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SERUM BIOCHEMISTRY AND HAEMATOLOGY ALTERATIONS IN SLED DOGS BEFORE AND AFTER A RACE

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ABSTRACT

Long-distance sled dogs are known for their great endurance and ability to run several hundred kilometres over the course of a few days. There are several factors to consider when selecting a team of high-performing sled dogs, including their physique, body score condition, appetite, paws, and ability to adapt to unknown environments and situations. The most common breed used in sled dog racing, Alaska Huskies, are known for their great work diligence, and determined mindset. It has previously been researched how well these dogs endure such intense physical activity using observation of behavioural patterns, physical examinations, and the analysis of alterations in blood parameters. This study aimed to evaluate serum chemistry and haematology alterations in dogs before and after completing a 300 km race in Norway. Changes were observed in haematology and serum chemistry between pre- and post-race blood sampling. Significant increases were observed in the white blood cell count, haemoglobin in blood and creatine phosphokine activity in serum (CK), and significant decreases were seen in the electrolytes (e.g., chlorides, potassium), cholesterol levels, liver (e.g., alkaline phosphatase) and pancreatic enzymes (α-amylase, lipase), and total red blood cell count. Several other parameters were measured, and resulted in insignificant changes. Our results indicated that long-distance racing, in fact, has an impact on the physiology of the dog, influencing muscular system, the gastrointestinal tract, electrolyte balance and haematopoiesis among others.

Key words: biochemistry; haematology; long distance racing; sled dog

INTRODUCTION

Long-distance sled dog racing is a popular sport in Europe and America, rooted in Arctic traditional transportation and hunting. Sled dogs, renowned for their great endurance, can cover several hundred kilometres over a few days. Successful and healthy dog sledding necessitates the following key elements: well-fed dogs, well-trained dogs, and good equipment. The most common breed used in sled dog racing, Alaska Huskies, are chosen because of their physique, great work diligence, and determined mindset.

Their ability to withstand the rigors of intense activity has previously been studied through behavioural observation, physical examinations, and blood analysis. By running blood before and after a race, researchers have found that long-distance racing causes alterations in serum biochemistry and haematology in sled dogs [6, 7, 13, 15].

Seriousness in alterations depended on the racing distance. Changes that have been observed in different studies include creatine phosphokinase (CK) enzyme activity, increases in white blood cells (WBC), changes in electrolyte balance, C-reactive protein (CRP) concentrations, total proteins, liver enzymes, cortisol, blood urea nitrogen (BUN), creatinine, red blood cells (RBC), haematocrit, and haemoglobin [4, 8, 10].

The aim of this study, was to evaluate serum chemistry and haematology alterations in dogs before and after completing a 300 km race in Norway.

MATERIALS AND METHODS

Animal welfare compliance

The procedures that were performed in connection with this study complied with the standard Animal Welfare Act [2], ensuring that no animals were harmed or unethically treated in order to obtain the test results. A team of 8 dogs (Alaska Huskies) were enrolled in this study once the owner provided consent. All dogs had a physical exam performed by a race veterinarian before the race start and at the finish, and all dogs were deemed healthy.

Prior to the race, the dogs had followed a training program over a course of about 4 months, running a total amount of 1 900 km since September 2023 up until the race in January 2024. The race consisted of 300 kilometres over varied terrain and a duration of 2 days in Norway. At the mid-point, each team was required to take a mandatory rest period of 10 hours. Throughout the study, all dogs consumed a similar diet designed by the musher and consisted of a mixture of beef, fish, tripe, and commercial dried dog food. Water intake was provided by warm water mixed into the food, as well as unlimited access to snow in their surroundings. Ambient temperatures ranged between -23 and -12 ºC.

