Orthomanual veterinary medicine as approach in treating lower back pain in dogs: a pilot study

Assessment of orthomanual treatment in dogs with degenerative lumbosacral stenosis using pressure plate analysis, video analysis and owner questionnaires.

Student: M. Geerts
Student number: 3779734

Daily Supervisor: D.C. Aharon
Practice for Orthomanual Veterinary Medicine
Geberastraat 2, 2431 XN Noorden, The Netherlands

Supervisor UU: P.J.J. Mandigers
Department of Clinical Sciences of Companion Animals
Faculty of Veterinary Medicine, Utrecht University

Statistician: J.C.M. Vernooij
Department of Farm Animal Health
Faculty of Veterinary Medicine, Utrecht University

CONTENS **PAGE**

1. ABSTRACT

Degenerative lumbosacral stenosis (DLSS) is a common cause of lower back problems in dogs. It is seen most often in older dogs of large breeds and giant breeds with a variety of clinical signs including unwillingness to jump, unilateral or bilateral pelvic limb lameness and expression of pain in the lumbosacral spine region. Currently several therapy strategies are developed for DLSS with various results. Depending on the condition of the patient the therapy can consist of non-steroidal anti-inflammatory drugs and a restricted exercise regime, surgery, or a combination of these therapies. During the last two decades orthomanual treatment has been added to this list of therapies, but until now there is no evidence based study performed to evaluate its effect.
The aim of this study was to investigate the effect of orthomanual treatment in dogs suffering from lower back problems using pressure plate analysis (PPA), video analysis and owner questionnaires. The study included twenty-four privately owned dogs randomly divided into two groups; one group was treated orthomanually and the other group was treated conservatively. All dogs were evaluated before and two weeks after treatment.
With the pressure plate the peak force (PF), vertical impulse (VI) and stance duration (SD) were determined and the Left/Right (L/R) and Thoracic/Pelvic (T/P) ratios were calculated. Pressure plate analysis (PPA) showed that both treatments made dogs with DLSS stand longer on their hind limbs whereas conservative treatment also made the dogs bear more their hind limbs. However, none of these differences within and between the two treatment group were statistically significant. Video analysis showed that both treatments did not have an effect on the gait of the majority of the dogs, however, most dogs whose gait ameliorated were treated conservatively. Based on the questionnaires both treatments decreased the pain experience and clinical symptoms and increased the activity level of the dogs. Furthermore, most owners were satisfied with the outcome after orthomanual respectively conservative treatment.
PPA and the questionnaire showed a trend in favour of both treatments, whereas video analysis showed a trend in favour of the conservative treatment.

2. INTRODUCTION

Lower back pain is a frequently observed problem in dogs. Many diseases may contribute to the development of lower back pain. Degenerative lumbosacral stenosis (DLSS) is the most common disease of the canine lumbosacrum seen mainly in large till giant breed dogs with a predisposition for the German Shepherd dog and working dogs (1-3). The average age at clinical presentation is 7 years. It appears to be more commonly seen in males compared to females (4-6).

2.1 Anatomy

During embryonic development, the spinal cord and vertebral column develop at a different rate, leading in the newborn animal to the vertebral column being longer than the spinal cord. The conus medullaris (end point of the spinal cord) is located between the caudal half of L6 and the cranial part of L7. In small breed dogs the conus medullaris ends further caudally.
The cauda equina originates from the conus medullaris and is formed by the spinal nerves L6, L7, S1-S3, Cd1-Cd5 and stretches from vertebrae L6 to Cd5. The peripheral nerves that originate from the cauda equina roots, have well-defined functions (Table 1) (1,4).

The canine lumbosacrum consists of the intervertebral disc (IVD) and two paired synovial facet joints. The IVD consists of a gel-like nucleus pulposus (consisting of water molecules bound by proteoglycans) surrounded by the annulus fibrosus (consisting of fibrous concentric rings). The disc functions as a shock absorber and pressure distributioner and, together with a complex network of supporting tissues (including ventral and dorsal longitudinal ligaments, the interspinous ligament, the interarcuate ligament (ligamentum flavum) and the surrounding muscles), creates stability and flexibility between two vertebrae (4,7).

Table 1. The peripheral nerves originating from the cauda equina with their normal function and findings in dogs with DLSS (1,4).

Nerve	Segment	Reflex	Sensory function	Motor function	Neurologic findings in DLSS
N. femoralis (Femoral nerve)	L4-L6	Patellar	Medial surface of pelvic limb	Flexion hip Extension stifle	Normal or pseudohyperreflexia
N. Ischiadicus (Sciatic nerve)	L6-S1	Cranial tibial Gastrocnemius Withdrawal	Lateral surface of pelvic limb	Extension hip Flexion stifle Flexion and extension tarsus Proprioception	Muscle atrophy Normal or decreased reflexes Normal or decreased conscious proprioception
N. pelvicus and sacralis (Pelvic and sacral nerves)	S1-S3		Pelvic canal	Urinary bladder	None or urinary incontinence
N. Pudendus (Pudendal nerve)	S1-S3	Perineal Anal	Perineum, anus, genitals	Anal and urinary bladder sphincters	None or decreased perineal reflex None or urinary or fecal incontinence
N. caudales (Tail nerves)	Cd1-Cd5		Tail	Tail tone	Normal or hypotonia

2.2 Pathophysiology

DLSS is a multifactorial degenerative disorder resulting in stenosis of the spinal canal and compression of the cauda equina or its blood supply. Several pathologies may contribute to DLSS such as: lumbosacral instability (ventral subluxation of S1), congenital vertebral anomalies (transitional or extra vertebrae), Hansen type II (or less commonly Hansen type I) IVD herniation, sacral osteochondrosis, proliferation of the soft tissues surrounding the cauda equina, vascular compromise of the blood supply to the spinal nerves and repetitive stress.

These pathologies, as described above, may cause an abnormal motion pattern of the lumbosacral junction. This abnormal motion pattern predisposes for degeneration of the IVD between L7 and S1. The IVD degeneration is initiated by degeneration of the proteoglycans. As the proteoglycans of the nucleus pulposus degenerate, the IVD has more difficulties absorbing water and nutrients and therefore dehydrates and starts to shrink. The increasing instability in the lumbosacral junction may lead to a ventral subluxation of the sacrum and eventually to herniation of the disc (usually a Hansen type II disc herniation (protrusion)). To compensate for the increasing instability, the cartilaginous end plates thicken and bony and soft tissue proliferations develop. This triggers a negative spiral that eventually results in stenosis of the spinal cord and compression of the cauda equina, resulting in lameness and neurological dysfunction. Furthermore, in response to a cell-mediated inflammatory process blood vessels and nerves grow into the damaged disc, which contributes to the lumbosacral pain (1,4-6).

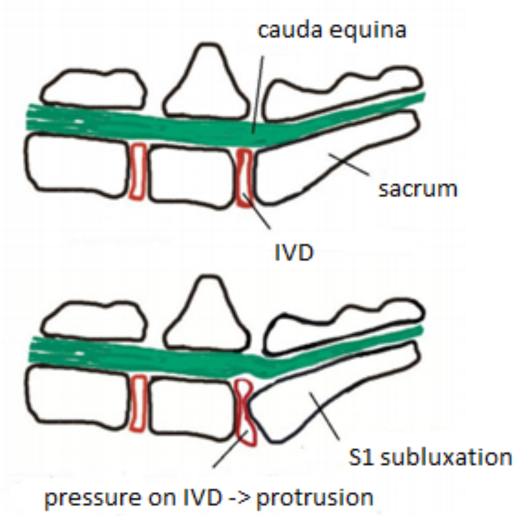


Figure 1. Pathophysiology of DLSS: Abnormal motion pattern of the lumbosacral junction → IVD degeneration → vertebral instability → ventral subluxation of L7 or S1 → pressure on the IVD → protrusion/extrusion → proliferation of bony and soft tissues → compression of the cauda equina → pain and neurological dysfunction
Picture: Dr. J. Heukels (DVM)

2.2.1 Lumbosacral transitional vertebrae

Lumbosacral transitional vertebrae (LTV), which have been reported to be inherited in German Shepherd dogs, are vertebral anomalies characterised by an unilateral or bilateral adhesion of L7 to the sacrum or a separation of the first and second sacral segments. This malformation causes an abnormal position of the spinal canal in relation to the pelvis. This abnormal position may lead to an abnormal or decreased range of motion of the lumbosacral junction. Furthermore, it is supposed that this malformation causes more pressure on the IVD which could eventually lead to degeneration of the disc (8-12).

2.3 Clinical signs

DLSS in dogs has a variety of clinical signs which may be acute to chronic and continuous to intermittent (13) and may be of orthopedic or neurological character (more often of orthopedic character). The clinical signs may include: lumbosacral pain/lower back pain, difficulties with rising up, sitting or lying down, unwillingness to jump or climb stairs, self-mutilation or hyperesthesia of the lumbosacral area or pelvic limbs, low tail carriage, muscle atrophy and/or unilateral or bilateral pelvic limb lameness. The unilateral pelvic limb lameness could be shown as the so-called nerve root signature (Figure 2), which is caused by unilateral entrapment of the L7 and/or S1 nerves with radiating nerve root pain. Severely affected dogs may show paresis posterior or urinary and/or fecal incontinence (1,4,14).

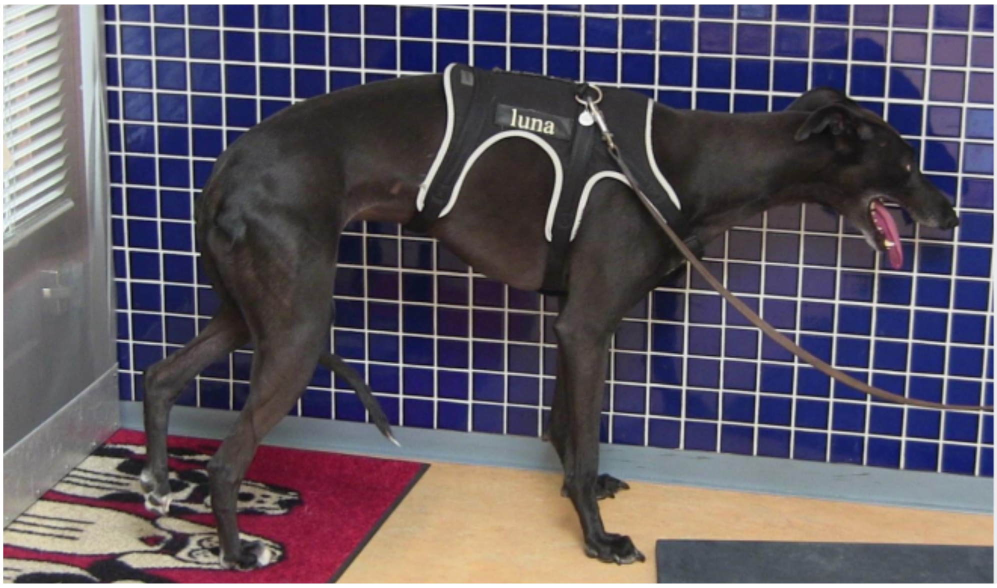


Figure 2. A dog with DLSS showing the so/called nerve root signature due to left nerve root entrapment at L7/S1. Picture: Practice for Orthomanual Veterinary Medicine.

2.4 Diagnosis

The preliminary diagnosis of DLSS in dogs is based on the history and clinical signs, combined with the findings during an orthopaedic or neurological examination. Diagnosis is confirmed with either radiography, CT or MRI.

2.4.1 Orthopaedic and neurological examination

Dogs with DLSS may react painful to palpation of the lumbosacral area, hyperextension of the tail and/or the lordosis test (hyperextension of the caudal lumbar spine with lumbosacral pressure). Furthermore, pelvic limb lameness can be evoked or worsened by hyperextension of the affected limb together with lumbosacral pressure.

