# The Physiological Response of Siberian Husky Dogs to Exercise: Effect of Interval Training

A. E. READY AND G. MORGAN

*Faculty of Physical Education and Recreation Studies, University of Manitoba, Winnipeg, Manitoba R3T 2N2*

SUMMARY

Five Siberian Husky Dogs participated in an initial study to determine their physiological response to three types of exercise. Blood samples were taken prior to, and three minutes following, a 7.5 km free run and 6 km team sled run for the determination of hemoglobin, hematocrit, red and white blood cell counts, mean corpuscular volume, mean corpuscular hemoglobin, mean corpuscular hemoglobin concentration, lactate dehydrogenase, creatine phosphokinase and serum glutamic pyruvic transaminase. Samples were also taken following a 90s sprint run. Heart rate was taken immediately after each run by palpation of the femoral pulse. Average heart rates following the 90s, 7.5 km and 6 km runs were 190 bpm, 211 bpm and 166 bpm, respectively. Mean lactate concentrations following the 90s, 7.5 km and 6 km runs were 1.74 mMol · $l^{-1}$, 0.70 mMol · $l^{-1}$, and 3.06 mMol · $l^{-1}$, respectively. Elevation of lactate dehydrogenase and creatine phosphokinase was greatest following the 6 km sled run. Three of the above dogs were then studied before and after a 12 week interval training program, while three other dogs served as controls. The animals completed a three stage, submaximal treadmill test prior to and following the program. Pre and postblood samples were taken, and rectal temperature and heart rate were recorded continuously throughout the test. An analysis of variance was used to examine the significance of differences between and within groups. Although the response of heart rate, lactate, temperature and serum enzymes to submaximal exercise did not change with training significant differences between groups suggested that a more prolonged program may have resulted in such adaptations.

**Key words:** Exertion, serum enzymes, hematological parameters.

RÉSUMÉ

**La réaction physiologique de chiens Esquimaux à l'exercice: effet de l'entraînement par intervalles**

Cette expérience consistait à soumettre cinq chiens Esquimaux à une étude initiale visant à déterminer leur réaction physiologique à trois types d'exercice. On préleva des échantillons de sang, juste avant et trois minutes après une course libre de cinq milles et une course d'attelages de traîneau de quatre milles, afin de déterminer les paramètres suivants: l'hémoglobine, l'hématocrite, le nombre de globules rouges et blancs, le volume globulaire moyen, la teneur globulaire moyenne en hémoglobine, la lacticodéshydrogénase, la créatine phosphokinase et la transaminase glutamique pyruvique. On préleva aussi des échantillons de sang, après une course de vitesse de 90 secondes. On enregistra la fréquence cardiaque, immédiatement après chacune des trois épreuves précitées, par le pouls fémoral, et on obtint respectivement 211, 166 et 190 battements à la minute. La concentration moyenne de lacticodéshydrogénase atteignit par ailleurs respectivement 0,70, 3,06 et 1,74 mMol · $l^{-1}$. L'élévation de la lacticodéshydrogénase et celle de la créatine phosphokinase atteignirent leur point culminant, après l'épreuve de quatre milles. Trois des cinq chiens expérimentaux subirent diverses épreuves, avant et après un programme d'entraînement par intervalles qui s'étalait sur une période de 12 semaines; trois autres chiens servirent de témoins. Ces chiens complétèrent une épreuve à trois étapes, dans une trépigneuse, avant et après chacune des sessions de ce programme. On préleva des échantillons de sang avant et après l'épreuve de la trépigneuse, tandis qu'on vérifia la température rectale et la fréquence cardiaque, tout au long de cette épreuve. On utilisa une analyse de variance pour déterminer la signification des différences enregistrées au sein d'un groupe, ou d'un groupe à l'autre. Même si les valeurs de la fréquence cardiaque, de la lacticodéshydrogénase, de la température et des enzymes sériques obtenues à la suite de l'épreuve de la trépigneuse ne varièrent pas au cours du programme d'entraînement, des différences significatives entre les groupes permettent de penser qu'un programme d'entraînement plus long aurait pu résulter en de telles adaptations.

