PHYSICAL FITNESS IN THE CONFINED DOG--CRITERIA AND MONITORING OF MUSCULAR PERFORMANCE

by

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INTRODUCTION

Synthesis of Problem

The conditions of optimal general care of the dog have received increasing attention because of this species's importance as a research animal. With laboratory animal medicine attaining a prominent place in veterinary medicine and with the quality of veterinary supervision of animal colonies paralleling the ever increasing demands of research units of all types, study of basic problems of husbandry is again being reviewed in a more discerning manner. It is primarily this consideration which has provoked or suggested a need for exploration as outlined in this study--although application of results could be expected in a diversity of aspects of veterinary medicine and canine zootechnics.

General health, whether it be in animals or man, is more than merely "the absence of disease"; it is a relative value encompassing a myriad of qualities. As a positive characteristic it might well include longevity, absence of morbidity, endurance and physical strength. Physical fitness is not synonymous with health but it is obviously a significant factor in the well-being of most animals.

The canine organs are not built for the resting state but for a higher level of activity, and husbandrymen have long

placed emphasis on exercise as an element in the optimal establishment of proper growth, development and maintenance in the canine. Physical fitness in the racing animals, the police and working dogs, and the hunting breeds is mandatory since the entire justification for subsistance of these individuals lies in their ability to perform adequately certain physical feats which account for their service to mankind. With increased urbanization even the companion dog, the house pet, has seen his freedom of activity markedly reduced until at the present time the veterinarian engaged in small animal practice is confronted with health problems in his patients that relate directly to lack of exercise and poor physical fitness.

The laboratory dog confined to a cage or housed in a modicum of space which strictly limits opportunities for exercise and which is not motivated or stimulated to accomplish work, might not be considered a "healthy, normal" individual of the species although his physical examination denotes no demonstrable disease processes. In the various complexities of modern medical experimentation where increasing stress is placed on the quality of a known biological tool, and where results of laboratory determinations are only as meaningful as the understanding of the physiology of the subject, it would appear that maintaining an animal in a state of general fitness consistent at least with that of an

average member of the species unencumbered by the added environmental stresses of the investigator's laboratory, might help assure uniformity of experimental subjects and promote maximal development of the animals in the research unit and in the breeding colony. The importance of this consideration is of interest to others (8).

Yet, even with the prodigious studies in nutrition, sanitation, and genetics of this most important laboratory animal and companion to man, physical conditioning is still much more of an art than a science, and although many physiological responses have been studied and some progress has been made in the human field in test development, an adequate understanding is yet to be accomplished.

Physical fitness as it applies to both man and dogs is a rather nebulous quantity; it is merely a concept--difficult to define and difficult to assess. Darling (17) states that it consists in the ability of the organism to maintain the various internal equilibria as closely as possible to the resting state during strenuous exertion and to restore promptly after exercise any equilibriums which have been disturbed.

Before attempting to assess fitness or design tests which give proper appraisals two fundamental hypotheses (25) must be accepted:

1. There are quantitatively measurable differences

between the fit and unfit.

2. A distinction can be made between fundamental physiological adaptations common to fitness for all types of exertion and the special skills necessary for the successful performance of different types of physical endeavor.

Interindividual and intraindividual comparisons of physical capabilities have been carried on since man and his animal subjects became social beings, the test comprising many forms of endeavor from those of the most crude nature to the more elaborate contests involving many qualities of strength, speed, endurance, and mechanical efficiency.

It has been only recently that with newer capabilities and advances in technology scientists have sought to define physical fitness in physiological terms and measure it with other than simple performance standards.

Purpose of Study

It is the intention of this study to apply some of the known criteria of fitness in man and assess certain changes occurring during an induced conditioning period in selected laboratory animals, in an effort to begin ascertation of applicable parameters of physical fitness in the dog.

REVIEW OF THE LITERATURE

General Considerations

Steinhaus (46) and Karpovich (28) have summarized various chronic bodily changes occurring as a result of training or exercise periods in dogs. Others (3, 4, 9, 10, 11, 18, 21, 34, 36, 41, 47, 50, 51, 52, 53, 56) have reported differences as they occurred during or after the exercise period itself or as a result of an extended conditioning period.

Young et al. (58) established specific work experiences for dogs testing their exercise performance in regard to feeding and nutritional supplementation.

The subject of fitness tests in man has been reviewed extensively by many observers; detailed critiques may be found in the volumes by Morehouse and Miller (32) and Karpovich (28), and articles by Simonsen and Enzer (42), Taylor (48), Johnson (25), Taylor and Brozek (49), and Åstrand (2). The ultimate conclusions that might be gained from these reviews are that there are, in fact, many differences between the fit and the unfit, that these differences can be measured, that these individual valuations have a decided relationship to ability to accomplish most types of strenuous exertion, and that the organisms' physical proficiency is best assessed by exposure to an arduous exercise. Cardiovascular,

pulmonary, and muscular provinces offer numerous constituents for assessment.

The generalized admonitions of Taylor and Brozek (49) and Cureton (16) are of import, emphasizing the fact that fitness consists of many elements and is hard to comprehend--no two or three items measuring all aspects of fitness. These specifics are subject to many influences and it is important in any assessment that the environmental, physiological and psychological conditions be strictly controlled.

Selected Studies

Postexercise blood lactate

Liljestrand and Wilson (30) cite the work of Fletcher (22), which demonstrates conclusively that lactic acid is formed in muscle during contraction.

Cook and Hurst (13) in 1933 found that during bodily rest the muscles supply no lactic acid to the blood--conversion of blood sugar (glycolysis) being the most probable source at rest; variations in lactate concentration during rest are due to stimulation or depression of glycolytic activity and assist the organism in its endeavor to maintain a constant blood reaction.

Lactic acid is rapidly diffusable and uniformly distributed through the body; the concentration of lactic acid

in the blood is proportional to the amount of lactic acid in the body at that time (31). The disappearance of lactic acid from the blood at recovery after severe exertion shows a lag which is not explained by a lag in diffusion from muscles to blood, by a slower oxidation of lactic acid, or by delayed lactic acid production. In a trained individual this period lasts six to eight minutes, while in the untrained the lag may last two to three times as long.

The work of Ryffel (39) in 1909, as cited by Crescitelli and Taylor (14), proved an increase in lactic acid concentration in the blood of man after muscular activity. Many other reports concerning this particular aspect of exercise physiology have since been reported and, more recently, the particular relationship these alterations have as indices of an individual's exercise tolerance have been published. Crescitelli and Taylor have summarized the work regarding the general changes in blood lactic acid concentration after muscular activity:

a. With the onset of exercise there is a rapid increase in the blood lactate concentration to a maximum; the magnitude of its maximum is greater, other factors remaining constant, the greater the intensity of exercise.

b. With cessation of exercise the blood lactate decreases, the recovery rate being such that the

logarithm of the excess lactate is a linear function of time.

c. Under some circumstances, especially with exercise of short duration, the blood lactate concentration continues to rise for some minutes after cessation of the activity.

d. One of the many factors which may determine the lactate response of an individual to a given exercise is the individual's exercise tolerance (physical fitness).

In an effort to explore the relationship between the lactate response and fitness, the above authors (14) divided 19 men into three groups on the basis of the subject's background and other performance tests:

a. Athletes or men who performed in a superior manner in the laboratory.

b. Men who have taken regular but not competitive exercise.

c. Laboratory workers who exercise little or not at all.

Group a exhibited the lowest lactate level, Group c the highest, and Group b maintained an intermediate position. In analyzing these groups using other physiological measures as well, it was found that blood lactate and urine lactate may serve to differentiate fitness groups better than heart rate and respiratory methods.

Identical experiments performed at different times but on the same individual indicated considerable day-to-day variation. In testing the reliability of any one lactate determination through test and retest procedures they found that although the coefficients were not high, that for testing purposes blood lactate determinations have at least as high, if not a higher, reliability than such measures as heart rate, ventilation, etc.

Dill et al. (19) observed changes in lactic acid accumulation in 19 subjects after running on a treadmill, the sample of venous blood being collected immediately after work. They state that this type of experiment furnishes an excellent guide to the capacity of individuals for great and sustained physical activity.

After a fixed work period, the lower the lactate (taken at constant time after work) the better the condition of the subject; the reverse is true if the subject continued to run to exhaustion (38). Venous blood drawn five minutes after cessation of exertion was used as a criterion of change in the lactic acid mechanism. Also, the basal blood lactate did not change with training.

Knehr et al. (29) conclude that capacity for accumulating lactic acid during training procedures and the high lactate levels attained by athletes give indication that this determination is a useful index of cardiovascular fitness.

Johnson and Brouha (26) offer a combination of determinations with lactate being a constituent as a fitness or "work index" (index = [duration of run] - [maximal pulse plus maximal lactate]), and state that this agrees well with a rating of physical fitness obtained by other criteria.

Taylor (48) in testing 31 subjects by standardized walking on a treadmill four minutes, resting four minutes, and then by standardized running to exhaustion, concluded that the heart rate and blood lactate were the most reliable submaximal (exercise) measures.

Darling (17) states that any of a variety of measurements made during heavy exertion or during recovery may serve as an index of fitness. These determinations must show a wide enough variance between known fit and unfit subjects, and must not be influenced by extraneous influences. Maximum pulse and blood lactate during nearly exhausting work were found to correlate well.

Åstrand (2, p. 324) in his review states that the investigation of different functions during recovery from muscular work does not give reliable information about the reaction of these systems to the work--an attractive test being one in which the subject does standard work at one or more work intensities during which different functions are examined in order to get an evaluation of the fitness of the individual (oxygen intake, lactic acid increase, and pulse

rate caused by the work are suggested). However, he (2) cites several references showing that the blood lactic acid level is reduced during submaximal exercise as a result of training.

Karpovich (28, pp. 160-161) reports that the accumulation of lactic acid depends on the relative intensity of the exercise, that as high as 300 mg. per 100 cc. has been reported by Taylor (48), and that the normal content of lactic acid in the blood of man is about 10 mg. per 100 cc. After strenuous exercise is discontinued, lactic acid continues to escape from the muscles into the blood--the period 2 to 8 minutes immediately after strenuous exercise marking a high unchanging level of lactic acid in the blood, after which it begins to decline, reaching pre-exercise levels in 30 to 90 minutes.

Postexercise pulse rate

Steinhaus (46) in reviewing the effects of exercise noted that athletes had lower resting pulses, although he found no difference in basal heart rate of dogs after a period of training.

Essex et al. (21) concluded that the pulse rate of the dog is a less reliable index of the rate of work than blood pressure. The maximum pulse rate at low levels of exercise were often found to be as great initially as in higher levels

of activity. These findings were disclosed with monitoring procedures during the stress period.

Many attempts have been made to correlate the pulse rate during and after exercise with man's ability to undergo various degrees of physical exertion. A brief digest of conclusions follows.

Åstrand (2) cites the work of numerous authors stating that the effect of training is to lower the pulse rate at rest and in submaximal work, probably due to an increase in stroke volume.

Morehouse and Miller (32, p. 270) in phrasing the differences between the fit and unfit reiterate that the heart rate after work returns to normal faster in the man who is physically fit.

In trying to assess physical fitness in college-age students Jung (27) reported that the use of a cardiac recovery index (similar to the Harvard Step-Up Test as outlined by Karpovich (28, p. 285)) was gratifying--test-retest correlations were high and the method appeared practical.

Knehr et al. (29) found that a regime of training, using 14 men conditioned by middle distance running over a period of 6 months, did not alter the decline of heart rate following exercise to complete exhaustion within a constant time limit of three to four minutes.

In studying the effect of different severities of

training on men Durnin et al. (20) found that the heart rate during exertion on the treadmill provided the most consistent data from the point of view of analysis. All of the exercise groups had a significant improvement, slowing, in the pulse rate as a result of their conditioning periods.

A corroboration of the conclusions of the above authors is given by Johnson (25) who summarizes by stating that if both unquestionably fit and unfit men of the same morphology are compared while performing the same work which both can sustain (submaximal) the fit individual will show a faster return of pulse rate to resting value after work.

Karpovich (28, pp. 190-209) reviews in detail changes in the pulse rate of man in relation to exercise and fitness; his conclusions might be listed as follows:

a. The effect of training is to decrease the rate in response to a standard exercise.

b. After strenuous exercise the postexercise pulse follows exponential curves; trained subjects recovered faster than untrained ones.

c. The intensity of exercise and the condition of the individual govern the time required for the pulse rate to return to normal.

d. The relationship between resting and postexercise pulse rates is not clearly defined, his opinion being that the postexercise rate is related to the

level of the basal or resting rate.

e. In taking resting pulse rate caution should be taken to get true rate with no influence as a result of food intake, emotions and physical activity.

f. Concerning tests of physical fitness, it seems apparent that the pulse rate curve during recovery from the stress exercise is the most useful single measure of circulatory fitness.

Numerous efforts have been made to design simple, applicable tests incorporating the pulse rate at rest, during, or after a standardized exercise (12, 17, 26, 27, 48, 54), to determine a person's physical capabilities.

Alkaline reserve

It is logical to assume that training might increase alkaline reserve (plasma bicarbonate). Experimental evidence on this subject is contradictory.

Robinson et al. (37) in studying 5 trained athletes found that they had bicarbonate levels like those of untrained men.

Robinson and Harmon (38) failed to find any change in bicarbonate levels during training.

Karpovich (28, p. 153) and Steinhaus (46) cite research done in Europe which shows a higher alkaline reserve average in athletes or men having experienced a training period.

Knehr et al. (29) found no significant changes in alkaline reserve in men which had undergone training for 6 months.

Observations on dogs do not tend to support either premise. Thörner (50) and Steinhaus (47) found no change in alkaline reserve in dogs under training. The latter author cites the reports of Rice and Steinhaus (36) which indicated that dogs' blood tends to become alkaline rather than acid while the animal is exercising on the treadmill, this phenomenon due to the animal's panting and blowing off CO_2. It is suggested that the studies in dogs be repeated, training them to swim in water at 15 to 25°C., this type of exercise being accompanied by blood changes toward the acid side (as found in man during exercise); this procedure would help clarify the role of acid in evoking a higher alkaline reserve. Davis and Brewer (18), however, found a steady rise in alkaline reserve in 4 dogs under training over a period of 7 to 9 weeks; 2 of the dogs were exercised by swimming in water at 30°C. for 2 hours daily while the others were exercised on a treadmill.

Although, as previously indicated by several authors (2, 25, 49), physical fitness is best determined by observing the subject during or after a stress exercise, it was decided to explore again the level of alkaline reserve in animals undergoing a specified conditioning period in an attempt to find a

parameter of fitness taken from the resting individual. Because of the controversy over this particular adaptation of an organism to training another inquiry in this area was thought to be indicated.

Hemoglobin

According to Hettinger et al. (24) during prolonged, heavy, physical work the individual's performance capacity depends largely on his ability to take, transport, and deliver oxygen to the working muscle. In consideration of this premise one might expect that the hemoglobin concentration or total hemoglobin, or, more aptly in application to a group of dogs, hemoglobin per unit of body weight might be a valid indicator of physical fitness.

Åstrand (2, p. 324) states that the best index of physical fitness in the resting individual is total hemoglobin.

Cullumbine (15) concluded that the blood hemoglobin concentration is correlated significantly with speed of movement, strength, and the ability to sustain prolonged moderate muscular effort. He reported no evidence of a significant correlation between the hemoglobin level and responses to severe or moderate exercise.

