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Original Research

Assessment of the Degree of Dehydration in Dogs Based on Biochemical Parameters Using Ordinal Logistic Regression

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Abstract

This experimental study was carried out in the faculty of veterinary medicine, at Suez Canal University, Ismailia, Egypt. A total of 40 dogs were categorized based on the severity of dehydration into three categories (mild, moderate, and severe) and a fourth group for dogs without dehydration. Many biochemical parameters were utilized to evaluate dehydration, including blood electrolytes (Na, K, CL, Ca, Mg, and P), liver enzymes (ALT and AST), kidney function parameters (urea, creatinine, and uric acid), and lactate. The most prevalent clinical manifestations of gastroenteritis in dogs were vomiting, followed by profuse watery yellowish to bloody diarrhea, anorexia, and mild, moderate, and severe degrees of dehydration manifested by STT retardation. Four OLR models ranging from univariable to multivariable logistic regression were developed. Lactate, AST, creatinine, urea, and uric acid were recorded as positive predictors for the severity of dehydration; however, only lactate, AST, and uric acid were recorded as positive significant ($p<0.05$) predictors for the degree of dehydration. Na, K, Cl, Ca, Mg, P, and ALT were all negative predictors of dehydration level. Na and K were significant (P0.05) negative predictors of the degree of dehydration, whereas the remaining variables were not substantially related to the degree of dehydration. It was observed that biochemical markers are good indicators of dehydration; including these factors in the OLR model will help in differentiating between different degrees of dehydration.

KEYWORDS
Biochemical parameters, Dehydration, Gastroenteritis, Ordinal logistic regression (OLR), Maximum likelihood estimates, Odds ratio (OR).

INTRODUCTION

The most prevalent cause of fatal hypovolemic shock in dogs is dehydration, which is the body's overall loss of fluid (David *et al.*, 2013). Low fluid intake, high fluid loss, or both can lead to a negative fluid balance, which in turn causes dehydration (Popkin *et al.*, 2010). Moreover, dehydration may result from vomiting and diarrhea, and it is widely regarded as the leading cause of death worldwide (Bhat *et al.*, 2013). Symptoms of hypovolemic shock include reduced tissue perfusion and the potential failure of numerous organs because of fluid loss (Wilson and Morley, 2003). Dehydration could be classified as mild, moderate, or severe (David *et al.*, 2013). Common diagnostic methods for determining the extent to which a dog with gastroenteritis is dehydrated include hematological and serum biochemical markers (Jagrič-Munih *et al.*, 2012).

The degree of dehydration is an ordinal categorical variable. Ordered logistic regression (OLR), as opposed to conventional logistic regression models, takes into account the data's natural order (Hosmer and Lemeshow, 2000), logistic regression is equivalent to ordinary least squares (OLS) regression (LR). Logistic regression models the dependent variable exclusively when it is discrete, in contrast to ordinary least squares regression, which models a continuous dependent variable in terms of one or more independent factors (Adeleke andAdepoju, 2010).

If the proportional odds assumptions are met, the cumulative logit model (also known as the proportional odds model) can handle ordered data (McCullagh, 1980; Hosmer and Lemeshow, 2000). Adeleke and Adepoju (2010) used the ordinal logistic regression model to estimate pregnancy outcomes, including live birth, stillbirth, and abortion, in terms of the three main components of environmental (previous caesareans, service availability), behavioral (antenatal care, diseases), and demographic (maternal age, marital status, and weight). Moreover, Dong (2007) used ordinal regression models in a study of self-efficacy in colorectal cancer screening.

Consequently, the purpose of this study was to use ordinal logistic regression to determine the severity of dehydration following gastroenteritis in dogs by analyzing biochemical markers.

MATERIALS AND METHODS

Ethical approval

All procedures used in the present study were approved by the Scientific Research Ethics Committee on animal research, Faculty of Veterinary Medicine, Suez Canal University, Egypt (2023024).