**Mots clés:** effort, enzymes sériques, paramètres hématologiques.

## INTRODUCTION

The sport of sled dog racing has become increasingly popular in North America and Europe. Teams consisting of three to 20 dogs compete over distances ranging from 4.5 to 75 km. Race duration varies between ten minutes and three hours. Racing season commences in mid December and continues until mid March. Regular training usually begins in the cool weather of September and often consists solely of distance workouts. Race distance is seldom considered in the design of programs and little documentation of training regimens exist (1,2).

Adaptation to chronic exercise, or training, may be monitored by measurement of the response of several physiological parameters during rest and exercise. Steady state heart rates, and postexercise blood lactate levels,

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indicate the extent to which training has affected the aerobic energy system (3,4). Alteration of the thermoregulatory response to exercise has also been demonstrated as the result of training in humans (5).

Measurement of hemoglobin concentration, hematocrit, and red and white blood cell counts at regular intervals during intense training has been reported to provide insight into the health status of elite athletes (6). Significant changes in these parameters are often considered to be indicative of staleness or overtraining (7,8). Erythrocyte parameters have been cited as useful indices of stress in horses (9) and dogs during the racing season (10).

Elevation of serum enzymes has also been used as an indicator of the severity of exercise (11). Increases in creatine phosphokinase (CPK) and lactate dehydrogenase (LDH) have been related to muscle cell membrane changes, while elevated serum glutamic pyruvic transaminase (SGPT) has been associated with liver damage. Less specific tissue damage is thought to be indicated by elevated serum glutamic oxaloacetic transaminase (SGOT) (12,13). It has been suggested that training may decrease serum enzyme elevation (13).

The purpose of this study was twofold: 1) to examine the response of blood lactate, serum enzymes and hematological parameters to several exercise intensities in Siberian Husky dogs and 2) to determine the effect of a 12 week interval training program on the response of the above parameters to a submaximal exercise test.

## MATERIALS AND METHODS

*Experiment A*

Three male and two female Siberian Huskies, ranging in age and weight from one to seven years, and 20.5 to 27.3 kg, respectively, participated in an initial study to determine the physiological response to three types of exercise. Testing occurred prior to the racing season, and the dogs maintained their activity levels throughout the study. All dogs were fed the same commercial diet (Performance, Hills Pet Products Inc., Topeka, Kansas).

The modes of exercise examined included a 7.5 km free run, a 6 km team sled run, and a 90s sprint. Blood samples were taken from the cephalic vein prior to the 6 and 7.5 km tests for determination of resting LDH, CPK and SGPT concentration, as well as hemoglobin (Hb), hematocrit (Hct), red and white blood cell counts (RBC, WBC), mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH) and mean corpuscular hemoglobin concentration (MCHC). Postexercise samples were taken three minutes following each event for determination of blood lactate concentration in addition to the above parameters. Heart rate was taken immediately after each run by palpation of the femoral pulse.

*Experiment B*

The effect of a 12 week interval training program was studied in a three dog team selected from the five animals tested previously. The animals were all male and their ages ranged from one and one-half to five years. All had undergone previous training programs. This group was designated the interval training (IT) group. Three male dogs of similar ages were selected as controls, and were referred to as the light exercise (LE) group as they were periodically run at low intensity. All six dogs were maintained on the same commercial diet mentioned previously.

Prior to the first test session the dogs were exposed to treadmill walking and running on several occasions. All exercise tests were performed in the evening to minimize diurnal variation in blood parameters. The animals were brought to the lab in a rested state following an eight hour fast. Venous blood was taken for the determination of resting Hb, Hct, RBC, WBC, MCV, MCH, MCHC, LDH, SGPT and SGOT. Preexercise heart rate was determined using an Exersentry heart rate monitor (Respironics Inc.) and rectal temperature was recorded.

The treadmill was calibrated prior to each testing session. A three minute warm up at 6 kph and 0% grade preceeded the continuous three stage test. Following the warm up speed was increased to 7.5 and 10.5 kph for each of two four minute stages. Grade was elevated to 8% during the final four minutes. Rectal temperature and heart rate were recorded continuously throughout the test. A blood sample was taken three minutes postexercise and blood lactate, as well as the hematological indices and serum enzymes examined at rest, were measured.