Neurological examination usually reveals a lower motor neuron problem including hyporeflexia of the cranial tibial or withdrawal reflex, decreased postural reactions, decreased proprioception, hyporeflexia of the perineal reflex, hypotonia of the tail tone or pseudo-hyperreflexia of the patellar reflex (“patellar override”)(Table 1). The patellar override develops as the muscle tone of the stifle extensors (innervated by the femoral nerve; not affected by DLSS) overrides the muscle tone of the stifle flexors (innervated by the sciatic nerve; affected by DLSS) (4,15).

2.4.2 Radiography

Abnormalities shown on an X-ray as a result of DLSS include collapse of the IVD space, lumbosacral step formation due to ventral subluxation of S1, sclerosis of the vertebral end plates, sacral osteochondrosis, spondylosis deformans, (lumbosacral) transitional vertebrae and the so-called “vacuum” phenomenon (4,15-17). This phenomenon is a radiolucent area seen in the IVD space, caused by an accumulation of nitrogen in a degenerated disc. This nitrogen originates from surrounding tissues (18).
In case no abnormalities are found, DLSS cannot be excluded. Furthermore, survey radiography cannot be used to predict development of DLSS (15).

2.4.3 Computed tomography

The findings on a computed tomography (CT) include the abnormalities which can be found by radiography, but in addition CT shows Hansen type II disc herniation, hypertrophy of the joint capsules, hypertrophy of the interarcuate ligament, narrowing of the lateral recessus and narrowing of the foramen vertebrales (17,19-21).

2.4.4 Magnetic resonance imaging

Magnetic resonance imaging (MRI) gives a more detailed view of the IVD and the displacement of epidural fat and nervous tissue, making an earlier detection of IVD degeneration and compression of the nerve at the level of the foramen vertebralis possible (22).
On T1-weighted images, epidural fat gives a very bright signal, whereas a healthy IVD is slightly brighter than the bone marrow, spinal cord and nerve roots. DLSS can be shown by an interruption of the epidural fat due to protrusion or extrusion of the IVD.
On T2-weighted images healthy IVDs give a very bright signal. In dogs with DLSS the IVD gives a weak signal due to degeneration of the disc (4,17,20,23,24).

2.5 Treatment

DLSS can be treated in different ways depending on the condition of the patient.

2.5.1 Conservative treatment

Conservative treatment of DLSS is indicated in dogs with mild to moderate lumbosacral pain and no neurologic deficits. The treatment consists of the use of nonsteroidal anti-inflammatory drugs (NSAID’s), a restricted exercise regime and, if necessary, body weight reduction (4,25).
The systemic use of corticosteroids is considered controversial as their analgesic effect can be achieved by NSAID’s as well, but with fewer side effects. The restricted exercise regime should include regular short leash walks to maintain muscle mass (4).
In case the dogs experience neurogenic pain, the treatment can be supplemented by tramadol or gabapentine (25).
A local epidural infiltration treatment with methylprednisolone is described recently showing to achieve clinical results comparable to those of decompressive surgery (26).

2.5.2 Surgical treatment

Surgical treatment of DLSS is indicated in dogs with moderate to severe lumbosacral pain and/or neurologic deficits and in dogs that do not respond (enough) to conservative treatment. The aim of the surgical treatment is to decompress the cauda equina, free the entrapped nerve and/or to stabilize the lumbosacral junction (4,27).

2.5.2.1 Dorsal laminectomy

Dorsal laminectomy is the primary surgical procedure for DLSS in dogs, which can be extended with partial discectomy, foraminotomy or facetectomy when further decompression is required. The dorsal laminectomy is performed by removing the caudal two-third of the L7 laminar bone but the slot may be extended up to L6 when necessary. The L7 and S1 nerve roots in the lateral recesses are freed by removing bone as far lateral as possible. Furthermore, new bone formation is prevented by harvesting a free subcutaneous fat graft (3,4,14,26,28,29).
Partial discectomy is performed when the IVD is herniated or prolapsed. This procedure starts with an annulectomy and is continued by a nucleotomy after which the degenerated disc material is removed. Foraminotomy is indicated when decompression is required at the level of the foramen vertebrales of L7 (13). Facetectomy should be avoided whenever possible because this procedure increases lumbosacral instability.
In case nerve root compression is the core problem and no spinal canal stenosis is present, surgical treatment consisting of foraminotomy alone is enough (4).

2.5.2.2 Fixation

Stabilization by fixation and fusion is indicated when ventral subluxation of S1 is present, or to prevent further development of lumbosacral instability. This technique may be combined with dorsal laminectomy at the level of S1. The stabilization is achieved by pins or pedicle screws and rods, which are driven in a cross-directive fashion through the base of the L7-spinous process, across the L7-S1 facet joints into the ilial wings. This stabilization in combination with an autologous bone graft reduces the range of motion of the degenerated lumbosacral junction and thus, reduces pain originating from excessive or abnormal motion (30-32).

2.6 Prognosis

The prognosis of DLSS in dogs depends on the age of the dog, the use of the dog and the degree of neurological deficit. The prognosis gets more unfavourable in case the dog gets older, needs to do heavy work or has severe neurological deficits (3,28,29).
Different studies have been performed to evaluate the effect of treatment in dogs with DLSS. The study of De Decker et al. showed an overall success rate of 55% after the dogs had been treated conservatively (25). In the study of Janssens et al. thirty-eight dogs were treated with epidural infiltration of methylprednisolone; 79% of the dogs were considered to have improved and 53% were totally cured (26). Multiple studies evaluated the effect of dorsal laminectomy in dogs with DLSS showing a success rate varying from 76-93% (3,13,14,20,28,33). Furthermore, it is found that dogs with urinary or fecal incontinence have a worse prognosis than dogs that are continent before surgery (29).

2.7 Orthomanual veterinary medicine

Orthomanual veterinary medicine (OVM) is an uninvasive treatment based on the symmetry of the spine and skeleton. This treatment is based on the central idea that misalignment of skeletal components can cause a loss of function, movement limitations and pain. Correction of these misalignments decreases the pressure on the IVD and spinal cord and in this way creates an environment that facilitates an improvement in the neurological state.

OVM is indicated in dogs with orthopaedic disorders; acute or chronic lameness, neurological disorders; hernia or hernia-like symptoms, lameness of the forelimbs or pelvic limbs, pain in the neck, (lower) back pain and/or DLSS and behavioural disorders; pain-related agitation, anxiety and/or aggression.

2.7.1 Orthomanual examination and manipulation

Orthomanual examination is performed with the dog standing "in a square". The owner holds the head and an assistant supports the dog with two hands underneath the belly. The vertebral column is palpated from the tail to the neck by placing both thumbs on the transversal processes (Figures 3 and 4). By means of inspection and palpation attention is paid to symmetry, muscle tone, muscle atrophy and position of the vertebrae.

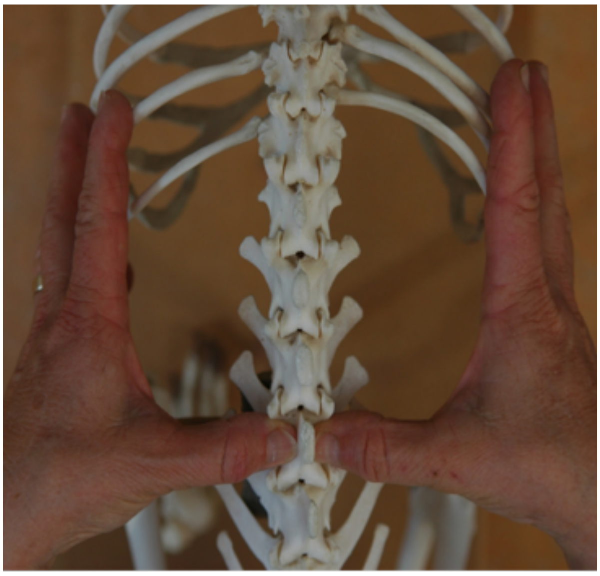


Figure 3. Orthomanual examination. Here we look at the position and symmetry of the transversal processes of L5 on a skeleton. Picture : Practice for Orthomanual Veterinary Medicine.

Figure 4. Orthomanual examination. Here we look at the position and symmetry of the transversal processes at the thoracolumbal junction of a dog. Picture: Practice for Orthomanual Veterinary Medicine.

Orthomanual manipulation can be described as a direct force, used on an osseous structure of the spine with a malposition or malfunction, using a short lever within a segment in the direction of the natural position or function (Figure 5). The force applied is pulsating or with a fast impulse (34).

Figure 5. Orthomanual examination and manipulation. (a) The transversal processes of the vertebrae at the thoracolumbal junction are not at the same level; the right side is at a lower level. (b) Correction of the misalignment (c and d) Palpation again to see if the correction was successful and if both processes are on the same level.
Picture: Practice for Orthomanual Veterinary Medicine.

2.7.2 Orthomanual veterinary medicine and DLSS

Orthomanual veterinary medicine (OVM) is used to diagnose and treat DLSS in dogs.
Orthomanual inspection of dogs with DLSS can reveal that the pubic bones are not on the same level or that the level of the talocrural joints is deviated. During orthomanual palpation misalignment between L7-S1 or S1-S2, or a cranioventral position of the sacrum can be found.
The way orthomanual manipulation is performed depends on which vertebrae have an abnormal position and the position of the misaligned vertebrae. In case the L7 has an abnormal position, the correction is performed by a direct force on that part of the skeleton that has an abnormal position followed by a light impulse on the processus spinosus. In case the sacrum has an abnormal position, the orthomanipulation is performed by unhooking the sacrum.

The orthomanual manipulation is followed by a restricted exercise regime consisting of the following points; (1) the dog is not allowed to jump, climb or play, (2) before the dogs starts walking the muscles of the front limbs, hind limbs and neck should be massaged by rubbing your hands over the skin until your hands feel warm, (3) the amount of exercise must be build up gradually: the first week 4 times a day 20 minutes (on a leash), the second week 4 times a day 25 minutes (on a leash), the third week 4 times a day 30 minutes (on a leash) and the fourth week 4 times a day 35 minutes (on a leash) and (4) in order to make the dog stronger in the hind limbs and back the dogs must walk on small bridges and hills.

The orthomanual treatment aims to interrupt the vicious circle, as described in section 2.2 and figure 2, at different points. By correcting the lumbosacral instability a normal motion pattern is created. These changes decrease the pressure on the IVD and together with the restricted exercise regime give the dog the opportunity to recover.
Based on the observations of Dr. D.C. Aharon (DVM, oral report) orthomanual veterinary medicine has successfully been used for years as a treatment for DLSS in dogs. However, so far it has not been supported by comparative scientific studies.

2.8 Aim of the study

The aim of this study was to investigate the effect of orthomanual treatment in dogs suffering from lower back problems. The hypothesis of this study was that orthomanual treatment may ameliorate lower back problems seen in dogs.

3. MATERIALS AND METHODS

3.1 Experimental design

Dogs with DLSS were referred to the Practice for Orthomanual Veterinary Medicine (Noorden, The Netherlands). Each dog underwent a thorough orthopaedic, neurological and orthomanual examination, performed by Dorit Aharon (DVM), to see if they met the inclusion criteria. The dogs then were divided *ad random* into two treatment groups, one group received orthomanual treatment and the other group received conservative treatment consisting of Firocoxib[1]. Both treatments were followed by a restricted exercise regime.

The restricted exercise regime consisted of the following points:
- The dog was not allowed to jump, climb or play. Swimming was allowed.
- Before the dog starts walking, the muscles of the front legs, hind legs and neck should be massaged by rubbing your hands over the skin until your hands feel warm.
- The amount of exercise was build up gradually following the scheme below:
    - First week: 4 times a day 20 minutes (on a leash)
    - Second week: 4 times a day 25 minutes (on a leash)
- In order to make the dog stronger in his/her hind legs and back we recommended to walk on small bridges and hills starting with a small slope and gradually build it up to more slope.

