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Evaluation of the thermographic response of the lumbar region in dogs with bilateral hip osteoarthritis

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ABSTRACT

Infrared thermography is suggested as a method of medical assistance for evaluating anatomical regions where there may be some inflammatory or painful condition that requires immediate medical attention. For this reason, this study aimed to characterize digital thermography of the lumbar region in police working dogs with hip osteoarthritis, 47 dogs with bilateral hip osteoarthritis were evaluated. A thermographic dorsoventral view of the dogs' backs were obtained, and mean and maximum temperatures were determined. In addition, results from the Canine Brief Pain Inventory, Liverpool Osteoarthritis in Dogs (LOAD), the Canine Orthopedic Index, and weight-bearing distribution evaluation were collected. Results were compared with an Independent Samples T-Test or ANOVA, followed by an LSD post hoc. Multiple regression was run to predict temperatures from age, sex, breed, body weight, and Orthopedic Foundation for Animals hip score and to predict clinical metrology scores and weight-bearing distribution results from temperature results. The sample included 28 males and 19 females, with a mean age of 6.3 ± 2.5 years and bodyweight of 26.9 ± 5.1 kg, with osteoarthritis hip scores of mild (70.2%), moderate (21.3%), and severe (8.5%). Significant differences were observed in mean temperatures between German Shepherd Dogs (GSD) and Labrador Retrievers (LR) ($p < 0.01$), and LR and Belgian Malinois (BM) ($p=0.02$). Mean temperature contributed to the prediction of LOAD and stiffness. LR showed significantly higher temperature values than GSD and BM. No differences were observed between osteoarthritis hip scores and mean temperature values contributed to LOAD scores' prediction. This relation needs to be addressed in further studies, involving a larger number of animals, and to determine changes in response to treatment.

1. Introduction

Hip osteoarthritis (OA) commonly affects police working dogs due to breed predisposition and continuous high activity levels (Alves et al., 2021a; Baltzer et al., 2019; Bliss, 2018). Additional risk factors for OA include neutering status, a higher body weight, and age over eight years (Anderson et al., 2018). OA is a low-grade inflammatory disease, where the inflammatory process affects the progression of the disease (Alves et al., 2022c). Dogs with hip OA often present with the pelvic limbs tucked under the body, with the back arched and a change of gait patterns, increasing stress on paraspinal structures (Davidson and Kerwin, 2014; Witte and Scott, 2011). These factors are more common in the case of animals intended exclusively for companionship. In the case of dogs destined to guard and protection, OA of the hip can derive in spinal pain due to the activity that represents their work. The same occurs in other types of work, such as search and rescue, contributing to the animal's overall pain perception, stiffness, gait, and activity level. Evaluating paraspinal structures can be challenging for the clinician (Alves et al., 2021; Alves et al., 2018).

To obtain a detailed evaluation of each patient, getting information on the multiple dimensions of the disease is paramount (Lascelles et al., 2019). As objective measures, weight distribution platforms have been proven to provide repeatable and accurate results, compared to a pressure-sensitive walkway (Bosscher et al., 2017), allowing the

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selection of the best candidates for certain procedures and the assessment of response to treatment (Ben-Amotz et al., 2020; White et al., 2020). Also, several clinical metrology instruments have been developed to evaluate individual patients and measure outcomes in different dimensions. In dogs, some of the most commonly used are the Canine Brief Pain Inventory (CBPI), the Liverpool Osteoarthritis in Dogs (LOAD), the Canine Orthopaedic Index (COI), and the Hudson Visual Analogue Scale (HVAS) (Alves et al., 2021; Muller et al., 2016; Walton et al., 2013).

Digital thermography can be an assistance tool and add relevant information for the clinician during patients' evaluation, reflected in a growing number of reports in dogs, where thermography was used to assess a wide range of conditions and structures, from the hip, stifle, elbow, intervertebral disc, neoplasia, and exercise (Alves et al., 2021b; Brown and Henneman, 2018; Grossbard et al., 2014; Infernuso et al., 2010; Loughin and Marino, 2007; McGowan et al., 2015; Sung et al., 2019; Vainionpää et al., 2012). Recently, thermography has been used to evaluate back pain and response to treatment in dogs with different conditions, including hip OA (Freeman et al., 2021). Thermography can identify changes in skin temperature and temperature patterns produced by changes in blood flow on the site of interest (Hildebrandt et al., 2010; Jiang et al., 2005; Marino and Loughin, 2010; Ring and Ammer, 2012). Specific guidelines for its use have been developed so that digital thermography can provide a reproducible screening tool (Jin, 2013; Ring, 2004).