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Animal and study design

This research was conducted at a private small animal clinic in Ismailia Governorate, Egypt, on household dogs with gastroenteritis disorders. Forty dogs were divided into four groups: those with no signs of dehydration (five), those with mild dehydration (eight), those with moderate dehydration (twenty), and those with severe dehydration (seven). Côté *et al*. (2015) method was used to conduct a complete investigation and clinical examination of each dog. General inspection, assessment of respiration and pulse rate, recording of rectal body temperature, examination of mucous membranes, and Skin Turgor Test (STT) for evaluation of dehydration according to the Clinical and Laboratory Standards Institute (CLSI) criteria are all part of the examination (David *et al*., 2013).

Sampling

The following 40 blood samples were collected: 5 samples from dogs with no dehydration, 8 samples from mildly dehydrated dogs, 20 samples from moderately dehydrated dogs, and 7 samples from sever dehydrated dogs. Each dog's cephalic vein blood sample was taken into a plain tube, left to clot for 30 to 60 minutes, and then centrifuged at 3000 rpm for 20 minutes to separate sera. For further biochemical analysis, serum samples were placed into microcentrifuge tubes and stored at - 20°C (Coles, 1986).

Biochemical analysis

Serum electrolyte levels, including sodium (Na^+), potassium (K^+), chloride (CL^-), calcium (Ca^{++}), magnesium (Mg^{++}), and phosphorus (P^-), as well as serum lactate levels, were determined calorimetrically using commercial kits given by Spectrum, Egypt. Serum enzymatic activities of alanine aminotransferase (ALT) and aspartate aminotransferase (AST) was determined colorimetrically using kits supplied by Elitech (Egypt). Meanwhile, the serum levels of creatinine, urea, and uric acid were measured colorimetrically using kits supplied by Spectrum, Egypt.

Statistical Analysis

Study variables, data collection, and measurements

The response variable in this study is the ordinal levels of dehydration, which are categorized as follows:

$$Y_i = \begin{cases} 0, \text{Normal}, \\ 1, \text{Mild}, \\ 2, \text{Moderate}, \\ 3, \text{Sever}. \end{cases}$$

A total number of 40 dogs were classified according to the degree of dehydration into 5 normal dogs with no dehydration, 8 dogs express a mild degree of dehydration, 20 dogs with an express a moderate degree of dehydration, and 7 dogs express a severe degree of dehydration. To assess dehydration, several biochemical parameters were used, including blood electrolytes (Na, K, CL, Ca, Mg, and P), liver enzymes (ALT and AST), kidney function parameters (urea, creatinine, and uric acid), and lactate.

Proportional odds model (POM)

Due to the ordinal character of animal dehydration levels, numerous univariate and multivariate logistic regression models were utilized to investigate the categories of these outcomes. The multivariable OLR model fitted several independent variables for predicting one ordinal dependent variable, whereas the univariable OLR model only fitted one predictor for estimating the level of dehydration. POM is the most widely used ordinal logistic regression model (O'Connell, 2000; Tesfaledet *et al*., 2019) initially developed as a cumulative logit model by Walker and Duncan (1967) but was later renamed the proportional odds model. The proportional odds assumption (Equality of the log odds across the multiple cut points (categories) of the outcome variable) is widely used in epidemiological and biomedical research that assures identical odds ratios for all categories. By far, the most popular regression model for ordinal data is the PO model (Tesfaledet *et al*., 2019). Let Y be the degree of dehydration with C-ordered categories.

The univariate OLR models expressed log odds of the degree of dehydration as a linear function of the predictors (Peng *et al*., 2002).

$$Logit(y \le i) = \log(odds) = \log\left[\frac{\pi_i}{1-\pi_i}\right] = \alpha_i + \beta x,\ i = 1, 2\dots, c-1 \quad (1)$$

Where πi is the probability of the degree of dehydration as an outcome variable, X is the predictor variable, α and β are the maximum likelihood estimates for the OLR model.

