

## Research Article

## Characterization of Weight-bearing Compensation in Dogs With Bilateral Hip Osteoarthritis

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## A B S T R A C T

To describe the weight-bearing compensation in working dogs with bilateral hip osteoarthritis (OA), 50 police working dogs were evaluated with a weight distribution platform at the initial evaluation and after intra-articular treatment (a negative control – 0.9% sodium chloride (NaCl), a platelet concentrate, Hylan G-F 20, triamcinolone hexacetonide or stanozolol). Six evaluation sessions were performed, over a 180-day period. Results were compared by breed, age, sex, weight and Orthopedic Foundation for Animals hip grade scores with the Independent Samples T-Test, repeated samples Analysis of variance and Pearson correlation coefficient,  $P < .05$ .

Animals had a mean age of  $6.5 \pm 2.4$  years and a bodyweight of  $26.7 \pm 5.2$ kg. No significant differences were observed when comparing weight-bearing for different breeds, sex, hip grades or weight during the initial evaluation. Significant differences were observed in deviation ( $P < .01$ ) and symmetry index ( $P < .01$ ) between the control and treatment groups during the follow-up period. A weight shift from pelvic to thoracic limbs was observed, with a weak, although a significant, correlation between a pelvic limb and the opposing contralateral thoracic limb. Labrador Retrievers showed higher symmetry index and deviation from normal values during the follow-up period than German Shepherd Dogs and Dutch Shepherd Dogs. Male dogs also showed higher symmetry index and deviation compared with females. At this period, the symmetry index showed a weak, although significant, correlation with body weight. Weight-bearing of all limbs correlated with the remaining limbs, reflecting a more balanced weight distribution than the initial evaluation. The weight distribution platform can be used to evaluate patients, at the initial presentation and during the assessment of response to treatment.

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## Introduction

Gait analysis, and the measurement of ground reaction forces, are well-established methods to describe gait and severity of an existing lameness, with a 90% sensitivity and specificity.<sup>1-3</sup> It is an area of increasing interest to assess response to surgical procedures, treatment outcome, orthopedic conditions, and breed differences.<sup>4-8</sup> Osteoarthritis (OA) represents at least 80% of the cases of lameness and joint diseases in companion animals, making it the most frequently diagnosed joint disease in veterinary medicine.<sup>9,10</sup> There are several described risk factors: having higher body weight, being of a specific breed, neutered, and being older than 8 years.<sup>11,12</sup> Sporting and working animals are at increased risk, as they are exposed to chronic fatigue injuries, leading to joint tissues damage and ultimate joint disease. In addition, many breeds commonly used are predisposed to hip OA.<sup>13,14</sup> Although measuring changes in limb function does not directly correlate to changes due to joint pain, one could expect function in the limb to have comparable changes as a consequence of it.<sup>15</sup> Ground reaction forces have been described as outcome measures reflecting pain-related functional impairments in the context of OA, being abnormal lower.<sup>16-18</sup> The use of weight distribution platforms has been described and presented as accurate and repeatable measurement, with a pressure-sensitive walkway as a reference.<sup>19</sup> Weight distribution platforms consist of a scale with four different quadrants to independently assess the four limbs.<sup>20</sup>

When a limb is affected, adaptations occur on all limbs, both at a stance or dynamic phase. The described compensation mechanism is that most pronounced changes occur in the affected limb, followed by the contralateral limb, the opposing contralateral limb, and, to a lesser extent, the opposing ipsilateral limb.<sup>21</sup> Animals with hip OA present complex changes in gait, which involve more joints than just the affected hip alone. While ground reaction forces of the affected limb can be similar to those of the limbs of non-affected dogs, the contralateral limb usually shows higher ground reaction forces values.<sup>22</sup> Weight distribution and off-loading or limb favoring at the stance is a commonly used subjective assessment during the orthopedic examination. Yet, lameness may be difficult to detect during gait evaluation.<sup>23</sup> The way and degree to which these adaptations occur has not been fully described and have not been characterized in specific diseases, such as hip OA. Stance analysis has been reported as sensitive for detecting lameness in dogs, particularly in large breed dogs.<sup>24</sup>

