Effect of exercise on kinetic gait analysis of dogs afflicted by osteoarthritis

R. Béraud¹; M. Moreau²; B. Lussier¹

Faculty of Veterinary Medicine, Université de Montréal, Small Animal Surgery, St. Hyacinthe, Quebec, Canada; ²Faculty of Veterinary Medicine, Université de Montréal, The Companion Animal Research Group, Department of Clinical Sciences, St. Hyacinthe, Quebec, Canada

Summary

Objective: To evaluate the effects of moderate exercise on kinetic gait analysis using a force platform in dogs with hindlimb lameness due to osteoarthritis (OA).

Methods: Ten control dogs (Control) and 10 dogs presented with chronic and stable hindlimb lameness (OA) were recruited. Dogs were subjected to force platform gait analysis to determine baseline data. They were thereafter trotted for a distance of 1.2 km on a short leash, lead by the same handler at a gait convenient for each of them (ranging from slow to fast trot), after which the gait analysis was immediately repeated to determine post-exercise values. Peak and impulse of the vertical and braking/propulsion forces were analysed using a linear model for repeated measures and Bonferroni sequential correction.

Results: In the Control group, the differences between baseline and post-exercise data were not significant. Conversely, post-exercise peak (p = 0.020) and impulse (p = 0.009) values of the vertical force, as well as the peak of the propulsion force (p = 0.009) values were significantly lower than baseline in the OA group.

Clinical relevance: This study demonstrates the significant effect of a moderate amount of exercise in exacerbating hindlimb lameness in dogs clinically afflicted by OA. It is suggested that 1) exercise should be considered as a potential factor of variation in future force platform gait analyses and an effort should be made to limit bias in data recording; and 2) an exercise-based protocol could be added to the standard force platform gait analysis to potentially increase its sensitivity in the detection of lame dogs.

Introduction

Force platform gait analysis is an objective, quantitative, non-invasive and reliable method of characterising ground reaction forces during locomotion, and has become an accepted technique for accurate evaluation of limb function in humans and animals (1–3). Over the last decade, the use of this kinetic tool has increased in veterinary medicine. For instance, it is now being used to identify pathological gaits and quantify the efficacy of various therapies. Force platform gait analysis is also being used to evaluate the effects of various pathologies on limb function and numerous medical and surgical treatments in orthopaedic diseases (such as hip dysplasia, cruciate ligament disease, and elbow dysplasia), and neurology (degenerative lumbosacral stenosis) (4–22).

It has also been used as a ’gold standard’ for validating many subjective rating systems or questionnaires (23–26).

However, the collection of kinetic data with a force platform must be carefully controlled. Indeed, several factors are known to affect ground reaction forces, such as inter-day testing, habituation of the dog to the ’runway’, use of different handlers, large changes in velocity or stance time, large acceleration or deceleration changes and varying starting distances (27–33). It is the responsibility of the investigator to maintain as much consistency as possible so as to allow for an analysis of non-biased data. Therefore, factors of variation have to be 1) identified, 2) controlled within the same study and 3) standardised in multicentric studies.

To the authors’ knowledge, the effect of exercise on force-platform data has never been evaluated in dogs. Furthermore, as physical activity could potentially modulate limb function, exercise could be another potential factor of variation, especially in dogs afflicted by osteoarthritis (OA) (6,34). The hypothesis of this study was that exercise would affect to a significant manner the vertical, braking, and propulsion forces recorded in dogs afflicted by OA.

Therefore, to test our hypothesis, we designed a prospective controlled study using force plate gait analysis to evaluate the effect of a moderate exercise programme in dogs with lameness secondary to OA and in a control group of normal dogs.

Materials and methods

Inclusion and exclusion criteria

Dogs of any breed that weighed more than 20 kg and that were older than 12 months...
were eligible for inclusion in our study. Ten dogs with hindlimb lameness (OA group), which had been chronic and stable for a minimum of six months as reported by the owners, were recruited. The lameness had to be secondary to tarsal, stifle or coxofemoral joint(s) OA as evidenced by the orthopaedic examination and radiographic evaluation (subchondral bone sclerosis, bone remodelling or osteophytes or enthesiophytes). Dogs with cranial cruciate ligament disease were admitted if they had been diagnosed more than one year previously, were without surgical correction, and also without stifle instability (drawer sign) when examined. Dogs had to meet the following withdrawal times: four weeks for oral non-steroidal anti-inflammatory drugs, 12 weeks for oral corticosteroids, and six weeks for oral nutraceuticals. Dog that had received injectable corticosteroids or an injectable formulation of polysulphated glycosaminoglycans were excluded. Dogs with neurological, immune-mediated or other musculoskeletal pathologies (including any forelimb pathology), and those that had undergone orthopaedic surgery or arthrocentesis within one year were also excluded.

