylin this would tend to outweigh considerations of the type of training to which he had subjected himself.

Benedict and Riddle[30] found that prolonged physical activity decreased the metabolism of pigeons and, with Harris,[31] decreased the B.M.R. of a dog 22% by prolonging an inactive state for several months.

On the basis of the studies reviewed, the assertion that a low B.M.R. may mean low cardiovascular condition[32] cannot be justified. A "yardstick" to assess the type of training undergone by subjects and the relative degree to which such training improves cellular

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[28] Cureton, op. cit. , p. 28 citing Leilich, Roy E. The Comparison of Various Education Groups on Basal Metabolism, p. 60, (Unpubl. Master's Thesis, Univ. of Illinois, 1948).

[29] Nylin, G. "Investigations on the Blood Circulations of Gunder Haegg and Arne Anderson," Cardiologica, 9-10:311, 1945-6.

[30] Benedict, F. E. and Riddle, D. "The Measurement of Basal Heat Production in Pigeons," Journal of Nutrition, 1:530, 1929.

[31] Harris, J. A. and Benedict, F. G. "A Biometric Study of Basal Metabolism," Carnegie Inst. Report No. 279, 1919, p. 245.

[32] Cureton, op. cit., p. 288.

efficiency and muscular development would be an asset to this field of study.

Basal Oxygen Pulse

There has been no work on the effects of training on basal oxygen pulse but some theoretical discussion is of such import that it would appear timely to develop this field of study.

Brody[33] maintains that the greater the blood volume pumped by the heart per pulse for an animal of given weight, the slower will be the pulse rate. The oxygen pulse per unit of body weight is then an index of systolic output or heart capacity, the usual limiting factor in hard muscular work.

A theory not to be neglected, is that of Brody and Kibler[34] who maintain that the rate of oxygen consumption is probably the same for a slow or a rapid pulse rate and it thus follows that high oxygen transport capacity is associated with high oxygen consumption per heart beat.

Henderson and Prince[35] have maintained that maximum oxygen pulse depends not only on the systolic discharge but also on the blood

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[33] Brody, Samuel, Bioenergetics and Growth, p. 932, Reinhold Publ. Corp., New York, 1945.

[34] Kibler, H. H. and Brody, S. "Growth and Development. LVII. An Index of Muscular Work Capacity." Univ. of Missouri Agricultural Experiment Station Research Bulletin, No. 367, 1943.

[35] Henderson, Y. and Prince, A. L. "The Oxygen Pulse and the Systolic Discharge." American Journal of Physiology, 35:106, 1914.

hemoglobin index. If this were true of basal oxygen pulse it would indeed be of use in assessing cardio-vascular fitness.

However, following computation of data collected by Henderson and Haggard[36] on members of a sculling crew, Brody [37] was forced to the conclusion that such a resting index may not always be a reliable index of work capacity. In this instance Brody calculated an oxygen pulse of .09 ccs. O_2/Kg. of body weight for two members of the crew and only .05 ccs. O_2/Kg. of body weight for a third member. He felt that there was a possibility that excitement may have altered the relation between pulse rate and oxygen consumption and as such this index was not nearly as valuable as an index based on working conditions. Such a conclusion can be drawn for all basal tests but as Henry[38] points out, tests of the resting circulation should always command a certain respect as an indirect reflection of the active system.

Brody[39] has prepared a chart that illustrates that athletic creatures (man, horses, dogs and cats) have higher oxygen pulses than non-athletic animals (beef cattle, "tame" rabbits and sheep).

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[36] Henderson, Y. and Haggard, H. H. "The Circulation and its Measurement." American Journal of Physiology, 73:193, 1925.

[37] Brody, op. cit., pp. 935-6.

[38] Henry, Franklin M. "Influence of Athletic Training on Resting Cardiovascular System." Research Quarterly, 25:28, 1954.

[39] Brody, op. cit., p. 935.

Bock and co-workers[40] present a famous marathon runner's O_2 pulse as .081 ccs. O_2/Kg. of body weight as compared with two sedentary adults indices of .059 and .054. This single study is the extent of comparative figures for athletes and non-athletes.

In summary, little is known of the value of the measure in the field of physical fitness research, but extensive experimentation seems more than justified.

Arterial Blood Pressure

In the absence of disease, marked changes in resting arterial blood pressure are transitory due to sensitive compensatory mechanisms. Poiseuille[41] was the first to calculate that pressure in the arterial system is diversely proportional to blood minute volume and peripheral resistance. In turn the minute volume is proportional to systolic discharge and to heart rate. This systolic discharge is modified directly by the physiological condition of the heart musculature and the venous return and inversely by the heart rate. The peripheral resistance is inversely proportional to the square of the cross sectional area of the blood vessels. Each of these factors is affected by athletic training but due to the restraint they impose on each

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[40] Bock, A. V. *et al*. "Studies in Muscular Activity. III. Dynamic changes occurring in Man at Work." *Journal of Physiology*, 66:136, 1928.

[41] Houssay, *op. cit.*, p. 178, citing Poiseuille, J. "Recherches sur les causes du movement du sang dans les vaisseaux capillaires." *Memoires presentes par divers savans a l'Acadamie Science de L' Institute de France.*

other the resultant arterial pressure tends to remain constant. This holds true for a body free from disease, a body in the highly-trained state, and a body beginning athletic training.[42]

Henry's[43] careful study of 18 athletes before, during and after a season of competitive athletics is in keeping with modern theoretical concepts of compensatory mechanisms. Beginning with the hypothesis that an increase in resting stroke volume should be accompanied by a corresponding decrease in heart rate, he illustrated that although training will affect each factor that regulates blood pressure, the over-all effect is homeostatic.

This study is concerned with changes in systolic pressure from lying to standing. Interest was initially aroused in this function after a series of original experiments led Hill[44] to the observation that "the effect of changing the position affords a most delicate test of splanchnic motor function," for it is only by vaso-constriction of the splanchnic blood vessels that the systolic pressure can be maintained when posture changes from the horizontal to the erect position.

The assertion that Hill introduced the arguments for a postural blood pressure test of condition[45] is not in keeping with Hill's

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[42] Ibid., p. 179.

[43] Henry, op. cit.

[44] Hill, Leonard, "The Influence of the Force of Gravity on the Circulation of the Blood," Journal of Physiology, 18:15, 1895.

[45] Cureton, Thomas K. Physical Fitness Appraisal and Guidance, p. 193, C. V. Mosby Co., St. Louis, 1947.

belief that "gravity exerts but little disturbing influence owing to the perfection of the compensatory mechanism,"[46] in man. Hill's sole interest and discussion in this field is related to proof that shock, anemia, hemorrhage and chloroform poisoning are largely affected by the position of the body.

However, Crampton went on to devise his blood ptosis test with the rationale that a test of the gravity resisting function of the heart is an estimate of the "efficiency of the influences which bring the blood to the heart in the upright position."[47] Crampton based this postulation on his observation that the function varied with the general state of the body, there being an increase in systolic pressure on assuming an erect position when a subject was fresh and a decrease when fatigued. His blood ptosis index is calculated from the changes in systolic pressure and heart rate when changing position and the standards for his index are based on the assumption that these two factors are directly related in this function. Crampton additionally claimed that this test could separate the highly-trained and normally healthy state with the fitter the subject the greater the likelihood of an increased vertical over horizontal systolic pressure. His test was widely acclaimed, McCloy maintaining that the index score

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[46] Hill, op. cit.

[47] Crampton, C. W. "The Gravity Resisting Ability of the Circulation, Its Measurement and Significance (Blood Ptosis)." American Journal of Medical Sciences, 20:721, 1921.

was even of use in predicting athletic performance on any given day.[48]

Conflicting data soon appeared. Crampton's belief that his test indicated the degree of physical and mental alertness was disputed by Scott[49] who found the test could not disqualify pilots incapable of flying on a given day. He compared Crampton's differentiation procedure to a medical differentiation that disqualified any pilot who displayed any three of the following symptoms:

1. increased psychomotor tension
2. prolonged secondary dilation of the pupils
3. relaxed peripheral circulation
4. nervous tics
5. nervous tremors

Of the group that were acceptable on the Crampton index, 118 qualified and 19 failed Scott's test and of the group disqualified by Crampton 37 passed and 26 failed Scott's test.

Schneider and Truesdell[50] could not demonstrate a high correlation between systolic and heart rate postural changes when they established for 2,000 young men a slight inverse relationship (r = -.213±.014) for these factors and stated that "the interdependence of the factors had been unduly emphasized."[51]

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[48] Ibid., citing personal communication from C. H. McCloy.

[49] Scott, V. T. "The Application of Certain Physical Efficiency Tests." Journal of the American Medical Association, 76:705, 1921.

[50] Schneider, E. C. and Truesdell, D. "Statistical Study of the Pulse Rate and the Arterial Blood Pressures in Recumberency, Standing and after Standard Exercise." American Journal of Physiology, 61:429, 1922.

[51] Ibid.

The rationale for McCloy's support of such a test is in conflict with a study by Larson[52] that gives a -.124 correlation of the index with 440 yard swim time.

Crampton's belief that the more healthy the person the more the likelihood of an increased systolic pressure on standing is not valid in light of Barach's[53] study that before a marathon race 10 subjects recorded an increase in systolic pressure on standing, 11 a decrease, and 3 were unchanged. Immediately after the race when the group could surely be labelled "in the fatigued state," five recorded an increase, twelve a decrease and three were unchanged. In similar vein, Rothacher[54] established a mean lying arterial blood pressure for 40 athletes of 124.3 mm. Hg. and for 40 non-athletes 127.4 mm. Hg. The standing means were 121.9 mm. Hg. for the athletes and 127.3 mm. Hg. for the non-athletes.

Despite the above studies an interest has prevailed in the postural change in blood pressure, as a test of cardio-vascular fitness.

Blood Hemoglobin

A major limiting factor in man's ability to perform strenuous activity is his oxygen supply to active protoplasm. Hence, changes

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[52] Cureton, op cit., citing Larson, L. A. "The Prediction of Success in Swimming 440 Yards." Unpubl. Report, New York Univ., 1937.

[53] Barach, J. V. "Physiological and Pathalogical Effects of Severe Exertion." American Physical Education Review, 15:651, 1910.

[54] Rothacher, J. L. "Athletic Conditioning in Relation to Circulation and Weight." Research Quarterly (Supplement) 6:69, May, 1935.

in the quantity and percentage of hemoglobin in the blood and variations in hemoglobin affinity for oxygen vitally affect man's endurance capabilities.

