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https://dx.doi.org/10.4314/nvj.v39i2.10 **ORIGINAL ARTICLE**

# Non-Invasive Determination of Reference Arterial Blood Pressure Indices of Healthy Alsatian and Boerboel Dogs

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## SUMMARY
In order to evaluate and manage Boerboels and Alsatians under critical and emergency care, knowledge of ranges and causes of variability of normal arterial blood pressure (ABP) indices is desirable. The systolic arterial pressure (SAP), diastolic arterial pressure (DAP) and mean arterial pressure (MAP) of 30 healthy dogs were evaluated with human sphygmomanometer and neonatal cuff. The age, sex, breed, weight, height, weight to height ratio (WTH), of each dog was recorded. The mean and range of ABP values for Alsatians and Boerboels were similar to those of some other breeds. There were no age, breed and sex differences in ABP indices of dogs. The coefficient of variations and ranges of DAP and MAP were significantly higher than SAP measurements. In all dogs, SAP was influenced by breed and interaction of breed and sex when all confounders were controlled. The WTH and sex were found to independently influence SAP in presence of confounders. In Alsatian, WTH and sex interaction influenced all pressures in presence of confounders. The DAP was significantly influenced by heart rate and WTH in presence and absence of confounders respectively. Although age did not influence ABP in all dogs, it influenced SAP and DAP in females and Boerboel. The absence of age, sex, and breed differences in ABP of dogs may be due to multiple interactions between these factors. The human sphygmomanometer has the best precision for SAP measurements and WTH may be used as canine's body mass index (BMI) because of its influence on ABP.

**Key words:** Blood pressure, dogs, breed, sex, age, oscillometry.

## INTRODUCTION
The use of arterial blood pressure monitoring in emergency and critical care medicine, during anesthesia and management of cardiac and other related disorders is fast gaining popularity among small animal clinician in many parts of the world. Since blood pressures are known to vary with breed, sex, age, equipment used and site of cuff placement (Bodey *et al.*, 1994; Bodey and Michell 1996), a single range of blood pressure is inadequate and impracticable for clinical use in all breeds. There is thus a need to have a breed specification for blood pressures.

The dearth of information on normal blood pressure ranges of dogs in Nigeria has made it difficult for clinicians to include blood pressure examination in their clinical workup data of critical care patients. The South African mastiff (Boerboels) and German shepherd (Alsatians) are the two most popular exotic dog breeds among dog owners in Nigeria. These large dog breeds are not native to Nigeria and are thus susceptible to cardiac disorders and many tropical dog diseases. Although reference blood pressure values have been published for quite a number of breeds (Bodey and Michell, 1996; Sanan and Arslan, 2007) information on normal ABP values for South African mastiff and Alsatians are scarce. Arterial blood pressures in humans have been found to be dependent on geographical location of residence (Duranton *et al.,* 2018). A similar trend in dogs could therefore render values obtained for Alsatians and Boerbels elsewhere inadequate for our own environment.

The usefulness of Arterial blood pressure measurement in small animal clinic is therefore hinged on knowing the normal range of blood pressure of a breed and understanding factors responsible for its variation. Using the weight to height ratio (WTH) as a surrogate of body mass index, statistical cut-off points were used to define overweight and underweight dogs.

In this study, an attempt was made to define the reference Arterial blood pressures values for Boerboels and Alsatians. The sex, age, and breed related differences in blood pressure which have been reported in other breeds were investigated in Boerbel and Alsatian dogs. The predictive influences of body weight, height, WTH, breed, sex, and age on arterial blood pressure were also evaluated.

## MATERIAL AND METHODS

Thirty apparently healthy intact dogs of both sexes with limb circumference of 10 and 14cm above the carpus and belonging to clients of Veterinary Teaching Hospital, Federal University of Agriculture, Abeokuta, Ogun State, Nigeria, were recruited into this study. The dogs were certified healthy based on clinical history and examination. Dogs of between 2 and 6 months are classed as young while those of between 7 months and above are considered adult. The breed of dogs was determined based on physical appearance.

A visit each was made by the investigator to the homes of the dog owners at agreed dates and time for the purpose of obtaining arterial blood pressure (ABP) parameters. The blood pressures of the dogs were obtained between 8.00 am and 11.00 am on the designated days. The ABP were obtained from individual dogs on right lateral recumbency without sedation. A single neonatal cuff of 5cm cuff bladder width was used or applied on all dogs. The cuff bladder width was 30-50% of the limb circumferences and was applied above the carpus at the distal-third area of the radius (Bodey *et al.,* 1996). The circumference of the limb at the point of application of the cuff was measured using a tape rule. The blood pressure of the dogs was determined non-invasively by oscillometric technique using a blood pressure monitor (Model; FT C11B, Omron Health care, Netherland).

