

# Comparison of a human portable blood glucose meter and automated chemistry analyser for measurement of blood glucose concentrations in healthy dogs

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## Abstract

Blood glucose measurement is one of the most commonly performed clinical diagnostic tests used to monitor glycaemia in several animal diseases. Usually, these laboratory analyses are performed on blood venous samples in remote laboratories, and the results are delayed, at best. The use of portable glucometers could evidently solve many constraints but veterinary-use glucometers are not usually available. The present study aimed to compare blood glucose levels obtained by Bionime glucometer to the reference method using glucose oxidase. Venous blood was collected from a total number of 140 healthy dogs (72 males and 68 females), of different breeds (28 German Shepherd, 27 Pitt bull, 21 Boxer, 24 Rottweiler and 40 cross-bred dogs) and different ages (range: 3 months–14 years) for glucose measurement using the reference laboratory method. Capillary blood samples were used to conduct a glucose measurement with a human-use glucometer. Our results revealed that there was no significant difference between the mean capillary blood glucose (CBG) measured with the human-use glucometer ( $5.06 \pm 0.84$  mmol/L) and the mean venous blood glucose (VBG) measured with the laboratory reference method ( $4.90 \pm 0.73$  mmol/L) ( $p = 0.42$ ). Similarly, there was no significant difference of the mean CBG and VBG in male dogs ( $5.11 \pm 0.88$  and  $4.97 \pm 0.75$  mmol/L, respectively) and female dogs ( $5.01 \pm 0.81$  and  $5.07 \pm 0.72$  mmol/L, respectively) ( $p = 0.73$  and  $0.21$ , respectively), and no correlation to neither age ( $5.43 \pm 0.90$  and  $5.20 \pm 0.70$  mmol/L in 3 to 6 month-old dogs,  $5.03 \pm 0.82$  and  $4.94 \pm 0.79$  mmol/L in 6 months to 1 year-old,  $4.94 \pm 0.67$  and  $5.13 \pm 0.66$  mmol/L in 1 to 4 year-old dogs;  $4.88 \pm 0.94$  and  $4.80 \pm 0.75$  mmol/L in dogs older than 4 years, respectively,  $p < 0.05$ ), nor to breed ( $4.94 \pm 1.01$  and  $4.99 \pm 0.79$  mmol/L in German Shepherd,  $5.13 \pm 0.84$  and  $4.99 \pm 0.79$  mmol/L in Pitt Bull,  $5.07 \pm 0.94$  and  $5.07 \pm 0.77$  mmol/L in Boxer,  $5.40 \pm 0.59$  and  $5.48 \pm 0.55$  mmol/L in Rottweiler and  $4.89 \pm 0.75$  and  $4.77 \pm 0.59$  mmol/L in cross-bred dogs, respectively,  $p < 0.05$ ). The present study confirms that human glucometer can be used to measure glucose in dogs with a good accuracy.

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**KEYWORDS**

capillary blood, dogs, glucose measurement, glycaemia, human-use glucometer, reference method, venous blood

## 1 | INTRODUCTION

Blood glucose determination is one of the most commonly used clinical tests for the establishment of diagnosis of several conditions in both human and veterinary practice (Cohn et al., 2000). Most clinicians have access to laboratories equipped with automated chemistry analysers that measure plasma glucose concentration via either hexokinase (Neese et al., 1976) or glucose oxidase reactions (Trinder, 1969). Colorimetric/spectrophotometric estimation of plasma glucose using glucose oxidase method is the gold standard for glucose estimation (Trinder, 1969), but it has the disadvantage of providing delayed analysis results. Hence, the recourse to remote laboratories is not suitable for emergency cases (Sharma et al., 2017). Nowadays, the concentration of blood glucose can be measured using several portable devices, photometric, oxidation-reduction and measuring electrode techniques (Bader et al., 1992; Gonzales et al., 2019; Heise et al., 1989; Jensen & Kjelgaard-Hansen, 2006; Moodley et al., 2015).