Ten clinically normal dogs (Control group), as determined by the owner and the medical history (including orthopaedic examination, neurological examination, and radiographic evaluation of both elbows, hips and stifles) were also recruited.

**Study protocol**

The research protocol was approved by the Institutional Animal Care Committee for the Faculty of Veterinary Medicine of the Université de Montréal. An informed consent form was completed by the owner before study initiation. The gait analysis was performed to record baseline data and to allocate dogs to their respective groups. Based on previously reported data (35), the absence (Control group) or presence (OA group) of hindlimb lameness was confirmed. All dogs were thereafter trotted for a distance of 1.2 km on a short leash, lead by the same handler (R.B.) at a gate convenient for each dog (ranging from slow to fast trot). Immediately after, another gait analysis was performed to record post-exercise data.

**Force platform gait analysis**

The gait analysis was performed using a single, permanently mounted, biomechanical force platform\(^4\) levelled with the floor. The platform was interfaced with a dedicated computer using software\(^5\) specially designed for the acquisition, numerical conversion and storage of data. All the dogs were led at a trot by the same person with a short leash without traction. A valid trial was determined by a single strike of the ipsilateral limbs on the force platform, at a velocity between 1.9 and 2.2 m/sec and an acceleration of ± 0.5 m/s\(^2\), as measured by three photoelectric cells\(^6\). Gait analysis recorded the peak vertical force (PVF) and the vertical impulse (VI), as well as the braking and propulsion peaks (respectively BP and PP), and the braking and propulsion impulses (respectively BI and PI). For the studied hindlimb (right or left), data of the first five valid trials were recorded and then normalised relative to the dog’s body weight (% BW) for statistical analysis. When bilateral hindlimb lameness was present, the more severely affected limb was selected for evaluation based on the PVF. In the Control group, one hindlimb was randomly selected for analysis.

**Statistical analysis**

Statistical analysis was performed with commercially-available software\(^6\). A linear model for repeated measures with group (Control versus OA) as a between-subject factor and exercise status (baseline versus post-exercise) as a within-subject factor

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\( ^4 \) Model OR6–6: Advanced Mechanical Technology Inc, Watertown, MA, USA  
\( ^5 \) Verforce: Sharon Software, Dewitt, MI, USA  
\( ^6 \) MEK92-PAD: Sircon Controls, Mississauga, ON, Canada  
\( ^7 \) SAS\(^\text{®} \) system version 9.1: SAS, Cary, N.C., USA
was used for each dependent variable. The Bonferroni sequential correction procedure (Holm’s method) was applied to the contrasts used in each model. Specifically, a comparison was made between the groups at each time period, and between the two time periods in each group. For each dog, data from the five valid trials (pre- and post-exercise) were pooled for subsequent analysis. The family-wise alpha level was set at 0.05. Data are reported as mean ± standard deviation.

Results

The Control group was composed of 10 dogs of various breeds, 2.0 ± 1.5 years of age, and with a mean weight of 31.2 ± 8.0 kg. The OA group was composed of 10 dogs of various breed. Three were excluded because they were neither able to comfortably perform the exercise, nor able to perform five valid force platform trials (even with incomplete exercise). The remaining seven dogs were 5.0 ± 3.0 years of age and weighed 36.0 ± 11.0 kg, which was not significantly different from the Control group (unequal variance t-test, respectively p = 0.09 and p = 0.61). Four dogs had right hindlimb lameness and three had left hindlimb lameness secondary to the OA of the hip, stifle, or tarsus (Table 1) (1, 6).

At baseline, the two groups were significantly different regarding PVF (p = 0.003), VI (p = 0.002) and PP (p = 0.010). However, there was not any difference between braking components and PI.

In the Control group, the mean velocity of the dogs was 1.99 m/s pre-exercise and 2 m/s post-exercise; mean acceleration was 0 m/s² pre-exercise and 0.03 m/s² post-exercise. The effect of exercise on vertical (p >0.2), braking (p >0.03) and propulsion (p >0.1) components was not significant (Fig. 1 and 2, Table 2). An average of 10.6 trials pre-exercise and 9.7 trials post-exercise were necessary to obtain five valid trials.