Then the odds of the first i cumulative probability are:

$$odds(Y \le i) = \frac{\pi_i}{1-\pi_i} = e^{\alpha+\beta x},\ i = 1, 2\dots, c-1 \quad (2)$$

For predicting the probability of the degree of dehydration using one predictor the following equation was used:

$$\pi_i(X) = pr(Y_j \le i \mid X) = \frac{e^{(\alpha_i+\beta x)}}{1+e^{(\alpha_i+\beta x)}} = \frac{1}{1+e^{-(\alpha_i+\beta x)}} \quad (3)$$

Where πi is the probability of the degree of dehydration as an outcome variable, X is the predictor variable, α is the Y-intercept, β is the regression coefficient, and e is the base of the natural logarithm (e= 2.718). In equation (1) the relation between logit(y) and x is linear, as the influence of X as a predictor variable over log odds of Y is additive, while in equations (2) and (3) the relation between the probability of Y and X is non-linear, as the influence of X as a predictor variable over odds and probability of Y is multiplicative.

The OLR model for multiple independent variables shared in the prediction of dehydration degree as an outcome variable is expressed as follows:

$$logit\left[Y_j \le i \mid X_j\right] = \log\left[\frac{\pi_i(X_j)}{1-\pi_i(X_j)}\right] = \alpha_i + \beta_1 x_{1j} + \dots + \beta_p x_{pj} \quad (4)$$

For $i = 1,2\dots, c-1;\ j = 1, 2, \dots, n.$

Where ß is a column vector of P regression coefficients and αi is ith intercept coefficient. Consider a collection of "*P*" explanatory variables for the ith subject denoted by the vector $X_j = (X_{1j}, X_{2j}, \dots, X_{pj})$, j = 1, 2, ..., n. Then the odds of the first i cumulative probability are:

$$odds\left[Y_j \le i \mid X_j\right] = \left[\frac{\pi_i(X_j)}{1-\pi_i(X_j)}\right] = \left[\frac{\pi_i}{\pi_{i+1}+\dots+\pi_c}\right], = e^{\alpha_i+\beta_1 x_{1j}+\dots+\beta_p x_{pj}},\ i = 1, 2, \dots, c-1 \quad (5)$$

For predicting the probability of the degree of dehydration using multiple predictors the following equation was used:

$$\pi_i(X_j) = pr(Y_j \le i \mid X_j) = \frac{e^{(\alpha_i + \beta_1 x_{1j} + ... + \beta p x_{pj})}}{1 + e^{(\alpha_i + \beta_1 x_{1j} + ... + \beta p x_{pj})}} = \frac{1}{1 + e^{-(\alpha_i + \beta_1 x_{1j} + ... + \beta p x_{pj})}} \quad (6)$$

$$i = 1, 2\ldots, c\text{-}1;\ j = 1, 2, \ldots, n$$

The estimation of the model parameters (α_i and β_j) is based on maximum-likelihood principles. Using Wald chi-square statistics, the significance of each independent variable's contribution to the logistic regression model was evaluated (Bewick *et al*., 2005):

$$W_j = \left(\frac{\beta}{SE}\right)^2 \quad (7)$$

Where, β: is the regression coefficient of a specific independent variable included in the model.

SE: is the standard error of the corresponding estimate.

Fitting the ordinal logit model

The full model (has a full set of predictors) and the null model (has only an intercept) are both given in the Model Fitting Information along with a chi-square to compare the -2 Loglikelihood (-2LL) values for the two models (Bewick *et al*., 2005; Reddy *et al*., 2015). If the fit of the entire model is better than the null model at the probability level (P< 0.05), at least one of the predictors must contribute to the explanation and prediction of the response variable.

Checking the model adequacy

The goodness of fit test fitting of the model for the data (Reddy *et al*., 2015), this approach helps determine how well a saturated model that includes a separate parameter for each observation fits the data.