This study aimed to characterize digital thermography of the back in police working dogs with hip OA and the relationship with the results of weight bearing distribution, clinical metrology instruments scores, with animals' age, breed, sex, the specific mission that the dog was involved in, and a previous diagnosis of orthopedic disease. We hypothesized that these factors influence observed digital thermography results.

2. Materials and methods

The study protocol was approved by the ethical review committee of the University of Évora (Órgão Responsável pelo Bem-estar dos Animais da Universidade de Évora, approval nº GD/37187/2021/P1) and complied with relevant institutional, national and ARRIVE guidelines for the care and use of animals. Written, informed consent was obtained from the Institution responsible for the animals.

The dogs in this sample constituted a convenience sample of 47 animals (N=47). All animals were active police working dogs, presenting at the Clínica Veterinária de Cães (Portuguese Gendarmerie Canine Clinic) to undergo bilateral hip OA treatment following initial diagnosis. In this prospective, double-blinded study, the initial diagnosis was based on a consistent history (difficulty rising and jumping and stiff gait), physical examination (joint pain and stiffness, with a reduced range of motion), and radiographic findings (following the Orthopedic Foundation for Animals - OFA, available online at https://www.ofa.org/diseases/hip-dysplasia/grades). Additional inclusion criteria were a body weight ≥15 kg and age >2 years. Orthopedic, neurological, or other diseases were ruled out through physical, orthopedic, neurological, and imagiological examination, complete blood count, and serum chemistry profile. All evaluations were performed in a single visit by the same researcher.

Procedures for digital thermography collection have been described previously (Vainionpää et al., 2012). Briefly, dogs were kept in a controlled temperature room for 30 min before imaging, with the temperature set at 21 °C, during which the dogs were allowed to walk freely around the room. Imaging was conducted early in the morning, before any activity or training other than a relaxation walk. During this period, the region of interest was not touched. The dogs were then positioned upright, as symmetrically as possible, and a dorsoventral image was obtained. The image was collected at a distance of 60 cm (Vainionpää et al., 2013) at a 90° angle, covering the area of the dog's lumbar region (Rizzo et al., 2017). Image settings were adjusted to include a range of 15–40 °C, an emissivity of 0.98. For this procedure, no sedation or anesthesia was required. All images were captured with the same infrared camera (ThermaCAM E25, FLIR Systems, Inc.) and processed with associated camera software (FLIR Systems, Inc.). A rainbow HC color pallet was used. A temperature box was placed, symmetrically on both sides with the spinal column as a reference, and mean and maximum temperatures were determined (Fig. 1).

Weight-bearing distribution was conducted with a Companion Stance Analyzer® (LiteCure LLC, Newark, Delaware, United States), following the previously described procedure (Alves et al., 2020; Clough et al., 2018). Briefly, the animal was encouraged to stand on the platform, with one foot on each quadrant, with the centre of gravity and stability near the center of the platform. At least 20 measurements were obtained for each animal to determine a mean value. With the results of weight-bearing distribution, two outcomes were calculated. A left-right symmetry index (SI), calculated with the following formula: $SI = [(WB_R\text{-}WB_L)/((WB_R+WB_L)x0.5)]x100$, where WB_R is the value of weight-bearing for the right pelvic limb, and WB_L is the value of weight-bearing for the left pelvic limb, and negative values were made positive (Volstad et al., 2017; Walton et al., 2013). Also, a deviation from the normal 40% weight-bearing for both pelvic limbs was calculated by subtracting combined weight-bearing from the normal 40% (Alves et al., 2021; Clough et al., 2018). Also, the trainers completed a digital copy of CBPI, COI, and LOAD, the same trainer in all of these clinical metrology instruments for each dog. The CBPI is composed of a pain severity score (PSS) and a pain interference score (PIS) (Brown et al., 2008), and the COI has four dimensions: stiffness, function, gait, and quality of life (Brown, 2014). All of the considered instruments have been previously validated in their Portuguese versions (Alves et al., 2022, 2022a, 2022b). All scores and dimensions were considered in the analysis.

Normality was assessed with a Shapiro-Wilk test. Mean and maximum temperatures were compared with an Independent Samples T-Test (when two groups were considered, like sex) or ANOVA, followed by a Least Significant Difference post hoc test for multiple comparisons (when more than two groups were considered). Multiple regression was run to predict mean and maximum temperatures from age, sex, breed, body weight, and OFA hip score. Multiple regression was also run to predict clinical metrology scores and weight-bearing distribution results from mean and maximum temperatures. The correlation between variables was assessed with the Pearson correlation coefficient. All results were analyzed with IBM SPSS Statistics version 20. Statistical significance was set at $P < 0.05$.