Steinhaus[55] reviewed what little work had been done up to 1932 and concluded that the hypoxia (lack of oxygen) induced by athletic training and that produced by lowering the tension of oxygen in environmental air (such as in rarified atmospheres) cannot elicit the same effects due to the transitory nature of exercise hypoxia. However, it is safe to argue that Steinhaus wrote this review at a time when the severity of training to which man has recently adapted, was unknown. The hypoxia of normal athletic contests (football, basketball, etc.) and their conditioning periods is certainly transitory. But the stress of middle distance training attempted since World War II is certainly of a far more severe and prolonged nature.

That adaption to prolonged hypoxia involves an increase in the blood hemoglobin level has been often proved.[56] That the extent of oxygen deprivation and the increase in hemoglobin has a direct relationship has also been demonstrated.[57] That the blood hemoglobin level can be appreciably elevated within 60 minutes after hypoxia

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[55] Steinhaus, A. H. "Chronic Effects of Exercise," Physiological Reviews, 13:103, 1933.

[56] Van Liere, E. J. Anoxia, Its Affect on the Body, p. 141. The University of Chicago Press, Chicago, 1942.

[57] Fitzgerald, M. P. "The Change in the Breathing and the Blood at Various Altitudes," Philosophical Transactions of the Royal Society of London, Series B. 203:351, 1913.

has begun[58] and such rapid elevation will be prolonged has been clearly shown.[59] That none of the above phenomena have been studied as man adapts to the stress of exhaustive exercise is, in light of the above, unusual.

It is not here the purpose to discuss the chemistry of hemoglobin regeneration nor to discuss the exact role of the hypoxic stimulus. Certainly it is not the intention to defend a belief that an exercise and an altitude hypoxia are one and the same. However, the type of studies cited and their results should surely promote an interest in the field of physical training research to see if an adaptation to the more exhausting methods of physical training is similar to altitude adaptation.

Five Minute Step Test Score

The general consensus of opinion in physical education research is that a pulse rate test is the simplest method of gauging cardiovascular fitness. It has been well established that athletes tend to have slower pulse rates than non-athletes both at rest and during exercise[60] and the effect of training is to lower the pulse rate.[61]

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[58] Gregg, H. W., Lutz, B. R. and Schneider, E. C. "The Changes in the Content of Hemoglobin and Erythrocytes of the Blood in Man During Short Exposures to Oxygen." American Journal of Physiology, 501:216, 1919.

[59] Van Liere, op. cit., pp. 15-6.

[60] Henderson, Y, Haggard, H. W. and Dolley, F. S. "The Efficiency of the Heart and the Significance of Rapid and Slow Rates." American Journal of Physiology, 82:152, 1927.

[61] Steinhaus, op. cit.

Salit and Tuttle feel that "of all the tests following exercise, the post-exercise pulse rate and increase due to exercise are found the most promising."[62]

Currently, the most widely used test of this nature is the Harvard Step Test.[63] It consists of recording thirty seconds of pulse rate 1-1½ minutes, 2-2½ minutes and 3-3½ minutes after five minutes of stepping up and down a 20" stool with each four-step cycle taking two seconds. An index is calculated from these rates. Soon after the test was made public, Brouha, Fradd and Savage[64] presented data on a large group of students illustrating that the test could distinguish between the trained, slightly trained and sedentary states and that the effect of training can be noted through index variations. To date, the validity of the test in this sphere has not been questioned.

Both Montoye[65] and Taylor[66] have shown that the significance of the test is not altered by eliminating the post 2-2½ min. and post 3-3½ min. pulses, and simply taking the 30 second pulse rate one minute after training.

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[62] Salit, E. P. and Tuttle, W. W. "The Validity of Heart Rates and Blood Pressure Determinations as Measures of Physical Fitness," Research Quarterly, 15:253, 1949.

[63] Brouha, L. "The Step Test. A Simple Method of Measuring Physical Fitness for Muscular Work in Young Men." Research Quarterly, 13:31, 1943.

[64] Brouha, L., Fradd, W. W., and Savage, B. M. "Studies in Physical Efficiency of College Students." Research Quarterly, 15:211, 1944.

[65] Montoye, H. J., "The 'Harvard Step Test' and Work Capacity," Revue Canadienne de Biologie, 11:491, 1953.

[66] Taylor, C. "A Maximum Pack Test of Exercise Tolerance." Research Quarterly, 15:201, 1944.

Summary

It is not difficult to justify the use of the selected measures in this study, even though doubt still exists as to their value in physical fitness research.

The outstanding conclusion that can be drawn from this review is that none of the cited studies have attempted to guage the type, duration or intensity of training needed to promote any physiological changes. Is it correct to assume that, because a certain program fails or succeeds to alter physiologic measures, the same holds true for any form, or any intensity or any duration of any athletic training program?

Future study should take cogniscance of the qualitative and quantitative nature of the experimental training program.

CHAPTER III

METHOD OF PROCEDURE

Instruments Utilized

The PC-2 Cardiotron

This instrument produces an electrocardiogram on a thermo-sensitive paper. The paper, ruled in one millimeter squares, moves at a rate of 25 millimeters per second. The records were standardized by adjusting the stylus to deflect 5 millimeters for every introduction of one millivolt, (0.001 volts). Such an excursion is half the regular setting but in no way adversely affects the validity or significance of the records.

The instrument is approved by the American Medical Association and is manufactured by Electro Physical Laboratories, Inc., New York.

The McKesson Recording Metabolor

This instrument consists of a closed circuit six liter spirometer with an attached electrically driven kymograph. The graph paper, ruled in one-tenth of an inch squares, moves at a speed of one inch per minute whilst a stylus deflection of one inch is equivalent to a one liter oxygen consumption.

The apparatus is patented by the McKesson Appliance Company, Toledo, Ohio.

The Baumanometer

This blood pressure apparatus stands over two feet high with the upper foot containing a slightly sloping mercury scale from 0-300 mm. Hg. The apparatus is light, portable and permits accurate and clear pressure reading.

The Baumanometer is made by the W. A. Baum Inc., New York.

Other Items

Blood hemoglobin levels were calculated with a Cenco Sheard Photelometer.[1] This work was carried out by the Department of Foods and Nutrition at Michigan State University.

Selection Of Subjects

The four athletes studied were members of the freshman track team. Each athlete was at a different stage of athletic ability but the basis of selection was their expressed desire to undergo a strenuous running program.

Two of the subjects were mile runners and were trained accordingly. One was a half miler and one a quarter miler moving up to the half mile for which distance they were trained. The group lived in mens' dormitories and were subjected to the same living arrangements, diet and study demands.

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[1] Central Scientific Co., Chicago, Ill.

Experimental Procedure

Training Program

Each athlete attempted approximately nine weeks of pace and nine weeks of speed training; wherever possible running five days a week. Each was assigned a goal in time considered a little beyond his reach. The speed needed to run each race at an even pace was mastered before the study was begun.

TABLE I

PACE DETERMINATIONS BASED ON BEST HIGH SCHOOL TIMES

Subject	Best High School Time min. - secs.	Distance	Set Study Time min. - secs.	Distance	Even Pace 220 Yd. Time-secs.
1	50	440 Yds	1 - 56	880 Yds	29
2	1 - 58	880 Yds	1 - 56	880 Yds	29
3	4 - 52	Mile	4 - 32	Mile	34
4	4 - 48	Mile	4 - 32	Mile	34

In the pace training routine the subjects were allowed an individual warm-up, followed by repititive efforts at maintaining the pace for as long a distance as possible. They were timed for each sectional 220 yds. and if any section were 3 seconds behind the set pace they were stopped, rested exactly 8 minutes and resumed in their next effort. When the accumulative distance run reached 2 miles for the milers or 1 mile for the half milers they had completed a day's workout.

The speed training consisted of running 6 maximum effort 220 yd. sprints with 8 minutes rest between efforts. Again the athletes were allowed individual warm-ups.

Competitive races at these and other distances were attempted throughout the study. Wherever possible this necessary check on racing ability was dovetailed into the freshman "telegraphic meet" schedule. An attempt was made to rest the subjects for one day prior to such races but sometimes the schedule prevented such a rest.

To prepare themselves for the study the athletes engaged in a Fall season of cross-country running, a period of unsupervised activity.

In the Winter quarter the "milers" attempted the pace program and the "half-milers" the speed program, on an indoor 220-lap dirt track. The procedure was reversed for the Spring quarter on an outdoor 440 lap red brick track. This plan was designed as a check on two possibilities. Seasonal variations might have upset basal determinations to such a degree that the relative physiological effect of each system could not be assessed. Also, it was felt that following the winter program the group would tend to perform better outdoors no matter what the training system. Even though the study was designed on a longitudinal rather than a comparative basis, it was felt this procedure was justifiable.

Testing Program

The subjects' physiological measures were recorded before, during, and after each program. Before the study was begun the subjects were thoroughly acquainted with the physiological testing procedures.

The subjects did not train the day before a test period. They slept for at least 8 hours the preceding night in one of the Michigan State University Human Energy Research Laboratories and were instructed to be in a 12 hour post-absorptive state the morning of testing.

After each subject was awakened he breathed through the basal metabolor mouthpiece (still directed to room air), while the electrocardiograph electrodes were attached to the body. The subject was then connected to the closed oxygen circuit and ECGs recorded whilst 2 six minute basal oxygen consumption tests were recorded. The leasser of these two tests was used for the BMR and O_2 pulse determination, the pulse rate being taken from the accompanying electrocardiogram. Blood pressure determinations followed, lying then standing, with a 5 minute step test concluding the testing period. Sometimes blood samples were taken before the step test but the usual occurrence was for the subjects to go to the Foods and Nutrition Department later in the day to give blood for hemoglobin analyses.

Sometimes it was not possible to record ECGs with the BMR due to technical difficulties. On these days a radial pulse record was recorded for the BMR and O_2 pulse determinations and the ECG was recorded within three days of the other measures.

Measurements and Calculations

Basal metabolic rate and oxygen pulse were determined from basal oxygen consumption.[2] The amplitudes and intervals of the P, R, and T waves of each electrocardiogram were measured as outlined by Wolff.[3] All measures were made with a pair of dividers, an acceptable procedure.[4] The magnitude and direction of each QRS electrical axis was derived from tables prepared by Jackson and Winsor.[5] The Food and Nutrition Department's determinations of blood hemoglobin levels was by the Alkalin Hematin Method as described by Hoffman.[6]

Analysis of Results

All raw scores in training and physiological performances were tabulated as shown in the Appendix.