Before and two weeks after the allocated treatment the dogs were filmed and walked on a pressure plate to evaluate their gait. Furthermore, the owners were asked to fill in a questionnaire.

Before admission, the owners were fully informed about the purpose of this study, the actions to follow and the consequences associated with this study (addendum 1). The owners signed an informed consent (see addendum 2) giving permission to use of the data for analysis.

3.2 Animals

Dogs participating in this study were divided into the following weight categories: 10 - <15, 15 - <20, 20 - <25, 25 - <30, 30 - <35, 35 - <40.

3.2.1. Inclusion and exclusion criteria

Inclusion criteria
The dogs were selected on the basis of the following criteria:
- Clinical symptoms typical for DLSS
- Weight between 10 to 40 kilogram
- Pain during palpation of the lumbosacral region
- Incongruent lumbosacral vertebrae diagnosed by orthomanual palpation
- Not previous treated for DLSS or a conservative treatment without (enough) success.

Exclusion criteria
Dogs were excluded from the trial if they meet one of the following criteria:
- Concurrent orthopaedic, neurologic or systemic disorders that might influence the outcome of lower back problems
- If they were pregnant (as Previcox® is contra-indicated for pregnant bitches)
- If they were younger than 10 weeks (as Previcox® is contra-indicated)

[1]*Firocoxib, a non-steroidal anti-inflammatory compound that acts as a COX-2 inhibitor, was administered by Previcox® chewing tablets. The dosage of Previcox ® to be used is 5 mg/kg. We only used the Previcox® 227 mg tablets.*

- Suffering from gastrointestinal bleeding or haemorrhagic disorders (as Previcox® is contra-indicated)

3.3 Pressure Plate and Pawlabeling

Before and two weeks after treatment the dogs were walked on a pressure plate (PP). A PP is a tool that can be used to assess locomotion, using both kinematic and temporospatial variables. It has been used to quantify normal locomotion, to detect lameness and to evaluate the effect of treatment in horses, cattle, pigs, cats and dogs (35-42).

A Footscan® 3D Scientific 2 m system (Rsscan International) with an active sensor surface of 1.95 m x 0.32 m containing 16384 sensors with a sensitivity of 0.27-127 N/cm^2 and a measuring frequency of 126 Hz was used. The PP was connected to a laptop with dedicated software (Footscan Scientific Gait 7 gait 2nd generation, Rsscan International). Two mats, each with a length of 1.0 m x 0.5 m, were positioned before and after the PP, creating a long walkway with sufficient space to allow for acceleration and deceleration. Before the measurements started, the PP was calibrated according to manufacturer instructions. Measurements lasted up to a maximum of 2 seconds, after which the PP stopped recording automatically.

By their owner the dogs were guided over the PP in a straight line. The dogs walked at their preference speed on both the right and the left side of their owner. During every session ten to fifteen useful measurements were collected. Each measurement included a series of paws.

Faulty measurements (f.i. the dog stands still on the PP, registration by the PP stopped before the dog reached the end of the plate, the dog jumps on the PP, the dog runs of the PP and the dog keeps looking at one side) were excluded from analysis. The remaining valid measurements were processed & analysed using Pawlabeling. Each paw print was manually assigned to their corresponding label: left front limb (LF), right front limb (RF), left hind limb (LH) and right hind limb(RH). For each paw print within a run, validity was checked. Contacts were considered valid when they were fully on the plate and were completely within the 2-second-measurement timeframe.

For each limb the peak force (PF), vertical impulse (VI) and stance duration (SD) were calculated. The PF is the vertical force with which the dog puts down his limb on the PP. The VI is the area under the time-force graph and the SD is the contact time. Furthermore, the Left/Right (L/R) and Thorax/Pelvic (T/P) ratios of the PF, VI and SD were calculated:

L/R-ratio = (front left + hind left)/(front right + hind right)

T/P-ratio = (front left + front right)/(hind left + hind right)

3.4 Video material

Before and two weeks after treatment the dogs were filmed outside guided by their owners. The dogs were filmed from the front and rear side both during walking and trotting. Furthermore, the dogs were filmed from the side at their preference speed. Their gait was evaluated/scored visually with a categorical scale; improved, deteriorated or remained the same. All videos were evaluated, blinded, by Dr. P.J.J. Mandigers.

3.5 Questionnaire

Before and two weeks after treatment the owners were asked to fill in a questionnaire (see addendum 3). The purpose was to assess behavioural changes of the dog and the owners perception of the dogs doing prior to admission and after two weeks of treatment.

3.6 Statistics

The data used for the statistical analysis of the PPA are the mean values of each individual paw.
The Paired t-test was used to asses statistical differences in gait analysis scores within the same treatment group. Statistical differences in gait analysis scores between the two treatment groups was assessed by the Independent t-test. The L/R-ratio of the vertical impulse within the conservative treatment group was LOG-transformed as this data was not distributed normally, but had a distribution skewed to the right. The T/P-ratio of the vertical impulse within the conservative treatment group was square transformed for analysis as this data was not distributed normally, but had a distribution skewed to the left. P values <0.05 were considered significant.
Statistical analysis of the pain score was assessed by the t-test.

4. RESULTS

4.1 Animals

Twenty-four privately owned dogs participated in this study; one was withdrawn directly after admission as the owner did not agree with the allocated treatment. Therefore, this dog is excluded from analysis.
Hence fourteen males (7 neutered) and nine females (7 neutered) were included. The dogs varied in age between 12 to 140 months (mean 56). Weight of the dogs varied from 13.8 to 39.4 kg (mean 25.3). Weight categories were defined 10 - <15, 15 - <20, 20 - <25, 25 - <30, 30 - <35, 35 - <40 and the weight categories consisted of respectively 1, 6, 7, 5, 0 and 5 dogs. The dogs were from 23 breeds including 3 German Shepherd dogs, a White Shepherd dog, a Australian Shepherd dog, a Nova Scotia Duck Tolling Retriever, a Border Collie, a Frisian Pointer, a German Pointer, 2 English Setters, a English Springer Spaniel, a Cocker Spaniel, a Siberian Husky, 2 Galgo Españols, a Podenco Canario, 2 Boxers, a Schnauzer, a Bernese Mountain dog, a Rhodesian Ridgeback and a crossbreed. (Table 2)

4.2 Treatment

Orthomanual treatment
Thirteen dogs, 7 males (3 neutered) and 6 females (5 neutered) with an age of 12 to 140 months (mean 69 months) and a weight varying from 13.8 to 35.3 kg (mean 23.8 kg) received an orthomanual treatment. The orthomanual treatment consisted of orthomanipulation.

Conservative treatment
Ten dogs, 7 males (4 neutered) and 3 females (2 neutered) with an age of 12 to 74 months (mean 38 months) and a weight varying from 16.6 to 39.4 kg (mean 27.2 kg) received a conservative treatment. The conservative treatment consisted of Firocoxib[1], administered by chewing tablets.

[1]Firocoxib, a non-steroidal anti-inflammatory compound that acts as a COX-2 inhibitor, was administered by Previcox® chewing tablets. The dosage of Previcox ® to be used is 5 mg/kg. We only used the Previcox® 227 mg tablets.

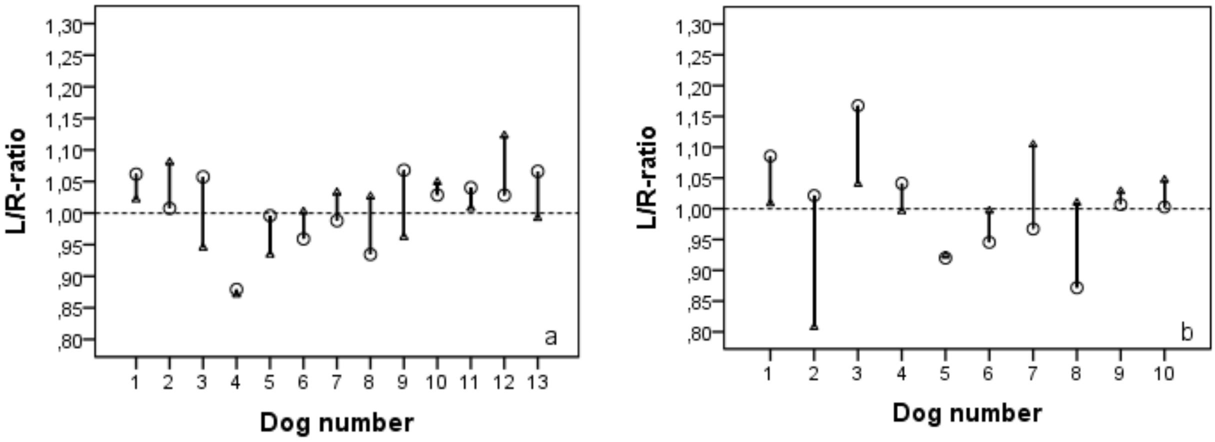
Table 2. An overview of the dogs participating in this research including breed, sex, age and weight. The red balk resembles the dog that was withdrawn for the research.
(M = male, MN = male neutered, F = female, FN = female neutered, O = orthomanual treatment, C = conservative treatment)

Dog number	Breed	Sex	Age (months)	Weight (kg)	Treatment
1	German Shepherd dog	FN	51	28.9	O
2	English Springer Spaniel	M	94	24.2	O
3	Boxer	MN	76	35.3	O
4	German Shepherd dog	M	24	29.1	C
5	German Shepherd dog	F	65	29.4	C
6	Boxer	M	63	39.4	C
7	Nova Duck Tolling Retriever	MN	27	21.7	C
8	Cocker Spaniel	M	86	13.8	O
9	Australian Shepherd dog	F	12	18.1	O
10	Border Collie	FN	17	16.7	C
11	Crossbreed	FN	140	22.2	O
12	English Setter	M	49	20.1	O
13	Galgo Español	FN	89	25.1	O
14	Podenco Canario	MN	24	21.0	C
15					
16	English Setter	M	31	21.8	O
17	White Shepherd dog	MN	74	38.3	C
18	Frisian Pointer	M	12	19.4	C
19	German Pointer	MN	24	29.5	O
20	Schnauzer	MN	128	18.4	O
21	Siberian Husky	FN	28	16.5	O
22	Galgo Español	FN	41	18.5	C
23	Bernese Mountain dog	FN	90	35.3	O
24	Rhodesian Ridgeback	MN	36	38.8	C

4.3 Pressure Plate analysis

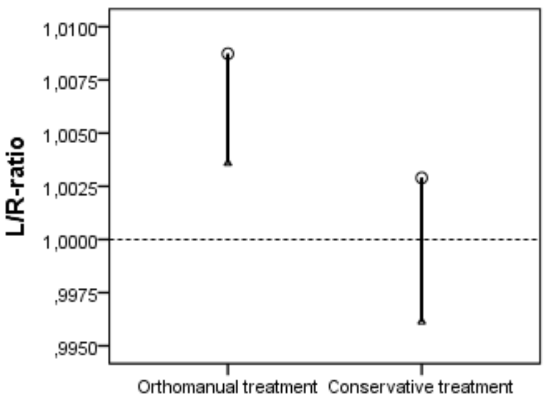
4.3.1 Peak force (PF)

4.3.1.1 L/R-ratio PF

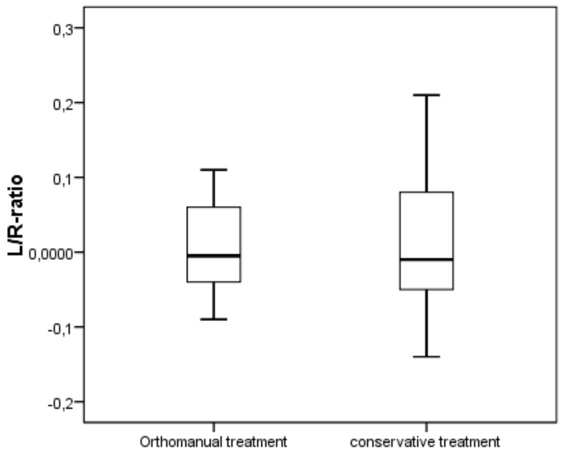


Graph 1. The L/R-ratio of the peak force before (○) and two weeks after (Δ) orthomanual treatment (a) and conservative treatment (b) for each individual dog. The change within two weeks is indicated with a vertical line. A horizontal "reference-line" is presented at the level of 1,00.