The likelihood-ratio statistic for this test is the deviance of the model and Pearson of the model. The Pearson statistics for testing goodness of fit is

$$\chi^2 = \sum\sum \frac{(O_{ij} - E_{ij})^2}{E_{ij}} \quad (8)$$

$$Deviance\ statistics\ (G^2) = 2\sum\sum\sum O_{ij} \ln\left(\frac{O_{ij}}{E_{ij}}\right) \quad (9)$$

Where O_{ij} and E_{ij} are the observed and expected frequencies, respectively. Both measures approximated chi-square null distributions. A larger value of G^2 ($L_1 > L_0$), means that the model is of good fit or the predictors significantly affect the response variable (Reject H0).

All data were submitted to ordinal logistic regression analysis (OLR) using a statistical package for social science software version 26 (SPSS V. 26.0) (Ibm, 2019).

RESULTS

Clinical signs

Dogs who appeared to be in good health had normal values for rectal temperature, respiration rate, and pulse rate, and they also had a healthy appetite and pink mucous membranes. Meanwhile, in dogs with gastroenteritis (n=35), vomiting and diarrhea ranging from watery yellow to bloody was the most common clinical sign. Other symptoms included a loss of appetite, mild, moderate, and severe dehydration as measured by the specific temperature test (STT), and mucous membranes that were various shades of pink to white.

Univariable and multivariable OLR models developed

In the current study, OLR models were developed for the estimation of regression coefficients (the change in logit Y per unit change in X), and for the direction of association between the predictors and the logit of the outcome variable. The summary of the univariable (model 1), and multivariable OLR models is presented in Tables 3, and 4. The five models were:

Null model= Log odds of degree of dehydration = α_i

α_i: Intercept of the corresponding degree (threshold) of dehydration

Model 1= Log odds of degree of dehydration= α_i+0.900 lactate

Model 2= Log odds of degree of dehydration= α_i-0.663 Na-2.296 K - 0.064 Cl- 2.587 Ca - 0.372 Mg

Model 3= Log odds of degree of dehydration= α_i-0.170 ALT + 0.447 AST - 2.979 Ca - 1.204 Mg - 0.330 P

Model 4= Log odds of degree of dehydration= α_i +0.032 Urea + 1.872 Creatinine + 0.421 Uric acid

Multicollinearity and proportional odds assumption

This study was conducted for predicting the degree of dehydration by analyzing some biochemical parameters. Before developing the multivariable ordinal logistic regression models, the multicollinearity diagnostic tests had carried out to check multicollinearity among the independent variables, and it was observed the absence of multicollinearity among studied covariates in the current study. In the current study, the effects of explanatory variables across different thresholds of all possible comparisons were consistent or proportional, referring to that the proportional odds assumption was detected to be satisfactory in the ordinal regression model for each independent variable. The proportionality assumption was said to be met and not violated if the p-value for the parallel line test was larger than 0.05. The insignificant results for the parallel line test (p>0.05), suggest that the proportional odds assumption was met and not violated (Table 1).

Ordinal logistic regression models evaluation

The maximum likelihood principles were used to assess the relationship between the outcome and explanatory variables. For the overall evaluation of the developed OLR models, they were tested against the null model which is considered a good reference because of the absence of any explanatory variable. The -2LL estimate for the concerned model was compared with that of the null model. The model with the lowest -2LL estimated is considered the best model to fit the data. The difference between the -2LL estimate between the given model and that of the null model gives the chi-square value for the likelihood ratio test. The chi-square test statistics for the likelihood ratio test showed a significant improvement in the fit of the developed OLR models over the null model (p<0.05), but it was highly significant for model 2, and model 3 (χ^2= 30.009, df= 6, and χ^2= 23.09, df= 5, respectively). Also, the fitting of the model for the dataset was detected using Pearson's chi-square and deviance tests. The non-significant test results indicate that the model fits the data well. In the present study, both Pearson's chi-square and deviance test statistics for the developed OLR models were all non-significant (i.e., P>0.05), this revealed that the developed models fitted the data well. The -2 LL estimates and the likelihood-ratio test results indicate that there was a significant improvement in the fit of the developed OLR models over the null model, besides the goodness of fit test results (i.e., Pearson's chi-square and Deviance tests), which indicate that the developed models fitted the data well were presented in Table 2.