Three consecutive readings were obtained within 5 minutes and averaged. The systolic and diastolic arterial pressures, as well as the heart rate were obtained from the monitor, but mean arterial pressure (MAP) was derived using the formula: 2/3 DAP + 1/3 SAP (Guyton and Hall, 2005). All measurements were made by the same investigator.

The height of the dog was measured from the forelimb contact on the ground to the highest point of the shoulder using a meter rule. The weight of the dog in kg was measured using bathroom scale. The weight to height ratio (WTH) was estimated by dividing the weight of the dog in pounds by the square of the height in inches.

Data obtained were expressed as Mean ± Standard Error (Standard deviation). The normal distribution of data was assessed with Kolmagorov Smirnov test. The student t-test for independent sample was used to compare mean values of two groups. The

Pearson correlation test was done to evaluate strength of association between two continuous variables (r). Stepwise multiple regressions were used to find predictive influences of age, sex, breed, weight, WTH and height on the arterial blood pressure indices. The statistical cut off points for overweightness and underweightness was defined as Mean WTH±2 SD. The level of significance was set at $p<0.05$. All data analysis was done using SPSS version 16

**RESULTS**

A total of 90 blood pressure readings were got from 30 dogs comprising 17 Alsatian and 13 Boerboel**,** 12 males and 18 females, 22 adults and 8 young dogs respectively.

TABLE 1 showed the Mean ± SEM (SD) and the range of values for MAP, SAP, DAP, WTH, weight, and height across the population of dogs studied.

As shown in TABLE 2, there were no significant differences in height, weight, body mass index, SAP, DAP, MAP, of all male and female dogs across the breeds and ages studied.

In TABLE 3, however, the height, weight and WTH of Boerboels was significantly larger than values obtained for Alsatians ($p<0.01$).

In TABLE 4, when the ABP and demographic indices of young and adult dogs were compared, it was found that the weight, height, WTH ratio and the age of the dogs in young group were significantly lower ($p<0.05$) than the adult group.

**TABLE I**: Mean ± SEM (SD) of arterial blood pressure and demographic indices of all dogs

| Parameters | Mean ± SEM(SD) | Minimum Value(s) | Maximum Value(s) | Range |
|---|---|---|---|---|
| SAP(mmHg) | 146.68 ± 4.17 (23.25) | 107 | 197 | 90 |
| DAP(mmHg) | 89.16 ± 4.52 (25.18) | 42 | 146 | 104 |
| MAP(mmHg) | 108.16 ± 3.84 (21.38) | 79 | 154 | 75 |
| Heart rate(b/m) | 83.96 ± 4.55 (25.35) | 47 | 135 | 88 |
| Height(cm) | 61.95 ± 1.09 (6.09) | 49 | 73 | 24 |
| Weight(kg) | 27.64 ± 1.93(10.76) | 12 | 54 | 42 |
| WTH(Ibs/inches) | 2.45±0.14(0.77) | 1.34 | 4.25 | 2.91 |
| Age(years) | 1.49±0.27(1.46) | 0.33 | 7 | 6.67 |
| Limb circumference(cm) | 13.21±0.41(2.32) | 9.5 | 20.50 | 11 |

SAP; Systolic arterial pressure, DAP; Diastolic arterial pressure, MAP; Mean arterial pressure, WTH; Weight to Height ratio

**TABLE II**: The Mean±SEM (SD) of the arterial blood pressure and demographic indices of Boerboels and Alsatian dogs

| Parameters | Alsatians (17) | Boerboel (13) |
|---|---|---|
| SAP(mmHg) | 141.76 ± 6.24(25.75) | 152.64 ± 5.08(19.01) |
| DAP(mmHg) | 91.17 ± 5.02(20.71) | 86.71 ± 8.12 (30.39) |
| MAP(mmHg) | 107.94 ± 5.16(21.27) | 108.43 ± 5.96(22.32) |
| Heart rate(b/m) | 80.29 ± 6.33(26.13) | 88.42 ± 6.56(24.57) |
| Height(cm) | 59.55 ± 1.49(6.16)$^{a}$ | 64.85 ± 1.26(4.73)$^{b}$ |
| Weight(cm) | 20.94 ± 1.48(6.11)$^{a}$ | 35.78 ± 2.55(9.54)$^{b}$ |
| WTH(Ibs/inches) | 1.92 ± 0.10(0.40)$^{a}$ | 3.05 ± 0.17(0.65)$^{b}$ |
| Limb circumference(cm) | 11.89 ± 0.29(1.20)$^{a}$ | 14.82 ± 0.63(2.37)$^{b}$ |
| Age(years) | 1.71±0.45(1.86) | 1.21±0.17(0.63) |