Even a short period of physical training may produce an increase in blood volume and total hemoglobin according to

Sjöstrand (43).

Knehr et al. (29) in studying men in training over a period of 6 months found no significant differences in hemoglobin concentration.

Robinson et al. (37) in checking various athletes found the hemoglobin concentration like that of untrained men.

In studying a group of 4 men at high environmental temperatures and using various procedures which altered the hemoglobin concentration, Spealman et al. (44) found no indication of a correlation between hemoglobin concentration and exercise performance; they did conclude, however, that performance correlated well with estimated level of blood volume.

In 1933, Steinhaus (46) stated that the belief that training brings about an increase in the per cent of hemoglobin, the total mass of corpuscles, and the total volume of blood, rests on but meager experimental data. The work of Thörner (52) was cited showing that trained dogs had a reduction in hemoglobin as compared to untrained littermates.

Tsuchiya (53) exercised four groups of dogs as follows:

Group A. Exercised for 2 hours daily for 14 days continually on the treadmill inclined at 11°

Group B. Exercised for 3 hours daily for 14 days continually on the treadmill inclined at 11°

Group C. Exercised for 4 hours daily for 14 days

continually on the treadmill inclined at 11°

Group D. Daily rapid running for 12 days was instituted on the horizontal treadmill until fatigued.

Three dogs were in each group. The velocity of running was not given--it was so regulated that speed was adjusted to each individual; according to individuality, to ingenuity of running and physical strength, the capacity of running was different. Dogs unable to run the fixed distance and the required number of days were discarded. Hemoglobin content showed stronger diminution with more rapid running, all groups showing a decrease during the relatively short exercise period.

Davis and Brewer (18) in exercising four dogs by swimming (two hours daily) or by treadmill exercise (25 per cent grade, 6 miles daily; speed not given) found that blood volume was markedly decreased in the first week of exercise in 3 of the 4 dogs. All dogs after 6 weeks of exercise showed a blood volume higher than normal. The hemoglobin per unit volume of blood was lowered significantly in all 4 dogs during the first week, but recovered during the exercise period and in no case exceeded the normal level. However, the total circulating hemoglobin was increased significantly by 5 to 7 weeks of exercise.

The work of Broun (10, 11) in 1923, exposing confined dogs to exercise on the treadmill, emphasizes the fact that

exercise must be an important factor in the maintenance of an efficient hematopoietic tissue.

In view of the above findings it was considered feasible to undertake a cursory exploration of hemoglobin and blood volume of the experimental subjects during the conditioning period not only to verify findings already reported but to determine if these measurable changes are of enough significance to be a parameter of physical fitness in the dog.

Size of skeletal muscle fibers

If we consider the tissues or organs most apt to be affected by the stress of training, the possibility of discovering reliable indices of fitness are strengthened. As emphasized by others (2, 25, 28, 32) the cardiovascular and respiratory systems offer valuable criteria. An area which is also amenable for study and for applicable assessment, at least in the dog, and which has received a paucity of attention, is the skeletal muscle mass itself. As suggested by Bock et al. (6) the capacity for exercise is bound up with changes in the oxidative processes within the muscle cells themselves.

Measurable chemical changes take place in muscles subjected to a conditioning process. The phosphocreatine, glycogen, and myoglobin content of worked muscle increases with training. But besides these chemical changes, or

perhaps even associated with them, the size of muscle can be changed by exercise. Petrén et al. (35) stated that some increase in size of muscle mass is due to an increase in the number of capillaries.

Steinhaus (47) cited the work of Morpurgo (33) who studied histologically the fibers in the sartorius muscle removed from one leg of each of two dogs before and from the other leg after months of very strenuous running exercise. An increase in muscle mass was due entirely to a true hypertrophy of individual fibers and not to appearance of new fibers.

Bowden and Goyer (7) studied measurements made on the diameters of muscle fibers taken at autopsy from children ranging in age from birth to nine years. They suggested that the size of muscle fibers is directly related to function and their work supports the premise that muscles increase in size and power by growth of the individual fibers.

Walls (55) stated that a range in fiber diameter of 10 to 100 microns is commonly accepted. The fiber size differs in the major animal classes and even in differing muscles of the same animal. Muscle fibers increase in diameter in response to exercise--this is reported as a well known fact.

If a moderate conditioning program brings about measurable differences in fiber size, then these differences,

if of sufficient magnitude, might serve as parameters of quality of the training regime and, with more elaborate information from extended studies, might serve as indices of physical fitness.

METHODS

Husbandry of Subjects

Nine adult dogs of mixed breeding were used as experimental subjects; two dogs were used as controls. These animals had been closely confined in cages 36 inches in length, 30 inches in width, and 32 inches in height (Figure 1) for varying periods of time as indicated in Table 2, with the exception of approximately a ten minute period each day when they were allowed out of the cages while kennels were being cleaned.

Animals were fed a standard diet of commercial canned dog food ("Friskies", Carnation Company, Los Angeles, California, "Petglo", Carnation Company, Los Angeles, California) according to the manufacturer's directions. Two subjects were maintained on a prescription type food ("i/d", Hill Packing Company, Topeka, Kansas) because of enteric sensitivity to the standard diet.

The subjects had been given a routine physical examination, had been checked for intestinal parasitism and treated accordingly, had been examined for Dirofilaria immitis, and had routinely been vaccinated for canine distemper and hepatitis ("Distemperoid TC+, Fromm Laboratories, Inc., Grafton, Wisconsin) and rabies (chick-embryo origin vaccine,

Figure 1. Kennelling area for experimental subjects showing cages in which dogs were confined

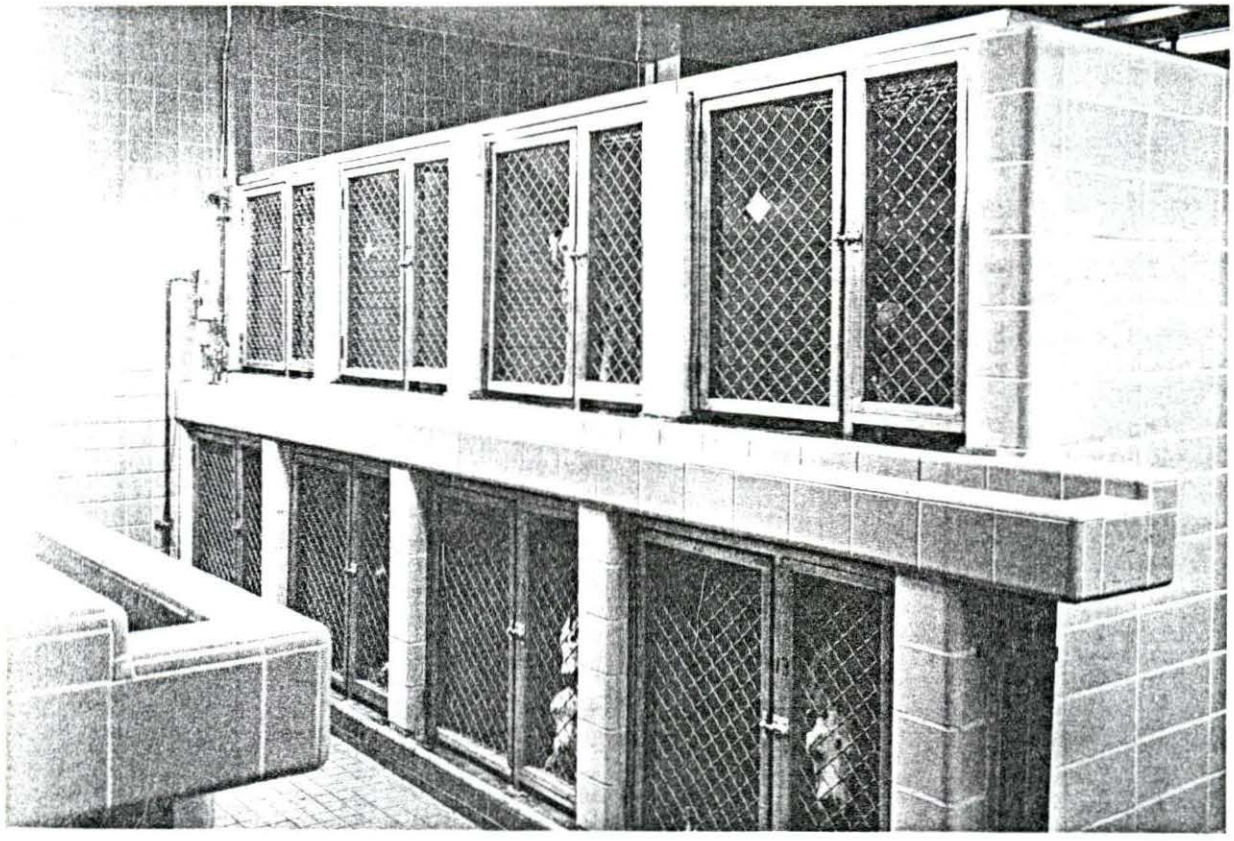

Table 1. Observed stride frequencies of experimental subjects

Subject	Stride frequency[a], 3 m.p.h.			Stride frequency[a], 4 m.p.h.		
	Mean	Range	S. D.[b]	Mean	Range	S. D.[b]
Y-22	149.2	132-175	13.1	178.2	166-196	10.3
Y-21	155.0	147-174	7.4	175.1	165-183	6.2
K-1	106.8	103-111	2.8	122.6	116-131	5.6
K-14	135.3	121-146	7.4	153.5	144-161	6.1
K-3	124.9	116-130	4.6	139.8	134-145	3.5
K-16	104.2	98-109	3.1	115.3	107-120	3.7
K-10	112.1	106-122	6.2	131.6	122-140	5.9
K-17	110.2	109-111	< 1.0	123.9	120-127	2.3
Y-23	106.6	102-110	3.5	121.2	118-128	3.5
K-19[c]	109.3	103-116	4.6	133.0	126-143	5.7
K-6[c]	73.3	73- 77	2.0	92.0	88- 95	2.2

[a]Number of times right forefoot is brought forward/minute; 10 observations at each speed (0° grade).

[b]Standard deviation = $\sqrt{(\Sigma\ d^2) / (N - 1)}$.

[c]Control subjects--not exercised during experiment.

Allied Laboratories, Indianapolis, Indiana).

Short bouts of arduous exercise five days weekly, beginning at the test rates and increasing weekly as indicated in speed and length of time exercised, were used as conditioning periods. The increased periods of exercise varied upon the individual capabilities of the dog but ranged from 10 to 18 minutes. Speed was increased (over the six week period) a total of approximately .5 m.p.h. on each animal. Grade remained maximal at 33 per cent with the exception of K-16 who was always exercised at 25 per cent grade because of an inability to maintain balance and stride at a greater grade.

Establishment of Test Exercise

No information was found concerning the establishment of "fitness tests" per se for the dog. The number of procedures mentioned involving the canine as a subject of standardized conditioning programs or testing procedures was minimal.

Certain obvious general requirements for an appropriate testing procedure are always of first consideration. Tests of fitness must be simple, economical, and have a minimum of adverse effects on the subject to be of great value in veterinary and experimental medicine. These factors plus relative validity and reliability would insure an inter-laboratory usage.

In establishing any test of physical fitness certain tenets must be kept in mind. The physiologic equilibria must be displaced so that differences are measurable; this means a strenuous exertion must be made. Secondly, the stress should not be maximal for some and submaximal for other subjects to be tested unless time run to exhaustion is to be considered in the assessment. In man where motivation is a factor--this could be a factor in the dog also--exercise to exhaustion may not strictly assess true physiologic limits.

Regardless of the type of test employed, the results obviously measure only the fitness for the test itself. The relationship between the test and the basic type of exertion to which the subject is commonly exposed, and for which the experimenter is trying to determine generalized fitness, should be close. In dealing with the dog rather than man there are some apparent advantages in this regard. Tests of ambulation are much more closely related to the general character of common work experiences which the canine must accomplish as opposed to the wide variety of physical stress situations that man encounters in performance of his specific occupational specialty; for this reason alone it might be suspected that an index of physical fitness could be even more applicable in the dog.

Skill and mechanical efficiency are factors in any type of performance examination; this cannot be eliminated in any

test but by relying on exercises of ambulation one can minimize these factors.

Morphological and psychological fitness, accompanying physiological fitness, will be encompassed in the test, and obvious variances should be detected clinically if possible and taken into consideration.

An effort must be made to scale the test to account for great morphological differences between subjects. In dealing with any heterogeneous group of dogs varying in size, breed, and age, some compensation must be made in the stress protocol to adjust for these differences. Upon the design of the test itself depends much of the reliability of interindividual comparisons. Such considerations were held paramount in empirically formulating the stress exercise as follows:

1. Subjects were weighed and measured, the height being taken at the shoulders (the most dorsal point of the scapulae).
2. With the treadmill (Model 18-49-13, W. E. Quinton Instrument Company, Seattle, Washington) running at rates of 1 to 2 m.p.h. and with no increment of grade, the dogs were introduced to the machine. This necessitated forceful, firm restraint with the use of a choke chain and tie ropes. Manual positioning and encouragement were repeatedly indicated until the animals became accustomed to the situation.

3. After adjusting to the treadmill, the speed was set at 3 m.p.h. and the number of strides were counted per minute by visual observation and the use of a hand tally counter. Ten counts, of one minute duration each, were taken at rates of 3 and 4 m.p.h. (Table 1). At these speeds all animals regardless of size were trotting and easily maintained their gait.
4. The 10 counts at each of the two rates were averaged and the two means added together. This figure then (representing the average number of strides at the two given rates in summation), which will be subsequently termed the stride frequency, was used to calculate the speed at which the test was formulated for each individual.
5. With the above mentioned figure a test was prescribed for each subject. The maximum capacity of treadmill was 6 m.p.h. and 33 per cent grade. In order to make the test submaximal and yet strenuous for all subjects a maximal pitch (33 per cent) was decided upon. Allowing the dog with the lowest stride frequency to perform at a certain speed, the largest dog running at treadmill maximum, the rate of the others was calculated using the following simple formula:

$$\frac{\text{stride frequency of fixed subject}}{\text{stride frequency of subject Y}} \times \text{fixed rate subject's speed}$$

$$= \text{rate in m.p.h. of subject Y (to nearest tenth mile)}$$

Two different speeds were calculated, the lesser rate to be used as a substitute if the animals would not perform at the higher speed (Table 2). The length of the test was arbitrarily fixed at 10 minutes.

Protocol Peculiar to Selected Studies

Postexercise blood lactate

The animals were fasted and rested for at least 12 hours prior to the weekly test period. They were allowed in the runs without the company of other dogs for 10 minutes just prior to the exercise to promote evacuation of bladder and colon.

Each animal was placed on the treadmill and the speed of the belt rapidly raised until the subject was running uniformly at his particular rate. The timing clock was then started and the test was conducted.

All tests were performed during the hours of 8:00 to 12:00 A.M.