Graph 1a and b show the L/R-ratio of the peak force before and two weeks after orthomanual treatment and before and two weeks after conservative treatment of each individual dog. The ideal L/R-ratio is 1, because this indicates that the left and right limbs load an equal amount of weight.



Graph 2. The mean of the L/R-ratio of the peak force before (○) and two weeks after (Δ) orthomanual treatment and before (○) and two weeks after (Δ) conservative treatment. The change within a group is indicated with a vertical line.
A horizontal "reference-line" is presented at the level of 1,00.



Graph 3. A boxplot of the difference between the L/R-ratio of the peak force before and two weeks after orthomanual treatment resp. conservative treatment.

Graph 2 shows the mean of the L/R-ratio of the peak force before and two weeks after orthomanual resp. conservative treatment.

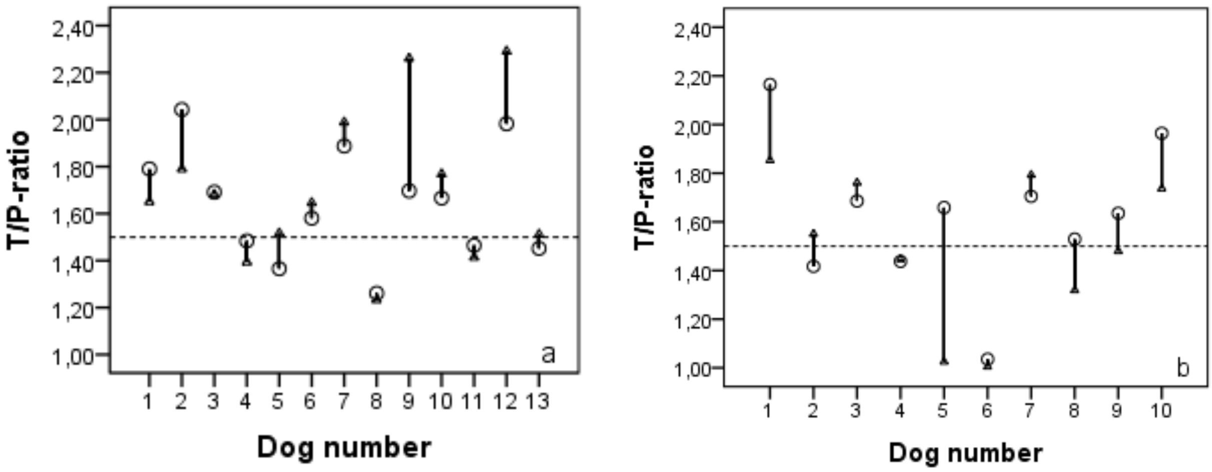
The mean of the L/R-ratio of the peak force before orthomanual treatment (1,0087) is higher than the mean of the L/R-ratio of the peak force two weeks after orthomanual treatment (1,0036). This difference between treatment means (+0,00515, 95% confidence interval (95% CI)=(-0,03842, +0,04871)) is not significant (P = 0,801).
The mean of the L/R-ratio of the peak force before conservative treatment (1,0029) is higher than the mean of the L/R-ratio of the peak force two weeks after conservative treatment (0,9961). This difference between treatment means (+0,00675, 95% CI = (-0,07311, +0,08662)) is not significant (P = 0,853).

The difference between the L/R-ratio before orthomanual and conservative treatment (0,00584, 95% CI = (-0,05557, +0,06724)) is not significant (P = 0,845).
The difference between the L/R-ratio two weeks after orthomanual and conservative treatment (0,00744, 95% CI = (-0,05582, +0,07071)) is not significant (P = 0,809). (Graph 2)

Two weeks after treatment the L/R-ratio decreased within both treatment groups; the L/R-ratio of the group that received an orthomanual treatment is closer to 1.00 and the L/R-ratio of the group that received a conservative treatment is slightly further from 1,00. However, these differences are not significant. (Graph 2)

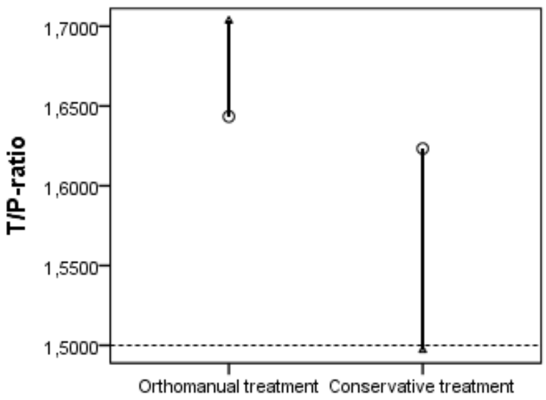
Graph 3 shows a boxplot of the difference between the L/R-ratio of the peak force before and two weeks after orthomanual resp. conservative treatment. This graph shows the effect of orthomanual resp. conservative treatment. There is no significant difference between the effect of orthomanual and conservative treatment (95% CI = (-0,00185, +0,03812), P = 0,962).

4.3.1.2 T/P-ratio PF

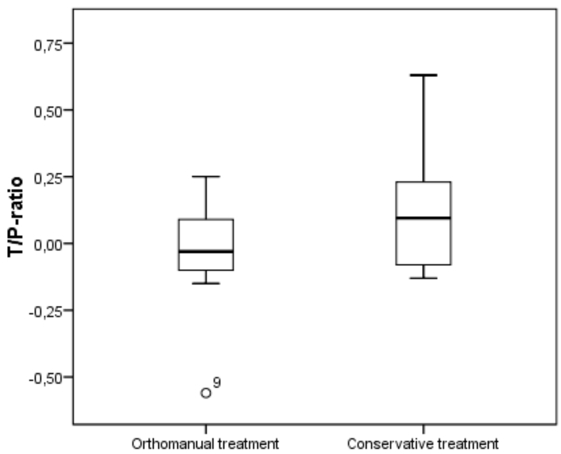


Graph 4. The T/P-ratio of the peak force before (○) and two weeks after (Δ) orthomanual treatment (a) and conservative treatment (b) for each individual dog. The change within two weeks is indicated with a vertical line. A horizontal “reference-line” is presented at the level of 1,50.

Graph 4a and b shows the T/P-ratio of the peak force before and two weeks after orthomanual treatment and before and two weeks after conservative treatment of each individual dog. The ideal T/P-ratio 1.5, because dogs normally bear around 60% of their weight on their front limbs and around 40% of their weight on their hind limbs.



Graph 5. The mean of the T/P-ratio of the peak force before (○) and two weeks after (Δ) orthomanual treatment and before (○) and two weeks after (Δ) conservative treatment. The change within a group is indicated with a vertical line.
A horizontal “reference-line” is presented at the level of 1,50.



Graph 6. A boxplot of the difference between the T/P-ratio of the peak force before and two weeks after orthomanual resp. conservative treatment.

Graph 5 shows the mean of the T/P-ratio of the peak force before and two weeks after orthomanual resp. conservative treatment.
The mean of the T/P-ratio of the peak force before orthomanual treatment (1,6434) is lower than the mean of the T/P-ratio of the peak force two weeks after orthomanual treatment (1,7034).

This difference between treatment means (-0,06003, 95% CI = (-0,18503, +0,06496)) is not significant (P = 0,316).
The mean of the T/P-ratio of the peak force before conservative treatment (1,6233) is higher than the mean of the T/P-ratio of the peak force two weeks after conservative treatment (1,4970). This difference between treatment means (+0,12632, 95% CI = (-0,04069, +0,29333)) is not significant (P = 0,121).

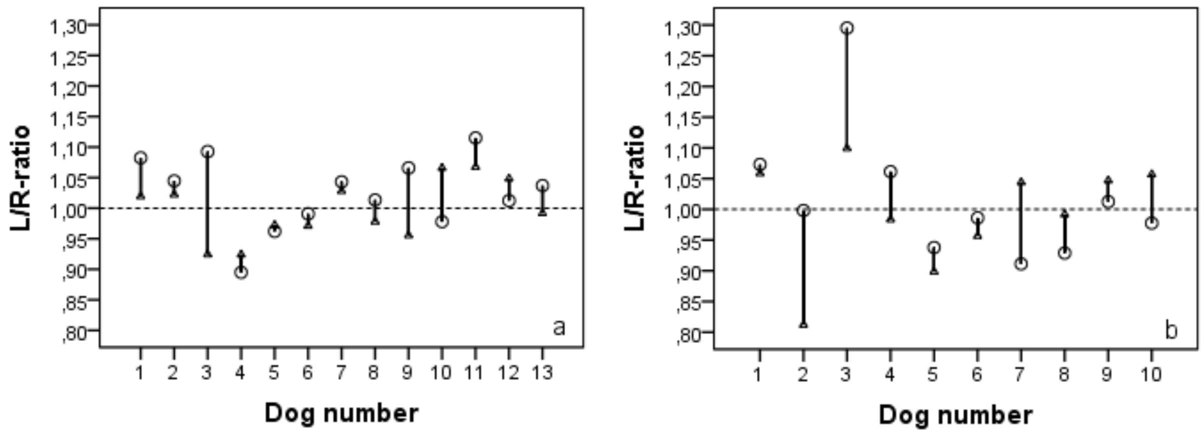
The difference between the T/P-ratio before orthomanual and conservative treatment (0,21412, 95% CI = (-0,02012, +0,44836)) is not significant (P = 0,071).
The difference between the T/P-ratio two weeks after orthomanual and conservative treatment (0,20642, 95% CI = (-0,06828, +0,48112)) is not significant (P = 0,133). (Graph 5)

Two weeks after treatment the T/P-ratio increased within the group that received an orthomanual treatment and decreased within the group that received a conservative treatment; the T/P-ratio of the group that received an orthomanual treatment is further away from 1.50 and the T/P-ratio of the group that received a conservative treatment is almost 1.50. However, these differences are not significant. (Graph 5)

Graph 6 shows a boxplot of the difference between the T/P-ratio of the peak force before and two weeks after orthomanual resp. conservative treatment. This graph shows the effect of orthomanual resp. conservative treatment. There is no significant difference between the effect of orthomanual and conservative treatment (95% CI = (-0,37658,+0,00458), P = 0,055).

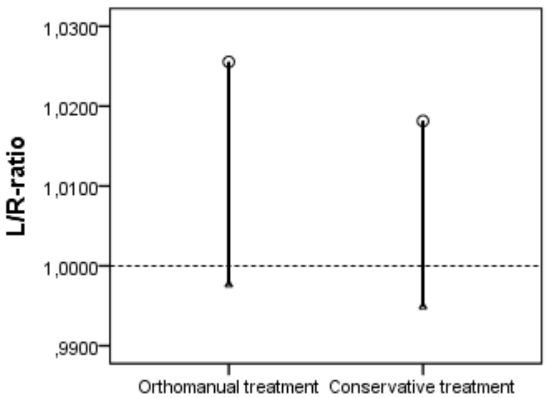
4.3.2 Vertical impulse (VI)

4.3.2.1 L/R-ratio VI

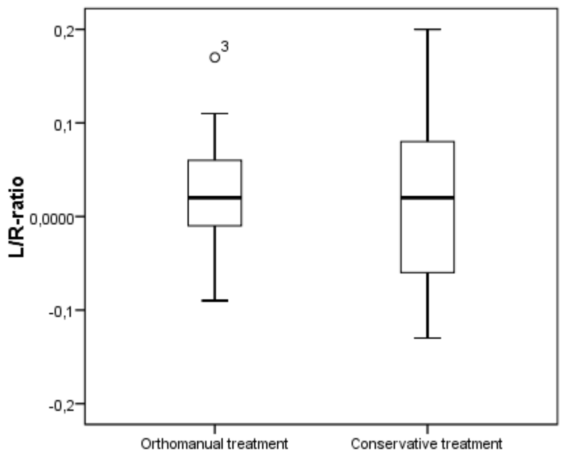


Graph 7. The L/R-ratio of the vertical impulse before (○) and two weeks after (Δ) orthomanual treatment (a) and conservative treatment (b) for each individual dog. The change within two weeks is indicated with a vertical line. A horizontal "reference-line" is presented at the level of 1,00.