Testing the significance of predictors in different developed OLR models

The univariable OLR model associated with lactate revealed that lactate was a significant positive predictor for the degree of dehydration as an outcome variable (Wald chi-square statistic= 4.717, p<0.05), because of a positive relationship between lactate and degree of dehydration there is a predicted increase in the log odds of being in a higher level of dehydration with 0.9 for every unite increase in lactate, also OR of being the animal in a higher level of dehydration increased by the multiplicative factor 2.46 for every unite increase in lactate. In model 1 concerning lactate, the odds of being in a moderate level of dehydration is about 14.09 (OR for moderate threshold/OR for mild threshold) times of being in the mild level of dehydration, and about 32.27 (OR for moderate threshold/OR for normal threshold) times of being normal (Table 3).

The testing of significance and OR for predictors assembled in multivariable OLR models were presented in table 4. Beginning with model 2 (blood electrolytes without P), LR coefficients for all predictors were negative indicating that for every unit increase in the predictor variable, there is a decrease in log odds of the outcome variable by β units. Na and K as blood electrolytes were significant (p<0.05) negative predictors for the degree of dehydration. For every unit increase in Na, there is a predicted decrease in log odds in favor of a higher level of dehydration by 0.663. OR for Na was 0.515 which is < 1, this indicates that the predicted odds in favor of a higher level of dehydration will decrease by a multiplicative factor of 0.515 for every unit increase in Na. The increase in K by uniting will lead to a decrease in the log odds in favor of a higher level of dehydration by 2.296, also the predicted odds will decrease by the multiplicative factor 0.101. The rest of the predictors assembled in the model were non-sig-

Table 1. Test of parallel lines (proportional odds assumption).

	Model	-2 Log Likelihood	Chi-square	df	P-value
Model 1	Null hypothesis	43.35			
	General	43.02	0.32	2	0.85
Model 2	Null hypothesis	19.33			
	General	9.27	10.07	10	0.44
Model 3	Null hypothesis	26.25			
	General	20.75	5.5	10	0.86
Model 4	Null hypothesis	39.08			
	General	33.29	6.52	6	0.37

Table 2. Overall evaluation and goodness of fit for model.

Model	Test	χ^2- value	df	P value	-2 Log Likelihood
Null model					49.34
Model 1 (Lactate only)	Overall model evaluation				43.35
	Likelihood ratio test	5.99	1	0.01	
	Pearson's chi-square	45.52	47	0.53	
	Deviance	43.35	47	0.63	
Model 2 (blood electrolytes without P)	Overall model evaluation				18.94
	Likelihood ratio test	30.01	5	<0.001	
	Pearson's chi-square	22.36	49	1	
	Deviance	19.33	49	1	
Model 3 (liver enzymes +Ca +Mg +P)	Overall model evaluation				19.33
	Likelihood ratio test	23.09	5	<0.001	
	Pearson's chi-square	60.61	49	0.12	
	Deviance	26.25	49	0.10	
Model 4 (kidney function parameters)	Overall model evaluation				39.8
	Likelihood ratio test	9.54	3	0.02	
	Pearson's chi-square	60.14	51	0.18	
	Deviance	39.8	51	0.87	

nificant negative predictors for log odds in favor of higher levels of dehydration, so removing such predictors from model 2 does not have any significant impact.

In the multivariable LR (model 3) in which liver enzymes + Ca + Mg + P assembled as predictors for the degree of dehydration, ALT, Ca, Mg, and P were non-significant ($p>0.05$) negative predictors for the degree of dehydration, but AST was a positive significant predictor for dehydration ($p<0.05$), increasing AST by unite will increase the log odds in favor of higher level of dehydration by 0.447, and the predicted odds will increase in multiplicative factor 1.564.