Five cubic centimeter samples of blood were withdrawn

Table 2. General data and calculated exercise rates of experimental subjects

Subject	Sex	Height (inches)	Confinement (weeks)	Initial weight (kg.)	Stride frequency[a]	Rate (m.p.h.)	Alternate rate (m.p.h.)
Y-22	M	11	8	5.90	327	3.5	3.3
Y-21	F	12 1/4	4	7.40	330	3.5	3.3
K-1	F	15 3/4	16	12.00	229	5.0	4.7
K-14	F	14 1/8	16	8.00	289	4.0	3.7
K-3	M	14 1/2	16	10.80	265	4.3	4.0
K-16	M	20 1/8	16	25.30	220	5.3	4.9
K-10	F	17 3/8	16	10.80	244	4.8	4.4
K-17	M	20 1/4	16	20.30	232	5.0	4.6
Y-23	M	19 3/8	4	15.60	228	5.1	4.7
K-19[b]	F	16 3/8	16	12.60	242	4.8	4.4
K-6[b]	M	23 3/8	16	24.80	165	7.0	6.5

[a]Sum of arithmetic means of 10 one minute tests each at 3 and 4 m.p.h.; 0° grade.

[b]Held without exercise as controls.

from the right or left jugular vein exactly two minutes after the conclusion of the exercise. "Sodium fluoride--thymol tablets" (Cambridge Chemical Products, Inc., Dearborn, Michigan) were used as the anticoagulant.

All test exercises were accomplished at a room temperature of 72°F. (± 2°) and at a relative humidity of 48 per cent. Air movement and lighting were constant.

Lactic acid determinations were made using the method of Barker and Summerson (5).

Resting lactate levels were determined by the same procedures except samples were taken one hour before instituting the exercise.

Postexercise pulse rate

Standard calculated text exercises were used as previously outlined and as indicated in Table 2. K-16 was exercised at a reduced rate and grade as mentioned above.

All animals were rested and fasted for 12 hours prior to the exercise period, and were again allowed in the runs just prior to the test period for evacuation of wastes.

The dogs were then quietly walked or carried to the exercise room and placed in position on the treadmill with the use of the restraining ropes (Figure 2). The machine was started at a rate of speed below that of the exercise rate and coincident with the subject's observed ability to commence

Figure 2. Dog restrained in exercising position prior to commencing stress exertion at predetermined rate and time

running without undue excitement and loss of balance, and, as the animal adjusted to the movement of the belt, the speed was rapidly increased so that in a period of approximately 10 to 15 seconds the subject was trotting uniformly at his prescribed speed. The timing clock was then set and the exercise completed under constant supervision. It was occasionally necessary to encourage the dog or supplement the effect of the tie ropes in helping maintain balance and a subsequent steady gait and comfortable exercise. This mode of exercise duplicated the procedure used in lactate determination.

Immediately after the conclusion of the stress period the animal was allowed to stand quietly on the machine while the belt with the electrodes was placed unobstreperously over previously shaved areas (at the level of the fifth intercostal space and the costochondral area). The two limb leads, "right arm" and "left arm", were used on their respective sides of the chest. This procedure was easily and rapidly accomplished at least 45 seconds after the conclusion of the test period and the paper of the electrocardiograph[1] was started (chart speed 25 mm. per second), recording commencing exactly at one minute postexercise and continued for 1.5 minutes (Figure 3).

At all times during the course of the exercise, and

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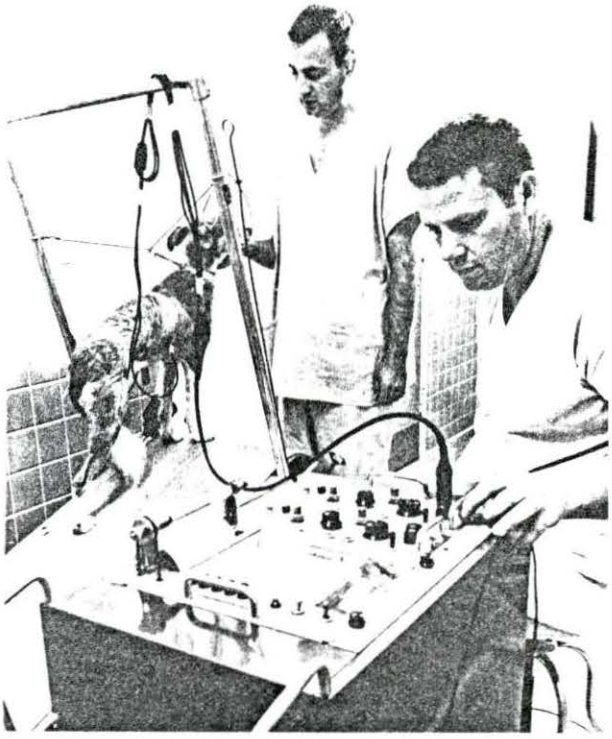
[1]Sanborn Two Channel Recording System, Model 296, Sanborn Company, Waltham 54, Massachusetts.

Figure 3. Pulse recording after stress exercise with the use of the electrocardiograph



particularly just before and coinciding with the period of pulse recording, special effort was made to avoid unnecessary movement and obtrusive mannerisms on the part of attending personnel. All pulse rate tests were taken on weekends in a closed room to avoid outside influence and minimize environmental stimuli which might influence pulse rate.

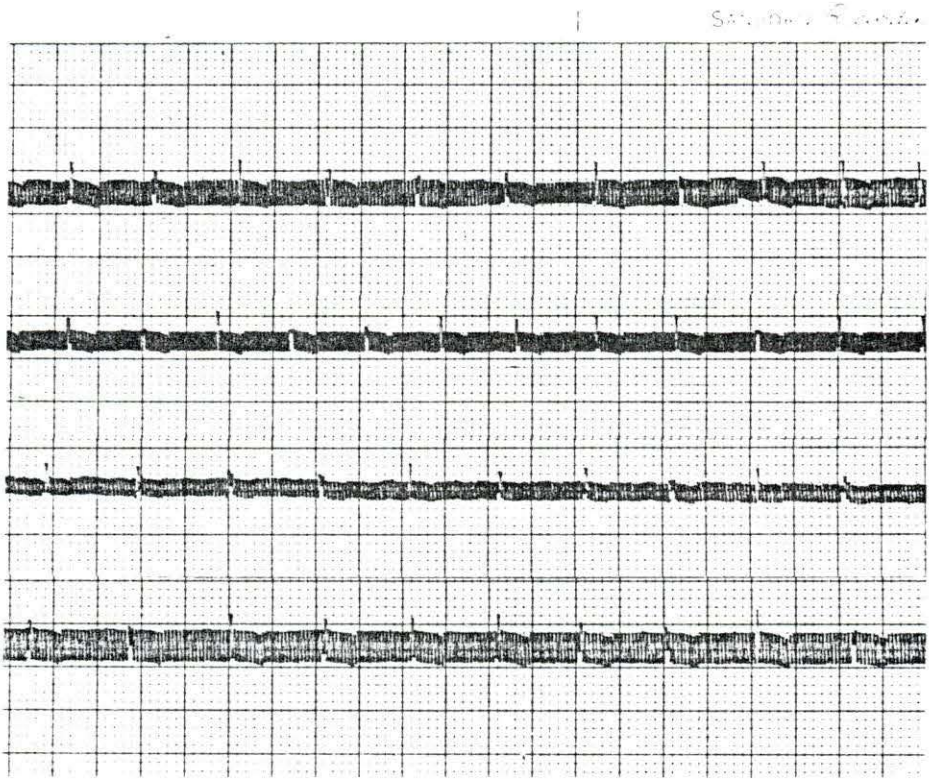
Temperature, humidity, light, and air movement remained constant as previously described.

Pulse counting was accomplished by visual enumeration of the R-waves as they appeared on the recording paper (Figure 4) between one and two minutes postexercise. A one minute postexercise pulse recovery period was thus determined.

Assessment of true resting pulse rate in the dog is difficult. To overcome the apprehension associated with removal of the dog from his accustomed habitat or the application of any type of mechanical device, it was decided to conduct all resting determinations in the subject's cage by palpation. The time of such determination was chosen as 2 to 3 hours after exercise.

By a quiet entry into the dog's cage, and by reassurance of the animal through petting, a serene subject was observed and the pulse was counted through palpation of the femoral artery. A relative slowing of heart beat was usually observed after a few minutes in the cage; the pulse was recorded only after detecting three equal pulse rates at periods of 15 or

Figure 4. Charts of R-waves--a graphic recording of pulse rate in the dog with the use of two chest electrodes, lead I, and the electrocardiograph



30 seconds.

Several "resting" pulse rates were taken for each animal at various times during the training period with the subject standing quietly on the treadmill just prior to exercise and with the use of the electrocardiograph.

Four subjects, Y-22, Y-21, K-1, and K-17, were exercised and the pulse rate recovery was observed through the use of the machine and by counting R-waves for 15 second periods at specific postexercise times.

Alkaline reserve

All subjects, including controls, were tested initially and finally and at biweekly intervals during the conditioning period.

Five cubic centimeter blood samples were taken from the jugular veins of dogs with a syringe containing heparin. Blood was collected from resting animals at least 12 hours after feeding or exercise. Samples were placed in stoppered tubes prior to laboratory analysis.

Plasma CO_2 capacity was determined by the manometric method of Van Slyke and Cullen (Hawk et al., 23, p. 649) using the Van Slyke Manometric Apparatus (Arthur H. Thomas Company, Philadelphia, Pennsylvania).

Hemoglobin

Samples of venous blood taken from the cephalic vein and heparinized were analyzed for hemoglobin concentration at the beginning of the conditioning period, during the third week, and again at the conclusion of the experimental period.

The cyanmethemoglobin method of determination as outlined by Wintrobe (57) was used. Commercially prepared Drabkin's diluent solution (Aculute, Ortho Pharmaceutical Corporation, Raritan, New Jersey) was used and results were read directly with the use of a photometer (Hemophotometer, Model 55, Fisher Scientific Company, Chicago, Illinois).

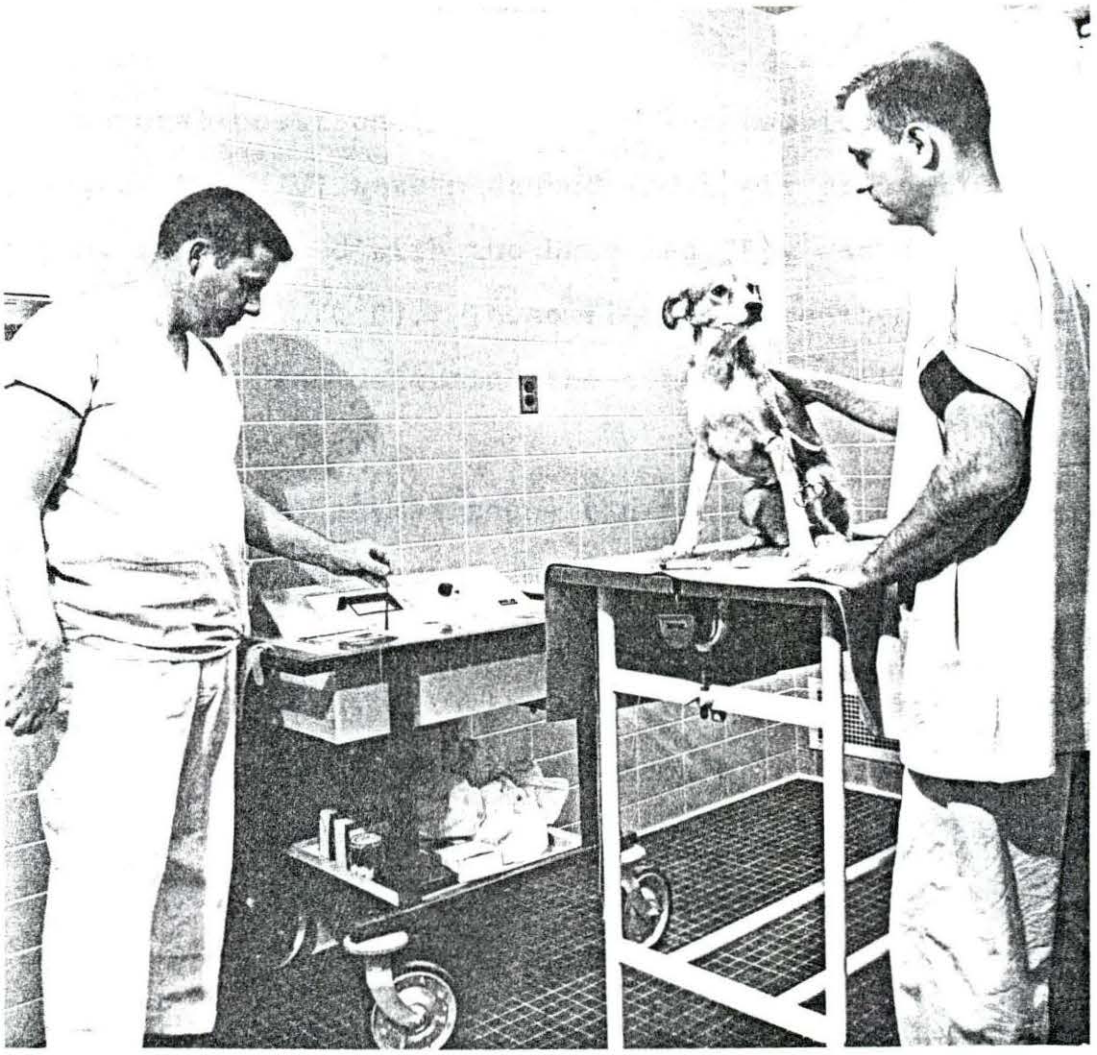
Blood volume was determined with the use of radioiodinated human serum albumin and the Volemetron (Atomium Corporation, Waltham, Massachusetts). Determinations were completed at the time of hemoglobin assay. See Figure 5.

Muscle biopsy

A method was empirically formulated to give a measure of assurance that tissue samples would be taken from similar locations in all subjects and in the same subject on the contralateral leg.

By gross selection of a superficial location in a centralized area of the biceps femoris muscle on a cadaver, an obtuse angled triangle was produced, the base composed of the length of the femur and the angles formed by the most

Figure 5. Blood volume determination by injection of radio-iodinated human serum albumin and subsequent measurement of a blood sample by the apparatus as pictured (Volemetron, Atomium Corporation)



dorsal point of the trochanter major and the most prominent (most cranial) point of the patella, this with the leg lying in a natural position (Figure 6). The two legs of the triangle (D and V) were measured and their proportional length, as compared with the base leg (F), was determined (D = .39 F; V = .71 F). These figures were then used to calculate legs and determine the size of the figure on the experimental subjects.

On any given animal then, the length of the femur from the palpable tip of the trochanter major to the patella was measured using a caliper, the lengths of the legs of the triangle calculated, with the use of a compass the locating angle marked (Figure 7) by the intersecting arcs, and the incision accomplished so that it paralleled the fibers of the underlying biceps femoris--the tissue sample being removed from directly beneath the incision.

Certain flaws in this determinative procedure are obvious. It presupposes certain morphological relationships between muscle and bone in dogs of varying size, it has no three-dimensional attributes, and it presumes that limbs of varying subjects are in the same relative position. Such shortcomings must be mentioned, but in consideration of the problems involved the method was deemed experimentally expedient and of sufficient reliability.