Graph 7a and b shows the L/R-ratio of the vertical impulse before and two weeks after orthomanual treatment and before and two weeks after conservative treatment of each individual dog. As described earlier the ideal L/R-ratio is 1, because this indicates that the left and right limbs load an equal amount of weight.



Graph 8. The mean of the L/R-ratio of the vertical impulse before (○) and two weeks after (Δ) orthomanual treatment and before (○) and two weeks after (Δ) conservative treatment. The change within a group is indicated with a vertical line. A horizontal "reference-line" is presented at the level of 1,00.



Graph 9. A boxplot of the difference between the L/R-ratio of the vertical impulse before and two weeks after orthomanual resp. conservative treatment.

Graph 8 shows the mean of the L/R-ratio of the vertical impulse before and two weeks after orthomanual resp. conservative treatment.
The mean of L/R-ratio of the vertical impulse before orthomanual treatment (1,0255) is higher than the mean of the L/R-ratio of the vertical impulse two weeks after orthomanual treatment (0,9977).

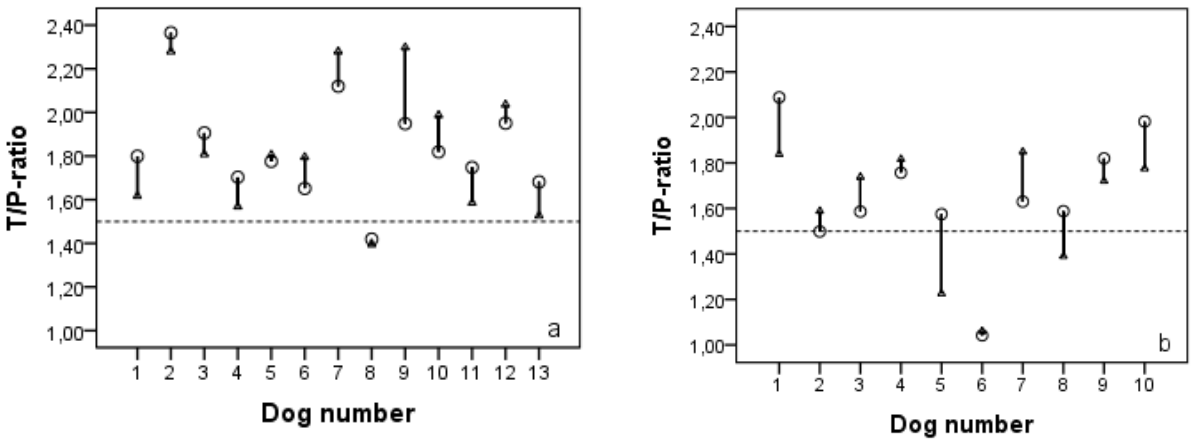
This difference between treatment means (+0,02788, 95% CI = (-0,01150, +0,06725)) is not significant (P = 0,149).
The mean of the L/R-ratio of the vertical impulse before conservative treatment (1,0181) is higher than the mean of the L/R-ratio of the vertical impulse two weeks after conservative treatment (0,9949). This difference between treatment means (+0,02323, 95% CI = (-0,05418, +0,10063)) is not significant (P = 0,514).

The difference between the L/R-ratio before orthomanual and conservative treatment (0,00741, 95% CI = (-0,06742, +0,08223)) is not significant (P = 0,839).
The difference between the L/R-ratio two weeks after orthomanual and conservative treatment (0,00275, 95% CI = (-0,05663, +0,06214)) is not significant (P = 0,924). (Graph 8)

Two weeks after treatment the L/R-ratio decreased within both treatment groups; the L/R-ratio of both groups are closer to 1.00. However, these differences are not significant. (Graph 8)

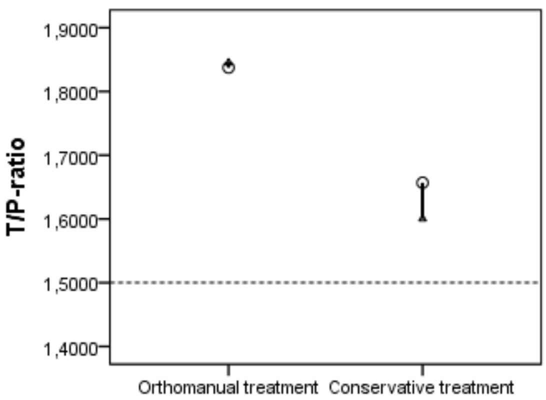
Graph 9 shows a boxplot of the difference between the L/R-ratio of the vertical impulse before and two weeks after orthomanual resp. conservative treatment. This graph shows the effect of orthomanual resp. conservative treatment. There is no significant difference between the effect of orthomanual and conservative treatment (95% CI = (-0,07270, +0,07963), P = 0,926).

4.3.2.2 T/P-ratio VI

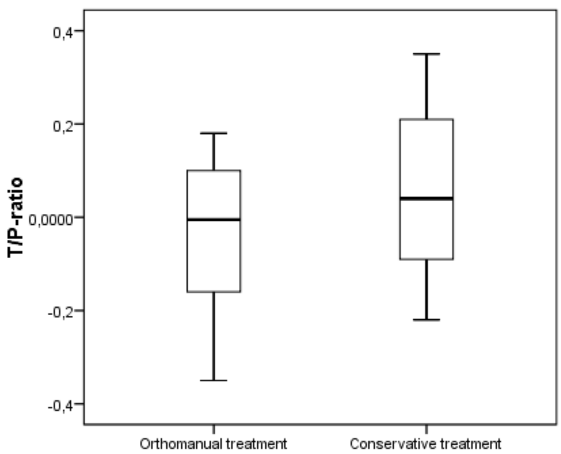


Graph 10. The T/P-ratio of the vertical impulse before (○) and two weeks after (Δ) orthomanual treatment (a) and conservative treatment (b) for each individual dog. The change within two weeks is indicated with a vertical line. A horizontal “reference-line” is presented at the level of 1,50.

Graph 10a and b shows the T/P-ratio of the vertical impulse before and two weeks after orthomanual treatment and before and two weeks after conservative treatment of each individual dog. As described earlier the ideal T/P-ratio 1.5, because dogs normally bear around 60% of their weight on their front limbs and around 40% of their weight on their hind limbs.



Graph 11. The mean of the T/P-ratio of the vertical impulse before (○) and two weeks after (Δ) orthomanual treatment and before (○) and two weeks after (Δ) conservative treatment. The change within a group is indicated with a vertical line. A horizontal “reference-line” is presented at the level of 1,50.



Graph 12. A boxplot of the difference between the T/P-ratio of the vertical impulse before and two weeks after orthomanual resp. conservative treatment.

Graph 11 shows the mean of the L/R-ratio of the vertical impulse before and two weeks after orthomanual resp. conservative treatment.
The mean of the T/P-ratio of the vertical impulse before orthomanual treatment (1,8374) is lower than the T/P-ratio two weeks after orthomanual treatment (1,8451). This difference between treatment means (-0,00762, 95% CI =(-0,10674, +0,09149)) is not significant (P = 0,870).

The mean of the T/P-ratio of the vertical impulse before conservative treatment (1,6567) is higher than the T/P-ratio of the vertical impulse two weeks after conservative treatment (1,6003). This difference between treatment means (+0,05642, 95% CI = (-0,08012, +0,19296)) is not significant (P = 0,374).

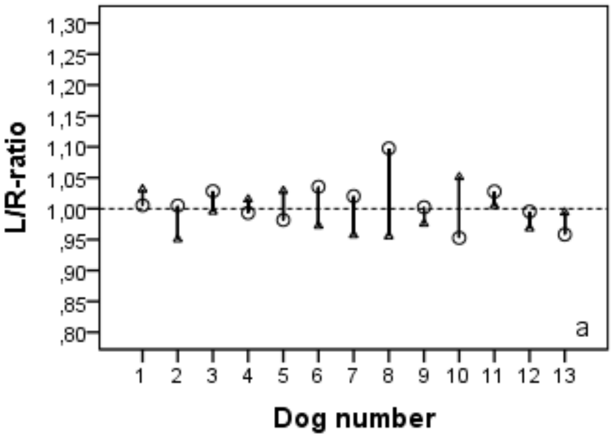
The difference between the T/P-ratio before orthomanual and conservative treatment (0,18071, 95% CI = (-0,04529, +0,40670)) is not significant (P = 0,111).
The difference between the T/P-ratio two weeks after orthomanual and conservative treatment (0,24475, 95% CI = (-0,01496, +0,50445)) is not significant (P = 0,063). (Graph 11)

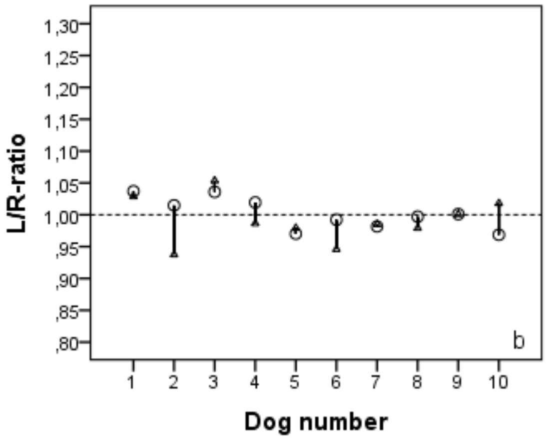
Two weeks after treatment the T/P-ratio increased within the group that received an orthomanual treatment and decreased within the group that received a conservative treatment; the T/P-ratio of the group that received an orthomanual treatment remained almost the same and the T/P-ratio of the group that received a conservative treatment is closer to 1.50. However, these differences are not significant. (Graph 11)

Graph 12 shows a boxplot of the difference between the T/P-ratio of the vertical impulse before and two weeks after orthomanual resp. conservative treatment. This graph shows the effect of orthomanual resp. conservative treatment. There is no significant difference between the effect of orthomanual and conservative treatment (95% CI = (-0,06546, +0,07401), P = 0,386).

4.3.3 Stance duration (SD)

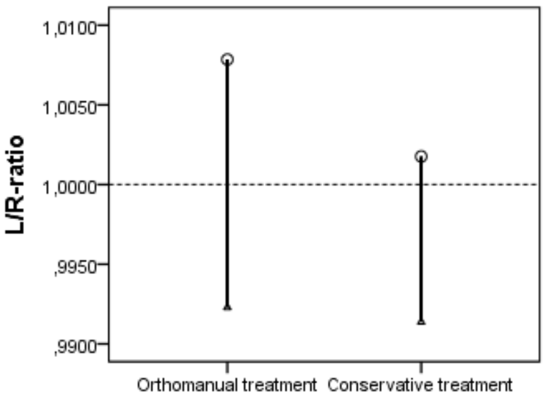
4.3.3.1 L/R-ratio SD



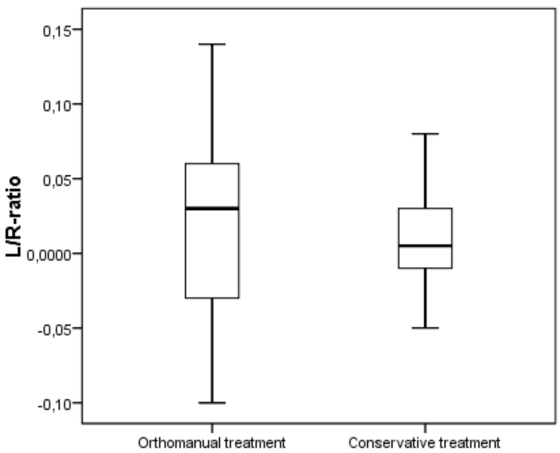


Graph 13. The L/R-ratio of the stance duration before (○) and two weeks after (Δ) orthomanual treatment (a) and conservative treatment (b) for each individual dog. The change within two weeks is indicated with a vertical line. A horizontal "reference-line" is presented at the level of 1,00.