Blood sampling and analysis

All dogs were rested for at least 24 hours before collection of the pre-race blood samples. Two blood samples were collected from each individual dog via the cephalic or saphenous vein. One sample was collected into a 4 ml red top serum tube with no anticoagulant and the other sample was collected into a 2 ml lavender top tube with EDTA anticoagulant. The pre-race blood sampling was performed approximately 24 hours before the start of the race. The post-race samples were taken within 90 minutes after completion of the race. Blood samples were in theory supposed to be taken from fasting dogs, but they were fed smaller meals/snacks while still on the trail. Blood samples were transported to the local veterinary hospital laboratory Alta Dyreklinikk, Norway, for diagnostics. The red top serum tubes were centrifuged at 3500 x *g* for 15 minutes within 40 minutes after blood draw, and the serum was harvested and analysed using an automated chemistry analyser (IDEXX®, Netherlands). The following parameters were analysed by the machine: SDMA (symmetric dimethylarginine), creatinine, urea, sodium, chloride, potassium, inorganic phosphatase, bilirubin, ALT (alanine transaminase), ALP (alkaline phosphatase), GGT (gamma-glutamyl transferase), AST (aspartate aminotransferase), GLDH (glutamate dehydrogenase), total protein, albumin, globulin, glucose, α-amylase, lipase, cholesterol, fructosamine, CK (creatine phosphokinase), calcium, magnesium, triglycerides, and CRP (C-reactive protein).

The blood samples collected in the lavender top tube with EDTA anticoagulant were analysed using an automated Haematology analyser ProCyte Dx (IDEXX®, Netherlands). The following parameters were analysed by the machine: leukocytes, erythrocytes, haemoglobin concentration, PCV (packed cell volume), MCV (mean corpuscular volume), MCH (mean corpuscular haemoglobin), MCHC (mean corpuscular haemoglobin concentration), and PLT (platelet count). The reference ranges used for both the biochemical and haematological parameters were automatically adjusted by the IDEXX® laboratory systems.

Statistical analysis

A paired Student's *t* test was used to compare pre- and post-race haematological and serum chemistry values.

Table 1. Haematological alterations of dogs before and after a 300 km race

Parameter	Pre-race	Post-race	Reference range	P-value
WBC (109.l^{-1})	9.82 ± 0.570	14.67 ± 0.806	4.9–17.6	< 0.05
RBC (1012.l^{-1})	7.63 ± 0.185	7.07 ± 0.300	5.4–8.7	< 0.05
HGB (g.dl^{-1})	13.33 ± 0.794	17.00 ± 0.668	13.4–20.7	< 0.05
PCV (%)	50.23 ± 1.63	50.82 ± 1.37	38.3–56.5	NS
MCV (fl)	67.85 ± 1.02	67.83 ± 0.844	56–76	NS
MCH (pg)	23.60 ± 0.355	23.67 ± 0.268	21.9–26.1	NS
MCHC	34.5 3± 0.213	34.9 0 ± 0.520	32.6–39.2	NS
PLT (109.l^{-1})	266.8 ± 25.22	337.2 ± 17.76	143– 448	NS

Results are expressed as mean ± SEM; n = 6; NS – not significant

Table 2. Serum chemistry alteration of dogs before and after a 300 km race

Parameter	Pre-race	Post-race	Reference range	P-value
SDMA (µg.dl^{-1})	10.17 ± 0.79	11.33 ± 0.88	0–14	NS
Creatinine (µmol.l^{-1})	68.50 ± 4.89	72.11 ± 5.35	44–133	NS
Urea (mmol.l^{-1})	7.23 ± 0.47	11.07 ± 1.13	3.2–10.3	NS
Sodium (mmol.l^{-1})	149.2 ± 1.42	149.2 ± 1.14	142–153	NS
Chloride (mmol.l^{-1})	113.2 ± 1.72	109.5 ± 0.80	106–120	< 0.05
Potassium (mmol.l^{-1})	4.97 ± 0.223	4.37 ± 0.206	3.9–5.8	< 0.05
Inorganic phosphate (mmol.l^{-1})	1.33 ± 0.099	1.28 ± 0.127	0.9–1.7	NS
Bilirubin (total) (µmol.l^{-1})	2.17 ± 0.389	2.92 ± 0.668	0–6.8	NS
ALT (U.l^{-1})	61.17 ± 5.89	59.00 ± 4.55	25–122	NS
ALP (U.l^{-1})	44.50 ± 4.43	42.17 ± 4.03	14–147	< 0.05
GGT (U.l^{-1})	5.00 ± 0.856	4.83 ± 0.91	2–13	NS
AST (U.l^{-1})	38.17 ± 3.70	40.67 ± 3.83	14–59	NS
GLDH (U.l^{-1})	5.67 ± 1.41	5.0 ± 0.730	1–18	NS
Total protein (g.l^{-1})	64.00 ± 2.71	62.33 ± 2.43	54–76	NS
Albumin (g.l^{-1})	35.50 ±1.67	34.50 ± 1.18	28–43	NS
Globulin (g.l^{-1})	28.50 ± 1.48	28.50 ± 1.06	24–43	NS
Glucose (mmol.l^{-1})	4.87 ± 0.390	4.97 ± 0.314	3.2–7.0	NS
α-Amylase (U.l^{-1})	463.8 ± 42.39	429.8 ± 36.04	333–1264	< 0.05
Lipase (U.l^{-1})	77.00 ± 5.27	50.83 ± 4.10	0–250	< 0.05
Cholesterol (mmol.l^{-1})	6.45 ± 0.637	5.37 ± 0.443	3.6–10.3	< 0.05
Fructosamine (µmol.l^{-1})	238.2 ± 16.88	222.0 ± 9.70	177–314	NS
CK (U.l^{-1})	176.0 ± 22.00	286.7 ± 35.30	41–378	< 0.05
Calcium (mmol.l^{-1})	2.40 ± 0.126	2.45 ± 0.092	2.1–2.9	NS
Magnesium (mmol.l^{-1})	0.900 ± 0.045	0.93 ± 0.061	0.7–1.1	NS
Triglycerides (mmol.l^{-1})	0.880 ± 0.346	1.48 ± 0.320	0.3–5.3	NS
CRP (C-reactive protein) (mg.l^{-1})	6.22 ± 0.440	9.50 ± 1.72	0–10.7	NS