Animals were anesthetized, the appropriate leg prepared

Figure 6. Location of muscle biopsy site on the hind limb of a dog by triangulation, using the patella and trochanter major as points of demarkation and the distance (F) between the two points as a factor in the determination of the lengths of the legs (D and V) of the triangle

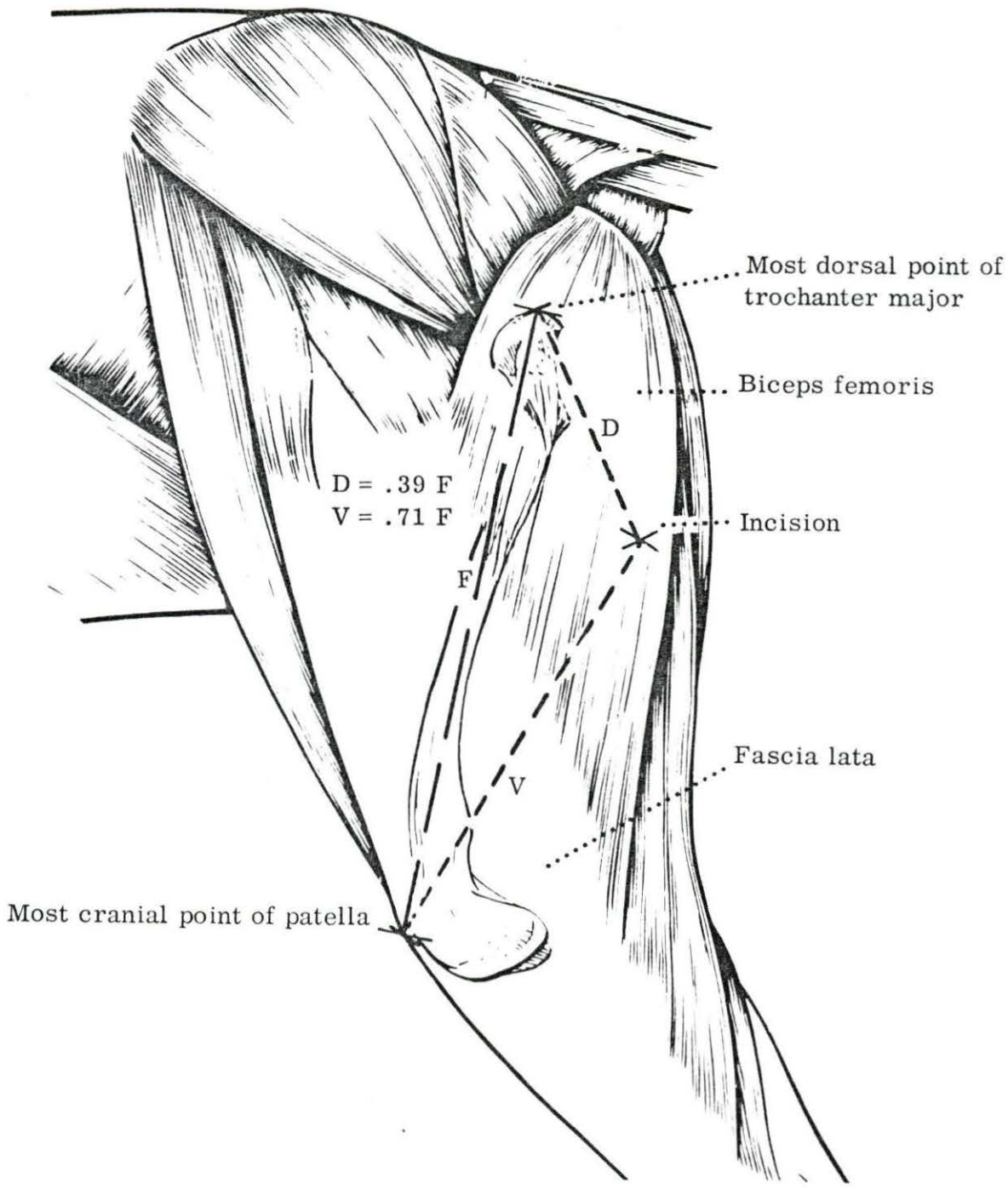
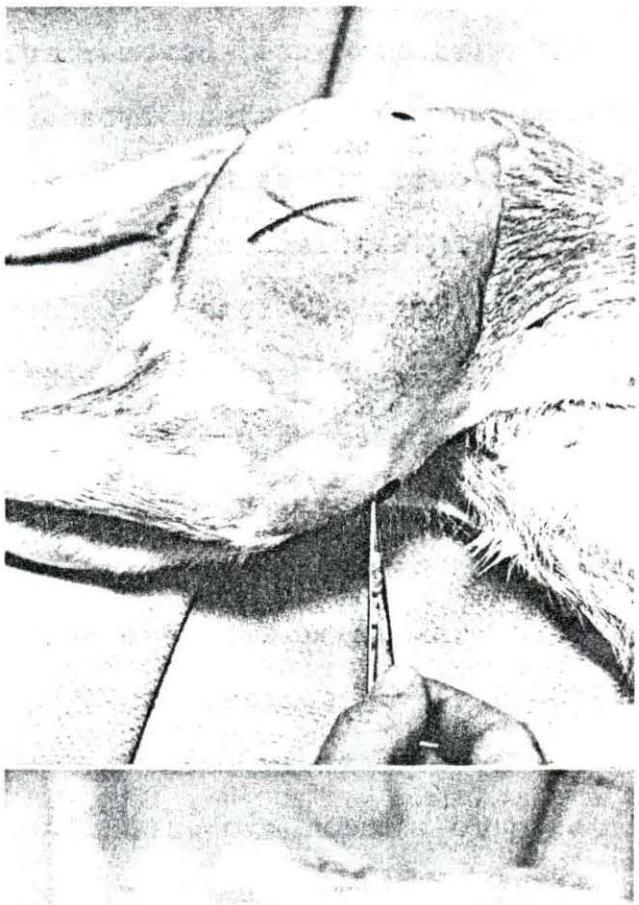
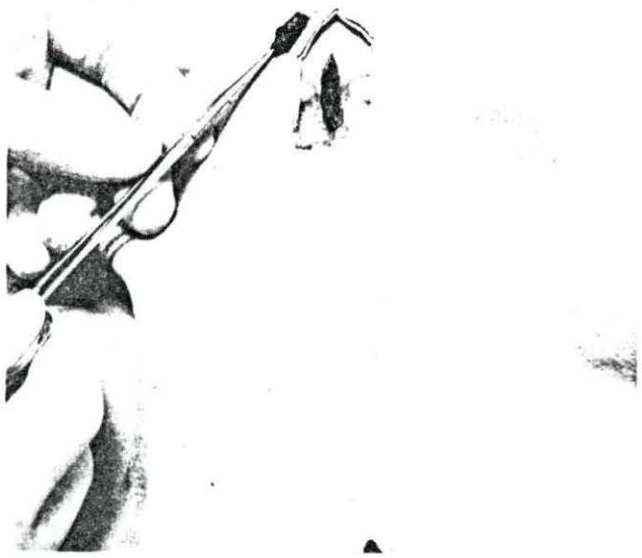

Most dorsal point of trochanter major
Biceps femoris
D
D = .39 F
V = .71 F
Incision
F
Fascia lata
V
Most cranial point of patella

Figure 7. Location of biopsy site in the biceps femoris and the surgical wound showing removal of muscle tissue sample (trochanter major and patella shown by black dots)





for surgery, the area of incision marked, and a small piece of muscle tissue removed (approximately 0.5 x 0.5 x 1.5 cm.). One or two 000 chromic catgut interrupted sutures were used to close the muscle while three interrupted sutures of 00 silk brought skin edges into apposition. Biopsies were taken on one leg before the start of the conditioning period and on the contralateral leg at the conclusion of the study.

Tissue samples were placed immediately into 10 per cent buffered formalin and held for a minimum of 48 hours.

Upon removal from the specimen bottles the tissue was cut so that cross-sectional areas were prominent and then placed in 10 per cent formalin for four hours, distilled water for one hour, three baths each of 95 per cent and absolute ethyl alcohol, two changes of paraffin, and finally embedded in paraffin ("Peel-a-way paraffin", Peel-A-Way Scientific, Long Beach, California). Sections were cut at a thickness of 6 to 7 microns and were stained with hematoxylin and eosin in the following manner:

1.	Xylol, two changes	5 minutes each
2.	Absolute ethyl alcohol, two changes	2 minutes each
3.	95 per cent ethyl alcohol	2 minutes
4.	Rinsed in tap water	rinse plus 1 minute
5.	Hematoxylin	10 minutes
6.	Tap water	5-10 dips
7.	Acid alcohol	3 dips
8.	Tap water	5-10 dips
9.	Ammonia water (0.5 per cent)	10 dips
10.	Distilled water	1 minute
11.	Eosin Y	1 minute

12.	Isopropyl alcohol, two changes	1 minute each
13.	Isopropyl alcohol	2 minutes
14.	Xylol	2 minutes
15.	Xylol, two changes	3 minutes each
16.	Cover slip	

The maximal diameters of 100 fibers, seen in cross section, and randomly selected, were measured using a calibrated microscopic ocular scale and at 97x (oil immersion). Mean diameters were then calculated.

RESULTS AND DISCUSSION

Assessment of Test Exercise

Some evaluation of the stress procedures as empirically formulated must be made. An analysis of the operation of the experiment as outlined revealed some observations which supplement the general study.

It appeared that the tests to some degree allowed for morphological variation between subjects. In a brief check of several subjects running at their formulated respective rates and at 33 per cent incline, the number of strides as counted visually with the use of a hand tally counter for a five minute period of exercise showed some similarity on an interindividual basis. See Table 3. Initial test results (Table 4) regarding postexercise blood lactate levels show some uniformity and, coupled with gross observation of the animals' reaction to the exercise procedure, give support to an attempt at establishment of uniform exertion protocols. Further studies dealing with valid methods of measure as well as rational ways of establishing procedures which are equitable to dogs of varying size would undoubtedly lead to more consistent results.

Difficulty was encountered in making the stress procedures strenuous enough to get maximal displacement of

Table 3. Visual stride frequency check at test exercise rates (K-14 and K-16 not included)

Subject	Grade (per cent)	Exercise rate (in m.p.h.)	Stride frequency[a] (for 5 minutes)
Y-22	33	3.5	789
Y-21	33	3.5	811
K-1	33	5.0	749
K-3	33	4.3	757
K-10	33	4.8	729
K-17	33	5.0	721
Y-23	33	5.1	749

[a]Number of times forefoot is brought forward during exercise. Mean = 758; S. D. = 29.7; coefficient of variation = 3.9 per cent.

of homeostatic equilibria. During the initial period certain of the animals objected to running at the prescribed rates and this necessitated their testing being accomplished at a secondary speed or a reduced grade. With conditioning the exercise procedures became easier for each subject. The subjects varied considerably in their willingness to complete the stress period, and several would not perform at all with increased incline and speed at test rates. Finding appropriate procedures for each animal which offer a submaximal

yet arduous exertion to which the subject will submit can be onerous. Other forms of exertion (e.g. swimming--with or without a handicap) might be developed and be proved to be more applicable to testing methods.

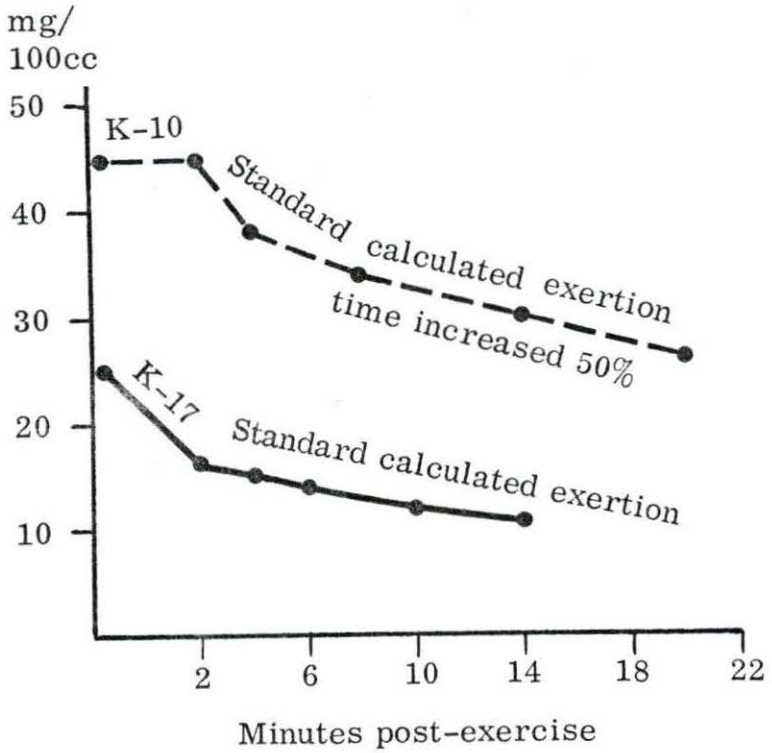
The character of the daily exercise periods necessarily influenced the results. The periods varying only from 10 to 18 minutes daily were definitely not of the type which would be expected to promote marked changes in endurance of the subject. Although the amount of work accomplished daily was relatively small, the rate of exercise was great, probably influencing the animal's relative strength more than endurance. It is felt that the exercise would only be classified as submaximal and moderate.

Selected Studies

Postexercise blood lactate

The time of obtaining the blood sample was initially and arbitrarily fixed at two minutes postexercise. For stress procedures involving nearly maximal efforts this time for the dog appears optimal (Figure 8) with the lactate level remaining high or perhaps even increasing as reported by Karpovich (28, p. 161). For less strenuous procedures the greatest lactate level might be found immediately after exercise. It should seem reasonable to assume, however, that if the time

Figure 8. Blood lactate recovery curves on two selected subjects following stress exercise where the resting blood lactate level is 14 mg./100 cc. for K-10 and 11 mg./100 cc. for K-17


mg/
100cc
50
40
30
20
10
K-10
Standard calculated exertion
time increased 50%
K-17
Standard calculated exertion
2
6
10
14
18
22
Minutes post-exercise

is kept constant in relation to sample taking, the results will be consistent in giving reliable indices of lactate production and recovery.

To verify the nature of postexercise lactate levels in the dog two subjects were exercised at a prescribed rate and samples were taken at specific times after the exercise periods. See Figure 8.

K-17 was exercised at the standard rate. Thirty seconds after cessation of exercise the lactate level was 25 mg./100 cc., this value diminishing with the passage of time so that at 15 minutes the lactate level was very nearly the pre-exercise resting level (11 mg./100 cc.).

K-10 was exercised at the standard speed and incline but for 15 minutes rather than the usual 10 minutes. It can be seen that for the first two minutes following the cessation of this more severe test the lactate level stayed constant then diminished uniformly, but still had not reached the pre-exercise level (14 mg. per cent) 20 minutes after the stress period.

These particular findings merely serve to emphasize the results of other workers using human subjects illustrating the general "recovery curve" after a bout of moderate exercise. It must be stated also that these findings would tend to support the taking of blood samples at two minutes, or perhaps even one minute, after the stress period, as

determined in these procedures, is concluded; it is anticipated that some difficulty would be encountered in getting a given subject to perform an exertion of sufficient magnitude to provoke a high unchanging level of lactic acid in the blood for a period of two to eight minutes as reported by Karpovich (28, p. 161) as being valid for man undergoing severe exercise.

The test results are reported in Table 4. Three subjects on the initial test would not perform at the prescribed rate and so were stressed with the alternate procedure. K-16 was unable to accomplish the calculated test at any time during the course of the experiment and so was held to a secondary procedure. K-14, during the course of the fifth week began to object to running in a uniform manner, injured herself during an exercise procedure and was destroyed.