Graph 13a and b shows the L/R-ratio of the stance duration before and two weeks after orthomanual treatment and before and two weeks after conservative treatment of each individual dog. For this parameter also applies that the ideal L/R-ratio is 1, because this indicates that the left and right limbs load an equal amount of weight.



Graph 14. The mean of the L/R-ratio of the stance duration before (○) and two weeks after (Δ) orthomanual treatment and before (○) and two weeks after (Δ) conservative treatment. The change within a group is indicated with a vertical line. A horizontal "reference-line" is presented at the level of 1,00.



Graph 15. A boxplot of the difference between the L/R-ratio of the stance duration before and two weeks after orthomanual resp. conservative treatment.

Graph 14 shows the mean of the L/R-ratio of the stance duration before and two weeks after orthomanual resp. conservative treatment.

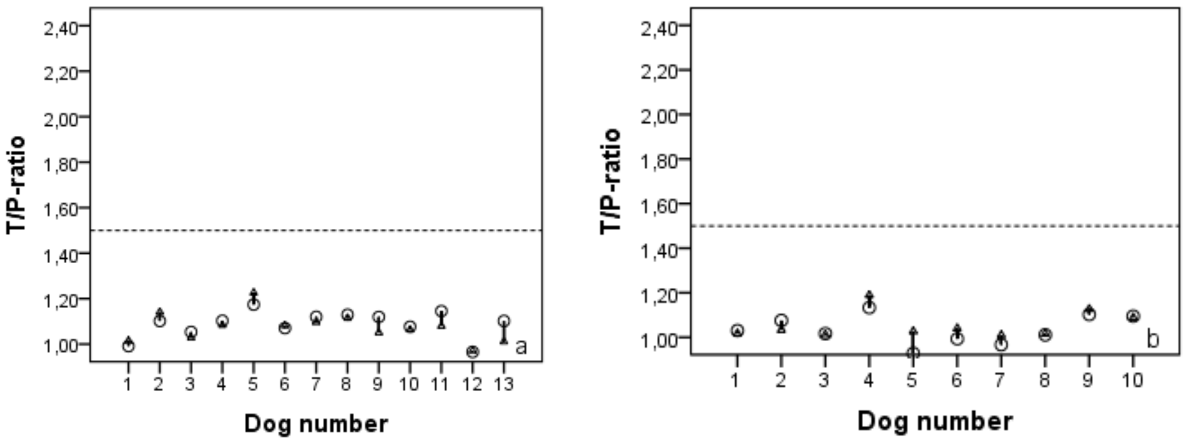
The mean of the L/R-ratio of the stance duration before orthomanual treatment (1,0079) is higher than the mean of the L/R-ratio of the stance duration two weeks after orthomanual treatment (0,9923). This difference between treatment means (+0,01557, 95% CI = (-0,02155, +0,05269)) is not significant (P = 0,379).
The mean of the L/R-ratio of the stance duration before conservative treatment (1,0018) is higher than the mean of the L/R-ratio of the stance duration two weeks after conservative treatment (0,9914). This difference (+0,01038, 95% CI =(-0,01506, +0,03582)) is not significant (P = 0,380).

The difference between the L/R-ratio before orthomanual and conservative treatment (0,00609, 95% CI = (-0,02216, +0,03434)) is not significant (P = 0,658).
The difference between the L/R-ratio two weeks after orthomanual and conservative treatment (0,00090, 95% CI = (-0,02865, +0,03045)) is not significant (P = 0,950).

Two weeks after treatment the L/R-ratio decreased within both treatment groups; the L/R-ratio of the group that received an orthomanual treatment is closer to 1.00 and the L/R-ratio of the group that received a conservative treatment is further away from 1,00. However, these differences are not significant.

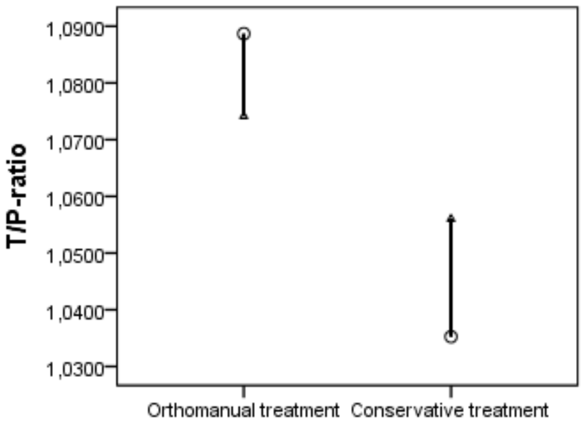
Graph 15 shows a boxplot of the difference between the L/R-ratio of the stance duration before and two weeks after orthomanual resp. conservative treatment. This graph shows the effect of orthomanual resp. conservative treatment. There is no significant difference between the effect of orthomanual and conservative treatment (95% CI = (-0,04289, +0,04858), P = 0,898).

4.3.3.2 T/P-ratio SD

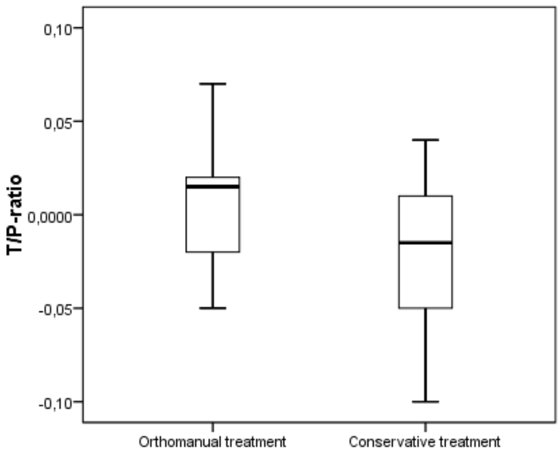


Graph 16. The T/P-ratio of the stance duration before (○) and two weeks after (Δ) orthomanual treatment (a) and conservative treatment (b) for each individual dog. The change within two weeks is indicated with a vertical line. A horizontal "reference-line" is presented at the level of 1,50.

Graph 16a and b shows the T/P-ratio of the stance duration before and two weeks after orthomanual treatment and before and two weeks after conservative treatment of each individual dog. For this parameter also applies that the ideal T/P-ratio 1.5, because dogs normally bear around 60% of their weight on their front limbs and around 40% of their weight on their hind limbs.



Graph 17. The mean of the T/P-ratio of the stance duration before (○) and two weeks after (Δ) orthomanual treatment and before (○) and two weeks after (Δ) conservative treatment. The change within a group is indicated with a vertical line. No horizontal "reference-line" is presented.



Graph 18. A boxplot of the difference between the T/P-ratio of the stance duration before and two weeks after orthomanual resp. conservative treatment.

Graph 17 shows the mean of the T/P-ratio of the stance duration before and two weeks after orthomanual resp. conservative treatment.
The mean of the T/P-ratio of the stance duration before orthomanual treatment (1,0887) is higher than the mean of the T/P-ratio of the stance duration two weeks after orthomanual treatment (1,0741). This difference (+0,01456, 95% CI = (-0,01106, +0,04018)) is not significant (P = 0,239).

The mean of the T/P-ratio of the stance duration before conservative treatment (1,0353) is lower than the mean of the T/P-ratio two weeks after conservative treatment (1,0560). This difference (-0,02074, 95% CI = (-0,05030, +0,00882)) is not significant (P = 0,147).

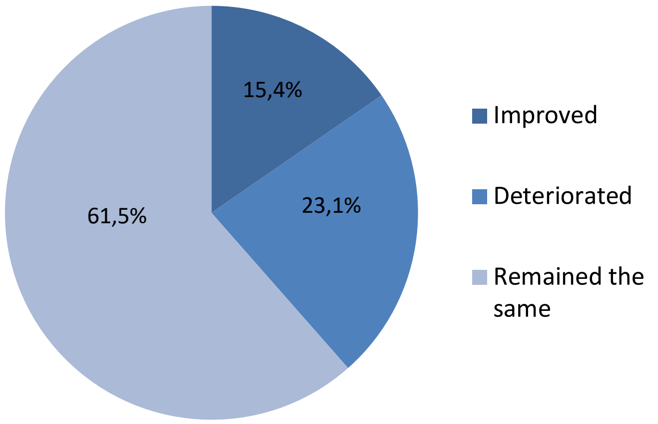
The difference between the T/P-ratio before orthomanual and conservative treatment (0,05343, 95% CI = (-0,00027, +0,10714)) is not significant (P = 0,051).
The difference between the T/P-ratio two weeks after orthomanual and conservative treatment (0,01813, 95% CI = (-0,03690, +0,07316)) is not significant (P = 0,501).

Two weeks after treatment the T/P-ratio decreased within the group that received an orthomanual treatment and increased within the group that received a conservative treatment; the T/P-ratio of the group that received an orthomanual treatment is further away from 1.50 and the T/P-ratio of the group that received a conservative treatment is closer to 1.50. However, these differences are not significant.

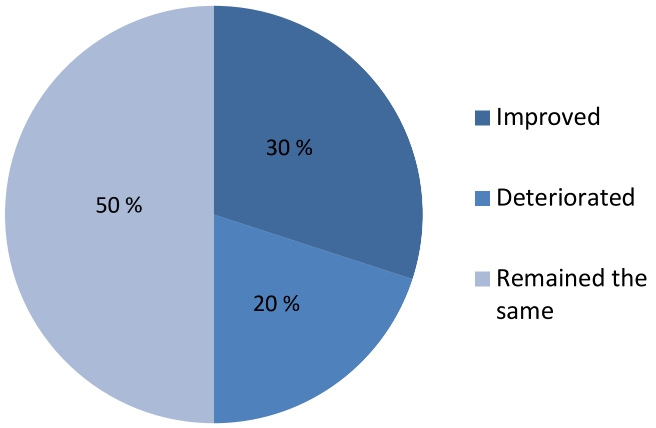
Graph 18 shows a boxplot of the difference between the L/R-ratio of the stance duration before and two weeks after orthomanual resp. conservative treatment. This graph shows the effect of orthomanual resp. conservative treatment. There is no significant difference between the effect of orthomanual and conservative treatment (95% CI = (-0,00121, +0,07244), P = 0,057).

4.2 Analysis of the video material

Analysis of the videos showed that within the group of dogs that received the orthomanual treatment the gait of 15,4% (2 out of 13) of the dogs improved, 23,1% (3 out of 13) deteriorated and 61,5% (8 out of 13) remained the same. (Graph 19) Within the group of dogs that received the conservative treatment the gait of 30% (3 out of 10) of the dogs improved, 20% (2 out of 10) deteriorated and 50% (5 out of 10) remained the same (Graph 20).



Graph 19. The results of the video analysis of the group that received the orthomanual treatment.