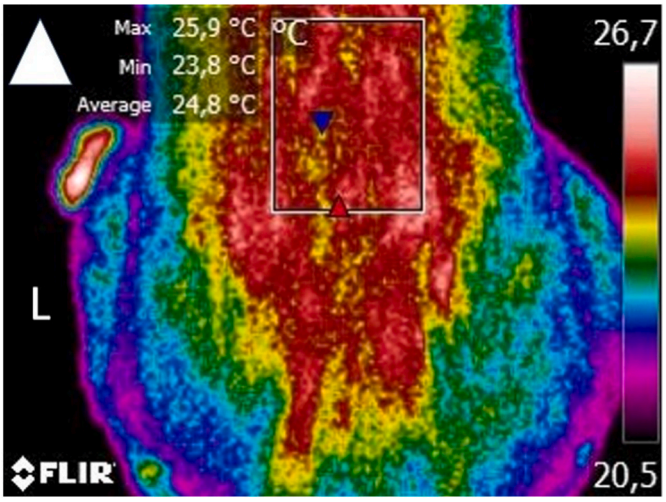

Fig. 1. – A dorsoventral view of including the region of interest of the back, at a distance of 60 cm. Arrowhead indicates cranial direction. A temperature box was placed over the region of interest, and mean and maximum were obtained.

3. Results

The sample included 47 Police working dogs, 28 males and 19 females, with a mean age of 6.3 ± 2.5 years, bodyweight of 26.9 ± 5.1 kg, and a body condition score of 4 (65%) or 5/9 (35%). Breeds included in the sample are commonly represented in police and military forces throughout the world and included German Shepherd Dogs (GSD, n=16), Belgian Malinois Shepherd Dogs (BM, n=15), Labrador Retrievers (LR, n=9), and Dutch Shepherd Dogs (DSD, n=7). Considering hip OA grading, 33 animals were classified as mild (70.2%), 10 as moderate (21.3%), and four as severe (8.5%).

Results of digital thermography evaluation by breed, sex, and OFA grades, are presented in Table 1. Significant differences in mean values were observed between GSD and RL ($p < 0.01$), and RL and BM ($p=0.02$) when breeds were compared. Considering maximum values, significant differences were observed between GSD and RL ($p < 0.01$). No significant differences were observed between sexes or OFA grades. Mean and standard deviation values for clinical metrology instruments and weight-bearing evaluation results are presented in Table 2.

Age, breed, sex, and OFA grade did not add statistical significance for the prediction of mean and maximum temperatures. Mean temperature contributed to the prediction of LOAD $F(9,36)=1.567$, $p=0.03$ and stiffness $F(9,36)=2.458$, $p < 0.05$, $r^2=0.102$ scores. Maximum temperature contributed to the prediction of LOAD scores $F(9,36)=2.651$, $p < 0.05$, $r^2=0.029$. A strong correlation was observed between mean and maximum temperatures ($r^2=0.956$, $p < 0.01$).

4. Discussion

Chronic back pain is common in dogs with hip OA, and working dogs are commonly described as having stiff backs (Alves et al., 2021; Alves et al., 2018). This study described thermographic evaluation results in police working dogs with hip OA, which adds further information regarding the characterization of the disease and can aid the clinician in assessing these patients.

The thermographic response during a painful process is the increase of temperature at a local level due to the presence of inflammatory substances such as cytokines, prostaglandins, serotonin, and bradykinin that cause local vasodilatation and therefore generate the increase of heat radiation that can be used as an indication of acute pain (Casas-Alvarado et al., 2022; Mota-Rojas et al., 2022). Previous reports on the thermographic evaluation of the canine back described a mean temperature value of 26.5 ± 1.4 °C (Rizzo et al., 2017). This value is higher than the mean value we determined in this study (24.7 ± 1.7 °C) and closer to the maximum values observed (26.3 ± 1.6 °C). Some factors may contribute to this finding. Animals in the previous report study were small dogs (Jack Russell Terrier/Miniature Pinscher mixed-breed dogs) with very different physical characteristics from those in the present sample.

Table 1
– Mean and standard values overall mean and maximum thermography values by breed, sex and Orthopedic Foundation for Animals hip score.