Dogs in the training group completed a progressive 12 week exercise program. Interval training was done twice a week during the initial four weeks, in addition to three continuous runs of 9 km per week. Interval durations ranged from four to eight minutes and a 1:1 or 2:1 work to rest ratio was employed. Total work duration during one interval training session progressed from 24 to 30 minutes. Interval training increased to three times per week for the final eight weeks of the program. Duration ranged from four to 12 minutes and a 1:1 or 2:1 work rest ratio was again employed. Total work duration increased from 30 to 36 minutes per session. Continuous runs were done twice a week and included one 9 km and one 6 km run.

An analysis of variance was used to ascertain the significance of differences between and within groups. When a significant F was obtained a posthoc comparison of means was made using Duncan's multiple range test. The significance of differences between blood parameters at rest and following exercise was determined using paired "t" tests. Prior to the investigation a 0.05 level of significance was established for all tests.

## RESULTS

*Experiment A*

Postexercise heart rates averaged 190 bpm, 211 bpm and 166 bpm folowing the 90's sprint, 7.5 km free run and 6 km sled run, respectively. Mean blood lactates following the 90s, 7.5 km and 6 km runs were 1.74 mMol $\cdot$ l$^{-1}$, 0.70 mMol $\cdot$ l$^{-1}$ and 3.06 mMol $\cdot$ l$^{-1}$. The preexercise measurements of Hb, Hct, RBC, WBC, MCV, MCH and MCHC were within the normal range reported for canines. Hemoglobin concentration increased 7.6% and 13.7% following the 7.5 km free run and 6 km sled run, respectively. Postexercise elevations of Hct and RBC were similar to that of Hb. Changes in WBC, MCV, MCH and MCHC following both types of exercise averaged less than 1.0%.

The exercise induced elevation of LDH and CPK was less following the sprint run than the longer distance

TABLE I
SERUM ENZYMES MEASURED PRIOR TO AND FOLLOWING THREE TYPES OF EXERCISE (N = 5)

| | | 90s sprint | | 7.5 km free run | | 6 km team sled run | |
|---|---|---|---|---|---|---|---|
| | | pre | post | pre | post | pre | post |
| LDH | X[a] | — | 81.8[d] | 49.8 | 125.0 | 18.2 | 210.2 |
| (units/L) | SD[b] | — | 62.5 | 13.5 | 82.6 | 5.7 | 59.4 |
| | R[c] | — | 42.0-175.0 | 33.0-65.0 | 55.0-256.0 | 11.0-27.0 | 142.0-289.0 |
| CPK | X | — | 46.7e | 31.2 | 101.0 | 57.2 | 137.6 |
| (units/L) | SD | — | 16.6 | 21.7 | 72.4 | 20.2 | 36.8 |
| | R | — | 29.0-62.0 | 15.0-68.0 | 13.0-193.0 | 31.0-86.0 | 98.0-196.0 |
| SGPT | X | — | — | 70.4 | 34.8 | 27.0 | 24.0 |
| (units/L) | SD | — | — | 14.4 | 6.4 | 5.7 | 5.5 |
| | R | — | — | 58.0-93.0 | 24.0-40.0 | 22.0-35.0 | 20.0-30.0 |

[a]Mean (for all tables).
[b]Standard deviation (for all tables).
[c]Range (for all tables).
[d]N = 4.
[e]N = 3.

events (Table I). Concentrations of both serum enzymes were considerably greater after the team sled run than the 7.5 km training run. A decrease of SGPT occurred in response to both endurance runs.

*Experiment B*

Steady state heart rates and rectal temperatures for each stage of the treadmill test are reported in Table II. There were no significant differences in HR between groups, either before or after training. Heart rates during the first two stages of the treadmill test increased significantly during the program in both groups. This was an unexpected finding, and will be discussed in greater detail. Although no significant changes occurred in rectal temperature, the values for the IT group were significantly lower than for the LE group at stages 2 and 3, prior to and following training.

Postexercise blood lactate did not differ between tests, but was significantly lower in the IT group. Values for these dogs averaged 0.57 mMol · l$^{-1}$ and 0.97 mMol · l$^{-1}$ pre and post-training, respectively. Corresponding values for the LE group were 1.50 mMol · l$^{-1}$ and 1.10 mMol · l$^{-1}$.