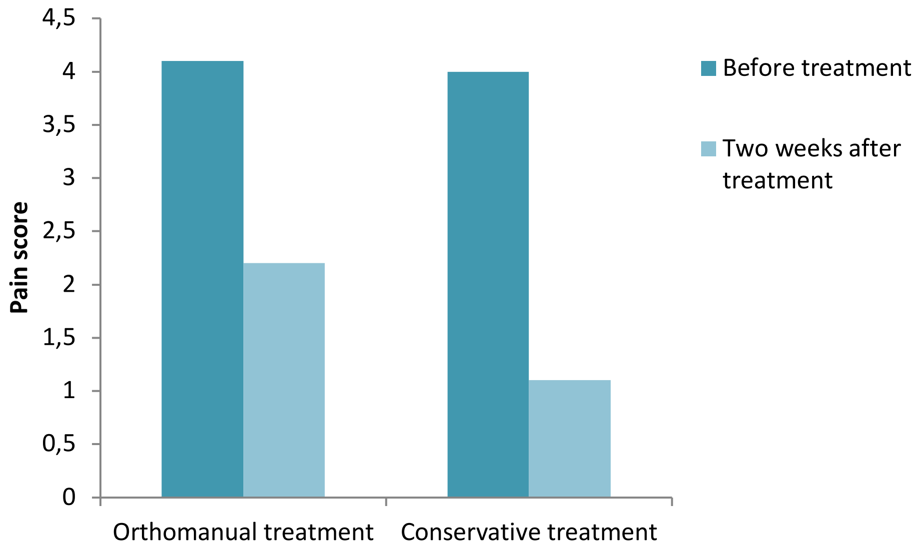


Graph 20. The results of the video analysis of the group that received the conservative treatment.

4.3 Analysis of the questionnaire

4.3.1 Pain score

According to their owners eight of the thirteen dogs that were allocated to the group that received the orthomanual treatment experienced pain with a mean pain score of 4.1, four dogs experienced no pain and one owner had absolutely no clue whether his/her dog experienced pain. Two weeks after orthomanual treatment five of the eight dogs still experienced pain with a mean pain score of 2.2 and the other eight dogs experienced no pain (Graph 21).
According to their owners six of the ten dogs that were allocated to the group that received the conservative treatment experienced pain with a mean pain score of 4.0, three dogs experienced no pain and one owner had absolutely no clue whether his/her dog experienced pain. Two weeks after conservative treatment three of the six dogs still experienced pain with a mean score of 1.1 and seven dogs experienced no pain (Graph 21).
The difference in pain score before and two weeks after treatment was not significant for both treatment groups.

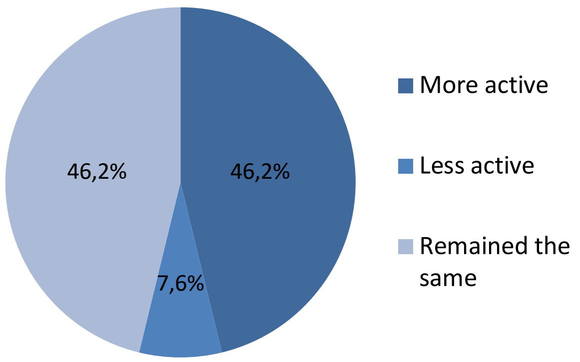


Graph 21. The mean of the pain score before and two weeks after orthomanual and conservative treatment. The pain score is based on a scale of 1 to 10; the higher the score, the more pain.

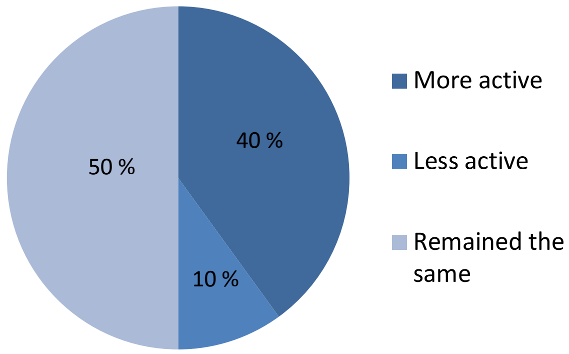
4.3.2 Activity level/behaviour

The owners were asked to fill in whether the activity level of their dog was higher, lower or the same compared to their “normal behaviour”/behaviour before the complaint started. Furthermore, they were asked to fill in whether the activity level of their dog increased, decreased or remained the same two weeks after treatment (despite the fact that each dog had to follow a restricted exercise regime for two weeks).
According to their owners 38,5% (5 out of 13) of the dogs that received the orthomanual treatment had a higher activity level before the complaint started, 7,6% (1 out of 13) had a lower activity level and 53,9% (7 out of 13) had the same activity level. Two weeks after treatment 46,2% (6 out of 13) of the dogs had a higher activity level compared to their behaviour before the treatment (NOT compared to their behaviour before the complaint started), 7,6% (1 out of 13) was less active and the remaining 46,2% (6 out of 13) had the same activity level (Graph 22).

According to their owners 80% (8 out of 10) of the dogs that received the conservative treatment had the same activity level before the complaint started. The owners of the other two dogs did not know whether the activity level of their dog was higher, lower or the same before the complaint started, because the dogs came from an animal shelter in Spain and already had the complaint. Two weeks after treatment 40% (4 out of 10) of the dogs had a higher activity level compared to their behaviour before the treatment, 10% (1 out of 10) had a lower activity level and 50% (5 out of 10) were as active as before the treatment (Graph 23).



Graph 22. The activity level of the dogs two weeks after orthomanual treatment compared to their behaviour before the complaint started.



Graph 23. The activity level of the dogs two weeks after conservative treatment compared to their behaviour before the complaint started.

4.3.3 Clinical signs

The results are shown in tables 3, 4, 5 and 6. These tables show that the dogs of both groups have similar clinical signs and no severe clinical signs, like urinary or fecal incontinence. Furthermore, it is shown that both treatments decrease/solve pain during palpation/exerting pressure on the lower back (orthomanual treatment: 4 out of 6; conservative treatment: 4 out of 5) and make it easier to stand up after a long or short rest (orthomanual: 1 out of 3; conservative treatment: 2 out of 3).

Within the group of dogs that received an orthomanual treatment the complaints were present varying from 2.5 to 104 weeks (mean 25 weeks). Within the group of dogs that received a conservative treatment the complaints were present varying from 5 to 130 weeks (mean 37 weeks).

Table 3. An overview of the clinical signs of dogs before the orthomanual treatment.

Dog number	**Does the dog have difficulties with jumping**	**Does the dog have difficulties with climbing**	**Does the dog have difficulties with walking the stairs**	**How does the dog get up after a long rest**	**How does the dog get up after a short rest**	**Does the dog react painful during touching of the lower back**	**Does the dog react painful or aggressive when other dogs come near his/her back**	**Does the dog let his/her tail hung down because of the lower back pain**	**Does the dog get easily into the "defecation position"**	**Fecal incontinence**	**Urinary incontinence**
1	Much difficulties	Much difficulties	Much difficulties	Without difficulties	Without difficulties	During exerting pressure	No	No	Yes	No	No
2	No	No	No	Difficult	Difficult	During exerting pressure	No	Yes	Yes	No	No
3	No			Without difficulties	Without difficulties	No	No		No	No	No
4	Difficulties	Much difficulties	Much difficulties	Without difficulties	Without difficulties	No	No	No	No	No	No
5	Much difficulties	Much difficulties	Much difficulties	Difficult	Without difficulties	During stroking and exerting pressure	No	No	No	No	No

6	No	No	No	Without difficulties	Without difficulties	During exerting pressure	No	No	Yes	No	No
7	No	No	No	Without difficulties	Without difficulties	No	No	No	Yes	No	No
8	Difficulties		No	Without difficulties	Without difficulties	No	No	No	Yes	No	No
9	No	No	No	Without difficulties	Without difficulties	No	No	No	Yes	No	No
10	Difficulties	Much difficulties	No	Without difficulties	Without difficulties	No	No	No	Yes	No	No
11	Difficulties	Much difficulties	Much difficulties	Without difficulties	Without difficulties	During exerting pressure	No	Yes	Yes	No	No
12	No	No	No	Without difficulties	Without difficulties	During exerting pressure	No	No	Yes	No	No
13	No	No	No	Without difficulties	Without difficulties	During exerting pressure	No	No	Yes	No	No

Table 4. An overview of the clinical signs of dogs two weeks after orthomanual treatment.

Dog number	How does the dog get up after a long rest	How does the dog get up after a short rest	Does the dog react painful during touching of the lower back	Does the dog react painful or aggressive when other dogs come near his/her back	Does the dog let his/her tail hung down because of the lower back pain	Does the dog get easily into the "defecation position"	Fecal incontinence	Urinary incontinence
1	Without difficulties	Without difficulties	No	No	No	Yes	No	No
2	Without difficulties	Without difficulties	No	No	No	Yes	No	No
3	Without difficulties	Without difficulties	No			No	No	No
4	Without difficulties	Without difficulties	No	No	No	No	No	No
5	Without difficulties	Without difficulties	No	No	No	Yes	No	No
6	Without difficulties	Without difficulties	During exerting pressure	No	No	Yes	No	No
7	Without difficulties	Without difficulties	No	No	No	Yes	No	No

8	Without difficulties	Without difficulties	No	No	No	Yes	No	No
9	Without difficulties	Without difficulties	No	No	No	Yes	No	No
10	Without difficulties	Without difficulties	No	No	No	Yes	No	No
11	Difficult	Without difficulties	No	No	No	Yes	No	No
12	Difficult	Without difficulties	During exerting pressure	When they jump on the back	No	Yes	No	No
13	Without difficulties	Without difficulties	No	No	No	Yes	No	No

Table 5. An overview of the clinical signs of dogs before conservative treatment.

Dog number	Does the dog have difficulties with jumping	Does the dog have difficulties with climbing	Does the dog have difficulties with walking the stairs	How does the dog get up after a long rest	How does the dog get up after a short rest	Does the dog react painful during touching of the lower back	Does the dog react painful or aggressive when other dogs come near his/her back	Does the dog let his/her tail hung down because of the lower back pain	Does the dog get easily into the "defecation position"	Fecal incontinence	Urinary incontinence
1	No	No	No	Difficult	Without difficulties	No idea	No	No	Yes	No	No
2	Much difficulties	No	No	Without difficulties	Without difficulties	No	No	No	Yes	No	No
3	Yes	Yes		Difficult	Without difficulties	No	No	No	Yes	No	No
4	No	No	No	Without difficulties	Without difficulties	During exerting pressure	No	No	Yes	No	No
5	No	No	No	Without difficulties	Without difficulties	During exerting pressure	When they come near his/her back	No	Yes	No	No
6	No			Without difficulties	Without difficulties	During exerting pressure	No	No	Yes	No	No
7	No	No		Difficult	Without difficulties	During stroking	When they jump on his/her back	No	Yes	No	No

8	No	No	No	Without difficulties	Without difficulties	During exerting pressure	No	Yes	Yes	No	No
9	No	No		Without difficulties	Without difficulties	No	No	No	Yes	No	No
10	No	No	No	Without difficulties	Without difficulties	During exerting pressure	No	No	Yes	No	No

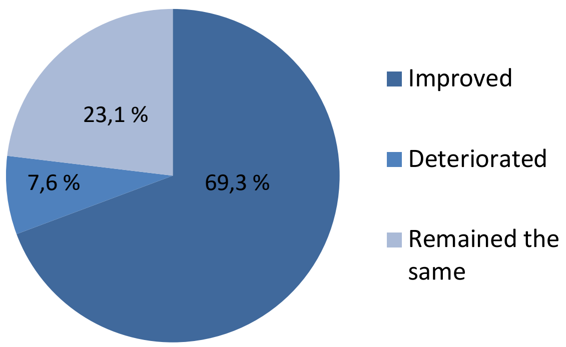
Table 6. An overview of the clinical signs of dogs two weeks after conservative treatment.