	Thermography mean (°C)		Thermography maximum (°C)	
	mean	SD	mean	SD
Overall	24.7	1.7	26.3	1.6
German Shepherd Dog	24.1	1.5	25.5	1.5
Belgian Malinois Shepherd Dog	24.4	1.7	26.4	1.6
Labrador Retriever	26.1	1.3	27.5	1.2
Dutch Shepherd Dog	25.1	1.5	26.4	1.2
Male	24.5	1.5	26.2	1.8
Female	24.9	1.9	26.4	1.8
Mild	24.7	1.6	26.3	1.5
Moderate	24.9	1.8	26.4	1.8
Severe	23.9	1.8	25.5	1.6

Table 2
Mean and standard overall results for clinical metrology instruments and weight bearing evaluation. Legend: CBPI – Canine Brief Pain Inventory; PIS – Pain Interference Score; PSS – Pain Severity Score; HVAS – Hudson Visual Analogue Scale; LOAD – Liverpool Osteoarthritis in Dogs; COI – Canine Orthopedic Index; QOL – Quality of Life.

Evaluation modality		Result	
		mean	SD
CBPI	**PIS (0-10)**	3.0	2.4
	PSS (0-10)	2.9	2.2
HVAS (0-10		6.6	1.4
LOAD (0-52)		13.4	10.6
COI	**Stiffness (0-16)**	3.3	3.4
	Function (0-16)	3.4	4.1
	Gait (0-20)	5.5	5.1
	QOL (0-12)	4.1	3.1
	Overall	16.4	14.8
Weight bearing	**Symmetry Index**	28.6	27.2
	Deviation	4.6	4.1

The coat's influence has to be documented (Infernuso et al., 2010; Loughin and Marino, 2007; Marino and Loughin, 2010; Rizzo et al., 2017), as hair coat in mammals, its color, length, shape, and density, interferes with thermoregulatory capacity or the ability to radiate heat, which will reflect in the thermographic evaluation (Mota-Rojas et al., 2021a, 2021b). Regarding coat color, the GSD of the sample were sable, BM were fawn, LR were yellow, and DSD were brindle. While all breeds included in this study had short hair, some, such as GSD, had a thick undercoat (Alves et al., 2020). These differences in coat thickness may partly account for the significantly lower values in GSD than LR and DSD. Although sex, age, and breed did not contribute to predicting thermographic results, the influence of specific characteristics in digital thermography results should be addressed by future studies.

While no differences were observed in mean and maximum temperatures between different OFA hip grades, lower values were observed in dogs with severe OA. These lower values could be attributed to similar phenomena observed in Human OA studies, where lower temperatures are observed in more severe disease cases (Varju, 2004), possibly due to the muscular hypotrophy caused by secondary disuse decreased physical activity, either spontaneous or from human influence (Hildebrandt et al., 2012; Loeser et al., 2012). As a large majority of mild OA was represented in the sample, and muscle masses were not evaluated, future studies should include a higher number of animals with the remaining hips grades to confirm whether these lower values represent a tendency.

Mean and maximum results showed a high correlation between themselves. Both contributed to the prediction of LOAD scores (in addition to stiffness, in the case of mean values) but not to the projections of the remaining clinical metrology instruments and weight-bearing distribution evaluations. This contrasts with previous reports, where thermographic results, particularly maximum values, showed a varying level of correlation with these evaluation measures. This finding can be attributed to the possibility that maximum temperature values would better reflect the inflammatory nature of OA pain (Alves et al., 2020, 2021b). Some reasons may account for these differences. Of all considered clinical metrology instruments, the LOAD is the only one specifically developed to assess OA patients, which was the case of the dogs in this sample, which may represent a higher sensitivity to evaluate these cases. Another possibility relates to the fact that most dogs had only mild disease, where compensatory changes may not have occurred. This has to be considered in future studies, particularly for GSD, a breed where pelvic limb weakness due to lumbosacral disease or OA has been reported (Alves et al., 2018; Alves et al., 2021a; Linn et al., 2003).

This study presents some limitations, namely the lack of a group composed of healthy dogs. This limitation arises from the sample's

convenience, consisting of a set of dogs specifically presenting for treatment. Although we only presented information from a single evaluation moment, it is impossible to comment if changes occur in response to treatment. These limitations should be addressed in future studies.

5. Conclusions

This study first described the thermographic evaluation of the canine back in dogs with bilateral hip OA. Mean temperature values contributed to the prediction of LOAD scores. GSD showed significantly lower mean temperature values than LR and DSD; no differences were observed between OFA hip scores. However, a tendency for lower values in dogs with severe disease may occur. Further studies with a larger sample are required to evaluate changes in response to treatment.

Author contribution

JCA designed the protocol, conducted treatments and prepared the manuscript.

PJ and AS selected patients and conducted treatments.

CL and LMC revised the protocol and prepared the manuscript.

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Declaration of competing interest

The authors have no conflict of interest to state.

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