Resting Hb, Hct and resting and postexercise RBC were significantly higher in the LE group (Table III). There were no significant changes in these parameters, or in WBC, in response to the training program. Increases in Hb and Hct following the exercise test were not significant.

Resting and postexercise MCHC was also significantly greater in the LE group while MCV and MCH were less (Table IV). Mean corpuscular volume at rest and following exercise, and MCHC at rest increased significantly during the 12 week program. The decrease in MCV in response to exercise was also significant.

Concentration of SGPT was significantly less in the IT group at rest and after exercise (Table V). Postexercise SGOT was also lower in the IT group than the LE group. Significant increases in both enzymes at rest and following exercise occurred during the study. Elevation of SGOT during the exercise test was significant.

## DISCUSSION

The results of this study have several useful applications to exercise prescription for Siberian Husky dogs. The merits of three types of training sessions were examined in Experiment A. Comparison between the physiological response to a 6 km team sled run and the responses to a 90s sprint and 7.5 km free run, evaluated the specificity of the latter runs to actual racing conditions.

Heart rates were not at maximum following any of the three sessions. Steady state exercise values as high as 280 to 308 bpm have been reported for dogs (14,15). Breed variation, lack of motivation, and possible inaccuracies of the palpation method employed in the present study may account in part for the lower rates. Although heart rates were greater following both the

TABLE II
EXERCISE RESPONSE OF HEART RATE (bpm) RECTAL TEMPERATURE (°C) PRIOR TO AND FOLLOWING A 12 WEEK INTERVAL TRAINING PROGRAM

| Group | | HR1[a] | | HR2[b] | | HR3[c] | | RT1[a] | | RT2[b] | | RT3[c] | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | pre | post | pre | post | pre | post | pre | post | pre | post | pre | post |
| IT | X | 121.3[e] | 142.3 | 132.7[e] | 159.7 | 161.3 | 172.7 | 38.7 | 38.6 | 38.8[d] | 38.7[d] | 39.0[d] | 39.0[d] |
| (N = 3) | SD | 4.5 | 26.6 | 6.0 | 25.5 | 18.6 | 22.7 | 0.1 | 0.2 | 0.2 | 0.2 | 0.3 | 0.1 |
| | R | 117.0-126.0 | 126.0-173.0 | 127.0-139.0 | 143.0-189.0 | 146.0-182.0 | 154.0-198.0 | 38.6-38.8 | 38.4-38.7 | 38.7-39.0 | 38.5-38.8 | 38.8-39.3 | 38.9-39.1 |
| LE | X | 125.3 | 154.0 | 145.0 | 173.3 | 175.3 | 190.7 | 38.9 | 38.8 | 39.1 | 39.0 | 39.4 | 39.4 |
| (N = 3) | SD | 10.6 | 8.7 | 17.3 | 7.6 | 30.7 | 9.0 | 0.4 | 0.3 | 0.5 | 0.3 | 0.5 | 0.4 |
| | R | 114.0-135.0 | 144.0-160.0 | 125.0-156.0 | 168.0-182.0 | 149.0-209.0 | 182.0-200.0 | 38.6-39.4 | 38.8-39.3 | 38.7-39.6 | 38.8-39.3 | 39.1-40.0 | 39.1-39.8 |

[a]Stage 1; workload = 5 MPH, 0% grade.
[b]Stage 2; workload = 7 MPH, 0% grade.
[c]Stage 3; workload = 7 MPH, 8% grade.
[d]Difference significant between groups ($p < 0.05$).
[e]Difference significant between pre and post tests ($p < 0.05$).