The average weekly results of all tests are graphically portrayed (Figure 9). It can easily be seen that there is a rapid lowering of the lactate level beginning with the first week and extending to the second week with subsequent minor fluctuations during the remainder of the conditioning period.

The above assessment is generally corroborated by the results of each individual's weekly tests with noticeable variations occurring (Figures 10-14).

Resting lactate levels taken at random during the trial period are relatively uniform and agree in general with

Table 4. Individual postexercise blood lactate levels and resting levels (in parenthesis) in mg./100 cc., during course of the conditioning period

Subject	Initial test	Test week 1	Test week 2	Test week 3	Test week 4	Test week 5	Test week 6
Y-22	49	36	13 (11)	26	29 (15)	18	21 (13)
Y-21	19[a]	25	9 (15)	14	17 (10)	13	13 (22)
K-1	40	42	26	23 (11)	40	26 (8)	23
K-14	53	28	19	17 (11)	18	11 (8)	
K-3	33	24	20	21 (13)	27	20 (9)	33
K-16[b]	97	22	14	14 (12)	18	15 (13)	25
K-10	41	44	24	30 (16)	20	26 (7)	29
K-17	24[a]	36 (7)	32	25 (11)	23	25 (13)	17 (11)
Y-23	53	25	19 (7)	24	19 (11)	17	22 (14)
K-19[c]			(7)				(12)
K-6[c]			(6)				(12)

[a]Reduced stress exercise used (25 per cent grade and calculated rate); subject would not perform at prescribed rate.

[b]Entire test series executed with alternate rate (4.9 m.p.h.) and 25 per cent grade.

[c]Control dogs with no test exercise.

Figure 9. Mean values of weekly postexercise blood lactate levels of exercised dogs illustrating group changes during the conditioning period

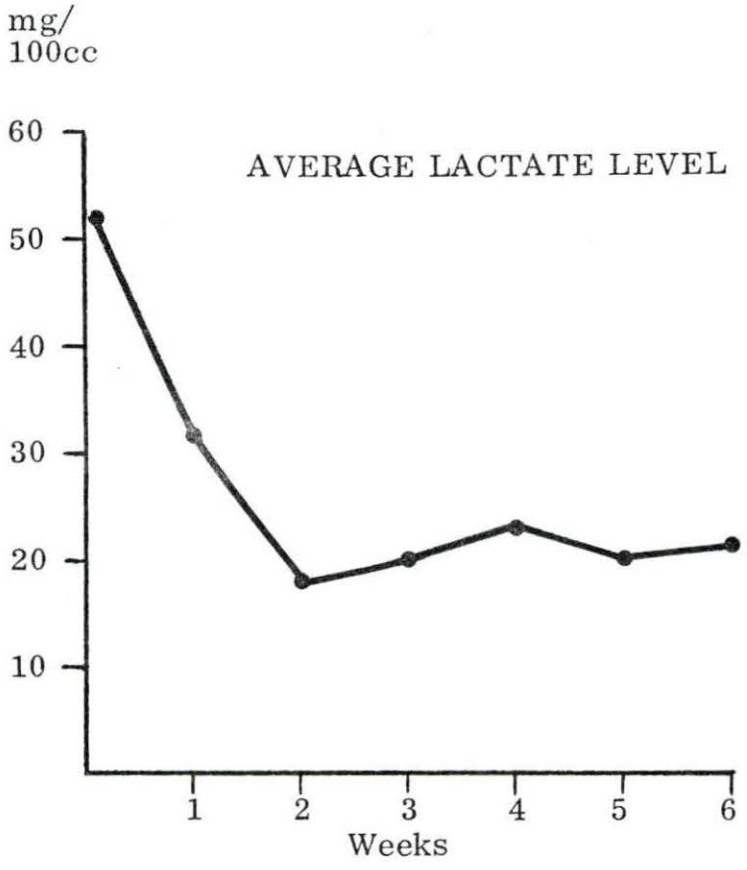
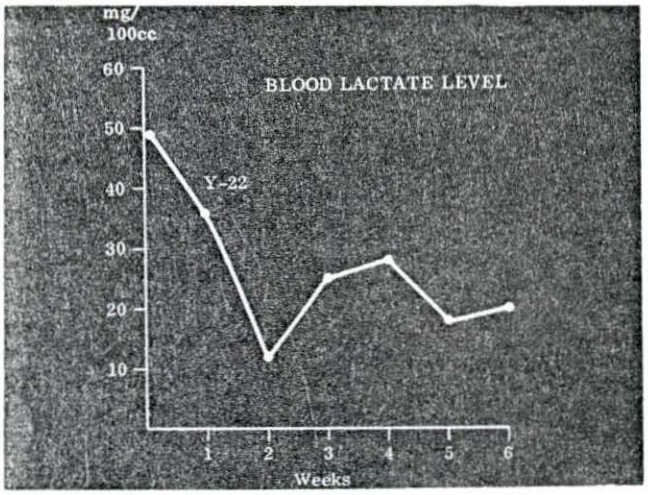
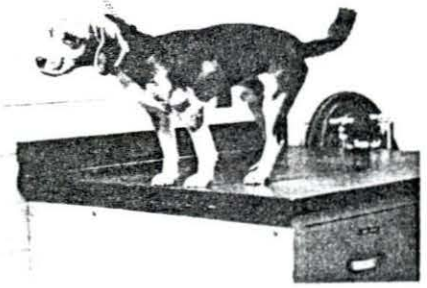
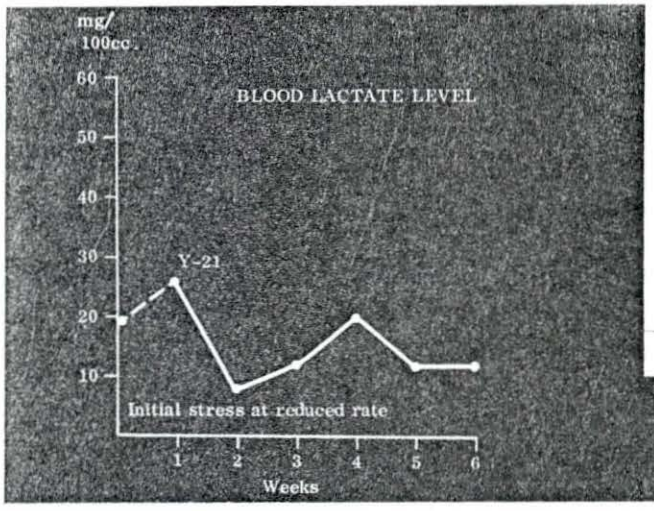

mg/
100cc
60
50
40
30
20
10
AVERAGE LACTATE LEVEL
1
2
3
4
5
6
Weeks

Figure 10. Weekly individual postexercise blood lactate levels during the course of the conditioning period for Y-22 and Y-21


mg/
100cc
BLOOD LACTATE LEVEL
60
50
40
30
20
10
Y-22
1
2
3
4
5
6
Weeks




mg/
100cc
BLOOD LACTATE LEVEL
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50
40
30
20
10
Y-21
Initial stress at reduced rate
1
2
3
4
5
6
Weeks

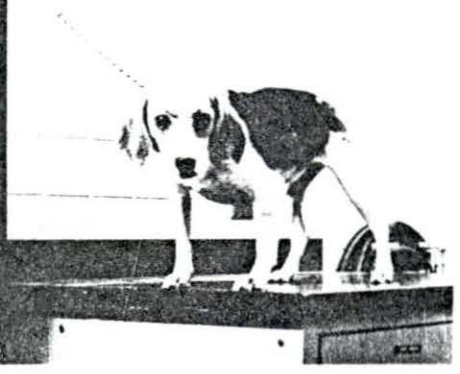
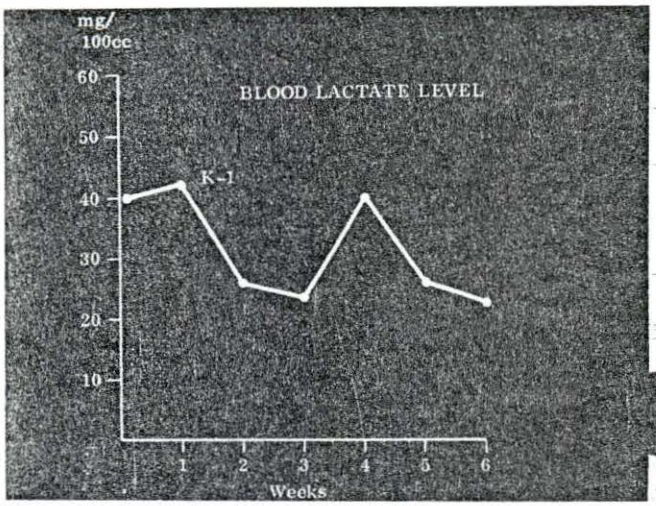
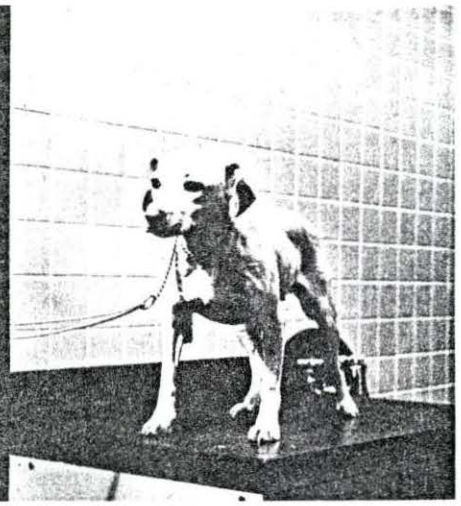
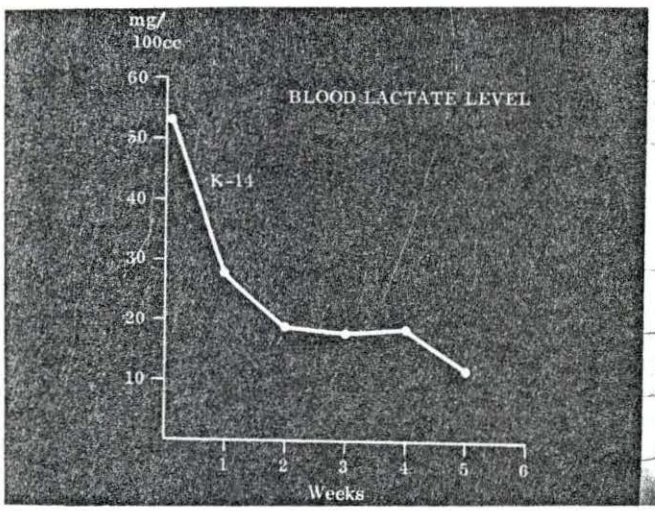


Figure 11. Weekly individual postexercise blood lactate levels during the course of the conditioning period for K-1 and K-14


mg/
100cc
BLOOD LACTATE LEVEL
K-1
60
50
40
30
20
10
1
2
3
4
5
6
Weeks




mg/
100cc
BLOOD LACTATE LEVEL
K-14
60
50
40
30
20
10
1
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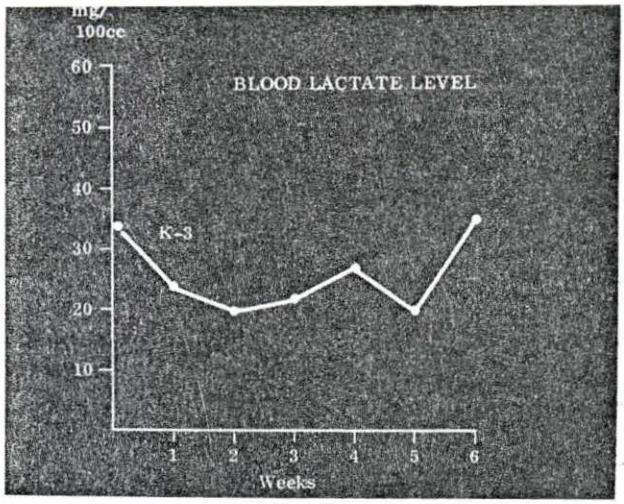
6
Weeks

Figure 12. Weekly individual postexercise blood lactate levels during the course of the conditioning period for K-3 and K-16


mg/
100cc
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10
BLOOD LACTATE LEVEL
K-3
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4
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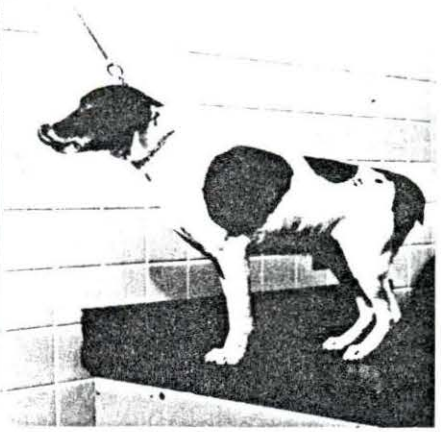
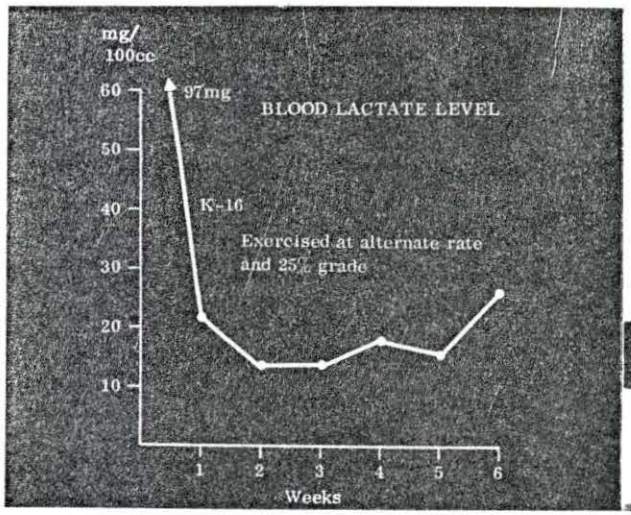
6
Weeks




mg/
100cc
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50
40
30
20
10
97mg
BLOOD LACTATE LEVEL
K-16
Exercised at alternate rate
and 25% grade
1
2
3
4
5
6
Weeks

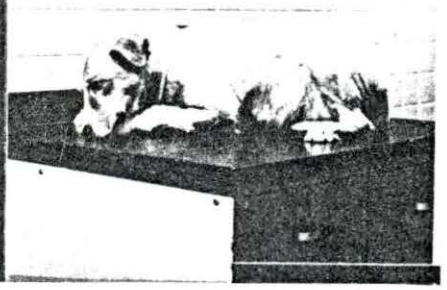
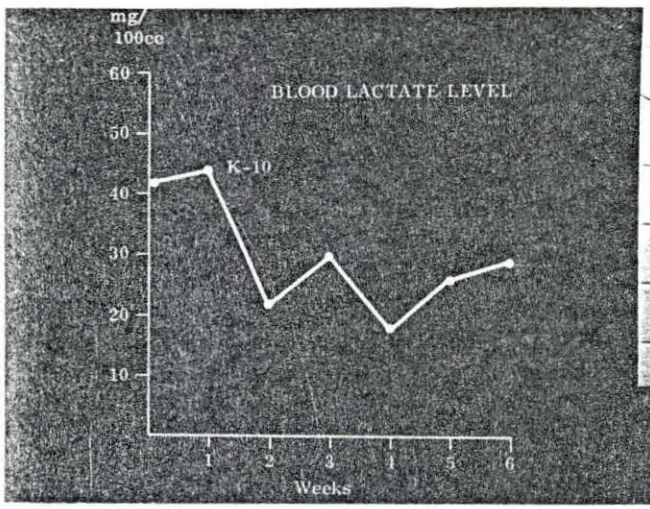