Portable blood glucose meters (PBGMs) are a convenient, cost effective and quick means to assess patient's blood glucose concentration (Jamaluddin et al., 2012). They can provide instant results in case of emergency and assist critical short-term therapeutic strategies. Besides, they are also convenient when multiple glucose measurements are required within short time intervals to construct glucose curves and can be helpful while monitoring critically ill patients to pre-empt hypoglycaemic incidents (Casella et al., 2005). These devices can be used as a screening tool to identify potential diabetes mellitus patients whose condition can then be confirmed by laboratory glucose analysis, and also to monitor diabetes in dogs and cats (Casella et al., 2005). PBGMs are very useful in veterinary practice (Buzzi et al., 2013; Miasaki et al., 2020). Indeed, using laboratory clinical method puts the patient in a non-familiar environment for several hours, prompting a huge bias in the measurement, considering the modification in glucose concentrations induced by the stress and alterations in food intake during the test (Casella et al., 2002). Moreover, glucometers offer a faster turnaround time and require a smaller sample volume compared to reference laboratory chemistry analysers (Winkelman et al., 1994).

PBGMs were initially developed to measure capillary blood glycaemia in humans; blood is collected using digital or heel puncture with either a lance or a hypodermic needle. These PBGMs measure the blood glucose concentration through reactions that occur in strips impregnated with glucose oxidase, peroxidase and chromogeny (Gerber & Freeman, 2016; Shapiro et al., 1981). PBGMs are preferably used to measure glucose as they are of low cost, used anytime and anywhere, they are automatic, rapid (around 5–25 s reaction duration), user-friendly and require small blood volumes to proceed (1–5  $\mu$ l) (Pftzner et al., 2013).

Digital and heel samples withdrawn in humans are replaced in veterinary practice by pinna and carpal vein samples because of their easy

access. Glycaemia measurement could even be realised by dog owners in order to achieve a permanent and immediate glycaemia monitoring of their animals (Bluwol et al., 2007; B. M. Johnson et al., 2009; Luppi et al., 2007).

The number of commercially available PBGMs is constantly increasing, making it challenging to determine whether certain glucometers may have benefits over others for veterinary testing. The challenge in selecting an appropriate PBGM from a quality perspective is compounded by the variety of analytic methods used to quantify glucose concentration and disparate statistical analysis in many published studies (Gerber & Freeman, 2016).

The aim of the present study is to compare blood glucose concentrations measured by human-use PBGM and the reference laboratory method in samples collected from healthy dogs.

## 2 | MATERIALS AND METHOD

### 2.1 | Dogs

The present study was carried out from April to July 2013 on healthy dogs presented for vaccination at the National School of Veterinary Medicine of Sidi Thabet (Tunisia). A total number of 140 healthy dogs (72 males and 68 females, sex ratio M:F = 1.05), aged between 3 months and 14 years (mean age: 2.5 years) were included in the present study. These dogs belonged to five breeds (German Shepherd, Pitt Bull, Boxer, Rottweiler and Cross breed) (Table 1).

### 2.2 | Sample collection

Capillary blood samples were collected from the pinna in our animals instead of the digits as in humans. The pinna of each dog was cleaned with dry cotton, then a drop of blood was collected and immediately used for glucose measurement with a PBGM.

Blood was also collected from the radial vein with a 20- or 22-gauge needle in heparinised vacutainer tubes from all dogs, after the disinfection of the puncture site. Samples were immediately transferred to the biochemistry laboratory within a maximum of half an hour in order to avoid erythrocytes' glycolysis. Blood samples were centrifuged at 3000 rpm for 10 min, then plasma was placed in dry tubes, stored at +4°C and analysed the same day.

### 2.3 | Determination of blood glucose

Glucose blood levels (mmol/L) were evaluated in our samples using a commercial kit (Biosystems) with an automatic biochemistry analyser

**TABLE 1** Blood glucose measured by human glucometer on capillary blood sample (CBG) and by reference laboratory method on venous blood samples (VBG) in different dogs' categories