With the majority of results, examination was by graphic analysis, statistical treatment being applied only when it was considered necessary to check the significance of certain graphic trends or when there was sufficient data to make such statistical treatment valid.

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[2] Consalazio, C. F., Johnson, R. E. and Marek, E. *Metabolic Methods, Clinical Procedure in the Study of Metabolic Function*, pp. 337-340, The C. V. Mosby Co., St. Louis, 1951.

[3] Wolff, L. *Electrocardiography Fundamentals and Clinical Application*, p. 25, W. B. Saunders Co., Philadelphia, 1953.

[4] Foerch, R. L. *A Comparison of Electrocardiographic Measurements of Athletes and Non-Athletes at Michigan State College*, p. 25, (Unpublished Master's thesis, Michigan State College, 1951), citing personal communication from Lansing Cardiologist, Dr. T. A. Hockman.

[5] Jackson, C. E., and Winsor, T. "Aids for Determining the Magnitude and Direction of Electrical Axes of the Electrocardiogram," *Circulation* L:975, 1950.

[6] Hoffman, W. F. *Photelometric Clinical Chemistry*, William Morrow and Co., New York, 1941.

Athletic variations throughout the study were graphed in terms of race trials and certain speed training performances. A "student t" test of significance was applied to these latter data. Pace training data were discussed solely in terms of the raw scores.

An analysis of variance was calculated for certain of the ECG measures. Graphs of variations in BMR, basal O_2-pulse and step test scores were graphed on the one figure to permit an analysis of their inter-relationships. A coefficient of correlation was computed for these data. Arterial systolic pressure changes from lying to standing and blood hemoglobin levels were separately graphed.

CHAPTER IV

RESULTS AND DISCUSSION

Results

Running Performance

No subject showed statistically significant race or training improvement during either or both running programs.

All subjects performed their first and last race trials without improvement (Figure 1, page 33). Subject 1 ran the 880 in 2-12 before beginning speed training, 2-09 at the conclusion of this system, 2-16 before and 2-10 at the conclusion of pace training. Subject 2 recorded 2-06, 2-06, 2-04 and 2-01 for the corresponding periods. Subject 3 ran the mile in 4-59 before and 4-57 after pace training and 4-52 and 4-59 before and after speed training. Subject 4 ran 4-46, 4-52, 4-46 and 4-52 for the corresponding trials.

With the thought that race trials may not have indicated actual running ability for any given period an attempt was made to analyse the speed program data. The mean 220 yd. time for the 12 efforts of the first two days of the first, middle and last weeks of the speed program was plotted for each subject (Figure 2, page 34). This graph illustrates that all subjects improved their speed and endurance during this program. Between the first and the last week of this system the mean 220 yd. time for subject 1 improved from 25.9 to

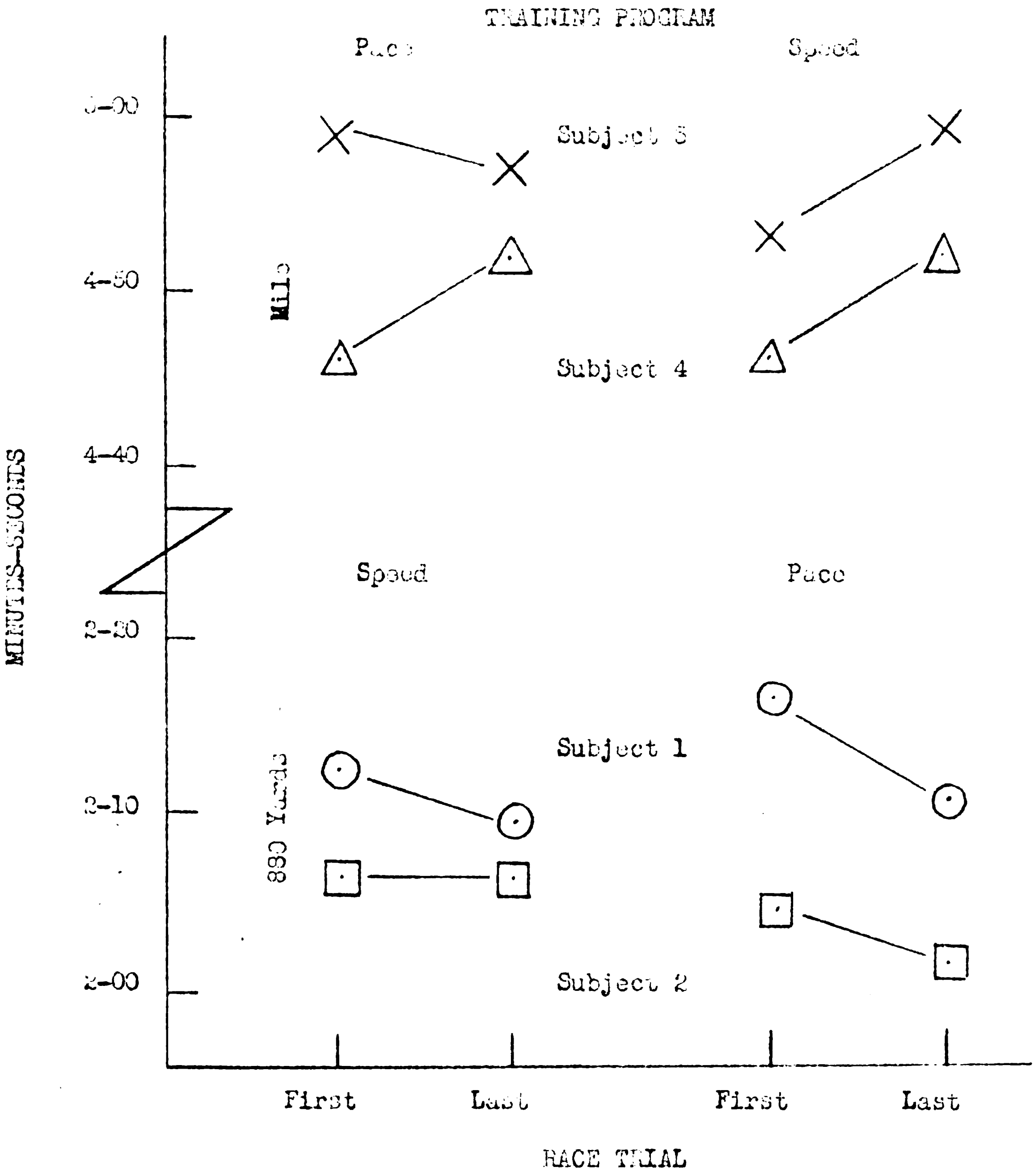

Figure 1. The Effect of Speed and Pace Training on Race Performance

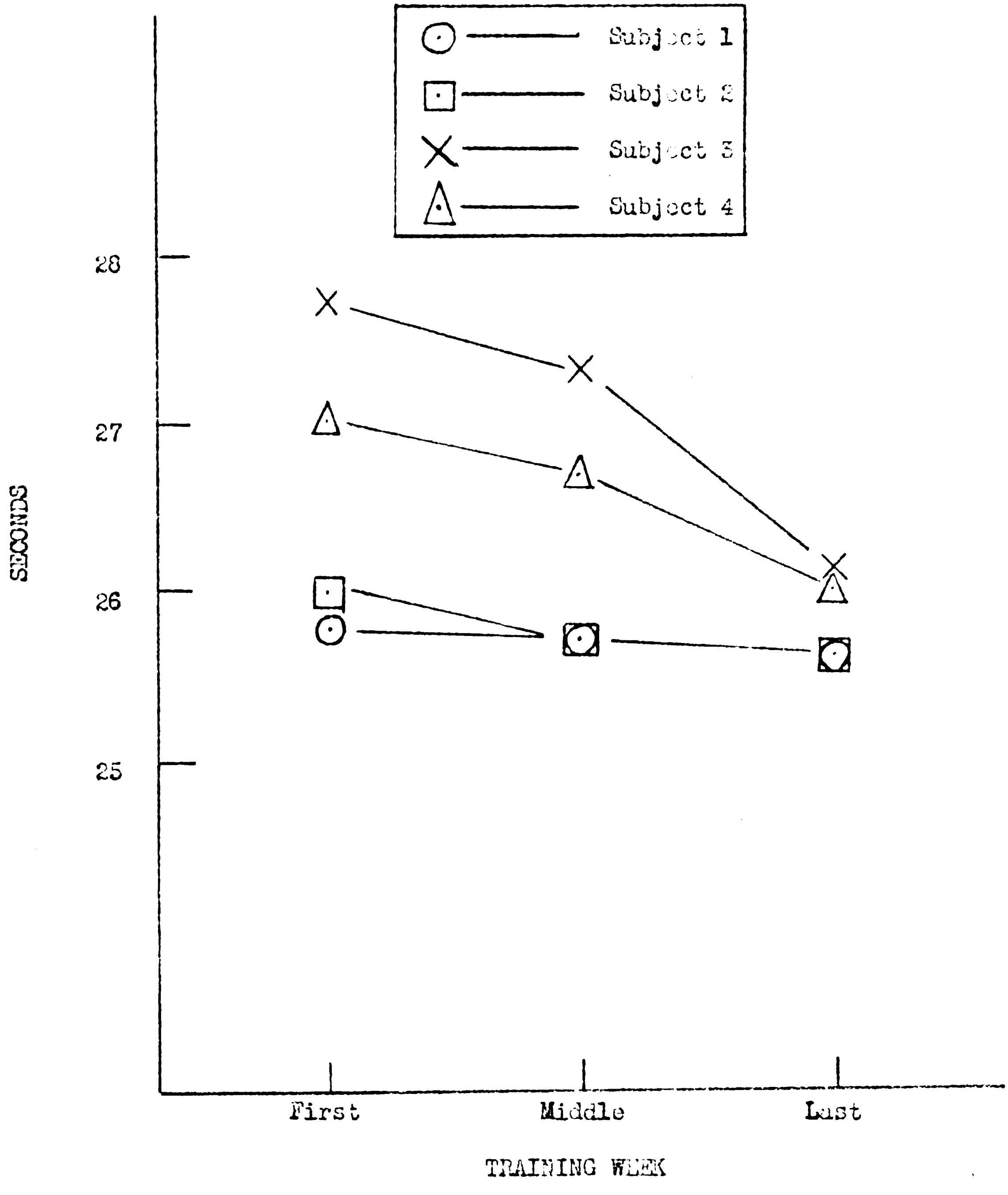

Figure 2. The Effect of Speed Training on Mean 220 Yard Effort Time

25.6 seconds, subject 2 from 26.0 to 25.6 seconds, subject 3 from 27.7 to 26.1 seconds and subject 4 improved from 27.0 seconds to 26.0 seconds. When these improvements were analyzed statistically they were shown to be insignificant, (t equalled 0.6, 0.4, 2.05 and 0.79 respectively), for each individual. Though a graphic trend was clear, in that all the subjects showed some improvement, the combined or group improvement was also found to be statistically insignificant (t = .17).