In the OA group, the mean velocity of the dogs was 1.99 m/s pre- and post-exercise; mean acceleration of dogs was -0.13 m/s² pre-exercise and -0.08 m/s² post-exercise. Within and between groups, comparison did not reveal any significant difference for velocity (p =0.17) or acceleration (p=0.06). Following exercise, dogs in the OA group had lower PVF (63 ± 5.3 % BW vs. 65.3 ± 4.5 % BW, p = 0.020), VI (8.7 ± 0.7 % BW x sec vs. 9.1 ± 0.8 % BW x sec, p = 0.009) and PP (3.6 ± 1.1 % BW vs. 4.3 ± 1.4 % BW, p = 0.020) than at baseline, while BP was higher (3.6 ± 0.9 % BW vs. 2.6 ± 1.1% BW, p = 0.003) (Fig. 1 and 2, Table 2). Braking and propulsion impulses were not affected by exercise (Fig. 1 and 2, Table 2). An average of 9.7 trials pre-exercise and 8.3 trials post-exercise were necessary to obtain five valid trials. Within and between groups comparison did not reveal any significant difference (p =0.31).

Discussion

The results demonstrate that exercise may cause a significant deterioration of limb function in dogs showing hindlimb lameness secondary to OA. In Control dogs, vertical forces recorded at baseline were comparable to those previously reported, thus validating their use in the present study (35–37). Although the baseline PVF and VI values recorded in OA dogs were slightly higher than those reported previously, they were significantly lower than the Control group, confirming a significant lameness (6, 35, 37). Baseline PP, but not PI or braking components in the OA group were sig-
significantly lower than the Control group. As most dogs in this study were affected by hip OA, this corroborates with previous reports stating that propulsion forces tend to be more affected than braking forces in dogs with coxarthrosis (11, 13, 14, 35). The decrease in PP in the OA group after exercise could be used as a 'signature' of hip function worsening, as reported by Madore et al., and is probably correlated to an exacerbation of the hip kinematic alterations previously described in dysplastic dogs (e.g. greater dynamic coxofemoral joint angular acceleration in the middle through the end of the stance phase) (35, 38). The increase in braking peak after exercise could also be explained by an exacerbation of the hip kinematic alterations, e.g. greater dynamic coxofemoral joint angular deceleration from the end of the stance phase to the early swing phase, and from the middle to the end of the swing phase (38). Evans et al. previously stated that the vertical average falling slope (combined with PVF) was optimal for discriminating sound and lame Labradors (25). However, dogs were walked over the force platform rather than trotted. Although no conclusion can therefore be drawn about the value of these data in kinetic evaluation of lameness in trotting dogs, we did not observe any significant effect of exercise on vertical falling slope of dogs from either of the groups (unreported data).

We demonstrated that moderate exercise causes a significant deterioration of hindlimb function in dogs with pre-existing lameness secondary to OA. Although this effect is significant for lame dogs, it is important to ask how this observation translates to clinical practice. Comparing our results with those reported in the literature, the recorded decrease in PVF of 2.3% BW is of similar magnitude to the improvement commonly observed in clinical studies evaluating the effect of licofelone and etodolac (6, 9).

The significant effect of exercise on the limb function of lame dogs has two implications. First, we suggest that exercise be considered a factor of bias and be standardised in future studies using force platform gait analysis. It would also be necessary to avoid a large difference in the number of trials on the force plate between studied dogs. Indeed, in order to validate five trials, some dogs will need two or three times more passages than others, and would therefore receive more exercise. Although 10 to 20 passages in the force plate corridor will hardly attain 1.2 km, it could still potentially induce a significant worsening of the lameness. However, this assumption would have to be verified. Moreover, this precaution should be emphasised with the newly described use of treadmill-mounted force plate, with which it would be easy to over-exercise dogs before obtaining valid trials (39–41). Secondly, we suggest that an exercise-based protocol be added to standard force plate analysis. The objective would be to mimic the daily exercise levels of tested dogs, and hopefully increase the sensitivity of the force platform analysis by exacerbating gait abnormalities. This protocol could therefore be integrated in the outcome measurement of different treatments of orthopaedic and neurological canine disorders. This concept concurs with the result of a study by Voss et al. who reported that force platform gait analysis at a trot was much more sensitive than at a walk for low-grade hindlimb lameness, but not for severe lameness (37, 42).