The administration of local therapies directly at the effect joint by intra-articular (IA) injection is a common and suitable approach.<sup>23</sup> Commonly used IA treatment modalities include corticosteroids (as triamcinolone hexacetonide), hyaluronan, and autologous platelets.<sup>24-26</sup>

This study aims to describe static weight-bearing compensation in police working dogs diagnosed with bilateral hip OA, and to describe weight-bearing redistribution in response to treatment, evaluating the feasibility of using this weight distribution platform to perform this evaluation. We hypothesize that different breeds and patients with varying grades of the hip, classified according to the Orthopedic Foundation for Animals (OFA) grading scheme, would show various degrees of body weight redistribution at the time of diagnosis and in response to treatment.

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## 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 n° GD/32055/2018/P1, September 25, 2018). Written, informed consent was obtained from the Institution responsible for the animals. Fifty (N = 50) active police working dogs with bilateral hip OA comprised the sample. It was a convenience sample, selected from the population of police working dogs of the Guarda Nacional Republicana (Portuguese Gendarmerie Canine Unit) to take part in a longitudinal double-blinded, negative controlled study, evaluating the use of intra-articular treatments (platelet concentrate, Hylan G-F 20, triamcinolone hexacetonide, stanozolol, and 0.9% sodium chloride (NaCl) - sterile saline as a negative control) in the management of OA. Diagnosis based on dog's history (difficulty rising, jumping, and maintaining obedience positions, stiffness and decreased overall performance), physical examination (pain during joint mobilization, stiffness, and reduced range of motion), and radiographic findings (OFA hip scores of mild, moderate or severe) consistent with bilateral hip OA. To be included in this study, the dog must have a body weight  $\geq 15$ kg, be over two years, and should not have received any medication or nutritional supplements for at least six weeks. The need for additional rescue analgesia was evaluated by the assisting veterinarian and recorded based on the clinical examination and pain scale scores (Canine Brief Pain Inventory). Animals with suspect or confirmed orthopedic disease other than OA, neurologic or concomitant disease (ruled out through physical, neurological, and orthopedic examination, complete blood count, and serum chemistry profile) were excluded. Dogs not tolerant of the necessary manipulation for data collection were also excluded. The same researcher (JCA) performed all evaluations on days 0, 8, 15, 30, 90, and 180, unaware of the patient's treatment group or previous assessments. For hip grading, the patient's information was removed from the radiographs. Data collected at the initial diagnostics evaluation was used as a cross-sectional cohort, while follow-up evaluations, assessing response to treatment, constituted the longitudinal cohort. As we aimed to determine the changes that occur following intra-articular treatment regardless of its nature and degree of change produced, the results of all considered treatments were analyzed as a single group.

Weight-bearing distribution was performed with a weight distribution platform (Companion Stance Analyzer; LiteCure LLC, Newark, Delaware, United States). Following the manufacturer's instructions, it was placed in the center of a room, at least 1 meter from the walls, calibrated at the beginning of each day, and zeroed before each data collection. For data collection, animals were then encouraged by their trainers to stand on the weight distribution platform while ensuring that the patient placed one foot on each quadrant of the platform and maintained a natural stance with their center of gravity and stability near the middle of the platform (measured by the platform). When required, gentle restraint was used to maintain the patient's head in a natural, forward-facing position. At least 20 measurements were obtained from each dog, and a mean value was determined. Normal weight distribution for each thoracic limb was considered 30% of total weight and 20% for each pelvic limb.<sup>20</sup> A left-right symmetry index (SI) was calculated for thoracic and pelvic limbs, with the following formula:  $SI = [(WB_R - WB_L) / ((WB_R + WB_L) \times 0.5)] \times 100$ .<sup>25,26</sup>  $WB_R$  is the value of weight-bearing for the right limb, and  $WB_L$  is the value of weight-bearing for the left limb. Values for right limbs are, by definition, negative and were made positive for the analysis.<sup>25</sup> We also considered deviations from normal weight-bearing for both thoracic and pelvic limbs, considered 60% and 40%, respectively. This was obtained by subtracting  $WB_R + WB_L$  to 60 for the thoracic limbs and 40 for the pelvic limbs.