Results are expressed as mean ± SEM; n = 6; NS – not significant

Data are presented as mean ± SEM. P values of < 0.05 were considered significant for all tests performed.

RESULTS

Of the 8 dogs that initially participated in the research, only 6 presented usable blood samples due to errors related to blood withdrawal in freezing ambient temperatures. However, all 8 dogs completed the race and physical examination of each dog at the checkpoints and finish line showed no illness or injury associated with racing. Out of the 6 dogs that are represented in our results, 5 are males and 1 is female, ranging from ages 4 to 9 years old. The changes in haematology and serum chemistry parameters between pre- and post-race samples are all reported in Table 1 and Table 2, respectively.

As presented in Table 1, the total white blood cell count and the haemoglobin concentration increased significantly from pre-race to post-race. Red blood cell count showed a significant decrease from pre-race to post-race. None of the significant changes did exceed any of the reference range. There were no significant changes in MCV, MCH, MCHC, PLT, or in PCV in the dogs enrolled in this study.

As presented in Table 2, the serum concentrations of electrolytes chloride and potassium and lipid metabolism parameter cholesterol decreased significantly from post-race to post-race. Serum alkaline phosphatase, α-amylase and lipase enzymes showed a significant decrease from pre-race to post-race. One parameter, creatine phosphokinase (CK), showed a significant increase in activity from pre-race to post-race. None of the significant changes did exceed any of the reference ranges.

DISCUSSION

To date, the number of scientific publications presenting complete serum biochemistry and haematology profiles in dogs participating in long-distance activities is limited. To compare the results of our study with other research results, it was necessary to take into consideration the differences between the racing distances/types of endurance exercises performed in the different studies.

White blood cells

In this study, we observed a significant increase in white blood cells (WBC). This was also seen in other similar studies on sled dogs, where an increase in neutrophils and a decrease in eosinophils were demonstrated [13, 17].

Similar WBC responses have been observed in long-distance running, both in humans and in sled dogs, which is an expected physiological response to intense exercise. Clinically, an increase in WBC is usually not of much help in diagnostics unless it is possible to do a complete leukogram. The significant increase in WBC seen in this study cannot be explained without further leukocyte differentiation. Leukocytosis may occur as a result of exercise or excitement, being mediated by increased epinephrine concentration [20]. In the case of for instance neutrophilia, the increase could have been an indication of inflammation, stress, or use of corticosteroids. Eosinophilia would have been the response to an allergic reaction or parasitic infestation. If monocytosis or lymphocytosis could have been detected, infection, chronic inflammation or other chronic diseases would have been suspected. Despite the overall increase in WBC, there might be chances of concurrent decrease in some types of white blood cells. For instance, lymphopenia and eosinopenia is a common reaction to stress or treatment with corticosteroids [20, 21].