N, represents the number of animals, Values along the same row with different superscript are significantly different. SAP; Systolic arterial pressure, DAP; Diastolic arterial pressure, MAP; Mean arterial pressure, WTH; Weight to Height ratio

**TABLE III**: The Mean±SEM (SD) of the arterial blood pressure and demographic indices of male and female dogs

| Parameters | MALE (12) | FEMALE(18) |
|---|---|---|
| SAP(mmHg) | 137.75 ± 5.86 (20.31) | 152.32 ± 5.43(23.71) |
| DAP(mmHg) | 83.66 ± 5.98 (20.71) | 92.63 ± 6.33(27.60) |
| MAP(mmHg) | 101.67 ± 4.84 (16.79) | 112.26 ± 5.35(23.32) |
| Heart rate(b/m) | 83.50 ± 6.90 (23.90) | 84.26 ± 6.16(26.87) |
| Height(cm) | 63.16 ± 1.70 (5.90) | 61.18 ± 1.43(6.25) |
| Weight(kg) | 29.41 ± 3.38 (11.73) | 26.52 ± 2.35(10.27) |
| WTH(Ibs/inches) | 2.55 ± 0.24 (0.86) | 2.38 ± 0.17(0.73) |
| Limb circumference(cm) | 13.45±0.66 (2.31) | 13.06 ± 0.54 (2.38) |
| Age(years) | 1.76 ± 0.60 (2.10) | 1.31 ± 0.19 (0.83) |

N, represents the number of animals. SAP; Systolic arterial pressure, DAP; Diastolic arterial pressure, MAP; Mean arterial pressure, WTH; Weight to height ratio

**TABLE IV**: The Mean±SEM (SD) of the arterial blood pressure and demographic indices of young and adult dogs

| Parameters | YOUNG(n=8) | ADULT(n=22) |
|---|---|---|
| SAP(mmHg) | 142.62 ± 7.44 (21.05) | 147.27 ± 5.22(24.49) |
| DAP(mmHg) | 90.87 ± 7.42 (21.01) | 87.40 ±5.74(26.93) |
| MAP(mmHg) | 108.25 ± 7.23 (20.47) | 107.09 ± 4.70 (22.08) |
| Heart rate(bpm) | 89.62 ± 10.90 (30.83) | 80.00 ± 4.71(22.11) |
| Height(cm) | 55.93 ±1.44 (4.09)[a] | 63.77 ± 1.11(5.21)[b] |
| Weight(cm) | 18.50 ± 2.21(6.25)[a] | 30.68±2.22(10.43)[b] |
| WTH(Ib/inches) | 1.82±0.18(0.51)[a] | 2.68 ± 0.16(0.75)[b] |
| Limb circumference(cm) | 11.92 ± 0.70(1.99) | 13.67 ± 0.50 (2.35) |
| Age(years) | 0.41 ± 0.01 (0.05)[a] | 1.88 ± 0.32(1.53)[b] |

N, represents the number of animals, Values along the same row with different superscript are significantly different. SAP; Systolic arterial pressure, DAP; Diastolic arterial pressure, MAP; Mean arterial pressure, WTH; Weight to height ratio

As shown in TABLE 5, the mean coefficient of variation of arterial blood pressure indices in the various categories of dogs were found to be largest with DAP. The lowest values were seen in SAP while the MAP values were intermediate. When the effects of other confounders on blood pressure were controlled in all dogs, the breed (p= 0.03, r= 0.31) and the interaction between breed and sex (p=0.017, r=0.395) influenced SAP. The MAP (p=0.00; r=0.95), SAP (p=0.000; r= 0.41) and heart rate (p=0.032; r=0.35) also significantly influenced DAP. The multiple regression model, SAP = 2.95 (MAP) +0.74 (WTH) +0.85 (MALE) -1.95 (DAP) -1.44, DAP =0.309 (WTH) +1.51 (MAP) -0.50 (SAP) -0.48 and MAP =0.66 (DAP) +0.34 (SAP)-0.21 (WTH) +0.33 significantly (p<0.05) describe the relationship between the arterial blood pressure indices and their predictors.

In Boerboel, when other cofounders were controlled there was a correlation between SAP and age (p= 0.05, r=0.467) and interaction of sex and age (p=0.043, r=0.494). There was also a partial correlation between DAP and height (p=0.042; r=0.497) and also between DAP and MAP (p=0.000; r= 0.959). The multiple regression model, DAP= 1.513(MAP)-0.499(SAP)-1.144 and MAP= 0.661(DAP) +0.330(SAP) +0.760 significantly (p<0.05) describe the ABP indices and their predictors.