Figure 13. Weekly individual postexercise blood lactate levels during the course of the conditioning period for K-10 and K-17


mg/
100cc
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40
30
20
10
BLOOD LACTATE LEVEL
K-10
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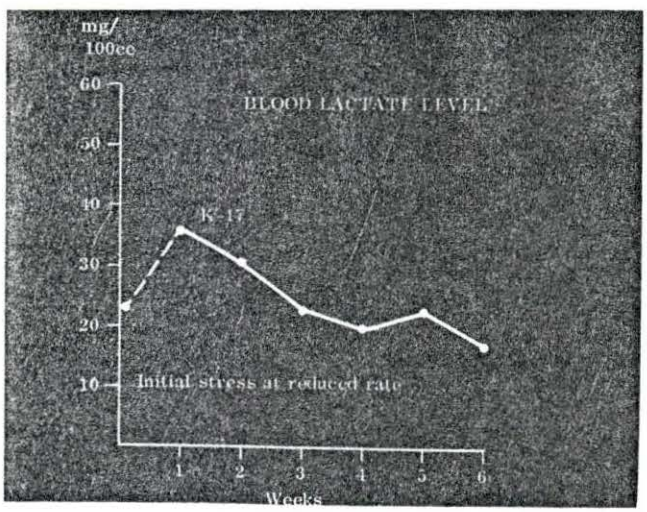
2
3
4
5
6
Weeks


mg/
100cc
60
50
40
30
20
10
BLOOD LACTATE LEVEL
K-17
Initial stress at reduced rate
1
2
3
4
5
6
Weeks

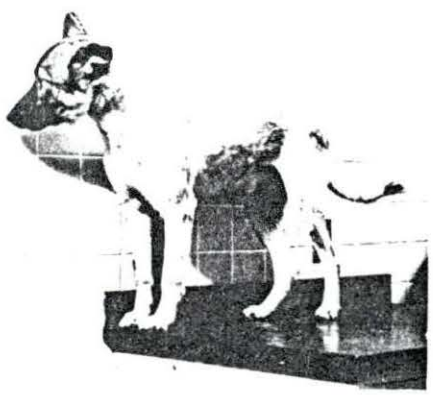
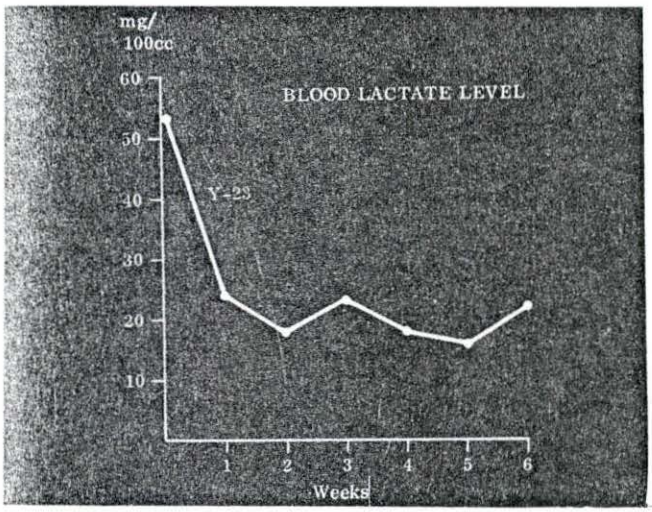


Figure 14. Weekly individual postexercise blood lactate levels during the course of the conditioning period for Y-23


mg/
100cc
60
50
40
30
20
10
BLOOD LACTATE LEVEL
Y-25
1
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5
6
Weeks

values reported by Albritton (1, p. 91) and Spector (45, p. 53). Values ranged from 6 mg./100 cc. to 22 mg./100 cc.; the mean of all tests was 11.3 mg./100 cc.

The lactate level was noticeably lowered in response to a standard exercise in all subjects tested during the course of the testing and conditioning period. This appears to indicate an ability brought about by the training period to increase the efficiency of oxygen supply to the tissues or increase the effectiveness of utilization of oxygen in the tissues, or both, during exercise with a subsequent lessened formation of lactic acid. An increased buffering ability may also be responsible for reduced lactate levels. No controls were used in an effort to confirm this supposition since the test itself presupposes exercise and conditioning experience.

Postexercise pulse rate

Pulse recovery curves are graphically presented for four of the experimental subjects (Figures 15 and 16). Y-22 and Y-21 were exercised at greater than calculated stress conditions (3.8 m.p.h. instead of 3.5 m.p.h. in case of Y-22, and 12 minutes rather than 10 minutes in the case of Y-21), while K-1 and K-17 were monitored after a standard calculated exertion. From observation of these graphs it is apparent that the greater exercise presented a more uniform curve. It could be surmised that a greater displacement of homeostatic equilibria brings about a smoother recovery unmarred by

Figure 15. Postexercise pulse recovery curves after a stress exercise on two selected subjects, Y-22 and Y-21

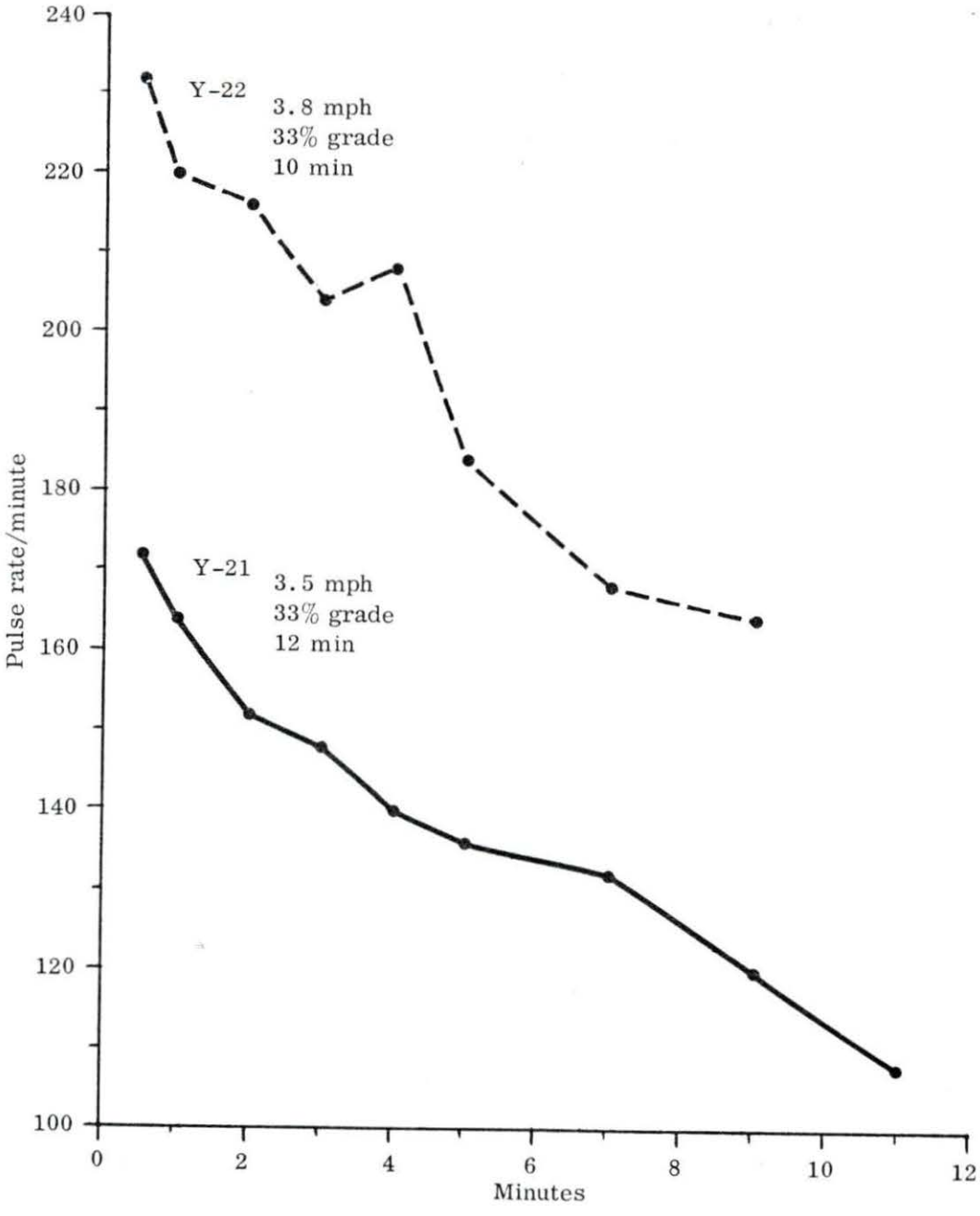
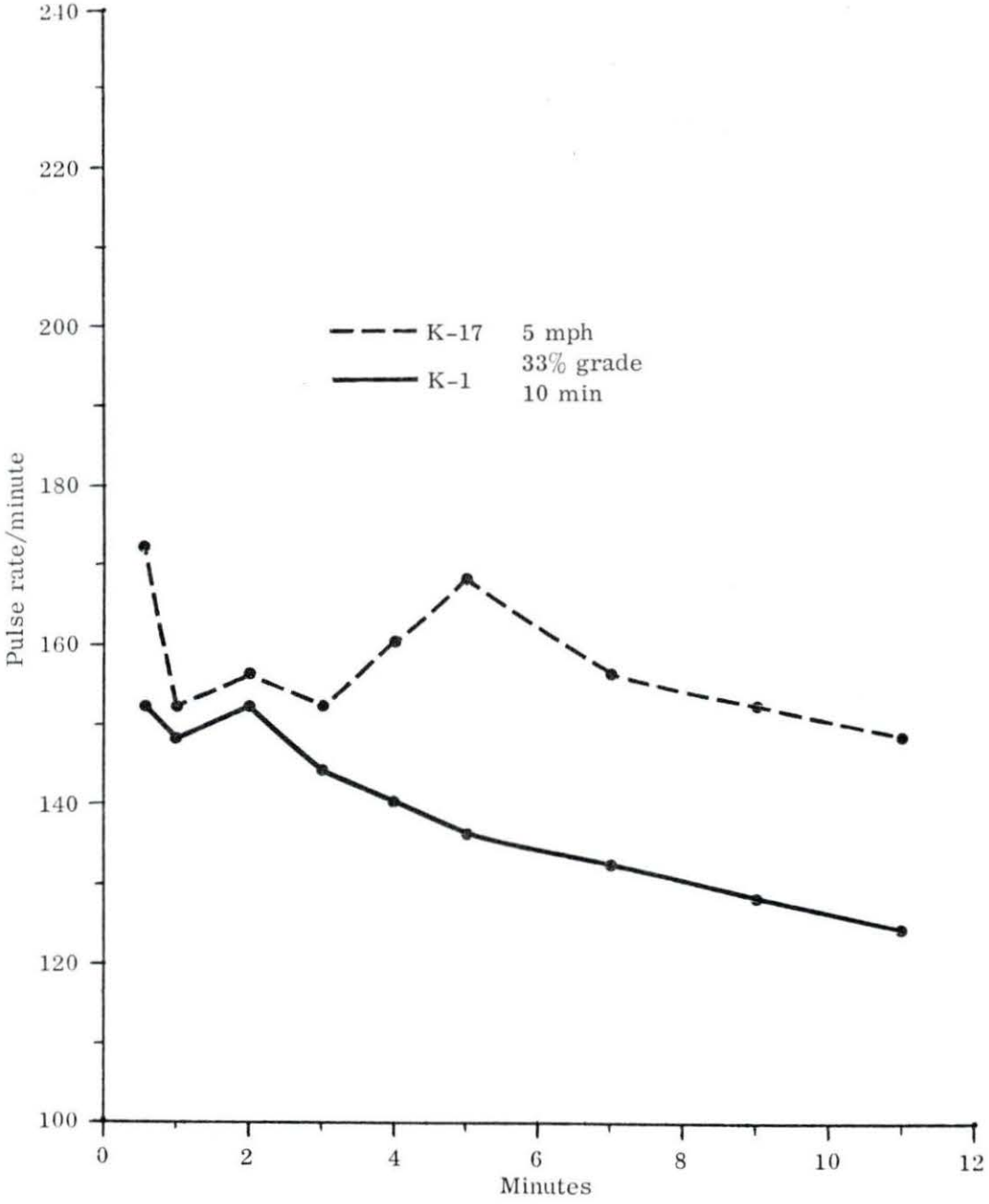

240
220
200
180
160
140
120
100
Pulse rate/minute
Y-22
3.8 mph
33% grade
10 min
Y-21
3.5 mph
33% grade
12 min
0
2
4
6
8
10
12
Minutes

Figure 16. Postexercise pulse recovery curves after a stress exercise on two selected subjects, K-1 and K-17


240
220
200
180
160
140
120
100
Pulse rate/minute
K-17
K-1
5 mph
33% grade
10 min
0
2
4
6
8
10
12
Minutes

variations caused by emotional disturbances and abstruse environmental stimuli. With prominent fluctuations in pulse rate as recorded occurring during the recovery phase, assessment of fitness through the use of counts at a particular time in the recovery period offers an opportunity for error. It was necessary to promulgate tests which included the capabilities of the majority of the subjects concerned during all phases of the conditioning period.

Table 5 summarizes the individual results of both postexercise and resting pulse rates as determined in this study. Postexercise rates ranged from a high of 200 to a low of 130 per minute. Resting determinations varied from 136 to 76 per minute.

Arithmetic means of the results of each weekly test period, as presented in Figure 17, reveal an initial resting average of 110.2 per minute decreasing to 92.3 on the sixth week. Postexercise means varied from 170.1 initially to a low of 156.3 per minute on the third week, and with a final reading of 160.2 per minute at the conclusion of the experiment.

Graphical portrayal of resting and postexercise rates, Figures 18 to 20, clearly stress the trend of the arithmetic means as mentioned above, but also show the major fluctuations that occur with the individual weekly tests, suggesting that any assessment of physical fitness using the described methods

Table 5. Individual results of weekly testing of postexercise and resting pulse rates, in rate/minute, during the course of the conditioning period

Subject		Initial test	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
Y-22	Rest	116	108	108	104	98	120	100
	Postexercise	167	152	155	155	147	170	154
Y-21	Rest	116	124	100	110	82	104	96
	Postexercise	155	147	139	142	130	155	166
K-1	Rest	118	116	108	102	100	112	86
	Postexercise	171	161	168	157	172	164	147
K-14	Rest	128	128	136	114	128		
	Postexercise	156	170	188	160	164		
K-3	Rest	118	120	112	108	120	120	124
	Postexercise	180	181	147	165	158	158	169
K-16[a]	Rest	100	100	84	82	76	84	84
	Postexercise	191	185	163	185	176	200	182
K-10	Rest	88	84	76	76	76	80	76
	Postexercise	171	165	166	154	162	146	154
K-17	Rest	88	84	88	88	82	88	84
	Postexercise	157	145	149	136	144	143	152
Y-23	Rest	120	92	98	96	80	88	88
	Postexercise	183	135	143	153	169	149	158

[a]Subject exercised at alternate rate: 25 per cent grade and 4.9 m.p.h.