The evaluation of WBC is often useful in combination with the measure of C-reactive protein (CRP) or other acute phase proteins to confirm a possible ongoing inflammatory process. As previously mentioned, acute phase proteins are more stable than WBC as WBC may shift even when inflammation is not involved. In this study, there was a slight increase in serum CRP concentrations, although the increase was insignificant. Therefore, there is reason to believe that the increase in WBC can be stress induced rather than infectious or inflammatory. To further investigate the impact of stress, an analysis of the concentration of cortisol in the blood could be recommended. A rise in endogenous cortisol is thought to be partly responsible for the stress leukogram seen after exercise in humans and horses, and should also be considered a potential cause in canine athletes [13]. The effects of intense exercise can increase the risk of developing both septic and non-septic inflammations partially due to the release of immunosuppressing hormones such as cortisol. These inflammations will again affect the WBC dynamic [19].

As previously mentioned, it has been proved in previous research on rats that acute stress induces an early increase/mobilisation of neutrophils, lymphocytes, helper T cells, cytolytic T cells, and B cells into the blood – followed by a decrease/trafficking of all cell types out of the blood (except neutrophils which continues to increase) [5]. From that study, it was found that mostly neutrophils were behind the increase in stress-induced leukocyte numbers, which also proposes a possible mild neutrophilia from the increased WBC count seen in this study.

Red blood cells, haemoglobin, and packed cell volume

Generally, a decrease in red blood cells (RBC) may be rooted in several factors. Most commonly, a decrease in RBC or haemoglobin (or both) represents anaemia. Anaemia is not a disease itself, but a result of an underlying disease process or condition. The results from this study showed a significant decrease in RBC, but not below the reference range. It is therefore not a considerable reason to believe that the dogs were anaemic. However, as previously mentioned, some researchers found that excessive training led to stress-induced anaemia in sled dogs due to a reduced erythropoiesis and increased destruction of RBC [17]. Later studies also proved a decrease in RBCs post-exercise in both sled dogs and working dogs [13, 15]. The reason for the decrease is unclear. In the study by J a h r et al. [13], enteritis, gastritis or gastric ulceration were presented as theories for the loss of red blood cells and proteins in sled dogs. This would have to be further investigated. Moreover, in our study there was a simultaneous increase in haemoglobin, which does not support the theory of anaemia. There is usually a correspondence between RBC, packed cell volume, and haemoglobin.

A decrease in RBC and increase in haemoglobin may also be seen in cases of dehydration. Dehydration leads to an overall decrease in blood volume, seen as increased concentration of RBC and haemoglobin per blood volume. However, no indication of dehydration was seen on our packed cell volume results. Regarding haemoglobin, most research done on exercising dogs showed either a decrease or no changes in haemoglobin concentration post-exercise, unlike the results from this study [1, 13, 19]. There was, however, one study proving an increase in haemoglobin in dogs after agility training [18]. It is unclear why the haemoglobin concentration increased in this study, but the results can be partly explained by the fact that cardiovascular parameters such as heart rate, blood pressure, and cardiac output increase to meet cellular oxygen requirements during exercise in dogs, like in humans [15]. The dogs were considered healthy at the finish line by race veterinarians, but slight dehydration is not uncommon in sled dogs after a race. Especially with very low ambient temperatures as appetite tends to decrease and meals are the main provision of water intake for the dogs during race.

Electrolytes

The post-race blood results in this study showed a significant decrease in the concentration of two electrolytes, i.e., chloride and potassium. It was difficult to foresee how the changes in concentrations of serum electrolytes would be after a 2-day race considering previous studies have represented both decreases and increases in post-race electrolyte concentrations. In some studies, there was found a slight increase in sodium concentrations after exercise, decreased potassium concentrations (but within reference range), and a significant increase in chloride concentrations with a few cases of hyperchloraemia [13, 16]. However, it was found in a study by E r m o n et al. [6] that alterations in serum electrolyte were mostly mild and clinically unimportant, showing modest differences between day 0 and day 2 of racing. Another study proved a mild, but significant decrease in potassium and sodium on day 2 of racing [7]. This is, however, not as dramatic as some of the results seen in studies from the 1990s investigating similar long-distance races. It has been said that dogs no longer suffer from hypokalemia and hyponatremia because current diets adopted by the mushers are based on more commercial dog food than meat, which better meets the electrolyte requirements [6].