After weight-bearing distribution, and for each animal, a ventro-dorsal radiographic view was obtained to determine OFA hip grade.

All radiographic studies were conducted under light sedation, using a combination of medetomidine (0.01 mg/kg) and butorphanol (0.1 mg/kg), given intravenously. After the radiographic examination, the treatment was administered according to the assigned group: 2 mL of sterile saline per hip joint; 1 mL of 20 mg/1mL triamcinolone hexacetonide (Bluxam, Riemser Pharma, Portugal) per hip joint; stanozolol (Estrombol, Laboratório Fundacion) at 0.3 mg/kg per hip joint (mean volume of 1mL); 2 mL of 10 mg/2mL Hylan G-F 20 (Synvisc, Sanofi, Portugal) per hip joint; and 3 mL of platelet concentrate (V-PET, PALL Corporation) per hip joint. V-PET had a 4-fold platelet concentration, a 2-fold leukocyte concentration, and a 50% reduction in platelet concentrate hematocrit than the values of whole blood. A single administration was carried out, on day 0, following a protocol previously described.<sup>27,28</sup> Ultrasound guidance was available when required.

Normality was assessed with a Shapiro-Wilk test, and measured parameters were compared with Repeated Measures ANOVA, with a Huynh-Feldt correction or, in the case of comparisons between different bodyweight cut-offs (20, 25, 30, and 35 kg), with an Independent Samples T-Test. Correlation between parameters was assessed with the Pearson correlation coefficient. All results were analyzed with IBM SPSS Statistics version 20, and a significance level of  $P < .05$  was set.

## Results

The sample for this study included 50 active police working dogs, 30 males and 20 females, representing four breeds: German Shepherd Dogs (GSD,  $n = 17$ ), Belgian Malinois Shepherd Dogs (BM,  $n = 15$ ), Labrador Retriever (LR,  $n = 10$ ), and Dutch Shepherd Dog (DSD,  $n = 8$ ). Animals had a mean age of  $6.5 \pm 2.4$  years and a bodyweight of  $26.7 \pm 5.2$ kg, with both genders being represented (30 males and 20 females). In concern to OFA hip grading, 35 animals were classified as mild (70%), 10 as moderate (20%), and 5 as severe (10%). All intra-articular treatments were successfully administered, and all animals were followed until the 180-day evaluation moment. Mean values of overall weight, age, and weight-bearing distribution of each limb by breed, sex, and OFA hip grades at the moment of initial evaluation are presented in Table 1. No significant differences were observed when comparing values for different breeds and sex, nor with varying cut-offs for weight at the time of initial evaluation. During the follow-up period (from 8 to 180 days post-treatment), significant differences were observed in deviation ( $P < .01$ ) and SI ( $P < .01$ ) between the control and treatment groups. Detailed information on the effect of each treatment is reported elsewhere.<sup>29</sup> The platelet concentrate produced with Correlations for weight-bearing distribution for each limb at the moment of the initial evaluation is presented in Table 2. During the follow-up period, no significant differences were found regarding SI and deviation comparing animals with the different weight cut-off values by breed, sex, or OFA hip grade. A strong correlation was found between SI and deviation scores ( $r = 1.0$ ,  $P < .01$ ). During the initial evaluation period, significant differences were observed in the weight-bearing distribution of individual thoracic limbs considering a weight cut-off value of 20 kg, but not on the combined value of both. No significant differences were found with the remaining cut-offs values. LR showed significantly higher weight-bearing on the right thoracic limb than GSD ( $P < .01$ ) and BM ( $P < .01$ ). They also had significantly lower weight-bearing on the right pelvic limb and the combined value of both pelvic limbs than GSD ( $P = .02$  for both), BM ( $P < .01$  for both), and DSD ( $P = .02$  and  $P = .04$ , respectively). Female dogs showed significantly lower weight-bearing on the left pelvic limb ( $P < .01$ ) and combined pelvic limbs ( $P = .01$ ) and higher right thoracic limb ( $P < .01$ ). Animals with a severe OA hip grade showed significantly lower weight-bearing on the combination of both pelvic limbs when compared with mild and