The exclusion of three dogs from our study because of an inability to complete the exercise stresses the fact that an exercise-based protocol would be too demanding for some dogs, especially those exhibiting severe lameness, as reported by Evans et al. (42). However, we think that this protocol could still be used in these dogs: evaluation of the outcome might thus be semi-quantitative by comparing the number of dogs able to complete the exercise, rather than quantitatively comparing ground reaction forces.

Our study sustained some limitations. The small number of dogs in our study decreased our statistical power and may have hindered the detection of an actual impact of exercise in normal dogs. We calculated a posteriori that, to show a significant difference, 80% of the time (with a family-wise p value of 0.05) between pre- and post-exercise PVF and VI respectively, 200 dogs would be needed for PVF and 35 dogs for VI. The exclusion of three dogs in the OA group might have created a bias in our analysis. As these dogs were not able to complete five valid post-exercise trials because of a significant exacerbation of their lameness, their exclusion most likely skewed our results toward a less important pre-post-exercise difference than really existed. Indeed, we performed a 'virtual' statistical analysis by replacing the missing data from these three dogs by those from the 'worst-case-scenario' OA dog. Results were similar to those mentioned although the difference between pre- and post-exercise data, and therefore significance, was increased (p = 0.0006 and 0.0004 for PVF and VI respectively). Therefore we felt that it was more appropriate to proceed that way instead of adding three additional dogs, which could also be seen as a potential bias. Ideally, a group of dogs with OA, but not exercised and passed twice on the force platform, would be to mimic the daily exercise levels of tested dogs, and hopefully increase the sensitivity of the force platform analysis by exacerbating gait abnormalities. This protocol could therefore be integrated in the outcome measurement of different treatments of orthopaedic and neurological canine disorders. This concept concurs with the result of a study by Voss et al. who reported that force platform gait analysis at a trot was much more sensitive than at a walk for low-grade hindlimb lameness, but not for severe lameness (37, 42).

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Table 2 Effect of exercise on the peak and impulse of the braking and propulsion forces in sound (Control) and lame (OA) dogs.

<table>
<thead>
<tr>
<th></th>
<th>Control group</th>
<th>OA group</th>
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<tbody>
<tr>
<td></td>
<td>Baseline</td>
<td>Post-exercise</td>
</tr>
<tr>
<td>Braking peak (% body weight)</td>
<td>2.1 ± 1</td>
<td>2.7 ± 1.3</td>
</tr>
<tr>
<td>Braking impulse (% body weight x sec)</td>
<td>0.1 ± 0.1</td>
<td>0.1 ± 0.1</td>
</tr>
<tr>
<td>Propulsion peak (% body weight)</td>
<td>5.8 ± 0.8</td>
<td>5.5 ± 1.2</td>
</tr>
<tr>
<td>Propulsion impulse (% body weight x sec)</td>
<td>0.5 ± 0.1</td>
<td>0.5 ± 0.1</td>
</tr>
</tbody>
</table>

Data are reported as mean ± SD.
* Significant difference from baseline (within group comparison)
plate would be needed to evaluate intra-day variability and allow for a stronger conclusion. However, from a practical point of view, this raises a major problem: passing these dogs for the pre-exercise trials on the force plate would exercise them and thus negate the value of the subsequent post-exercise trials and thus the value of that group as a purely negative control. The Bonferroni sequential method was used; however, it is less conservative than the original Bonferroni method, and there is an increased type I error rate. In order to standardise our population, we only included dogs with hindlimb lameness due to OA. However, OA varied in location and degree between dogs, and could have lead to different gait alterations as reported by Madore et al. in a study comparing dogs with hip or stifle OA (33). Ideally, subgroups would have been made according to these factors; however, doing so with our low number of dogs would have dramatically lowered our statistical power. Moreover, it is well recognised that the degree of OA does not correlate with limb function, as reported by Gordon for stifle OA (34). Every dog underwent the same trotting distance, but the total effort varied as each dog determined its own gait. Ideally, dogs would have been trotted on a treadmill at one set speed for a set distance. However, we were concerned that it would possibly make some dogs uncomfortable and unable to complete the exercise. Finally, we focused on a kinetic evaluation of limb function without addressing the extent, speed, and direction of joint movements.

In this study, we have demonstrated the significant effect of moderate exercise (1.2 km trot) in exacerbating pre-existing hindlimb lameness secondary to OA in dogs. Therefore, exercise should be considered as a potential bias in study recording force platform data. An exercise-based protocol coupled to gait analysis appears interesting because it may increase sensitivity in the detection of lameness.

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