Figure 17. Arithmetic means of resting and postexercise pulse rates of all subjects as determined by weekly test exercises during the conditioning period and monitoring of basal rate

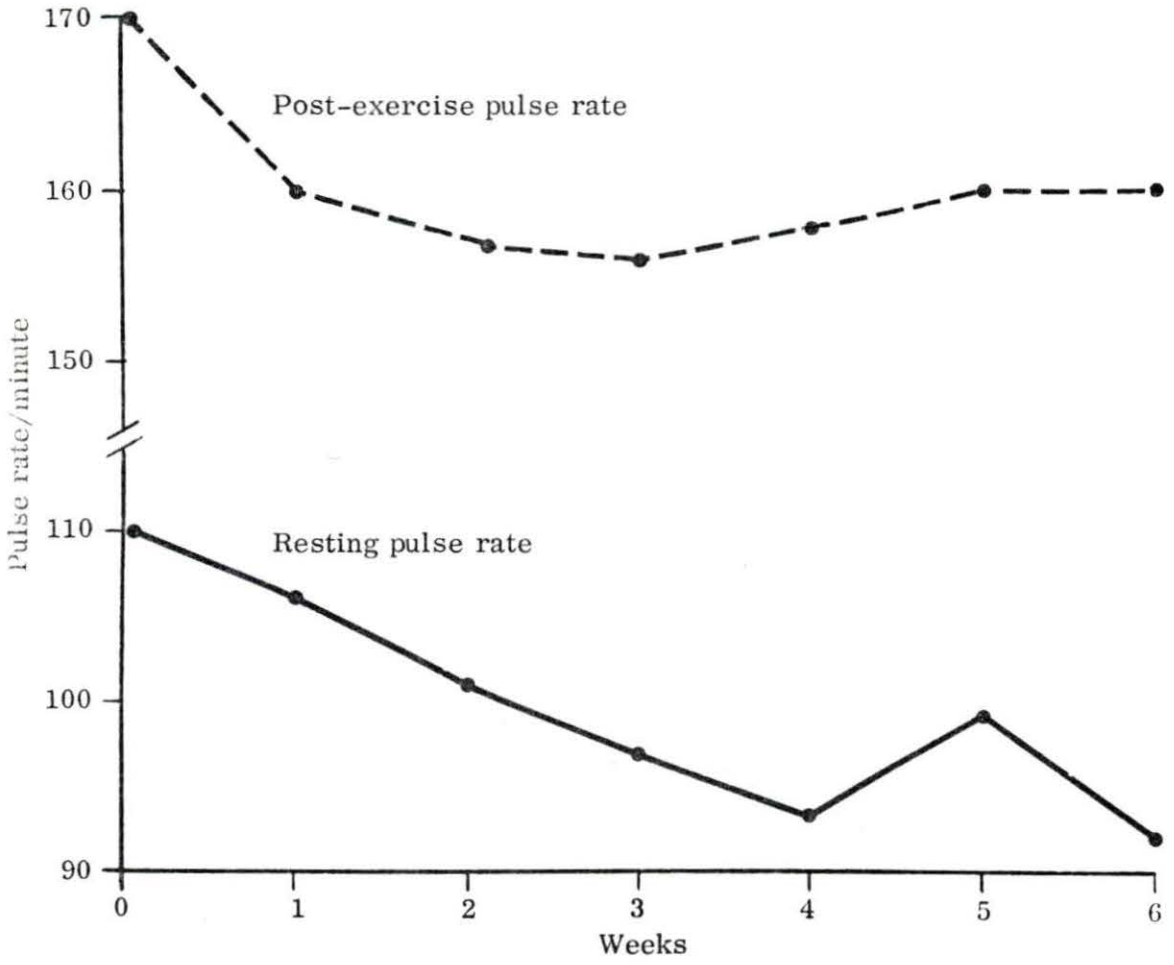

170
160
150
110
100
90
Pulse rate/minute
Post-exercise pulse rate
Resting pulse rate
0
1
2
3
4
5
6
Weeks

Figure 18. Changes in individual weekly postexercise and resting pulse rates during the conditioning period for Y-22, Y-21, and K-1

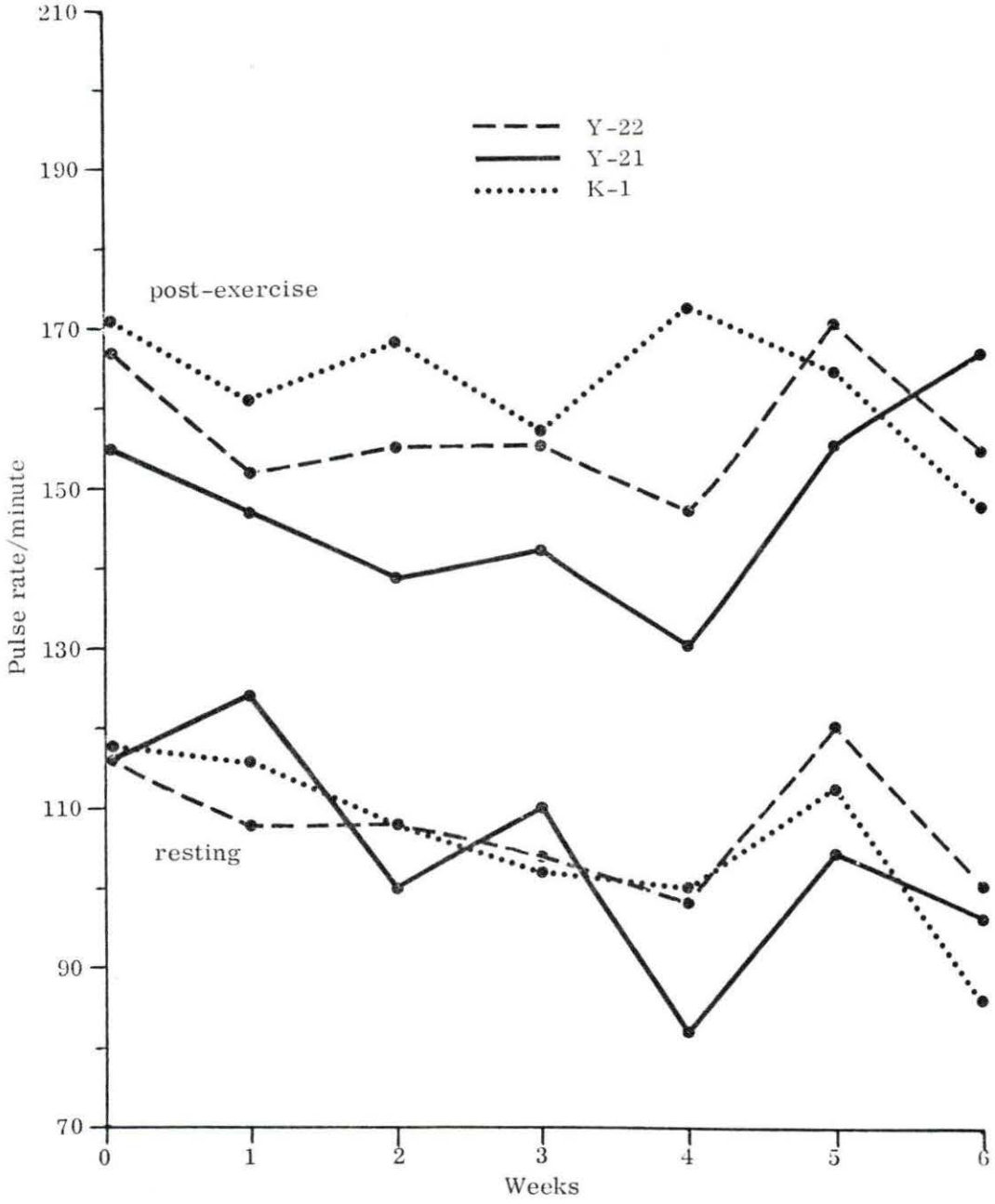

210
190
170
150
130
110
90
70
Pulse rate/minute
Y-22
Y-21
K-1
post-exercise
resting
0
1
2
3
4
5
6
Weeks

Figure 19. Changes in individual weekly postexercise and resting pulse rates during the conditioning period for K-14, K-3, and K-16

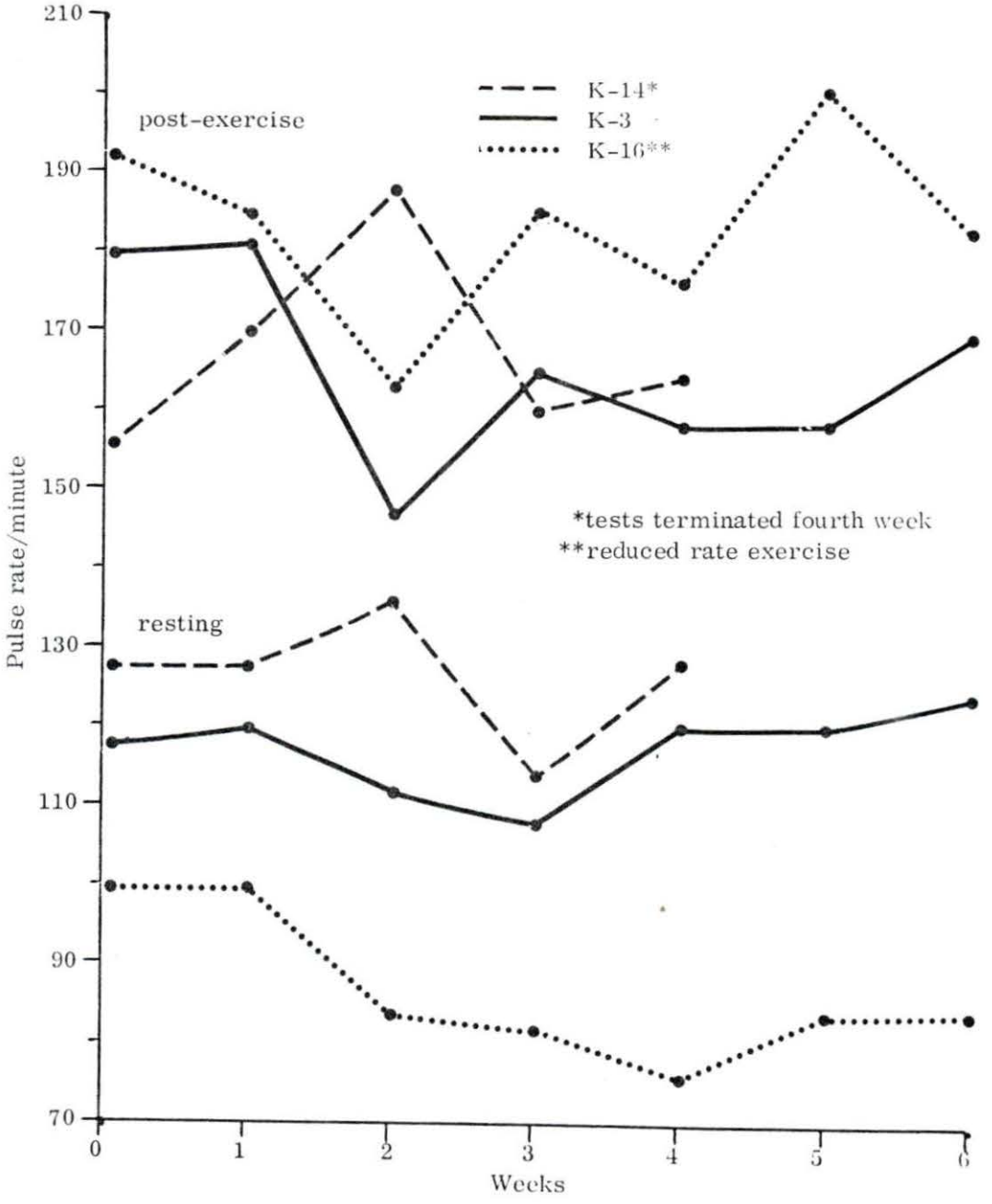

210
190
170
150
130
110
90
70
Pulse rate/minute
post-exercise
resting
K-14*
K-3
K-16**
*tests terminated fourth week
**reduced rate exercise
0
1
2
3
4
5
6
Weeks

Figure 20. Changes in individual weekly postexercise and resting pulse rates during the conditioning period for K-10, K-17, and Y-23

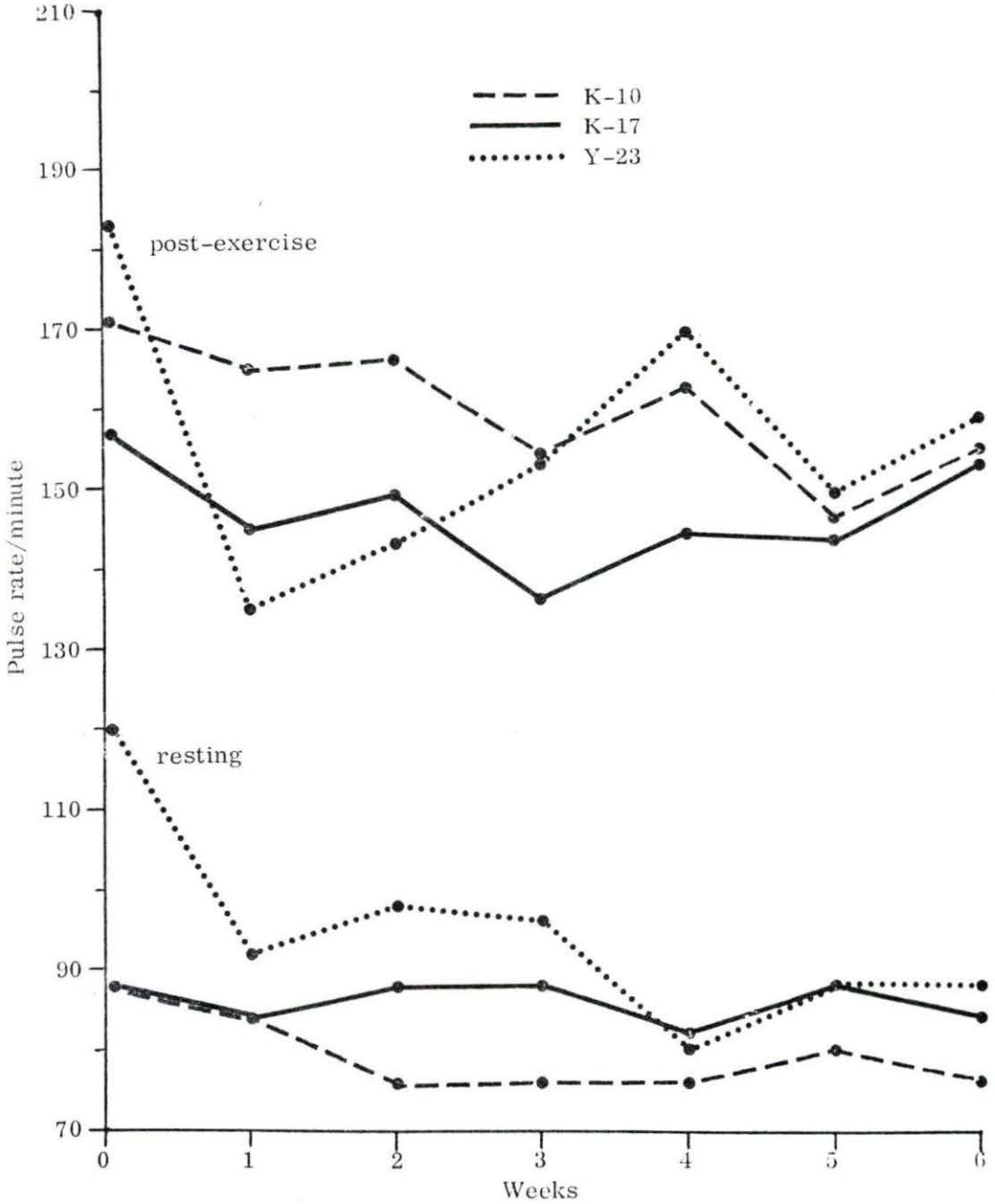

210
190
170
150
130
110
90
70
Pulse rate/minute
K-10
K-17
Y-23
post-exercise
resting
0
1
2
3
4
5
6
Weeks

Table 6. Two comparisons of basal or resting pulse with animal standing on treadmill and confined in cage

Subject	Resting pulse, treadmill rate/minute	Resting pulse, cage rate/minute
Y-22	102	108
	104	104
Y-21	116	100
	96	82
K-1	160	102
	120	100
K-14	162	136
	149	114
K-3	152	112
	148	108
K-16	134	82
	136	76
K-10	140	76
	108	76
K-17	92	88
	96	82
Y-23	112	96
	120	80

and basal and/or postexercise pulse rate should consider multiple testing with opportunity of minimizing error.