Physiological Measures

No subject showed statistically significant changes in any of the selected physiological measures.

Certain of the mean ECG measures for the 4 subjects were in keeping with data presented by Cureton,[1] Wolf,[2] and Foerch[3] as shown in Table II.

The table illustrates that the 4 subjects on this study tended to have higher R and T waves and longer P-R intervals than the other groups.

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[1] Cureton, T. K. Physical Fitness of Champion Athletes, pp. 148-149, The University of Illinois Press, Urbana, 1951.

[2] Ibid., p. 159 citing Wolf, J. A. "Electrocardiogram Standards for Normal Young Men," (Unpubl. Master's Thesis, The University of Illinois, 1951).

[3] Foerch, R. L. "A Comparison of the Electrocardiographic Measurements of Athletes and Non Athletes at Michigan State College," (Unpubl. Master's Thesis, Michigan State College, 1951).

TABLE II

COMPARISON OF CERTAIN ECG MEASUREMENTS FROM FOUR STUDIES

Amplitudes (In Millivolts)									Intervals (In Seconds)						Group	Study	Reference
P Wave			R Wave			T Wave			P-R			Q-S					
I	II	III	I	II	III	I	II	III	I	II	III	I	II	III			
.08	.15	.09	.46	1.88	1.36	.35	.42	.16	.19	.19	.18	.08	.11	.11	Trained 4 athletes (pre-program)	Stuart	
.16	.08	.10	.61	1.83	1.44	.35	.42	.12	.16	.18	.18	.08	.09	.08	Trained 4 athletes (post-program)	Stuart	
.07	.10	.06	.59	1.31	.85	.32	.43	.17	.13	.17	.17	.06	.07	.07	20 athletes	Foerch	3
.06	.11	.08	.51	1.18	.81	.25	.34	.13	.13	.13	.14	.08	.09	.11	20 non-athletes	Foerch	
.07	.06	.07	.60	1.30	.78	.32	.35	.06	.17	.16	.16	.06-.10			56 athletes	Cureton	1
.09	.13	.10	.53	1.32	.94	.28	.42	.18	.18	.18	.17	.07	.07	.07	81 normal young men	Wolf	2

Certain of the ECG leads were analysed for variance between testing periods to detect, for the four subjects, possible changes due to either or both programs:

TABLE III

ANALYSES OF VARIANCE BETWEEN SIX ECG'S OF FOUR SUBJECTS

Measure		F Value
P_I	Amplitude	23.5
P_{II}	Amplitude	0.265
P_{III}	Amplitude	1.84
T_I	Amplitude	0.374
T_{II}	Amplitude	0.518
T_{III}	Amplitude	0.494
$P\text{-}R_I$	Interval	0.586
$Q\text{-}S_I$	Interval	0.14
$Q\text{-}T_I$	Interval	0.39
QRS Electrical Axis		
	Magnitude	0.95
	Degrees	0.007

The high F score for P_I was found to be a meaningless score when the raw data were examined. In light of the above analyses the other initially selected leads were not handled statistically for their raw scores indicated that they also displayed little variation between testing periods.

No trends could be noted graphically for the basal metabolism, basal oxygen pulse, or five minute step test score for any of the 4 subjects as shown in Figure 3 (page 39). The same can be said for changes in the arterial systolic pressure from lying to standing, (Figure 4, page 40), and blood hemoglobin levels, (Figure 5, page 41). For this reason it was not felt necessary to analyse any of these measures statistically.

The basal metabolism of the 4 subjects when compared to the normal standards for their age and sex[4] showed the following deviations for each of the six testing periods.

TABLE IV

PERCENTAGE DEVIATIONS OF THE BMR OF FOUR SUBJECTS

	Testing Period						
Subject	1	2	3	4	5	6	Mean Deviation
	Percentage Deviation						
1	+6	-4	+5	-6	-2	-2	-0.5
2	+2	-9	-9	+9	-7	0	-2.5
3	-1	-1	+5	-8	-10	0	-2.5
4	-2	-11	-4	-11	+2	+5	-3.5

The slight trend noted for all subjects toward a lower than average BMR was not treated statistically.

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[4] Consalazio, C. F., Johnson, R. E., and Marek, E. Metabolic Methods. Clinical Procedure in the Study of Metabolic Function, p. 340, the C. V. Mosby Co., St. Louis, 1951.

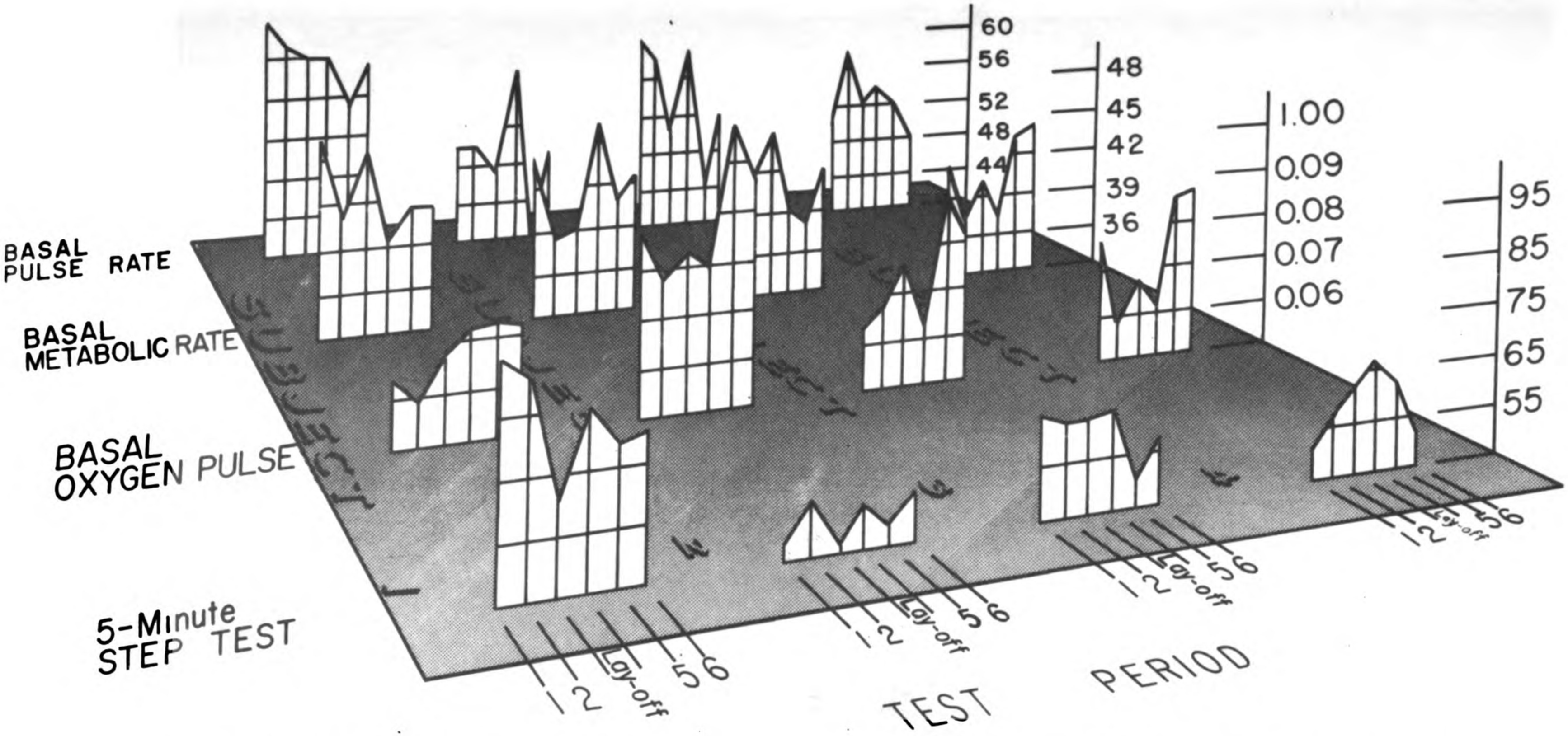

Figure 3. Certain Physiological Measures before, during and after Speed and Pace Training (Testing periods 1-3 refer to pre, mid and post speed program for subjects 1-2 and pace program for subjects 3-4. The programs are reversed for tests 4-6.)

Measure - Units
Basal Pulse - Beats/min.
Basal Met. Rate - Cals./hr./M^2
Basal O_2 Pulse - Cc. O_2 /beat/Kg.
5 Mn. Step Test - Pulse count, 30-60 secs. post exercise