The results from our study showed no significant difference between pre-race and post-race sodium concentrations, but significant decrease for both chloride and potassium. Even with these significant decreases, values were still within reference ranges, and there was therefore no basis for suspicion of hypochloraemia or hypokalaemia. As previously mentioned, there are several reasons for a decrease in electrolytes in dogs. These include vomiting, diarrhoea, and dietary deficiency among others. As far as we know, there were no signs of vomiting or diarrhoea in the dogs participating in this study.

Hyponatremia and hypokalaemia in dogs appear to happen due to excessive protein catabolism (urea generation), increased water turnover, and modest deficiency in sodium intake [6, 9]. The renin angiotensin aldosterone system (RAAS) will activate to conserve sodium, which again contributes to potassium losses and eventual hypokalaemia due to depletion of body reservoirs and increased renal losses.

The loss of electrolytes is easier to understand in exercising humans and horses, as the majority of heat loss happens through sweat, and not through respiration (panting) as is seen in dogs. Therefore, the changes in electrolytes in this study are only speculative. One theory simply supports the decrease in dietary intake of sodium, or an increased demand which is not met. Another theory is that there was diarrhoea on the trail unnoticed by the musher. Stress and exercise often induce loose stool in sled dogs and is frequently seen during races [3]. If so, this could be the explanation of the slight decrease in electrolytes, in addition to the slight increase in haemoglobin concurrently, together picturing a mild dehydration in the dogs.

Liver enzymes

Overall, the activity of liver enzymes in this study tended to slightly decrease in the dogs after the race. Alanine transaminase (ALT), gamma-glutamyl transferase (GGT), and glutamate dehydrogenase (GLDH) showed a slight decrease in the activity from pre-race to post-race, although insignificant. The liver enzyme alkaline phosphatase (ALP) showed a significant decrease. According to IDEXX® Laboratories [11], a decrease in liver enzymes usually have little importance in the clinical picture. It is hard to determine the reason behind the decrease in this study, but laboratory errors might play a role in the decrease of enzymes as they can start do degrade if samples sit for too long before they are analysed.

Most studies on racing sled dogs proved either a slight increase or significant increase in liver enzymes like ALP, ALT, and AST. Most of the studies supported the enzymes' relation to changes in muscle activity [6, 16]. while other studies supported their relation to the liver as well [7, 13]. The explanation of increased liver ALP and ALT is based on the increased metabolic demands and gastrointestinal dysfunction during heavy exercise.

As previously mentioned, ALT and AST are enzymes that might correlate with the concentration of creatine phosphokinase (CK), and often increase in conjunction with rises of CK, demonstrating muscle degeneration. In this study, there was a slight, but insignificant increase in AST. It is said that an increase in ALP, ALT, and/or AST without any changes in CK, is most likely related to altered hepatic function [6]. Considering that CK showed a significant increase in our study, the slight changes in liver enzymes are probably not related to hepatopathies, but rather to muscle activity.

In addition to the liver enzymes, there was a significant decrease in cholesterol concentration, although not below reference range. There is therefore little to no reason to believe that it was connected to liver disorders. A slight decrease in cholesterol is usually not of clinical importance. Hypothetically, the decrease seen in this study can be linked to inadequate diet.

Pancreatic enzymes

Of the pancreatic enzymes measured in this study, α-amylase and lipase were the ones showing significant decrease between pre- and post-race analyses. However, the results remained within reference ranges for both. These enzymes, especially lipase activity, is used as a marker of pancreatitis. Amylase activity does not decrease proportionally as the functional pancreatic tissue mass decreases and is therefore not the best marker. Unlike our results, a study on the effects of long-term endurance exercise on pancreatic activity performed in rats showed that pancreatic amylase activity increased, suggesting that chronic exercise enhances carbohydrate digestive capacity [14]. No studies were found explaining changes in pancreatic enzymes in sled dogs, which makes it harder to evaluate if the results in our study are substantial. In the case of for instance exocrine pancreatic insufficiency (EPI) or chronic pancreatitis, the changes in enzymes in our study would be expected to be more drastically changed. According to IDEXX® Laboratories [12], a slight decrease in pancreatic enzymes is usually not of clinical importance. There is also a chance that blood samples could be sitting for too long before being analysed, leading to certain enzyme levels to decrease due to degradation.