The influence of emotion and the effects of environmental stimuli on the pulse rate are seen in Table 6 which compares basal or resting pulse rates with the resting pulse of the animal standing on the treadmill just prior to exercise.

Alkaline reserve

The small number of subjects examined coupled with the once a week testing procedure makes an unqualified conclusion impossible. However, an observance of the central tendency shows definite changes and the results of this study appear to support the observations of Davis and Brewer (18). A slight reduction is noticed during the first week of training (Table 7). Subsequent determinations show a generalized but not uniform increase with weekly fluctuations and marked individual variations from week to week.

Albritton (1) reports plasma bicarbonate of the dog as 20.5 meq./L. with a range of 18 to 24 meq./L. while Spector (45) gives 18.6 meq./L. as a normal value; the mean value of the eight animals tested on the sixth and final week is 22.24 meq./L.

Control K-19 displayed no overall increase in alkaline reserve during the duration of experiment. However, the values obtained on K-6 vary widely from week to week with the final test giving a higher value than was obtained on the initial determination.

A study of test-retest correlations and monitoring of an animal through multiple determinations could provide values which would give some indication of the progress of a conditioning program and perhaps an ultimate index of physical fitness. The protocol of this particular study although

Table 7. Plasma bicarbonate values for individual subjects during course of conditioning period

Subject	Test periods (all values in meq./L.)						
	Initial	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
Y-22	15.53		20.70		20.70		20.25
Y-21	19.80		22.07		19.80		18.04
K-1	21.15	18.04		22.07		22.07	24.30
K-14	19.80	16.65		18.92		21.65	
K-3	23.40	21.15		21.65		20.70	25.20
K-16	20.70	19.80		19.80		21.65	22.98
K-10	20.03	19.80		22.55		19.35	21.65
K-17	18.04	24.30		18.04		19.35	23.40
Y-23	22.98		27.92		19.35		22.07
Means	20.16	19.97	23.56	20.50	19.95	20.79	22.24
K-19[a]	19.80		22.07		19.35		19.80
K-6[a]	19.80		30.15		18.92		22.55

[a]Dogs held without exercise as controls.

indicating group tendency was of no value in delineating individual indices of fitness.

Hemoglobin

The results of this portion of the study are found in Tables 8 and 9 and are graphically presented in Figure 21. The arithmetic means of values on the eight subjects used during each of the three tests are presented below.

A marked trend is noted in the values (Tables 8 and 9). Hemoglobin per kilogram of body weight is noticeably increased in all subjects through an increase in hemoglobin concentration (in six subjects and controls), weight loss (all subjects), and increase in blood volume (five animals and controls), or a combination of these factors.

Table 8. Arithmetic means (calculated from individual determinations on 8 available subjects) for hemoglobin and related values obtained during the three testing periods of the study

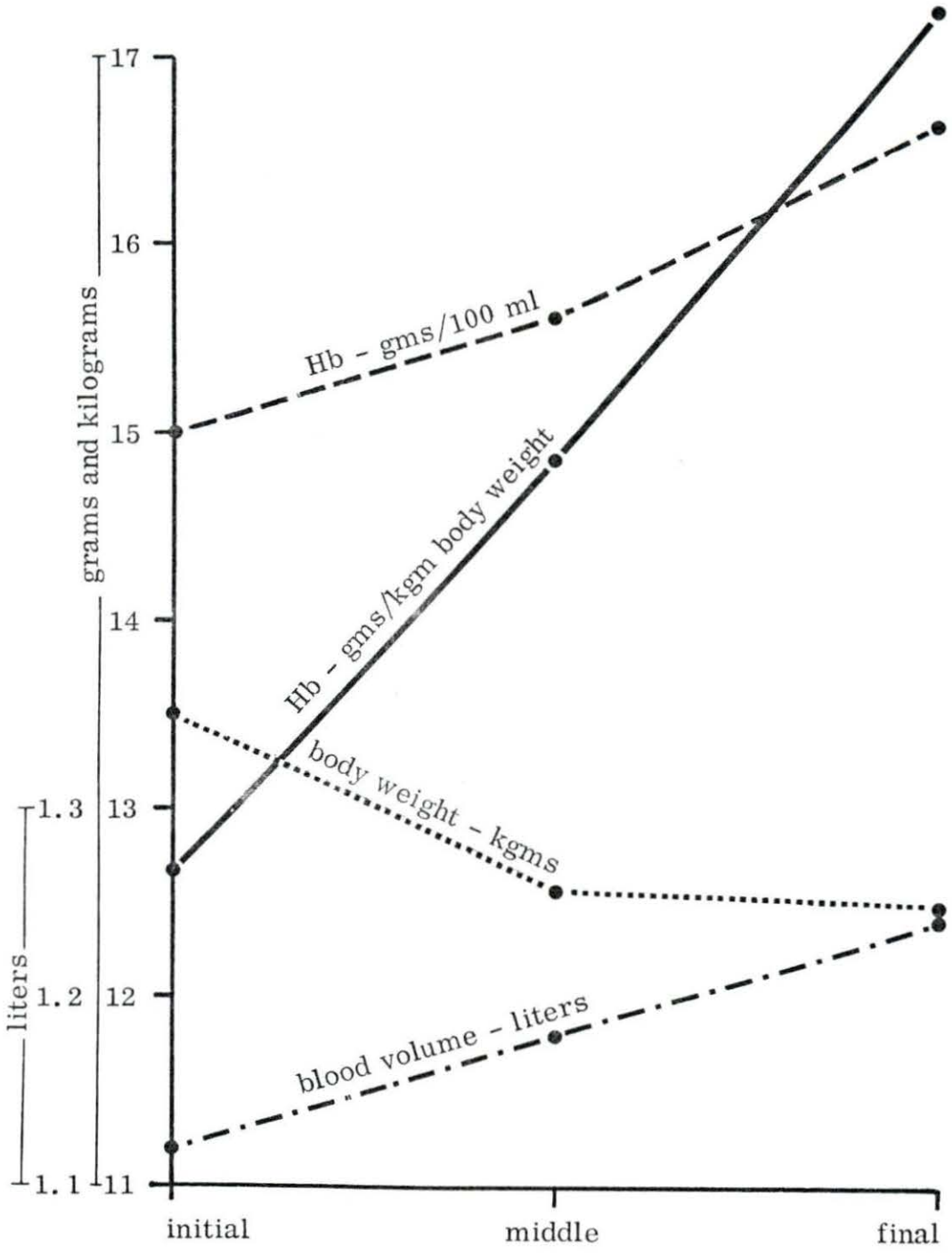
Values	Test periods		
	Initial	Intermediate	Final
Hemoglobin (gm./100 ml.)	15.00	15.60	16.60
Hb./kg. body wt. (gm./kg.)	12.68	14.85	17.22
Blood volume (L.)	1.12	1.18	1.24
Body weight (kg.)	13.51	12.56	12.49

Table 9. Individual hemoglobin and related values for the three test periods during the conditioning program

Subject	Test period	Hemoglobin (gm./100 ml.)	Blood volume (L.)	Body weight (kg.)	Hb./kg. body wt. (gm./kg.)
Y-22	Initial	16.1	.51	5.90	13.92
	Intermed.	13.9	.55	5.40	14.16
	Final	14.5	.54	5.45	14.37
Y-21	Initial	14.3	.68	7.40	13.14
	Intermed.	14.1	.73	6.75	15.25
	Final	16.2	.65	6.50	16.20
K-1	Initial	14.1	1.06	12.00	12.46
	Intermed.	16.0	.98	11.10	14.13
	Final	18.4	1.62	10.65	27.99
K-3	Initial	14.5	1.10	10.80	14.77
	Intermed.	14.5	.90	9.45	13.81
	Final	17.5	.84	9.50	15.47
K-16	Initial	16.7	1.82	25.30	12.01
	Intermed.	18.0	1.82	23.70	13.82
	Final	15.6	1.94	23.20	13.04
K-10	Initial	17.5	.81	10.80	13.13
	Intermed.	16.5	.92	10.30	14.74
	Final	18.5	1.10	9.95	20.45
K-17	Initial	12.1	1.68	20.30	10.01
	Intermed.	15.2	2.10	18.90	16.89
	Final	15.4	1.68	19.55	13.23
Y-23	Initial	14.3	1.30	15.60	11.92
	Intermed.	16.9	1.41	14.90	15.99
	Final	17.0	1.51	15.10	17.00
K-19[a]	Initial	14.6	1.81	12.60	20.97
	Intermed.	15.1	2.05	12.10	25.58
	Final	20.0	2.28	11.20	40.71
K-6[a]	Initial	14.0	2.00	24.80	11.29
	Intermed.	13.1	2.31	23.85	12.70
	Final	16.7	2.40	24.70	16.23

[a]Control animals.

Figure 21. Mean values of 8 experimental subjects showing changes in group tendency involving relationships between hemoglobin, blood volume, and body weight in respect to the conditioning period


17
16
15
14
13
12
11
grams and kilograms
1.3
1.2
1.1
liters
Hb - gms/100 ml
Hb - gms/kgm body weight
body weight - kgms
blood volume - liters
initial
middle
final

Because the two control dogs exhibited a response similar to the exercised animals (Table 9) ultimate conclusions concerning the effect of exercise on these variables is not feasible. It is suspected that exercise is responsible for some of these changes but certainly these figures fail to confirm adequately this supposition.

Any use of hemoglobin/kg. body weight or increase in blood volume as an index of physical fitness occurring during a training program would need to be substantiated by a more rigidly designed procedure and a more elaborate study.

Muscle biopsy

Table 10 lists the results of measurements of muscle fiber samples prior to the exercise period and at its conclusion. An increase in fiber diameter is noted in all exercised subjects except K-1, which exhibited a decrease, and in one control dog (K-19). The other control (K-6) exhibited a slightly reduced mean value.

It appears that even a moderate training program stimulates an increase in fiber diameter in the adult laboratory dog, and that this increase can be measured histologically by the method described, thus serving as a monitoring device.

The surgery involved in obtaining the biopsy in no way seemed to interfere with leg action and the animals appeared oblivious to the presence of the minor wound 24 hours after the tissue sample was removed.

Table 10. Results of measurement of muscle fiber diameter (biceps femoris) through biopsy initially and at termination of conditioning period

Subject	Initial test			Final test		
	Mean[a]	Range[a]	S.D.[b]	Mean[a]	Range[a]	S.D.[b]
Y-22	36.45	22-55	8.25	44.15	27-65	7.41
Y-21	46.95	22-91	12.93	52.44	32-84	9.33
K-1	54.51	27-88	11.31	49.81	24-81	9.80
K-3	43.61	19-73	10.30	52.27	32-78	9.22
K-16	53.21	34-81	8.49	58.82	42-82	8.54
K-10	50.32	27-76	11.83	52.44	27-83	9.49
K-17	50.81	27-81	9.59	53.76	35-81	9.80
Y-23	43.58	24-69	10.20	49.64	27-73	10.63
K-19[c]	43.48	22-70	10.15	48.23	24-78	9.00
K-6[c]	53.54	32-76	9.95	48.56	32-76	8.12

[a]Values in microns; 100 fibers measured.

[b]Standard deviation = $\sqrt{(\Sigma\ d^2) / N}$.

[c]Controls.

CONCLUSIONS AND RECOMMENDATIONS

Nine adult dogs of mixed breeding, which previously had been closely confined under controlled laboratory conditions for varying periods and with only minimal opportunities for mild exercise, were accustomed to exercise on a treadmill and were observed during this exercise in an effort to establish a uniform test procedure encompassing dogs of varying body type and size. They were conditioned or trained by daily bouts of moderate exercise on the treadmill, and were subjected to a battery of tests both after a standard stress exercise and at rest in order to determine what measurable changes take place during a training period and if, in general, these changes appear uniform and significant enough to be used as indices of changes in fitness. No attempt was made to assess relationships of age and morphological variance to relative fitness. Two animals were held without exercise but under similar conditions as controls.

As a result of this study certain generalized conclusions can be given and, in addition, appropriate recommendations can be offered:

1. It is possible through the use of simple procedures to devise a fitness test for dogs of variable morphology which has as its basis the action of the great muscle mass involved in ambulation. Such a test, though empirically formulated, appeared to account for bodily differences by

evoking a similar effort in the subjects during a specified time of stress exercise. Through advanced investigation of these procedures, with a more elaborate protocol involving further studies, refinement of test formulation might be accomplished with additions in reliability and validity.

2. Through a moderate conditioning program group changes were produced and conspicuous central tendencies noted in the following:

a. Postexercise blood lactate: Reduced individual and group means of lactate level as a result of the conditioning program indicate that this determination after a standardized exertion might serve to differentiate animals of varying physical fitness.

b. Postexercise (and basal) pulse rate: Although means of weekly determinations of all subjects gave evidence of uniform changes during the training period, great test-to-test individual fluctuations occurred indicating single post-exercise or basal pulse values as achieved in this procedure are of little value in assessing relative fitness in the dog. More strenuous stress exercises and/or multiple determinations on a given individual might improve reliability and make this criterion of some value.

Both reduced rates of basal or resting pulse and post-exercise pulse were noted during the training period.

c. Alkaline reserve: The dog's body does appear to

adjust chemically to the effects of chronic exercise through a relative increase in plasma bicarbonate. Although this determination may serve to monitor animals undergoing a training period it appears doubtful that differences are great enough for any interindividual comparisons; extensive, statistically evaluated studies could clarify the situation and might point out significant differences between the trained and the universal population.

d. Hemoglobin: No inferences are made concerning hemoglobin concentration and physical fitness in the laboratory dog. In this particular study there appeared to be gross changes in hemoglobin (hemoglobin/kg. body weight) values as a result of variation in body weight, hemoglobin concentration, and blood volume occurring during a training period. These changes might have been attributed to the effects of chronic exercise had it not been for a parallel reaction in the control animals.

e. Muscle biopsy: Moderate chronic exercise as established in this protocol appeared to cause muscle fiber hypertrophy. Elaborate studies of muscle morphology in relation to exercise and normal body morphology might supply data on which to base a relative index of muscular fitness and physical fitness in general in the canine.

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