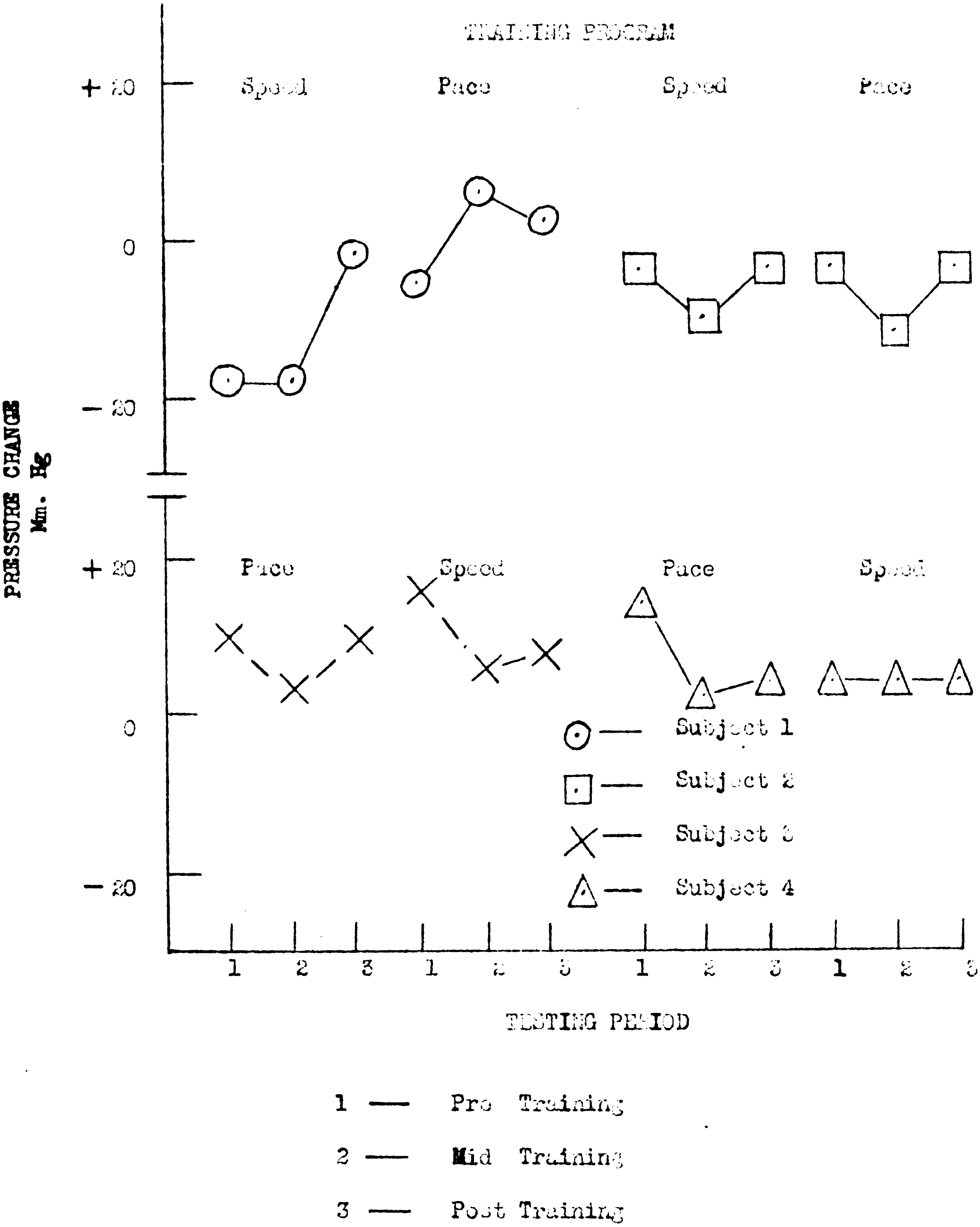

Figure 4. The Effect of Speed and Pace Training on the Change in Arterial Systolic Pressure from Lying to Standing

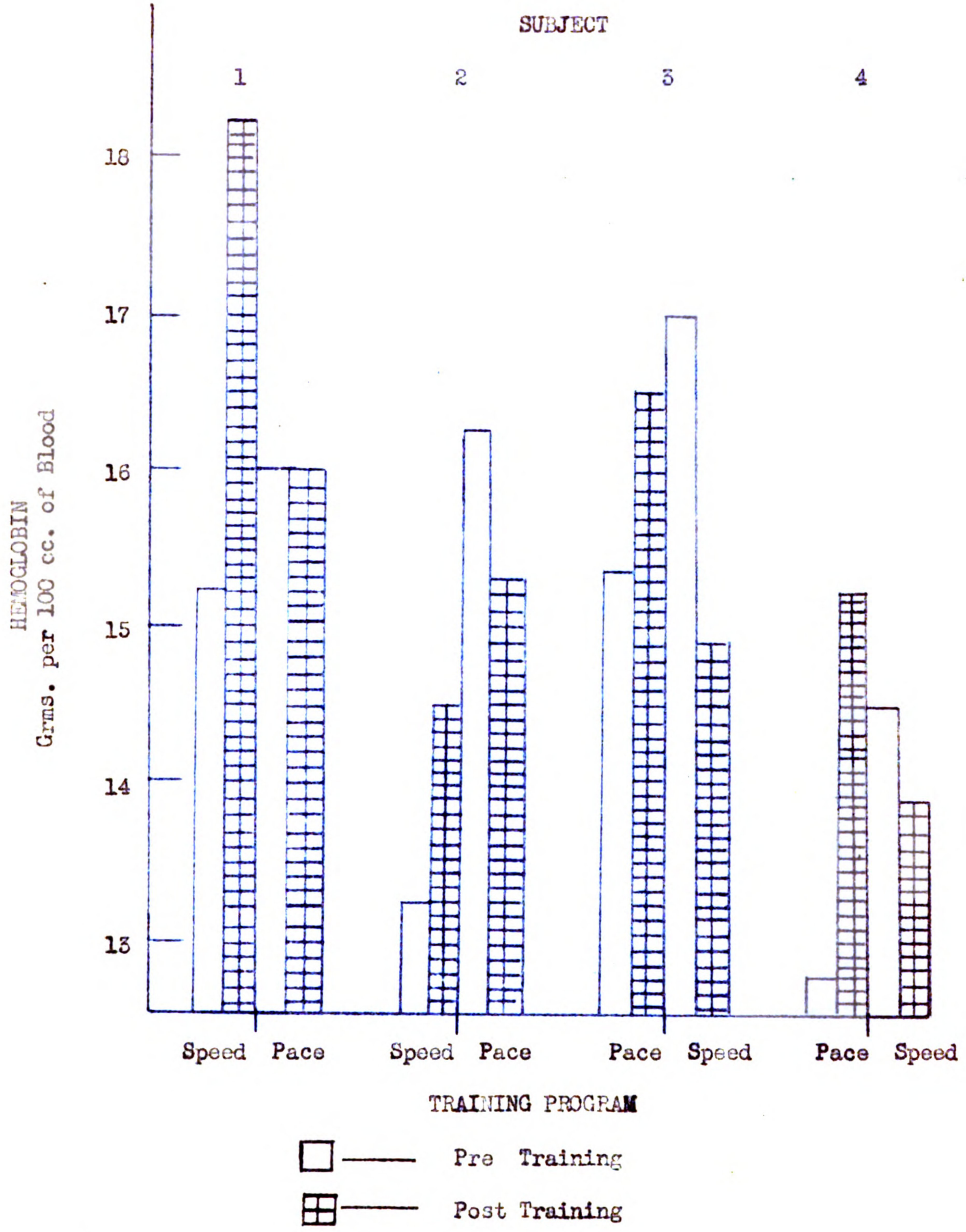

Figure 5. The Effect of Speed and Pace Training on Blood Hemoglobin Level

An analysis of the raw data indicated that systolic and diastolic pressures did not change markedly throughout the study. The relationship between each subjects variations from lying to standing arterial systolic pressure were compared to corresponding step test scores by taking the mean of the greatest pressure deviations and that of the corresponding step test scores, and comparing these to the means of the lesser pressure deviations and corresponding step test scores. This relationship is shown in Table V.

TABLE V

FIVE MINUTE STEP TEST SCORES ACCOMPANYING THE GREATER AND LESSER ARTERIAL SYSTOLIC PRESSURE CHANGES FROM LYING TO STANDING

Subject	Greater Pressure Change Mean	Step Test Mean	N	N	Lesser Pressure Change Mean	Step Test Mean
	mm. Hg.	Pulse count, 30-60 secs. post exercise			mm. Hg.	Pulse count, 30-60 secs. post exercise
1	-18	82.5	2	4	0	69
2	-11	52	2	4	-6	50.5
3	12	63	3	3	6	56.6
4	14	51	1	5	3.6	59.8

The possibility that a significant relationship might have existed between these two measures for all the testing periods and not only when a great pressure change variation was evidenced was examined by computing the coefficient of correlation between the pressure changes and step test scores for each of the four subjects and for the group. These coefficients are shown in Table VI.

TABLE VI

COEFFICIENT OF CORRELATION BETWEEN LYING TO STANDING ARTERIAL SYSTOLIC PRESSURE CHANGE AND FIVE MINUTE STEP TEST SCORE

Subject	"r" Value	Significant r Value 5%	 1%
1	-.83	.811	.917
2	-.13	.811	.917
3	+.33	.811	.917
4	-.55	.811	.917
Group	-.33	.404	.515

Wide variations were noted for all subjects in the 5 minute step test scores. The extreme scores recorded by each subject in this test were compared, as shown in Table VII, to the accompanying physiological measures for the testing periods in which the extremes were noted.

In line with Table VII the correlation between certain of the measures for all 6 testing periods were calculated for each subject. This was not considered a major aspect of the study but rather an interesting and pertinent adjunct to the area under examination.

TABLE VII

PHYSIOLOGICAL MEASURES ACCOMPANYING THE HIGHEST AND LOWEST STEP TEST SCORES OF FOUR SUBJECTS

		Subject 1		Subject 2		Subject 3		Subject 4	
Step Test Value (pulse count, 30-60 sec. post exercise)		84	62	55	48	64	50	66	51
Program Value Recorded		Pre Speed	Post Speed	Mid Speed	Post Speed	Pre Pace	Mid Speed	Pre Speed	Pre Pace
Program Order		1st	1st	1st	1st	1st	2nd	2nd	1st
BMR (Cals./hr./M^2)	Value	46.01	45.27	38.60	39.39	42.04	38.37	37.26	41.17
	Trend	-.74		+.79		-3.67		+3.91	
O_2 Pulse (O_2cc./beat/Kg.)	Value	.064	.068	.077	.083	.064	.090	.062	.077
	Trend	+.004		+.006		+.026		+.015	
Arterial Systolic Pressure Change (mm. Hg.)	Value	-18	-2	-10	-4	+10	+6	+4	+14
	Trend	Toward Zero		Toward Zero		Toward Zero		Away Zero	
Blood Hemoglobin Level (grms/100cc.)	Value	15.25	18.25			15.38	18.00	14.50	12.75
	Trend	+3.00				2.62		-1.75	

TABLE VIII

COEFFICIENT OF CORRELATION BETWEEN CERTAIN OF THE PHYSIOLOGICAL MEASURES

	Subject				
Measures Compared	1	2	3	4	Group
		r Value			
Basal pulse/BMR	.6	.8	.39	-.64	.57
Basal pulse/O_2 pulse	-.79	-.79	-.95	-.7	-.69
Basal pulse/Step test	.64	.46	.88	.47	.003
O_2 pulse/BMR	-.33	-.73	-.17	.85	.22
O_2 pulse/Step test	-.32	-.34	-.99	-.39	-.61

Note: For individual subjects r significants at 5% (1%) level when .811 (.917).
For group r significant at 5% (1%) level when .404 (.515).

Discussion

Running Performance

The failure of any of the subjects to improve in terms of racing or training ability under either or both programs is surprising. An examination of the raw data indicates that both systems involve more intense training than that normally undergone by members of a freshman track team.