**Table 1**

Mean Values (±standard deviation) of Overall Weight, Age and Weight-Bearing Distribution of Each Limb by Breed, Sex and Orthopedic Foundation for Animals Hip Grades on Initial Evaluation

	Weight (kg, mean ± SD)	Age (Years, mean ± SD)	Stance analysis left thoracic limb (%, mean ± SD)	Stance analysis right thoracic limb (%, mean ± SD)	Stance analysis left pelvic limb (°, mean ± SD)	Stance analysis right pelvic limb (°, mean ± SD)
Overall	26.7 ± 5.3	6.5 ± 2.2	31.6 ± 6.2	30.7 ± 6.7	19.0 ± 4.4	18.7 ± 4.2
German Shepherd Dog	29.9 ± 6.3	5.7 ± 1.8	31.7 ± 5.4	29.9 ± 5.6	20.0 ± 3.9	18.4 ± 3.6
Belgian Malinois Shepherd Dog	24.3 ± 4.1	6.5 ± 2.5	30.3 ± 8.4	32.1 ± 7.9	17.8 ± 5.5	19.8 ± 5.9
Labrador Retriever	24.3 ± 2.5	8.7 ± 2.4	31.9 ± 4.9	30.5 ± 5.7	19.9 ± 4.4	18.6 ± 3.2
Dutch Shepherd Dog	27.5 ± 3.9	5.3 ± 1.3	33.8 ± 4.6	30.3 ± 8.1	19.0 ± 4.4	17.4 ± 2.9
Male	29.0 ± 5.4	6.2 ± 2.3	31.3 ± 7.1	30.7 ± 7.4	19.0 ± 5.5	19.3 ± 4.8
Female	23.5 ± 2.8	6.9 ± 2.8	32.1 ± 4.7	30.6 ± 5.5	19.4 ± 3.5	17.9 ± 3.1
Mild	26.7 ± 5.2	6.5 ± 2.4	31.7 ± 6.9	30.2 ± 6.6	19.5 ± 4.4	18.9 ± 4.3
Moderate	26.5 ± 5.4	6.4 ± 2.4	30.5 ± 5.3	32.7 ± 8.3	17.7 ± 6.9	19.1 ± 4.8
Severe	26.4 ± 5.4	6.5 ± 2.5	33.6 ± 1.1	30.0 ± 2.6	19.8 ± 1.3	16.6 ± 2.1

moderate OA hip grades ( $P = .02$  and  $P < .01$ , respectively) and higher on the thoracic limbs ( $P = .05$  for mild and  $P = .03$  for moderate).

Considering the evolution of weight-bearing distribution in the treatment groups during the follow-up period, a significant decrease in weight-bearing was observed in the combined thoracic limbs compared with initial evaluation ( $P < .01$ ) and an increase in the combined pelvic limbs ( $P < .05$ ) compared with the initial evaluation. Correlations for weight-bearing distribution for each limb during follow-up evaluations are presented in Table 3. During the follow-up period, and regarding SI, heavier animals (analyzed with 30 and 35 kg cut-off points) had higher asymmetries on thoracic limbs ( $P = .02$  and  $P = .03$ , respectively) and also on pelvic limbs ( $P < .01$  for both). The same animals showed significantly higher deviations for thoracic limbs ( $P = .02$  and  $.03$ , respectively). Comparing animals by breed, LR showed significantly lower SI and deviation on both thoracic limbs than GSD ( $P = .03$  and  $.04$ , respectively) and BM ( $P < .01$  for both). LR had higher SI concerning pelvic limbs than DSD ( $P = .02$ ) and deviation than GSD ( $P = .03$ ). Male dogs had significantly higher SI and deviation than females ( $P < .01$ ). SI showed a weak, although significant, correlation with weight ( $r = -0.16$ ,  $P < .01$ ).