The kidney function parameters were assembled in model 4 for testing the significance of these predictors on the degree of dehydration. A positive significant relationship was observed between uric acid and degree of dehydration, increasing the value of uric acid by one unit to increase the value of log odds in favor of a higher level of dehydration by 0.421, and increasing the predicted odds by 1.524. However, creatinine was a non-significant positive predictor for the degree of dehydration, the increase in its value by one unit will lead to an increase in the log odds in favor of a higher level of dehydration by 1.872 and increasing in the predicted odds by 6.504. urea was a non-significant positive predictor for dehydration ($p>0.05$).

A comparison of the developed ordinal logistic regression models

To come up with the model that gives the best description for the dataset, Akaike's information criterion (AIC), and likeli-

Table 3. Univariable ordinal logistic regression models for modelling and predicting degree of dehydration.

Model	Parameter	β	SE (β)	Wald statistic	df	P value	OR	95% CI for OR	
								Lower	Upper
Null model	Normal threshold	-1.03	0.52	3.91	1	0.05	0.36	0.13	0.99
	Mild threshold	-0.03	0.46	0.47	1	0.49	0.73	0.29	1.81
	Moderate threshold	1.67	0.63	7.08	1	0.01	5.33	1.55	18.30
Model 1	Normal threshold	4.66	2.64	3.11	1	0.08	105.73	0.60	$1.9x10^{3}$
	Mild threshold	5.49	2.69	4.16	1	0.04	242.04	1.24	$4.7x10^{3}$
	Moderate threshold	8.14	3.15	6.65	1	0.01	3412.19	7.05	$1.7x10^{6}$
	Lactate	0.9	0.41	4.72	1	0.030*	2.46	1.09	5.54

β logistic regression coefficient, SE (β) standard error of estimate, df degree of freedom, OR odds ratio, and CI confidence interval.

Table 4. Multivariable logistic regression models for modelling and predicting degree of dehydration.

Model	Parameter	β	SE (β)	Wald statistic	df	P value	OR	95% CI for OR	
								Lower	Upper
Model 2	Normal threshold	-114.16	47.48	5.78	1	0.02	$2.637 x10^{-50}$	$1.023 x10^{-90}$	$6.80 x10^{-10}$
	Mild threshold	-110.60	46.31	5.70	1	0.02	$9.234 x10^{-49}$	$3.506 x10^{-88}$	$2.432x10^{-9}$
	Moderate threshold	-105.07	44.90	5.48	1	0.02	$2.342x10^{-46}$	$1.409 x10^{-84}$	$3.894x10^{-8}$
	Na	-0.66	0.31	4.68	1	0.031*	0.52	0.28	0.94
	K	-2.30	0.92	6.18	1	0.013*	0.10	0.02	0.62
	Cl	-0.06	0.04	2.74	1	0.10	0.94	0.87	1.01
	Ca	-2.59	3.92	0.44	1	0.51	0.08	3.46E-5	163.45
	Mg	-0.37	0.66	0.32	1	0.57	0.69	0.19	2.49
Model 3	Normal threshold	-4.65	5.14	0.82	1	0.37	0.01	$4.003x10^{-7}$	227.67
	Mild threshold	-1.79	4.65	0.15	1	0.7	0.17	$1.859x10^{-5}$	1507.75
	Moderate threshold	1.62	4.87	0.11	1	0.74	5.04	$357x10^{-6}$	71024.62
	ALT	-0.17	0.11	2.37	1	0.12	0.84	0.68	1.05
	AST	0.45	0.19	5.37	1	0.020*	1.56	1.07	2.28
	Ca	-2.98	3.16	0.89	1	0.35	0.05	$104x10^{-6}$	24.96
	Mg	-1.20	0.64	3.54	1	0.06	0.3	0.09	1.05
	P	-0.33	0.59	0.31	1	0.58	0.72	0.23	2.28
Model 4	Normal threshold	2.39	2.17	1.22	1	0.27	10.92	0.16	764.44
	Mild threshold	3.48	2.20	2.51	1	0.11	32.29	0.44	2385.62
	Moderate threshold	5.89	2.44	5.84	1	0.02	361.82	3.04	43096.84
	Urea	0.03	0.04	0.75	1	0.39	1.03	0.96	1.11
	Creatinine	1.87	1.37	1.87	1	0.17	6.50	0.45	95.13
	Uric acid	0.42	0.20	4.38	1	0.036*	1.52	1.03	2.26