Item (number)	Mean blood glucose $\pm$ SD [range] (mmol/L)		
	Capillary blood glucose (CBG)	Venous blood glucose (VBG)	p Value
Sex			
Male dogs (72)	5.11 $\pm$ 0.88 [3.06–7.73]	4.97 $\pm$ 0.75 [3.65–6.70]	0.729 <sup>a</sup>
Female dogs (68)	5.01 $\pm$ 0.81 [3.22–7.12]	5.07 $\pm$ 0.72 [3.20–6.50]	0.211 <sup>b</sup>
Breed			
German Shepherd (28)	4.94 $\pm$ 1.01 [3.06–7.73]	4.99 $\pm$ 0.79 [3.70–6.40]	0.078 <sup>a</sup>
Pitt bull (27)	5.13 $\pm$ 0.84 [4.17–7.67]	4.99 $\pm$ 0.79 [3.07–6.40]	0.420 <sup>b</sup>
Boxer (21)	5.07 $\pm$ 0.94 [3.34–7.12]	5.07 $\pm$ 0.77 [3.80–6.70]	
Rottweiler (24)	5.40 $\pm$ 0.59 [4.56–7.06]	5.48 $\pm$ 0.55 [4.60–6.50]	
Cross-bred (40)	4.89 $\pm$ 0.75 [3.39–6.73]	4.77 $\pm$ 0.59 [3.20–6.10]	
Age category			
3–6 months (31)	5.43 $\pm$ 0.90 [3.39–7.73]	5.20 $\pm$ 0.70 [3.90–6.50]	0.065 <sup>a</sup>
6 months–1 year (38)	5.03 $\pm$ 0.82 [3.22–6.73]	4.94 $\pm$ 0.79 [3.20–6.50]	0.161 <sup>b</sup>
>1–4 years (41)	4.94 $\pm$ 0.67 [3.06–7.12]	5.13 $\pm$ 0.66 [3.70–6.50]	
> 4 years (30)	4.88 $\pm$ 0.94 [3.61–7.67]	4.80 $\pm$ 0.75 [3.33–6.70]	
Overall (140)	5.06 $\pm$ 0.84 [3.06–7.73]	4.90 $\pm$ 0.73 [3.20–6.70]	

<sup>a</sup>Comparison of CBG values.<sup>b</sup>Comparison of VBG values.

(Random Access Clinical Analyser; DIALAB Autolyser, Diagnostics and Laboratory Equipment). The analyses were carried out according to the manufacturer's instructions including in each run, a reference serum for the quality control (Contronorm Plus, Analyticon). The result was obtained within an hour at least after sampling.

The Bionime glucometer (Rightest Glucose Meter GM 550; Bionime Corporation; <https://www.bionime.com/GM550.html>) uses both glucose oxidase reaction and reflectance photometry to estimate blood glucose concentration. As recommended by the manufacturer, capillary venous blood was used. It was obtained by pinna puncture after disinfection, and the drop of blood was instantly absorbed by the reagent strip. Capillary blood glucose (CBG) was determined in only 5 s.

## 2.4 | Statistical analyses

The results were expressed as means  $\pm$  SD. The data were analysed with Statistica 6.0.0 software (Tibco, California, USA). Wilcoxon test was used to compare the CBG levels obtained by PBGM. The correlation between CBG and venous blood glucose (VBG) was estimated with the Spearman correlation test. The effects of breed, sex and age were studied with Kruskal-Wallis test. All tests were considered as significant at 5% threshold.

## 3 | RESULTS

There was no statistically significant difference between mean CBG (5.06  $\pm$  0.84 mmol/L) measured by PBGM and VBG measured