TABLE III

HEMOGLOBIN, HEMATOCRIT, AND RED AND WHITE BLOOD CELL COUNTS AT REST AND POSTEXERCISE

| Group | | Hb (gm/dL) | | Hct | | RBC ($x10^{12}$/L)[d] | | WBC ($x10^9$/L)[d] | |
|---|---|---|---|---|---|---|---|---|---|
| | | R[a] | E[b] | R | E | R | E | R | E |
| | X | 14.3[c] | 15.2 | 40.7[c] | 42.9 | 5.70[c] | 6.09[c] | 14.3 | 13.9 |
| IT | SD | 0.8 | 0.8 | 2.3 | 1.5 | 0.26 | 0.25 | 6.2 | 5.9 |
| (N = 3) | R | 13.6-15.1 | 14.5-16.0 | 38.1-42.4 | 42.0-44.7 | 5.44-5.95 | 5.84-6.33 | 8.7-21.0 | 8.3-20.1 |
| | X | 17.2 | 17.0 | 47.5 | 46.4 | 7.06 | 6.98 | 10.1 | 9.5 |
| LE | SD | 0.5 | 1.1 | 1.3 | 2.7 | 0.15 | 0.30 | 2.6 | 2.1 |
| (N = 3) | R | 16.6-17.6 | 16.0-18.1 | 46.2-48.7 | 44.5-49.5 | 6.90-7.19 | 6.69-7.30 | 7.6-12.8 | 7.8-11.8 |

[a]Resting value.
[b]Postexercise value.
[c]Difference significant between groups ($p < 0.05$).
[d]Difference significant between rest and exercise ($p < 0.05$).

TABLE IV

MEAN CORPUSCULAR VOLUME, MEAN CORPUSCULAR HEMOGLOBIN AND MEAN CORPUSCULAR HEMOGLOBIN CONCENTRATION AT REST AND POSTEXERCISE PRIOR TO AND FOLLOWING A 12 WEEK INTERVAL TRAINING PROGRAM

| | | | MCV (fL)[d] | | MCH (pg) | | MCHC (gm/dL) | |
|---|---|---|---|---|---|---|---|---|
| | | | pre | post | pre | post | pre | post |
| | | X | 69.7[c,e] | 71.7 | 25.5[c] | 25.2 | 34.7[c,e] | 35.8 |
| IT | R[a] | SD | 1.5 | 1.5 | 0.3 | 0.7 | 0.8 | 1.4 |
| (N = 3) | | R | 68.0-71.0 | 70.0-73.0 | 25.3-25.8 | 24.4-25.7 | 33.7-35.2 | 34.5-37.2 |
| | | X | 69.3[c,e] | 71.3 | 25.4[c] | 24.9 | 34.9[c] | 35.7 |
| | E[b] | SD | 1.5 | 1.2 | 0.3 | 0.5 | 0.9 | 0.8 |
| | | R | 68.0-71.0 | 70.0-72.0 | 25.2-25.7 | 24.4-25.3 | 33.9-35.6 | 34.8-36.3 |
| | | X | 66.3 | 68.3 | 24.7 | 24.6 | 35.6 | 36.6 |
| | R | SD | 1.5 | 0.6 | 0.4 | 0.3 | 0.3 | 0.2 |
| | | R | 65.0-68.0 | 68.0-69.0 | 24.4-25.2 | 24.3-24.8 | 35.4-36.0 | 36.4-36.8 |
| | | X | 66.0 | 68.0 | 24.8 | 24.3 | 36.1 | 36.3 |
| LE | E | SD | 1.0 | 1.0 | 0.6 | 0.4 | 0.7 | 0.3 |
| (N = 3) | | R | 65.0-67.0 | 67.0-69.0 | 24.2-25.3 | 23.8-24.6 | 35.4-36.8 | 36.1-36.6 |

[a]Resting value.
[b]Postexercise value.
[c]Difference significant between groups ($p < 0.05$).
[d]Difference significant between rest and exercise ($p < 0.05$)
[e]Difference significant between pre and posttests ($p < 0.05$).