**Discussion**

This report characterizes weight distribution variations in dogs with bilateral hip OA. Subtle changes in posture or weight-bearing may occur in the early stages of the disease process, easily missed with the visual assessment.<sup>30-32</sup> Additionally, OA animals may not be overtly lame at a walk or a trot but exhibit subtle shifts in body weight distribution at a stance due to pain or instability associated with orthopedic or neural disease.<sup>20,33</sup> Weight distribution platform, as a pressure-sensitive walkway, can provide accurate and consistent measures of weight distribution with no significant difference between devices.<sup>19</sup> At the initial evaluation, a weight shift was

observed from the pelvic to the thoracic limbs. For dogs presenting with pelvic limb-lameness, a load redistribution more by side-to-side compensation rather than pelvic-to-thoracic has been described.<sup>34,35</sup> SIs are standardized comparisons of individual limbs, being a specific and reliable evaluation of individual limbs.<sup>36</sup> Our results contrast with this finding, which may be related to the fact that all animals exhibited bilateral disease, and therefore may try to relieve the pelvic limbs by transferring weight to the thoracic limbs. Also, a weak, although significant, the correlation was found between individual pelvic limbs and the opposing contralateral thoracic limb. This redistribution pattern is also observed in amputee patients,<sup>37</sup> which makes sense, as any OA patients show decreased weight support in affected limbs. Even in patients with bilateral disease, the clinical signs may not be the same when comparing contralateral limbs.<sup>38</sup>

Interestingly, no significant differences were observed in the compensation mechanism when comparing the various breeds represented in the sample. Still, some differences were observed in the degree to which it occurs. This contrasts with what has been described for gait analysis, where significant breed differences have been reported, both at a walk and trot, a probable reflection of different conformations.<sup>39</sup> Besides, no significant differences were observed when comparing animals by sex or with the other weight cut-off values. This may increase interest in weight distribution analysis as a diagnosis and response to treatment evaluation tool since it did not show significant variability for different sets of animals. Additionally, it does not require data normalization to compare different animals, as is required for gait analysis.<sup>40,41</sup>

Bodyweight distribution may have been proposed to be an equivalent or superior measurement of pain associated with hip OA than both vertical impulse and peak vertical force. It has the highest sensitivity and specificity with a cut-off of 2% below the expected value for the limb.<sup>20,42</sup> We have recorded values below and above this cut-off value. This may be due to all animals having bilateral disease. A

**Table 2**

Correlations for Weight-bearing Distribution for Each Limb on Initial Evaluation

Limb		LTL	RTL	LPL	RPL
LTL	rs	1	-0.83	-0.08	-0.20
	Sig.		<0.01*	0.14	<0.01*
RTL	rs	-0.83	1	-0.29	-0.14
	Sig.	<0.01*		<0.01*	<0.01*
LPL	rs	-0.08	-0.29	1	-0.14
	Sig.	0.14	<0.01*		0.02*
RPL	rs	-0.20	-0.14	-0.14	1
	Sig.	<0.01*	<0.01*	0.02*	

LPL, left pelvic limb; LTL, left thoracic limb; RPL, right pelvic limb; RTL, right thoracic limb.

\* indicates a significant correlation.

**Table 3**

Correlations for Weight-bearing Distribution for Each Limb During Follow-up Evaluations

Limb		LTL	RTL	LPL	RPL
LTL	rs	1	-0.87	-0.09	-0.16
	Sig.		<0.01*	0.186	0.01*
RTL	rs	-0.87	1	-0.23	-0.15
	Sig.	<0.01*		<0.01*	<0.01*
LPL	rs	-0.09	-0.23	1	-0.14
	Sig.	0.19	<0.01*		0.03*
RPL	rs	-0.16	-0.15	-0.14	1
	Sig.	0.01*	<0.01*	0.03*	

LPL, left pelvic limb; LTL, left thoracic limb; RPL, right pelvic limb; RTL, right thoracic limb.