A practical query to the above may possibly be that the standardized repititive nature of both programs lacked the variety empirically considered necessary in athletic training. As explained before it is not the purpose of this study to discuss such psychological factors as "emotionality," "attitudes" and "fatigue." However, in reply to the above query it can be answered that the interest displayed by the Varsity in the race trials and training efforts of the subjects, helpfully encouraged by the Track coaches, should have created a favorable "climate" for competition and training.

An analysis of Figure 6 (page 47), shows that though the whole study lasted 150 days the subjects only averaged a mean 29.3% of these days on either running program. This fact may help negate the query that "fatigue" could have impeded athletic progress but it also illustrates that the duration and intensity of the prescribed programs were adversely affected. It is still possible to argue that this 29.3% of actual training for a given number of days is a relatively accurate assessment of the number of days that a college freshman can train due to exams, vacations, rests prior to races etc. Thus the original postulation that both systems of training are more intensive than those normally attempted can be upheld.

Unfortunately it was still impossible to determine whether the major limiting factor in this failure to improve running performance was the 29.3% of total days that training took place, the total duration of the study or the intensity of each day's training. If the study were to be repeated and it were known that the former factor would again be evident either the length of the study or the intensity of the training would have to be increased, if racing and training improvement were to take place.

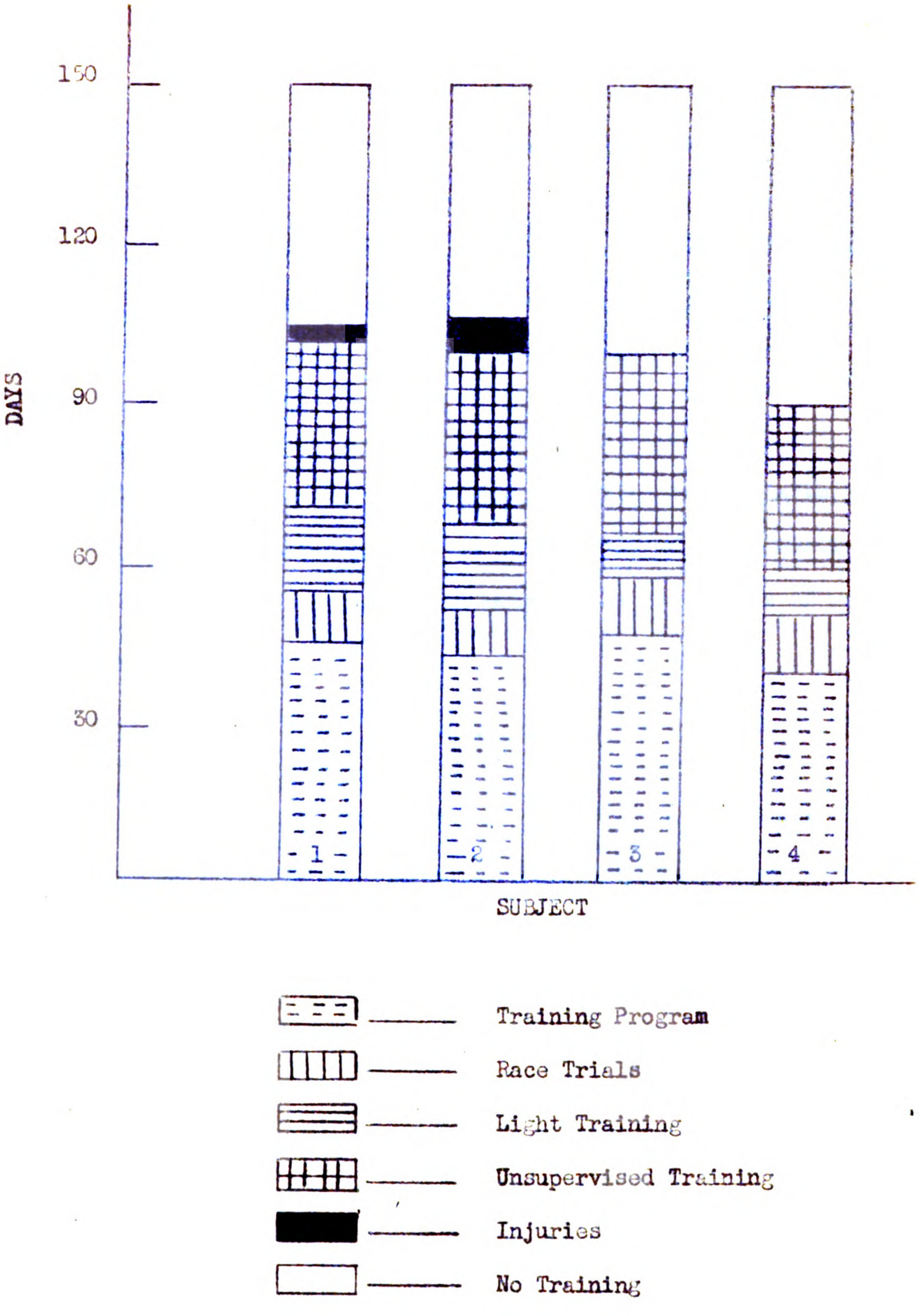

Figure 6. The Time Spent on Various Activities During the Study

Certainly there can be no doubt that the pre-study cross country running attempted by all the subjects brought them to a level of training and racing ability that neither of the study systems could improve. It is also impossible to attribute any superior advantage of the speed or pace system over the other in terms of either's ability to promote superior athletic performance.

Physiological Measures

The failure of the subjects to show improved athletic attainments during the course of the study limits an analysis of the effectiveness of any of the selected physiological measures as indicators of physical fitness.

The Electrocardiogram

In the review of literature it was stated that the electrocardiogram of an athlete tends to display a low P, high T and longer P-R interval. Table I, page 27, indicates that on such a classification the 4 subjects would tend to belong to the athletic rather than a non-athletic group. The low P wave was not evident but a high T wave a longer P-R interval could lead to the conclusion that athletic training had already elicited certain electrocardiographic changes characteristic of athletes, even though the duration and/or intensity of this study failed to markedly affect such records. This latter fact is in accord with data collected by Montoye, Collings and Stauffer.[5]

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[5] Unpublished data collected at Michigan State University on 10 Varsity basketball players throughout 1955 by H. J. Montoye, D. W. Collings and G. C. Stauffer.

Basal Metabolism

Neither the speed nor the pace nor the combined programs affected basal metabolism. Table III, page 37, illustrates the slight tendency for the 4 subjects to have a BMR lower than the normal standard for their age and sex. This may indicate that the type of training undergone in middle-distance running is such to promote an increase in cellular efficiency above and beyond any active protoplasm increase. With but 4 subjects and six testing periods it is not possible to form such a conclusion from this study.

Basal Oxygen Pulse

An analysis of the basal pulse graph on Figure 3, page 39, indicates that the duration of each program may have been insufficient to allow for significant variations to occur. For all subjects the last two measures are higher than the first but close examination of each subject's graph indicates that the testing may have ended at a critical time in that each subject's graph resembled a frequency polygon. Of all the selected measures it would appear from graphic analysis that this was the one test that may have indicated a significant trend if the study had been of longer duration.

Arterial Systolic Pressure

The change in arterial systolic pressure from lying to standing was relatively constant for all subjects and no trends can be attributed to either or both systems of training. Table V, page 42, shows an interesting relationship between the change and the step test score. If the step test is assumed to be a valid indicator of cardiovascular fitness then this table illustrates that there is a possibility that the postural pressure test is of use. Subjects 1 and 3 show a decreased step test score with the least pressure change. Subject 2 and subject 4 show no such indication indicating that discussion such as this is of little value with but 4 subjects. An analysis of the raw data on arterial systolic and diastolic pressure indicates that like the postural test no trends are evident.

Blood Hemoglobin Level

An analysis of Figure 5, page 41, illustrates an increase in blood hemoglobin level for subjects 1 and 2 throughout speed training and a decrease for subject 2 throughout pace training. Subjects 3 and 4 increased the level throughout pace training but showed a decrease throughout speed training. From another angle all subjects showed an increase in the measure during the Winter Quarter and 3 of the 4 a decrease during the spring. However, the variation for all subjects during the break between quarters, or the variation between the post winter program and the pre spring program is as great as the variation during either program. There can be little doubt that diet and season factors uncontrolled in this study, impeded a close examination of the effects of training on this measure. When comparing the pre first program score to the post second program score 2 subjects showed a moderate and one a slight increase whilst the fourth showed a slight decrease. The only conclusions possible are that neither nor both system markedly affected the measure and seasonal variations could quite possibly have been the major cause of the blood hemoglobin level variations.

Five Minute Step Test

The wide range in step test scores recorded by all subjects does not seem in keeping with the relatively constant running performances throughout the study. Table VI, page 43, shows that this range was not dependent on the program being undergone or the period of time a subject had been on either program. This fact is in keeping with the failure to graphically illustrate any marked trends in the measure throughout the study, (Figure 3, page 39). Further examination of Table VI illustrates maximum variation in step test scores was not marked by any associative trends in BMR, arterial systolic pressure change from lying to standing, or blood hemoglobin level. The oxygen pulse of all subjects was greater at the time the lowest step test scores were recorded. However, conclusions cannot be drawn from an examination of but two testing periods on four subjects.

It is difficult to accept the fact that the wide ranges demonstrated by all subjects are indicative of the same level of athletic ability yet for these four subjects that is the only conclusion possible.

Inter-Relation Between Measures

The coefficients of correlation presented in Table VII, page 44, give the relationships between certain of the measures. The last two BMR's recorded by subject 4 were unaccountably high and as a result negative correlations existed for this subject between basal pulse and BMR and between O_2 pulse and BMR. It is not here the contention that conclusions can be drawn from correlations based on but six records for 4 subjects but both the individual subjects and the grouped correlation values indicate interesting research possibilities.

A useful procedure is indicated by these values in that, on the basis of such correlations, experimental procedure in securing records of the measures could be validated. A certain relationship should exist between basal pulse, BMR, basal O_2 pulse and step test score, the presence or absence of which might possibly indicate the soundness of measuring technique.

It must be remembered that basal pulse rate and O_2 pulse contain the common factor of pulse rate and that BMR and O_2 pulse are both based on resting O_2 consumption. As a result a significant correlation would be anticipated between these measures. However, the relationship between O_2 pulse and the step test score was a comparison of relatively "isolated" physiological mechanisms and thus of interesting moment.