TABLE V

SERUM ENZYMES AT REST AND POSTEXERCISE PRIOR TO AND FOLLOWING A 12 WEEK INTERVAL TRAINING PROGRAM

| Group | | | LDH (units/L) | | SGPT (units/L) | | SGOT (units/L)[d] | |
|---|---|---|---|---|---|---|---|---|
| | | | pre | post | pre | post | pre | post |
| | | X | 40.3 | 42.0 | 30.7[c,e] | 42.0 | 21.3[e] | 23.5 |
| IT | R[a] | SD | 8.0 | 11.3 | 6.6 | 5.7 | 2.9 | 0.7 |
| (N = 3) | | R | 32.0-48.0 | 34.0-50.0 | 23.0-35.0 | 38.0-46.0 | 18.0-23.0 | 23.0-24.0 |
| | | X | 47.0 | 49.5 | 32.0[c,e] | 41.3 | 22.7[c,e] | 24.0 |
| | E[b] | SD | 16.3 | 27.6 | 6.9 | 8.1 | 2.3 | 1.7 |
| | | R | 29.0-61.0 | 30.0-69.0 | 24.0-36.0 | 34.0-50.0 | 20.0-24.0 | 23.0-26.0 |
| | | X | 44.0 | 30.3 | 46.3 | 64.0 | 22.3 | 31.7 |
| | R | SD | 10.8 | 4.9 | 3.5 | 2.0 | 4.0 | 4.5 |
| | | R | 32.0-53.0 | 27.0-36.0 | 43.0-50.0 | 62.0-66.0 | 18.0-26.0 | 27.0-36.0 |
| LE | | X | 46.0 | 28.7 | 46.0 | 63.7 | 25.5 | 32.3 |
| (N = 3) | E | SD | 7.1 | 14.3 | 2.8 | 5.9 | 0.7 | 3.2 |
| | | R | 41.0-51.0 | 13.0-41.0 | 44.0-48.0 | 57.0-68.0 | 25.0-26.0 | 30.0-36.0 |

[a]Resting value.
[b]Postexercise value.
[c]Difference significant between groups ($p < 0.05$).
[d]Difference significant between rest and exercise ($p < 0.05$)
[e]Difference significant between pre and posttests ($p < 0.05$).

sprint and 7.5 km run than the simulated race, values may be higher during a more competitive situation.

Lactate values were relatively low following each of the exercise sessions. Dogs do not have as great a capacity for energy production through anaerobic glycolysis as do humans or other species (14). Values of 3.8 mMol · l $^{-1}$ and 11.7 mMol · l $^{-1}$ are reported at rest and following exhaustive exercise. The lower postexercise values in this study suggest that none of the work sesisons were maximal.

Elevation of serum enzymes has also been used as an indicator of the severity of exercise (11). Concentrations of both LDH and CPK were considerably higher following the sled run than the other two sessions. Although preexercise values were not available for the 90s sprint, it appears that this form of exercise resulted in the least enzyme alteration. Increases in Hb, Hct and RBC following the 6 and 7.5 km runs may be explained by hemoconcentration, or an extravascular fluid shift (16).

It is apparent that a continuous 7.5 km run, or a 90s sprint, may not adequately prepare the dogs for racing. The higher postexercise blood lactate and serum enzymes reported for the sled run suggest that racing intensity is greater than in either of the other two modes.

The effect of a 12 week interval training program on several physiological parameters was examined in experiment B. Limitations encountered in this study included the activity level of the LE group which could not be completely controlled, and the measurement of HR with the Exersentry monitor. Although a submaximal treadmill test protocol was employed, other studies indicate that higher work intensities may have been more useful (15,17).

It is difficult to explain the increase in steady state heart rate at the first two exercise stages following the training program. The greater elevation in the LE group suggests that it was the result of external factors, and that the IT group was responding to the training program. Calibration of the treadmill prior to each test session ensured that exercise loads were accurate.

Nervous excitement may have been responsible for the unusual HR response. Barger *et al* (18) reported extreme variability in HR and other metabolic factors in dogs during the early stages of a progressive treadmill test. He recorded values of from 148 to 180 bpm in response to the same light exercise load. Lack of significant HR elevation during the higher intensity exercise of stage 3 at the posttest also suggests that excitement may have been a factor in this study.

There were no significant effects of training on rectal temperature during submaximal exercise. The significantly lower temperatures of the IT group at exercise stages 2 and 3 suggest that their temperature regulating mechanisms were more efficient. This may have been the result of prior training.

Although there were no significant effects of training on blood lactate following submaximal exercise, values were significantly less for the IT group than the LE group. The low values reported for all of the dogs in the present study suggest that the majority of energy production was oxidative. This finding is supported by the work of Hastings *et al* (14).

There were no changes in hematological parameters in response to the exercise program. Significantly greater Hb, Hct, and RBC in the LE group prior to training may indicate that they were in a more rested state than the IT dogs (7).