\* indicates a significant correlation.

weight-bearing mean value below 18% in one limb may correspond to a value above 18% in the contralateral limb in the animals exhibiting side-to-side compensation. Also, since these animals are active Police working dogs, it is possible that complaints and signs are detected in an earlier stage of the disease (the majority of animals were classified with a mild hip grade), and therefore still not exhibit compensation mechanisms to a large extent. Similar to what is observed with clinical signs of OA and vertical ground reaction forces,<sup>8</sup> no correlation has been found between hip grade and weight-bearing, SI or deviation. Is it well established that radiographic finding do not correlate with clinical signs and, in patients with bilateral disease, one side can be more severely affected and painful than the other.<sup>43</sup> Our results are in line with this finding.

During the follow-up period, and in response to treatment, a significant decrease in weight-bearing in the thoracic limbs was observed, counteracted by an increase in the pelvic limbs, approaching the described normal 30/30/20/20 (left thoracic limb/right thoracic limb/ left pelvic limb/right pelvic limb).<sup>19,44</sup> During this stage, weight-bearing of all limbs correlated with the remaining limbs, reflecting a more even, balanced weight distribution. It may also show that, at an early stage of the disease, weight-bearing compensations may be reversible, and a return to a normal stance is possible. There may exist a tendency to see fewer improvements in male dogs concerning bodyweight distribution with pelvic limb pain relief, as they naturally tend to carry more weight on the thoracic limbs.<sup>33</sup> We have observed a different tendency, with female dogs exhibiting significantly lower pelvic limb weight distribution at this stage.

In contrast, male dogs had higher SI and deviation values. This may reflect the higher body weight of male dogs since body weight showed a significant correlation with SI. When comparing animals by breed, LR showed lower pelvic limb weight distribution and higher SI and deviation than remaining breeds. On the other hand, SI and deviation values in the thoracic limb were significantly lower in LR, reflecting breed-specific conformation. Still, it is possible that this finding is representative of disease in each individual animal rather than being related to a breed, which should be clarified in further studies, enrolling a larger population and different breeds.

This study aimed not to evaluate the effect of individual treatments but to describe weight-bearing redistribution. We looked at correlations between individual limb's weight-bearing during the follow-up period. The Pearson correlation coefficient calculates how strong the association between two variables is to calculate this value, changes or lack of changes induced by any treatment (or control) will contribute to this calculation, as considered variables will change similarly (in the cases of strong correlations). For that reason, outlining the effect of each treatment would probably add some confusion to the report. One can even argue that different treatments could reach similar correlation values, even if an individual limb's weight-bearing did or did not change considerably. Still, a significant difference was observed between control and treatments during the follow-up period.

This study presents some limitations, namely the lack of a disease-free group with non-lame dogs. Also, since the sample was comprised exclusively of police working dogs, there is a need to evaluate animals of different breeds, conformations, activity levels, and a higher number of all hip grades. These limitations are due to the convenient nature of the sample, comprised of dogs specifically presenting for treatment. While the repeatability and accuracy of the weight distribution platform have been compared to force plate gait analysis and pressure-sensitive walkways,<sup>19,45</sup> it would have been of interest to compare our findings with those evaluation tools. Also, there is a need to compare different, well-established treatments, such as non-steroidal anti-inflammatory drugs. These commonly used therapies were not included in this study, as it aimed to evaluate only intra-articular treatment modalities. The effect of the use of different treatments and volumes must also be considered, as they cause different

degrees of joint distension, which may influence outcomes and weight-bearing compensations. This effect may be diminished in this study, as we looked at the correlation between limbs. For that reason, if a lower improvement is observed in a treated limb, higher compensatory support would be provided by another limb, and vice versa. Still, future studies should ideally look at a single treatment rather than multiple treatments.

## Conclusions

This study describes weight-bearing redistribution in dogs with bilateral hip OA and in response to treatment, providing relevant information regarding patient initial evaluation and assessment of 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.

## Conflict of Interest Statement

The Pall Corporation provided the V-PET kits used in this study, and Companion, LiteCure LLC, provided the Stance Analyzer used in this study of interest to state.

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