Muscle enzymes

Increase in muscle enzymes such as creatine phosphokinase (CK) and aspartate aminotransferase (AST) is commonly seen as a response to muscle degeneration. It must be noted that both enzymes are also present in other tissues in the body. AST can be linked to the liver and CK can be linked to organs like the heart. Without assessing specific CK isoenzymes, there is a possibility that an increase in serum CK could be attributed to the cardiac CK fraction of the enzyme, which is linked with cardiac insufficiency [16]. Nevertheless, the changes in CK activity in this study were most likely accompanying the dogs' increased muscle activity.

A modest elevation in serum CK activity is considered a natural physiological response in most animals after exercise. Increases in CK and AST levels due to musculoskeletal catabolism are expected to be seen also in healthy sled dogs [13]. However, if CK values reach over five times the upper limit of the reference range, it might be viewed as a defining biomarker for rhabdomyolysis [7, 16]. In endurance sled dogs, rhabdomyolysis is more likely to occur when concentrations exceed 10,000 $U.l^{-1}$, which is 30 times the upper reference limit. In the results from previously mentioned studies, the serum CK activities surpassed the upper reference limit, and in one study of a simulated sled dog race, the increase ranged significantly from 336 to 12,420 $U.l^{-1}$ [7, 13]. The CK activity in these studies peaked at three days of long-distance racing. In our study, the results of serum CK activity went from pre-race 176.0 ± 22.00 to 286.7 ± 35.30 $U.l^{-1}$ post-race. Considering the race only extended for maximally two days, it was possible to observe a slight increase in CK activity, although without exceeding the upper reference limit. Additionally, we observed a slight but insignificant increase in serum AST levels, suggesting only a very small correlation with the increased CK. According to the references, the elevation from this study would not be adequate to confirm an onset of rhabdomyolysis. However, the increase may still reflect the beginning of a muscle damage process. If the race was to be continued and expand past three days or more, there may have been other results obtained in this research, which might have been basis for suspicion of exertional rhabdomyolysis. In such cases, it would be an idea to follow up with another blood sample later in the race, and a urinalysis to possibly detect myoglobinuria.

Some of the parameters measured in this study can be compared with studies done on longer racing distances, and some parameters can compare with shorter, high-intensive activities. Based on the research that was presented in the theoretical section of this paper, certain haematological and biochemical values were expected to show alterations, like for instance serum CK, AST, electrolytes like potassium and sodium, WBC, and total proteins.

Some parameters that were expected to be altered in our study did not change, of which some of these were CRP, sodium, total proteins, and BUN.

For CRP, other studies presented significant increases in sled dogs after exercise, many exceeding the reference limit. It was concluded that it may have reflected an interaction with muscle degradation and inflammatory response [13]. Other studies on racing sled dogs demonstrated a significant increase in BUN, which seemed to be related to possible transient kidney dysfunction. It was suggested that exercise diminishes renal blood flow, and hence decreases glomerular filtration rates. Additionally, increase in BUN can be the result of high dietary protein intake combined with increased protein catabolism during racing [7, 13].

The increase in total proteins was seen in several other studies, hypothesising that it might be related to increased protein catabolism due to the high-energy demands, renal losses via microalbuminuria, gastrointestinal losses (of total proteins), or a potential state of chronic inflammation [6, 7, 13]. The reasons for not achieving such results in our study might be related to the shorter racing distance and allowing dogs adequate resting.

Stress prior to a race may influence the results of blood analysis. Since the samples were collected about 24 hours before the start of the race, and not immediately prior to the race, the possible impact from anticipation and stress should have been eliminated. However, errors cannot be excluded with certainty. Although handled by protocol, it cannot be excluded that the blood samples may have been affected by the cold ambient temperatures during blood withdraw or during transportation to the laboratory.

CONCLUSIONS

In conclusion, the results from this study suggest that two successive days of moderate distance endurance racing results in mild, but significant alterations in certain haematology and serum chemistry values. In our study, the most prominent changes were seen in white blood cells, electrolytes (chlorides, potassium), muscle enzyme (creatine phosphokinase), liver enzyme (alkaline phosphatase) and pancreatic enzymes (α-amylase and lipase) and serum cholesterol levels.

This topic warrants further investigations in order to completely understand the physiologic changes that appear in sled dogs. With more research carried out in racing environments, it will be possible to further develop the animal welfare of the dogs participating in such activities.

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