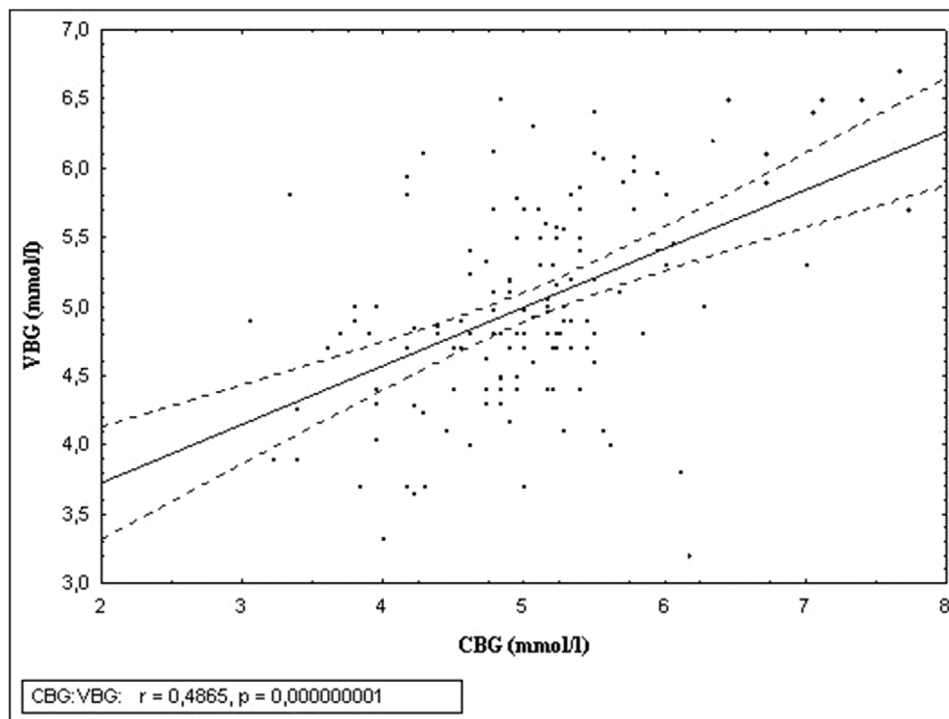
with the automatic biochemistry analyser (Dialab autolyser) (4.90  $\pm$  0.73 mmol/L) ( $p = 0.422$ ; Table 1). Likewise, there was no significant statistical difference in male dogs between mean CBG (5.11  $\pm$  0.88 mmol/L) and VBG (4.97  $\pm$  0.75 mmol/L) ( $p = 0.107$ ), nor in female dogs, where the mean CBG (5.01  $\pm$  0.81 mmol/L) and VBG (5.07  $\pm$  0.72 mmol/L) were also not statistically different ( $p = 0.609$ ). Finally, there was also no significant difference between males and females for both CBG and VBG ( $p = 0.729$  and  $0.211$ , respectively). The lowest mean of CBG was detected in German Shepherd (4.94  $\pm$  1.01 mmol/L) and the highest in Rottweiler dogs (5.40  $\pm$  0.59 mmol/L).

Moreover, differences between CBG measured by a PBGM and VBG measured using by the reference laboratory method for different breeds were not statistically significant, results varying between 0.05 (3%) and 0.12 mmol/L (7.2%) ( $p = 0.078$  and  $p = 0.420$ , respectively). Besides, the comparison of blood glucose concentrations between different age groups reveals no significant difference in both techniques (CBG and VBG;  $p = 0.065$  and  $p = 0.161$ , respectively).

Finally, the analysis of the results reveals a statistically significant positive correlation between glucose concentrations obtained with CBG and VBG ( $r = 0.48$ ;  $p < 0.001$ ) (Figure 1).

## 4 | DISCUSSION

The use of glucometer is very important in veterinary practice but veterinary-use glucometers are not always available and provide different levels of accuracy (B. M. Johnson et al., 2009). Human-use glucometers are more frequently used in veterinary hospitals (Cohn et al.,



**FIGURE 1** Correlation between capillary and venous blood glucose measurement in dogs (Spearman correlation coefficient  $r = 0.48$ ,  $p < 0.01$ ) (CBG, capillary blood glucose; VBG, venous blood glucose)

2000; Dobromylskij & Sparkes, 2010; B. M. Johnson et al., 2009; Kang et al., 2016; Weiss & Reusch, 2000a, 2000b). In the present study, we tested Bionime glucometer, used for dosing glucose in human blood. Bionime glucometer and the reference method resort to the same enzymatic method for glucose measurement, as recommended by the American Society for Veterinary Clinical Pathology (ASVCP) guidelines (Gerber & Freeman, 2016). Glucometers are user-friendly devices since only a few microliters of blood samples are deposited on a strip and migrate by capillary effect. This technique is more practical since it needs only a small lancet instead of a needle and a syringe requested for the conventional technique (Kim, 2010). Lancet preserves the welfare of animals as it causes less pain and stress, makes capillary blood collection easier and improves the owner's success with home blood glucose monitoring (B. M. Johnson et al., 2009). However, in some cases, the lancet's needle is too narrow, making it difficult to withdraw a drop of blood and therefore larger needles are required.