**TABLE V**: Mean coefficient of variation (%) of arterial blood pressure indices in different categories of dogs

| Parameters | SAP | DAP | MAP |
|---|---|---|---|
| All dogs | 15.95 | 28.24 | 19.76 |
| Alsatians | 18.16 | 22.71 | 19.70 |
| Boerboel | 12.44 | 35.04 | 20.58 |
| Males | 14.74 | 24.77 | 16.51 |
| Females | 15.56 | 29.79 | 20.77 |
| Young | 14.75 | 23.12 | 18.90 |
| Adult | 16.62 | 30.81 | 20.61 |

SAP; Systolic arterial pressure, DAP; Diastolic arterial pressure, MAP; Mean arterial pressure

In Alsatian, there was a partial correlation between SAP and DAP (r= 0.814; p= 0.000) and SAP and MAP (r= 0.919; p= 0.000) and DAP and MAP (r=0.977; p=0.00). The following models significantly (p<0.05) describes the relationship of arterial blood pressures and their predictors. SAP= 2.92 (MAP) +0.90 (WTH_MALE) - 1.94 (DAP) + 0.633, DAP= 1.49 (MAP) +0.46 (WTH_MALE) -0.51 (SAP) +0.15 and MAP= 0.667 (DAP) +0.34 (SAP)-0.307 (WTH_MALE)-0.116

In males, when other confounders were controlled, there were correlations between SAP and MAP (p= 0.022; r= 0.590), DAP and weight (p= 0.04; r= -0.519), height (p=0.03; r=-0.57) heart rate (p= 0.05; r= 0.496) and MAP (p=0.000; r= 0.917). MAP is correlated with heart rate (p=0.05; r=0.48). The multiple regression model (p<0.05) showed that SAP = 2.95(MAP) - 1.98 (DAP) +2.94, DAP is 1.49 (MAP) – 0.502 (SAP) + 1.34 and MAP= 0.34 (SAP) +0.67 (DAP)-0.87.

In the female dogs, there was partial correlations between SAP and DAP (p= 0.017; r= 0.50) SAP and MAP (p=0.000; r= 0.717) and DAP and MAP (p=0.000; r= 0.962). The multiple regression model (p<0.05) showed that SAP =3.0 (MAP) +0.65 (AGE) – 1.99 (DAP) – 1.470 DAP= 1.51 (MAP) +0.33 (AGE) -0.50 (SAP) -0.865 and MAP= 0.332 (SAP) +0.663 (DAP) – 0.219 (AGE) +0.572.

**DISCUSSION**

The arterial blood pressure values obtained in the current study may be considered normal for the different sexes, ages, breeds and all dogs studied. These values are comparable to those previously obtained for these categories of dogs (Bodey and Michell 1996) and are still below the standard values reported for hypertension in canine species (SAP ≥202mmhg; DAP ≥102mmhg; MAP ≥110 mmhg) (Sanan and Arslan, 2007).

This study has proven that adoption of human oscillometric sphygmomanometer and a single neonatal cuff size rather than varied cuff sizes could provide a fairly accurate blood pressure measurement. It could also be more convenient and less expensive in countries where veterinary equipment is scarce and expensive.

The precision of the blood pressure monitor used in this study may be more for SAP than other pressure indices. This is because the coefficient of variation and range of values obtained for DAP is the largest of all other pressure indices studied. Bodey *et al.* (1994) when comparing blood pressure values obtained from different sites of cuff placement in dogs reported a similar observation in DAP.

It was also established in this study that limb circumferences did not influence the ABP across population of dogs studied. This underscores the appropriateness of the limb circumference to cuff bladder width ratio.

This study had used cuff bladder width of between 30 and 50% of the limb circumference rather than 40 and 60% that has been popularly used in many similar studies (Bodey *et al*., 1994; Bodey and Michell, 1996).

In all dogs, SAP was influenced by breed and the interaction of breed and sex when the effects of other cofounders were controlled. This was however not the case for DAP and MAP. Some other reports have identified the influence of breed on SAP and also on DAP (Bodey and Michell, 1996). Although breed differences in arterial blood pressure indices have been reported by Bodey and Michell, (1996), there were no differences in the blood pressure values obtained for the two dog breeds studied. A possible explanation for this observation could be the interaction observed between breed and sex and between breed and age. The dogs used in this study are not pedigree dogs and so the true phenotypic differences expected between the breeds in blood pressure and other traits may not be seen.