The significant increase of SGOT as a result of the exercise test may be the result of general tissue damage in response to acute exercise (12). Although postexercise SGPT and SGOT were both considerably greater following training, their concentrations were significantly less in the IT group than the LE group. Further research is needed to examine the suggestion of Magazanik *et al* (13) that elevation of serum enzymes in response to exercise may decrease with training.

Several conclusions and recommendations may be made from this study:

1. The physiological response of Siberian Husky dogs to a 6 km sled run, 7.5 km free run and 90s sprint differs considerably. Specific racing requirements must be considered in the prescription of training for different events.
2. The low blood lactate values following the three modes of exercise suggest that anaerobic glycolysis was involved very little in the production of energy.
3. The testing protocol employed in experiment B did not appear to be of sufficient intensity to discriminate between training effects and the effects of nervous excitement. Future studies should employ higher intensity tests, as well as attempt to measure HR more accurately.
4. Although the 12 week training program did not affect the response of serum enzymes, rectal temperature or blood lactate to submaximal exercise, significantly lower values in the IT group indicate that more prolonged training may have resulted in a decreased response.
5. The significantly lower hematological measurements of the IT group, as compared to the LE group, prior to their entrance into the controlled interval training program indicates that they may have been in a state of staleness or overtraining. Additional research is needed to study the relationship between hematological parameters and overtraining, and its usefulness in exercise prescription for racing dogs.

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## ABSTRACTS

LUTLEY R, PÉTURSSON G, PÁLSSON PA, GEORGSSON G, KLEIN J, NATHANSON N. **Antigenic drift in visna: virus variation during long-term infection of Icelandic sheep.** *Journal of General Virology* 1983; 64: 1433-1440 (Inst. Exp. Path., Univ., Reykjavik, Iceland).

Twenty Icelandic sheep were infected intracerebrally with visna virus strain 1514, and 209 virus isolates were obtained from the blood, cerebrospinal fluid, and central nervous system (CNS) over 7 years, during which 8 animals developed clinical signs of visna necessitating slaughter. Using type-specific antisera, 12 (16%) of 76 isolates tested escaped neutralization. These 12 variant viruses were distributed randomly among animals and over time, and did not replace the infecting strain even though all sheep developed homotypic antibody within 3 months of infection. In one exception (sheep no. 1557: an animal without clinical visna), the last six isolates were variants. 35 blood and CNS isolates from 7 of these sheep (including 5 with clinical visna) were tested against serial samples of their own sera. Autologous antisera neutralized all isolates tested with the exception of isolates from sheep 1557. None of the isolates obtained at slaughter from the 5 sheep with clinical visna escaped neutralization with autologous antisera. These results suggest that although variant viruses are encountered at considerable frequency during long-term infection of Icelandic sheep, the variants usually do not replace the infecting strain. Antigenic drift does not appear to be essential for virus persistence or for the development of clinically evident CNS lesions.

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DELLA-PORTA AJ. **Current status of foot-and-mouth disease vaccines including the use of genetic engineering.** *Australian Veterinary Journal* 1983; 60: 129-135. (CSIRO Div. Anim. Hlth, Nat. Hlth Lab., Private Bag No. 1, PO, Parkville, Victoria 3052, Australia).

One of the four virus structural proteins, VP1, is believed to be the main protein that stimulates virus neutralizing antibodies and research has concentrated on its potential as a subunit vaccine. Genetic engineering has been used to clone the VP1 gene of FMDV and VP1 synthesized from the clone gene has been used in experimental vaccine. Experiments in small numbers of cattle and pigs demonstrated that two vaccinations with genetically engineered VP1 could confer protection against FMDV challenge. However, there are a number of areas that need further research before such a genetically engineered vaccine could be used commercially. The use of chemically synthesized antigenic fragments of VP1 has recently been reported, and these synthesized fragments appear to be potentially better at producing immunity to FMDV than the whole genetically engineered VP1 protein, perhaps because of conformational problems in the presentation of whole VP1. Other possible future directions in research and in the development of safe, effective FMDV vaccines are discussed. In conclusion, although very significant progress has been made in cloning FMDV-VP1 genes, researchers are still far from a genetically engineered VP1-FMDV subunit vaccine.

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