CHAPTER V

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary

The purpose of this study was to study certain physiological effects of speed and pace training on trained freshmen trackman. The four subjects conditioned themselves with a season of cross-country running before beginning a program of speed and a program of pace training. Before, during and after each program a record was made of each subject's electrocardiogram, basal metabolic rate, basal oxygen pulse, arterial systolic and diastolic lying and standing blood pressure, blood hemoglobin level and 5 minute step test score. As a subordinate investigation the inter-relationships of certain of these measures were determined for the six testing periods.

When the measures were graphed and certain of them treated statistically it was found that neither system of training nor their combination had produced any marked changes in any of the physiological measures or in racing and training ability of any subject.

Some statistically significant correlations were established with some of the subjects for certain of the physiological measures. In the main such correlation values were due to the compared measures containing common components. The O_2 pulse and the step test contained no such common element and two of the subjects and the group as a whole showed significant correlation between these two measures for the six testing periods.

Conclusions

It was not possible to assess the relative effects of either speed or pace training on the physiological or athletic status of any subject since neither system produced changes. Despite the initial belief that each of the systems was of considerable intensity each was only sufficient to maintain the subjects at a physiological and performance level that had already been reached by the accumulative effects of high school track competition and a pre study season of cross country running.

Either the intensity of each day's training or the duration of the whole study was insufficient to produce the anticipated changes.

Thus the effect of speed and pace training in this study was to maintain the "status quo."

The need existed for a correlation of O_2 pulse with a more fundamental measure than the step test before any claims could be made as to the validity of the former as an indicator of physical fitness. However, the correlation with the step test was of sufficient magnitude to justify any future study of O_2 pulse in the field of cardiovascular fitness research.

Recommendations

On the basis of the above conclusions the following recommendations are made:

1. The elevation of a trained middle distance freshman from one level of athletic achievement to another cannot be achieved by a mild training program. If such elevation is to occur during the freshman year then the intensity of training will have to be increased to at least a degree beyond that set in this study.

2. If the relative physiological effects of speed and pace training are to be successfully examined the duration and intensity of such training should be increased beyond that attempted in this study.

3. When such a study is again attempted the selection of a much greater number of subjects would permit a study of the inter-relationships between the selected physiological measures that would be statistically meaningful.

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APPENDIX

MICHIGAN STATE COLLEGE
DEPARTMENT OF PHYSICAL EDUCATION, HEALTH AND RECREATION FOR MEN
GRADUATE STUDIES AND RESEARCH

TOPIC RAW DATA

TABULATION SHEET

WINTER TRAINING

DATE OF TABULATION Summer 1956

TABULATED BY Doug Stuart

	SPEED												PACE												
	Subject 1						Subject 2						Subject 3						Subject 4						
EFFORT	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	Date
	4.3	4.8	6.1	5.8	6.3	7.6	4.7	5.9	5.6	6.1	6.6	7.3	880	880	660	440	440	220	880	880	880	440	440		Jan. 11
Pace Shows	4.5	4.8	6	5.9	6.1	7.3	4.3	6	5.6	6.3	6.8	7.1	660	660	440	440	440	220	660	880	440	660	440	440	12
Distance Run	4.1	4.9	5.9	5.6	6	7.5	4.5	5.7	5.4	5.8	6.2	6	880	880	660	440	440	440	1320	660	660	880	220		13
in Yards																									14
																									15
Speed Shows	3.8	4.9	5.8	8.5	9.2 2.6		4.9	4.4	5.9	6	6.4	6.8	880	660	440	440	660	440	880	1100	440	880	440		16
Time Run	4.5	3.8	6	8.6	6.3	7.5	5.2	5.3	6.1	6	6.2	7.2	880	660	660	440	660	220	1320	880	660	660			17
Each 220 Yds.	4.1	4.5	5.4	4.8	5.8	7	5.5	INJURED					880	880	660	660	440		1320	880	660	660			18
in Seconds	4.4	4.7	5.6	5.8	5.7	6.4	LIGHT TRAINING						880	880	660	660	440		1100	880	880	660			19
(Add 20 secs.	LIGHT TRAINING						LIGHT TRAINING																		20
to all speed																									21
figures)																									22
	LIGHT TRAINING						LIGHT TRAINING						1100	660	660	660	440		1320	880	660	660			23
		"	"	"	"	"	"	"	"		"	"	1100	880	660	660	220		1320	880	880	440			24
		"	"	"	"	"	"	"	"		"	"	880	880	880	660	220								25
Note		"	"	"	"	"	"	"	"		"	"													26
Pace for																									27
both miles	880 in 2-12						880 in 2-06						Mile in 4.59						Mile in 4.46						28
is 68 secs.																									29
per 440	8.2	6	5.4	6.4	6.7	6.2	6.7	5.4	5.6	6.9	8	8.3	1320	660	660	660	220		1320	1100	1100	660			30
for a	5.5	6.5	6.2	5.7	6.8	5.8	5.4	6.4	6.2	5.7	6.5	6.2	880	880	660	660	440		1100	1100	880	440			31
4.32 mile.	LIGHT TRAINING						LIGHT TRAINING																		Feb 1
																									2
	300 in 33.4						660 in 1:15						Mile in 5.02						Mile in 4.47						3
																									4
																									5
																									6
																									7
	4.4	4.9	5.4	5.8	5.6	6.3	5	5	4.8	6.9	7.3	7	1100	880	660	880			1100	1320	1100				8
	4.5	5.5	6	6.4	6.6	6.7	4.6	4.9	5.1	5.4	6.1	6.6	880	880	880	660	220		1100	1100	880	440			9
																									10
																									11
																									12
	5.6	5.5	5	5.4	5.5	7.4	Influenza						1100	880	880	660			1320	880	880	440			13
	5	4	4.5	6.4	5	6.8		"		"			880	880	880	660	220		1320	660	880	660			14
	4.9	4.9	5	5	5	5.6		"		"			880	880	660	660	440		1100	1100	880	440			15
	4.6	4.5	4.7	5.6	5.7	7.4		"		"			2 Mile 10:54												16
													Mile 4.57						Mile 4-38						17
																									18
																									19
																									20
	5.6	6.2	6.8	4.6	5.2	5	5.8	5.8	5.9	5.8	5.2	6.2	880	880	880	660	220		1320	1100	1100				21
	4.7	4.6	4.8	4.3	4.6	5.4	5.5	5.8	5.4	5.4	5.8	5.8	880	880	880	880			1100	1100	880	660			22
	5.2	6	6	6.2	6.7	6.6	5.8	6.1	6.8	6.6	6.2	6.2	1100	880	880	660									23
	LIGHT TRAINING						LIGHT TRAINING						LIGHT TRAINING						LIGHT TRAINING						24
																									25
																									26
																									27
																									28
	880 in 2-9						880 in 2-06						880 in 2-10						880 in 2-2						29
	440 in 52.4						440 in 52.6						Mile in 4.57						Mile in 4.52						March 30
																									2
																									3
																									4
	5.6	4.4	6.2	5.6	6	7	5.4	5.8	6.6	5.6	5.4	5.4													5
	3.8	4.3	5.2	5.8	8.2		4.5	5.5	5.5	5.4	5.4	6.4	1100	880	880	660			1320	880	880	440			6
	INJURED						5.6	5.5	6.1	5.9	6.4	6							1320	660	880	440			7
	INJURED						5.4	5.6	5.4	5.8	6.4	6	[illegible]	880	880	880			1100	1100	880	220			8

MICHIGAN STATE COLLEGE
DEPARTMENT OF PHYSICAL EDUCATION, HEALTH AND RECREATION FOR MEN
GRADUATE STUDIES AND RESEARCH

TABULATION SHEET

SPRING TRAINING

TOPIC RAW DATA

DATE OF TABULATION Summer, 1956

TABULATED BY Doug Stuart

DATE: April 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 May 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 June 1 2 3 4 5 6 7 8

SPEED: 4th Subject 1 2 3 4 5 6; 3rd Subject 1 2 3 4 5 6

PACE: 2nd Subject 1 2 3 4 5; 1st Subject 1 2 3 4 5

April 16–18 and April 22–24: TOO COLD – UNSUPERVISED X-COUNTRY RUNNING

April 19–21: Mile in 4.46; Mile in 4.52; 880 in 2.4; 880 in 2.16

May 4–6: Mile in 4:49; Mile in 5:04

May 7–9: 2 Mile in 11:30; 880 in 2:01.6; 880 in 2.10

May 16–18: Mile in 4.46; Mile in 5:03; Fast Laps; 440 in 53.9

May 25–27: 440 in 54.5; 440 in 53.36

June 6–8: Mile in 4:52; Mile in 4:59; 880 in 2.01; 880 in 2.10

Effort →

Pace Shows Distance Run Each Effort in Yards

Speed Shows Time Run Each 220 Yds in Seconds (Add 20 secs. to all speed figures)

Mile Pace 6 laps 4th tenths

14 58 secs.

Pr. 440

Pr.