As reported in previous studies on humans, cats and dogs, SAP was influenced by sex in the entire dog population studied. In agreement with the findings of Sanan and Arslan (2007), there were also no differences between SAP of both sexes. The interaction between sex and breed and also between age and sex may have accounted for this observation. The differing ages of dogs at sexual maturity may explain why there was no difference in the SAP of male and female dogs. Many workers have reported a higher blood pressure in male compared to female of both humans and animals (Bodey and Michell, 1996; Mishina *et al.,* 1997; Smulyan *et al.,* 2001; Payne *et al.,* 2017) We also found that the influence of sex on SAP is 0.864mmHg higher in males. The higher SAP seen in male animals has been attributed to the higher excitatory state of male compared to female animals.

The body condition score has been reported to influence blood pressure in many species (Montoya *et al.*, 2006; Davy and Hall 2004; Payne *et al.,* 2017). The BMI provides a reliable method of evaluating body condition in humans. Unlike humans, there is yet no standard formula for BMI determination in dogs. In some studies, human formula for BMI determination has been adopted for canine use (Ajadi and others, 2016). This has been largely unsuccessful because of inherent technical pitfalls related to the difference in the topographic anatomy of man and dogs.

When the effect of body condition score (BCS) on arterial blood pressure was investigated, it was found that BCS has only a minor effect on ABP (Bodey and Michell, 1996).

In this study, weight to height ratio (WTH) was used to evaluate BMI. This study is the first to elucidate the relationship between blood pressure and WTH. This index was found to predict SAP and DAP and may thus be reliably used as a surrogate of BMI. Quite unlike the purported minor effect BCS was said to have on ABP, we observed a major effect of WTH on blood pressure in the entire dog population. This effect was not related to age as was the report of Bodey and Michell (1996), but may be to sex because of the observed interaction between WTH and sex in Alsatians. This relationship between WTH and sex may explain why no difference in WTH was observed between sexes. The higher values of WTH obtained in Boerboel is expected because of their larger body size.

An attempt has been made to categorize dogs as overweight and underweight based on statistical cut off point obtained from the weight to height ratio. In this study, a weight to height ratio of above 4.35 and below 1.75 may be considered overweight and underweight respectively in the Boerboel. In Alsatian, WTH of above 2.72 and below

1.12 is considered overweight and underweight respectively. Male and female dogs of above 4.27 and 3.84 are considered overweight while WTH of below 0.83 and 0.92 are underweight.

The influence of weight and height on blood pressure has been described in humans (SONG, 2014). The systolic and diastolic pressure of males and female children are known to be height and weight dependent (Aullen *et al.*, 1980). Similarly, studies done on dogs have also found a relationship between blood pressure and weight. Hitherto, our knowledge of how the height of dogs relate to their blood pressure has been hazy. This current study has been able to provide some information on this. The height and weight of male dogs have been found to be related to DAP. Taller and bigger male dogs appear to have lower DAP values. This is quite opposite to what has been reported in humans. The male dogs used in this study are heavier and taller than the female dogs and so it thus appear that blood pressure are affected by weight and height at certain critical points

The influence of age on ABP has been widely reported in various species of animals (Sanan and Arslan, 2007; Bodey and Michell, 1996; Payne *et al.*, 2017). Except for female dogs whose arterial blood pressure indices were influenced by age, this current study like that of Montoya *et al* (2006) did not find a relationship between age and all arterial blood pressure indices in the entire population of dogs studied. The blood pressures of older animals have been previously reported to be above the younger ones (Bodey and Michell, 1996; Sanan and Arslan, 2007; Payne *et al.*, 2017). This was not the case in this study. Although the blood pressures of younger dogs were below those of the older ones, there was no statistical significant difference between them. The smaller number of dogs used could be a factor affecting the inferential power of the statistical test used in this study. Since the attainment of sexual maturity is a function of age, dogs used in this study may not have achieved puberty as they are relatively younger than the ones previously used by Sanan and Arslan, (2007) and Bodey and Michell (1996). At a mean age of 1.74, our dogs are adolescents and have not grown to 2years, the age of full sexual maturity of most larger breed dogs.

The influence of age and the interaction between age and sex as observed in female and Boerboel respectively may account for why there were no differences between ABP of different ages. The influences of age on both DAP and SAP in female alone could be due to other factors such as diet, hormones, season and other factors which were not studied.

The absence of age, sex, and breed differences in ABP of dogs may be due to multiple interactions between these factors. The relatively fewer number of dogs and the cross sectional nature of this study could also provide justification for the observations made. The human sphygmomanometer has the best precision for SAP measurements and WTH may be used as canine's BMI because of its influence on ABP.

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