The mean capillary and VBG levels were estimated in the present study to  $5.06 \pm 0.84$  and  $4.9 \pm 0.73$  mmol/L, respectively. The allowable total error, which must be lower than 20% in euglycemic dogs, equalled 0.98 mmol/L, the CBG falling in  $VBG \pm 20\%$  interval (3.92–5.88), which authorises us to conclude that the allowable error obtained by Bionime glucometer is acceptable to measure blood glucose in healthy dogs as recommended by the ASVCP guidelines (Gerber & Freeman, 2016).

The difference between capillary and venous glucose was not statistically significant. This difference was 0.16 mmol/L (9.16%), and this finding concurs with the results of Ferreira et al. (2013) who reported a difference of 0.22 mmol/L (12.6%) in healthy dogs without a statistical significance. Other authors reported differences that were not clin-

ically noticeable (Kang et al., 2016; Thompson et al., 2002; Weiss & Reusch, 2000a).

In diabetic dogs, blood glucose is 11.20% higher in capillaries than in veins blood since glucose is absorbed by the adjacent tissues as an energy source at the capillary level (Borin et al., 2012). This difference could be explained by the fact that capillary blood was richer with glucose than venous blood. Glucose is present in the aqueous fraction of the blood, and the concentration of water in the plasma and the cellular compartment are different (Burtis & Ashwood, 1999). Plasma contains more water and, therefore, the concentration of glucose is approximately 11%–12% higher than the whole blood (Burtis & Ashwood, 1999).

The difference between CBG and VBG may be due to the immediate analysis obtained with the glucometer and the time spent to perform the laboratory method, since erythrocytes catabolise glucose. This phenomenon induces a decrease of glucose concentration in the sample at a rate of 5%–7% per hour (Chan et al., 1989).

Sex, age and breed did not vary capillary and VBG levels. Our results are in agreement with those reported on both healthy (Chang et al., 2016; Connolly et al., 2020) and sick dogs (Pattanayak et al., 2014). Connolly et al. (2020) worked on sampled elite endurance-trained sled dogs and found that the VBG did vary according to the breed. Nevertheless, these authors reported that glucose level was higher in females than in males, while the lowest levels retrieved in dogs of 7.8 years' age from dogs aged between 1 and 12 years. In our study, differences were not statistically significant according to age. Similar observations were reported in venous blood samples, showing also higher values in dogs younger than 1 year, in comparison to adult dogs (Radisavljevic et al.,

2017). The latter work confirmed that there was no effect of both sex and age on VBG levels.

The blood glucose level is influenced by several factors like the physiological status, the sampling method, and environmental conditions. In order to reduce bias, in the present study, all sampled dogs belonged to middle or large-sized breeds in order to facilitate venous catheterization and avoid haemolysis which alters the sample quality (Lee et al., 2020). Neither pregnant nor lactating females were included in this study to avert the variations due to physiological status of the animal (C. A. Johnson, 2008). Our animals were sampled after up to half an hour of the initial contact in the presence of the owner to prevent the environment induced stress, leading to inscrutable glycaemia variation (Radisavljevic et al., 2017). The decision to limit our study to healthy dogs bars the interference of diseases and the effect of treatment on glucose homeostasis and measurement (Smith et al., 2005). The results of the present study indicate that human glucometers are suitable devices to measure blood glucose concentration in dogs with an acceptable accuracy, beside requiring minute blood volumes and yielding results within few seconds. It would be interesting to evaluate the use of Bionime glucometer in feline practice since many PBGMs are tested in cats and some of them are not suitable for estimation of blood glucose levels (Dobromylskyj & Sparkes, 2010). Especially for cats, the usage of a glucometer may reduce the stress and the sampling difficulty, responsible of false hyperglycaemia, helps without doubt home monitoring and it enables the frequent generation of blood glucose curves, crucial in cats that are difficult to regulate (Casella et al., 2005).

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#### CONFLICT OF INTEREST

The authors declare no conflict of interest.

#### AUTHOR CONTRIBUTIONS

Conceptualization, methodology, project administration, validation and visualization: Samir Ben Romdhane.

#### ETHICS STATEMENT

All owners of animals were aware of the objectives of this study, and the dogs were sampled with their permission, in their presence and with the supervision of a qualified veterinarian. The sampling procedures were performed according to the guidelines for the care and use of animals of the National School of Veterinary Medicine, Tunisia. During or after the sampling process, no animal was injured or dead.

#### PEER REVIEW

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