1 56 [illegible] mile

MICHIGAN STATE COLLEGE
DEPARTMENT OF PHYSICAL EDUCATION, HEALTH AND RECREATION FOR MEN

GRADUATE STUDIES AND RESEARCH

TABULATION SHEET

DATE OF TABULATION Summer, 1956

TOPIC RAW DATA

ELECTROCARDIOGRAM MEASURES

TABULATED BY Doug Stuart

	SUBJECT	DATE	WAVE AMPLITUDES (In Millivolts)																			QRS Electric. Axis			WAVE INTERVALS (In Seconds)																		
			P						R						T										P-Q						Q-S						Q-T						
			I	II	III	aVF	aVL	aVR	I	II	III	aVF	aVL	aVR	I	II	III	aVF	aVL	aVR		°	magn		I	II	III	aVF	aVL	aVR	I	II	III	aVF	aVL	aVR	I	II	III	aVF	aVL	aVR	
1	1	1.15.56	.04	.1	.1	.1	NOT DISTINGUISHED	-.06	.76	2.9	2.1	2.46	-.8	-1.8	.2	.5	.4	.4	NOT DISTINGUISHED	-.4		92.4	29.5		.18	.16	.16	.16	-	.16	.08	.08	.09	.12	.08	.12	.4	.44	.44	.44	-	.40	1
2	"	2.26.56	.04	.1	.12	.1		-.06	.9	3.02	2.16	2.4	-.52	-1.64	.22	.48	.2	.32		-.34		92.5	28.9		.12	.12	.16	.16	-	.18	.08	.08	.08	.08	.06	.08	.36	.44	.44	.42	-	.44	2
3	"	3.21.56	.04	.1	0	0		-.04	.92	3.03	2.15	2.46	-.8	-1.82	.26	.54	.22	.39		-.38		91.9	29.6		.18	.19	.16	.16	-	.18	.08	.08	.10	.08	.08	.08	.4	.44	.42	.40	-	.40	3
4																																											4
5	"	4.5.56	.04	.1	.06	.02		-.06	.8	3.2	2.0	2.8	-.5	-1.8	.2	.5	.24	.4		-.32		92.6	25.2		.16	.16	.16	.12	-	.16	.04	.08	.08	.08	.04	.08	.36	.38	.36	.36	-	.38	5
6	"	5.6.56	.02	.1	.1	.06		-.04	.84	2.7	1.9	2.16	-.26	-1.42	.2	.44/-.1	.4/-.14	.44/-.2		-.2		94.7	26.2		.13	.14	.15	.14	-	.14	.1	.15	.12	.14	.08	.08	.42	.58	.60	.64	-	.46	6
7	"	6.15.56	.04	.2	.1	.16		-.08	1.1	2.76	2.36	2.5	-.8	-2.1	.24	.46	.3	.4		-.3		69.9	29.9		.13	.12	.14	.13	-	.14	.08	.08	.07	.08	.08	.08	.42	.40	.40	.42	-	.40	7
8																																											8
9																																											9
10	2	1.15.56	.06	.2	.16	.2	-.04	-.1	-.24	1.5	1.5	1.4	-.6	-.58	.4	.3	-.16/.04	.16	.3	-.38		93	14.6		.16	.2	.2	.18	.16	.18	.08	.12	.14	.10	.12	.08	.46	.48	.52	.50	.46	.46	10
11	"	2.26.56	.06	.2	.1	.2	-.06	-.1	-.2	1.5	1.5	1.5	-.7	-.7	.44	.4	-.1/.1	.2	.3	-.44		92	14.7		.16	.16	.16	.16	.16	.16	.10	.12	.12	.10	.12	.08	.52	.50	.52	.54	.48	.48	11
12	"	3.21.56	.06	.2	.1	.2	-.06	-.1	-.3	1.5	1.6	1.4	-.8	-.8	.5	.46	-.16/.06	.2	.3	-.5		94	14.5		.16	.18	.16	.16	.14	.18	.08	.12	.10	.08	.10	.08	.42	.46	.50	.44	.44	.44	12
13																																											13
14	"	4.5.56	.06	.2	.1	.1	-.06	-.12	-.2	1.4	1.5	1.5	-.7	-.7	.5	.42	-.12/.04	.24	.3	-.46		92	13.6		.16	.18	.18	.17	.16	.18	.08	.12	.12	.10	.08	.08	.44	.48	.52	.48	.44	.44	14
15	"	5.6.56	.04	.12	.06	.1	-.02	-.1	-.2	1.4	1.4	1.42	-.76	-.7	.32	.28	-.06/.02	.14	.16	-.3		94	14.5		.14	.16	.14	.16	.14	.14	.09	.08	.12	.08	.12	.08	.44	.54	.40	.56	.44	.46	15
16	"	6.15.56	.06	.2	.16	.2	-.04	-.12	-.28	1.4	1.4	1.4	-.8	-.7	.36	.32	-.1/.04	.24	.3	-.4		98.5	13.5		.12	.16	.16	.16	.14	.16	.06	.10	.08	.12	.10	.10	.36	.52	.54	.56	.40	.42	16
17																																											17
18																																											18
19	3	1.15.56	.1	.1	-.02	.04	.02	-.06	.6	1.1	.4	.8	-.2	-.8	.4	.4	-.04/.1	.2	.26	-.4		54.2	7.7		.2	.2	.16	.18	.18	.2	.08	.10	.10	.10	.08	.08	.40	.42	.46	.44	.38	.42	19
20	"	2.26.56	-.06	-.02	.1	.06	-.06	.04	-.6	.5	1.0	.6	-.8	-.2	-.46	-.12	.4	.18	-.5	.4		113.5	7.5		.2	.22	.22	.24	.2	.18	.08	.08	.10	.08	.08	.10	.40	.34	.38	.38	.38	.38	20
21	"	3.21.56	.1	.06	-.06	.04	.06	-.1	.64	.96	.5	.7	-.4	-.8	.48	.44	-.1/.1	.2	.3	-.5		106	5.6		.22	.22	.18	.22	.18	.22	.10	.08	.08	.08	.06	.10	.42	.44	.48	.44	.40	.42	21
22																																											22
23	"	4.5.56	-.06	-.06	.06	.02	-.06	.06	-.7	.5	1.06	.8	-1.0	-.3	-.44	-.2	.36	.2	-.4	.3		113.5	7.5		.2	.22	.20	.20	.2	.22	.10	.08	.10	.08	.08	.08	.40	.36	.40	.40	.40	.36	23
24	"	5.6.56	.04	.04	.06	.06	-.04	.04	-.56	.36	1.0	.64	-.7	-.2	-.44	-.1/.06	.4	.2	-.4	.3		54.4	6.4		.2	.21	.21	.2	.2	.2	.10	.05	.10	.10	.12	.08	.41	.46	.46	.48	.44	.41	24
25	"	6.15.56	-.06	.12	.04	.06	.04	-.1	.7	1.04	.44	.6	-.2	-.84	.5	.4	-.1/.1	.2	.3	-.42		105	8.2		.18	.22	.21	.21	.2	.2	.08	.08	.08	.08	.16	.08	.40	.42	.44	.40	.36	.40	25
26																																											26
27																																											27
28	4	1.15.56	.1	.2	.1	.18	NOT DISTINGUISHED	-.1	.7	2	1.5	1.5	-.5	-1.2	.4	.46	.3	.4	.02/-.02	-.4		91.5	20.4		.2	.2	.2	.2	.18	.2	.08	.12	.12	.06	.14	.14	.40	.44	.42	.40	.42	.44	28
29	"	2.26.56	.04	.2	.1	.18		-.12	.8	2.1	1.4	1.9	-.6	-1.5	.3	.7	.2	.4	.02/-.02	-.44		92	19.4		.2	.22	.2	.2	.18	.2	.10	.12	.12	.12	.10	.10	.44	.46	.44	.44	.42	.42	29
30	"	3.21.56	.06	.2	.1	.2		-.12	.9	2.2	1.6	1.5	-.78	-1.44	.4	.7	.2	.5	.02/-.02	-.5		93.4	23.1		.2	.2	.2	.2	.22	.2	.10	.10	.12	.12	.08	.10	.44	.44	.46	.46	.44	.48	30
31	.																																										31
32	"	4.5.56	.06	.2	.12	.16		-.1	.9	2.4	1.66	1.8	-.5	-1.4	.4	.7	.3	.5	.12/-.02	-.5		92.8	23.6		.2	.2	.2	.2	.18	.18	.10	.08	.10	.06	.06	.08	.38	.42	.38	.38	.36	.38	32
33	"	5.6.56	.04	.2	.1	.16		-.06	.8	2.2	1.7	1.86	-.4	-1.0	.26	.56	.3	.4	.18/-.02	-.3		94	21.6		.2	.2	.19	.17	-	.19	.10	.10	.10	.10	.10	.10	.40	.40	.38	.40	.38	.40	33
34	"	6.15.56	.1	.2	.1	.2		-.1	.9	2.1	1.56	1.8	-.6	-1.56	.3	.5	.24	.4	.02/-.02	-.4		93.5	21		.2	.2	.2	.19	-	.18	.08	.08	.08	.08	.08	.08	.40	.40	.40	.40	.40	.40	34
35																																											35

MICHIGAN STATE COLLEGE
DEPARTMENT OF PHYSICAL EDUCATION, HEALTH
AND RECREATION FOR MEN

GRADUATE STUDIES AND RESEARCH

TOPIC RAW DATA

TABULATION SHEET

PHYSIOLOGICAL MEASURES

DATE OF TABULATION Summer 1956

TABULATED BY Doug Stuart

SUBJECT	TEST NO.	DATE	BASAL PULSE bts./min	BMR Cal./m²	BASAL O_2 PULSE cc./bt.	cc./bt./kg	ARTERIAL BLOOD PRESSURE (mm. Hg) Lying	Stand.	Lying	Stand.	Systolic Change	BLOOD [illegible] gms/[illegible]	5 Minute STEP TEST 30" pulse
1	1	1.11.56	64	46.01	4.82	.064	108	90	50	60	-18	15.25	54
"	2	2.21.56	61	41.04	4.51	.060	112	94	60	64	-18		81
"	3	3.21.56	60	45.27	5.06	.068	112	110	64	76	-2	18.25	62
"	4	4.4.56	60	40.25	5.37	.072	114	108	50	70	-6	16.0	75
"	5	5.2.56	55	41.04	5.46	.073	104	110	50	60	+6	16.25	69
"	6	6.2.56	59	41.04	5.37	.072	108	110	54	62	+2	16.0	70
2	1	1.11.56	50	43.88	5.53	.087	110	106	50	60	-4	13.25	48
"	2	2.21.56	50	38.60	4.87	.077	106	96	50	60	-10		55
"	3	3.21.56	47	39.39	5.28	.083	116	112	50	66	-4	14.5	47
"	4	4.4.56	58	41.43	5.14	.080	112	108	50	65	-4	11.25	53
"	5	5.2.56	40	39.92	69	.108	118	106	58	64	-12	14.88	49
"	6	6.2.56	49	42.56	6.12	.096	114	110	50	68	-4	15.3	54
3	1	1.11.56	60	42.04	4.89	.064	110	120	78	90	+10	15.38	64
"	2	2.21.56	58	41.89	5.12	.068	106	110	70	88	+4		62
"	3	3.21.56	54	44.87	5.74	.077	116	126	84	90	+10	16.5	62
"	4	4.4.56	59	39.26	4.69	.063	102	118	70	90	+16	17.0	63
"	5	5.2.56	44	38.37	6.72	.090	110	116	74	88	+6	18.0	50
"	6	6.2.56	56	42.04	5.65	.082	118	126	76	90	+8	14.9	58
4	1	1.11.56	50	41.17	5.23	.077	98	112	70	82	+14	12.75	51
"	2	2.21.56	58	37.09	4.11	.059	86	88	66	70	+2		57
"	3	3.21.56	52	40.17	4.70	.067	106	108	74	76	+2	15.25	62
"	4	4.4.56	54	37.26	4.29	.062	98	102	66	80	+4	14.5	66
"	5	5.2.56	52	43.17	5.93	.086	92	96	62	80	+4		62
"	6	6.2.56	48	43.84	5.9	.087	94	98	64	76	+4	13.9	52