β logistic regression coefficient, SE (β) standard error of estimate, df degree of freedom, OR odds ratio, and CI confidence interval.

hood-ratio test (LR) were applied. The evaluation of the four developed OLR models demonstrated that model 4, which models the kidney function parameters, is the preferred model for prediction and assessing the degree of dehydration, followed by model 1 (lactate only), Model 3 (liver enzymes + Ca +Mg + P), and finally, model 2 (blood electrolytes without P), based on AIC and LR test results (Table 5).

Table 5. A comparison of the developed ordinal logistic regression models.

Fitted model	LR	AIC
Model 1	-21.67	51.35
Model 2	-9.67	35.33
Model 3	-15.16	44.32
Model 4	-22.37	54.73

LR log likelihood ratio, and AIC Akaike's information criterion

DISCUSSION

Based on the results of this analysis, it appears that lactate is a reliable indicator of dehydration severity. This finding was consistent with that of Guzelbektes *et al*. (2007), who found a correlation between clinical dehydration and both base excess and anion gap. L-lactic acidosis is hypothesized to originate from inadequate tissue perfusion, due to dehydration or endotoxemia, with subsequent anaerobic glycolysis and impaired hepatic clearance of L-lactate (Omole *et al*., 2001).

The obtained findings revealed that urea is a good predictor of dehydration severity are corroborated by the findings of Guzelbektes *et al*. (2007), who showed that serum urea had increased in proportion to the severity of dehydration. Dehydrated dogs had elevated levels of urea and creatinine, as was also noted by Atata *et al*. (2018). An impaired glomeruli filtration rate (GFR) as a result of inadequate blood flow to tissues caused by dehydration likely accounts for elevated blood urea nitrogen levels (Shinde *et al*., 2000). A rise in serum urea and creatinine are reliable biochemical indicators of dehydration in dogs, as shown by the research of Atata *et al*. (2018). The dehydration ratio was shown to be responsible for the authors' observed elevations in urea, creatinine, and blood urea nitrogen concentrations. Previous reports had similar results (Capitelli and Crosta, 2013; Armstrong *et al*., 2016).

Given that ALT is a known biomarker of liver damage (Nathwani *et al*., 2005), the possibility that the liver is unaffected in the present investigation could account for the fact that it is not a significant predictor. Nevertheless, dehydration may affect skeletal muscle, which could explain why elevated AST levels, a positive predictor in the present investigation, were seen. Ozkan and Ibrahim (2016) found that wrestlers' AST levels increased following dehydration, which they attribute to muscle injury.

Because of the significant loss of electrolytes during diarrhea, which occurs in dehydration, we assume that in a high degree of dehydration, there is a significant loss of electrolytes, which was found to be the case in this study. Decreased electrolyte levels may be due to inflammation, which occurs during diarrhea and causes increased bowel permeability, resulting in fluid, electrolyte, protein, and cell loss (Biswas *et al*., 2005).

CONCLUSION

Dehydration severity is significantly predicted positively by lactate, AST, urea, and uric acid, and negatively by sodium and potassium. There is no statistical significant relationship between any of the other variables and dehydration levels. There are biochemical characteristics that have been demonstrated to be reliable predictors of dehydration; assembling these data into an OLR model will aid in distinguishing between varying degrees of dehydration.

CONFLICT OF INTEREST

Authors declare that they have no conflict of interest.

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