Dog number	**How does the dog get up after a long rest**	**How does the dog get up after a short rest**	**Does the dog react painful during touching of the lower back**	**Does the react painful or aggressive when other dogs come near his/her back**	**Does the dog let his/her tail hung down because of the lower back pain**	**Does the dog get easily into the "defecation position"**	**Fecal incontinence**	**Urinary incontinence**
1	Without difficulties	Without difficulties	No	No	No	Yes	No	No
2	Without difficulties	Without difficulties	During exerting pressure	No	No	Yes	No	No
3	Difficult	Without difficulties	No	When they jump on his/her back	No	Yes	No	No
4	Without difficulties	Without difficulties	No	No	No	Yes	No	No
5	Without difficulties	Without difficulties	No	When they come near his/her back	No	Yes	No	No
6	Without difficulties	Without difficulties	No	No	No	Yes	No	No

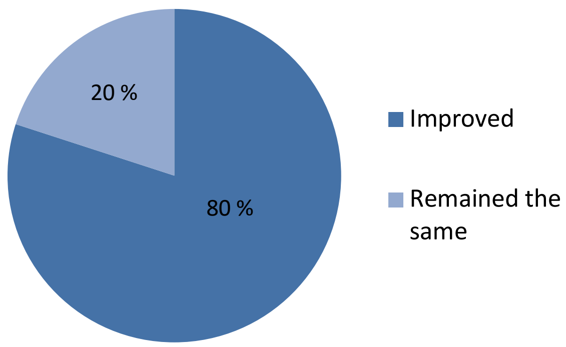
7	Without difficulties	Without difficulties	During stroking	When they jump on his/her back	No	Yes	No	No
8	Without difficulties	Without difficulties	No	No	No	Yes	No	No
9	Without difficulties	Without difficulties	No	No	No	Yes	No	No
10	Without difficulties	Without difficulties	No	No	No	Yes	No	No

4.3.4 Overall view

The owners were asked to fill in if their dog had improved, deteriorated or remained the same two weeks after treatment by looking at the pain experience, behaviour, clinical signs and overall view. Of the thirteen dogs that received the orthomanual treatment nine dogs improved, three remained the same and one deteriorated according to their owners (Graph 24).
Of the ten dogs that received the conservative treatment eight dogs improved, two remained the same and no dog deteriorated according to their owners (Graph 25).



Graph 24. This graph shows whether the dogs improved, deteriorated or remained the same two weeks after orthomanual treatment (according to their owner).



Graph 25. This graph shows whether the dogs improved, deteriorated or remained the same two weeks after conservative treatment (according to their owner).

5. DISCUSSION

In our population the German Shepherd dog was the most affected breed and mostly male dogs were affected. This is in accordance with other reports in the literature. Furthermore, most dogs presented with pain-induced lameness and/or reluctance to jump and reacted painful during examination of the lower back, which is also consistent with the literature. As such, our group can be considered to be comparable with other groups that have been described in the literature (1-6,17).

Currently, there is no accepted grading system for DLSS in dogs (25). However, DLSS and the effect of treatment, can be evaluated by visual scoring or kinetic and kinematic gait analysis (43).

Video analysis showed that within both treatment groups the gait two weeks after treatment was not different from that before treatment for the majority of the dogs. Most dogs whose gait ameliorated were treated conservatively. This might suggest that both treatments have a limited effect on the gait of dogs with DLSS in the short term; the conservative treatment slightly better than the orthomanual treatment. From questionnaire both treatments decreased the pain experience and clinical symptoms and increased the activity level of the dogs. Furthermore, most owners were satisfied with the outcome after orthomanual respectively conservative treatment. Although visual scoring is fast and cost-effective and video analysis was performed blind, both questionnaires and video analysis are subjective observation methods (44-46).

A more objective observation can be performed by kinetic and kinematic gait analysis. Kinetic and kinematic gait analysis can be performed by a force plate (FP) or pressure plate (PP) (33,47). Compared to a FP, a PP offers a number of advantages. First of all, collateral, consecutive and simultaneous paw prints can be recorded in a single passage, requiring fewer trials and compensating for inter-trial variability. Furthermore, a PP provides information about the distribution of forces within a paw print. On top of that a PP is able to provide information about spatiotemporal gait variables making it possible to evaluate dogs with neurological diseases (35,36,48). For these reasons we used a PP in our study.

Although a PP offers some distinct advantages over a FP, it shares some of the drawbacks as well. The parameters of both gait analysis systems are affected by a number of factors, including velocity (37-40,49,50). In order to minimise the influence of velocity, it is set within strict limits for runs to be valid. Another disadvantage for both the FP and PP is that large dogs need to walk several more times over the plate as fewer paw prints are collected in a single passage over the walkway compared to smaller dogs. In future, this problem could be solved by using a longer FP or PP.

Several human gait kinetics and kinematics are influenced by gender (52,53). However, this effect was not present in gait analysis studies of cats and foals (41,42).

Keebaugh et al. investigated the influence of leash side on gait characteristics. They found that leash side did not have an effect on any of the variables characterizing the hind limbs, but did influence front limb symmetry. (54). Therefore, in our study, we included an equal distribution of left- and right-sided leash-led trials to minimise this effect.

Furthermore, Keegan et al. investigated the effect of handlers on front and hind limb symmetry. There had been found an interaction between handlers and the amount of weight put on the right forelimb (54). This might influence the L/R- and T/P-ratio. For this reason, we made sure that each dog was guided by his owner and the same owner during both measurements on the PP.

Gait analysis using the L/R-ratio and T/P-ratio showed a high diagnostic accuracy for detecting front limb and hind limb lameness in dogs (33,37,38,47,51). This indicates that both parameters may be useful to study conditions that affect the hind limbs.

The initial level of the T/P-ratio of PF, VI and SD is higher in the group of dogs that was treated orthomanually compared to the group of dogs that was treated conservatively. In a FP study by Voss et al. the dogs with a lower body weight (mean 24.6 kg) had a higher PF of the hind limbs compared to dogs with a higher bodyweight (mean 35.5 kg). This could indicate that dogs with a higher bodyweight have a higher T/P-ratio (56). In our study, the dogs that were treated orthomanually had a lower bodyweight (mean 23.78 kg) compared to the dogs that were treated conservatively (mean 27.23 kg), which means that the dogs with a lower bodyweight have a higher T/P-ratio. This is in contrast with the findings in the study of Voss et al. Both the present study and the study by Voss et al. included several breeds with varying body conformations. It is possible that these different body conformations influence the front/hind distribution, i.f. breeds with a relatively broad chest and large head bear relatively more weight on their front limbs. Another study by Voss et al. and a study by Hof also found that breed and body conformation influence kinetic, kinematic and temporospatial parameters (57,58).

The L/R-ratio of PF and SD got closer to 1,00 within the group that was treated orthomanually, but got further away from 1,00 within the group that was treated conservatively. On the other hand, the L/R-ratio of the VI got closer to 1,00 within both groups. These results might suggest that both treatments make dogs with DLSS walk more equal, the orthomanual treatment slightly better than the conservative treatment. The T/P-ratio of each value got closer to 1,50 within the group that received a conservative treatment whereas only the T/P-ratio of the stance duration got closer to 1,50 within the group that received an orthomanual treatment. These results might suggest that both treatments make dogs with DLSS stand longer on their hind limbs whereas conservative treatment also makes the dogs bear more their hind limbs. However, these results must be interpreted carefully. First of all, none of the differences are significant and secondly we used a small sample size in our study.

The lack of a significant effect in our study may be due to the velocity at which we evaluated the gait, we only measured the gait of the dogs during trotting (their preference speed). In the study of Abdelhadi et al. the gait of Beagles with experimentally induced lameness was evaluated with a FP. It appeared that forelimb asymmetry was higher at the walk compared to the trot, however no statistics were performed to assess if this difference was significant (55). Therefore, more research is needed to investigate whether trotting is the ultimate velocity to evaluate the gait in dogs with DLSS with a PP. Furthermore, the lack of a significant effect may be due to the small sample size used in our study. On the other hand, a too small effect of both treatments must also be considered.

In the present study, an overall success rate of 20% according to the video analysis and 80% according to the questionnaire (mean success rate of 50%) was recorded after conservative treatment, which is in accordance with other studies that reported a success rate of 55-79% (25,26). An overall success rate of 15.4% according to the video analysis and 69.3% according to the questionnaire (mean success rate of 42.4%) was recorded after orthomanual treatment. However, as the success ratio varies considerably between the video analysis and the questionnaire the results must be interpreted with great caution. Furthermore, all dogs used in this study had mild DLSS. Therefore, no statement can be made about the effect of orthomanual treatment in dogs with severe DLSS.

The effect of orthomanual treatment was evaluated in comparison with a conservative treatment. The lack of a comparison with a matched control group was chosen based on ethical reasons.

However, as each dog received the same exercise regime for two weeks an influence of this regime on the concluded differences cannot be excluded. Therefore, results must be interpreted carefully. Furthermore, in order to eliminate the effect of the restricted exercise regime further research including a control group is needed.

This study investigated the effect of orthomanual treatment in dogs suffering from lower back pain over a short period of time. This short period of evaluation was chosen based on ethical reasons. The study of Suwankong et al. showed that the propulsive force of the hind limbs and T/P-ratio of the propulsive force, measured with a FP, decreased three days after surgery, increased during six months follow-up but remained the same with long-term follow-up (47). This indicates that long-term follow-up is needed.

6. CONCLUSION

In conclusion, both treatments, in both groups that received the same exercise regime, had a positive effect on lower back pain in dogs with DLSS; the conservative treatment slightly better than the orthomanual treatment. However, further studies are needed before this can be substantiated. Knowledge about the ultimate velocity to evaluate the gait of dogs with DLSS with a pressure plate is required to optimize the pressure plate analysis. Evaluation of orthomanual treatment in a larger canine sample size, during a longer period of time and including a control group is needed to draw valid conclusions regarding the effectiveness of orthomanual treatment in the short and long term.

7. ACKNOWLEDGEMENTS

We would like to thank Dr. D.C. Aharon (DVM) for the use of her practice and Mr. G.L. I. Flipse for technical assistance with the pressure plate analysis.

8. ATTACHMENTS

Addendum 1: Information for the owners
Addendum 2: Informed consent
Addendum 3: Questionnaire

9. REFERENCES

(1) Bergknut N, Egenvall A, Hagman R, Gustas P, Hazewinkel HA, Meij BP, et al. Incidence of intervertebral disk degeneration-related diseases and associated mortality rates in dogs. J Am Vet Med Assoc 2012;240(11):1300-1309.

(2) Worth AJ, Thompson DJ, Hartman AC. Degenerative lumbosacral stenosis in working dogs: current concepts and review. N Z Vet J 2009;57(6):319-330.

(3) Linn LL, Bartels KE, Rochat MC, Payton ME, Moore GE. Lumbosacral stenosis in 29 military working dogs: epidemiologic findings and outcome after surgical intervention (1990-1999). Vet Surg 2003;32(1):21-29.

(4) Meij BP, Bergknut N. Degenerative lumbosacral stenosis in dogs. Vet Clin North Am Small Anim Pract 2010;40(5):983-1009.

(5) Suwankong N. Degenerative lumbosacral stenosis in dogs. Utrecht; 2007. 206.

(6) Willems N. Degeneratieve lumbosacrale stenose bij de hond. www.diergeneeskunde.nl; 2012. 2-7.

(7) Bergknut N, Smolders LA, Grinwis GC, Hagman R, Lagerstedt AS, Hazewinkel HA, et al. Intervertebral disc degeneration in the dog. Part 1: Anatomy and physiology of the intervertebral disc and characteristics of intervertebral disc degeneration. Vet J 2013;195(3):282-291.

(8) Morgan JP. Transitional lumbosacral vertebral anomaly in the dog: a radiographic study. J Small Anim Pract 1999;40(4):167-172.

(9) Flückiger MA, Damur-Djuric N, Hässig M, Morgan JP, Steffen F. A lumbosacral transitional vertebra in the dog predisposes to cauda equina syndrome. Vet Radiol Ultrasound 2006;47(1):39-44.

(10) Steffen F. Degenerative lumbosacral stenosis in dogs-contributions to epidemiology, diagnostic imaging and treatment. University of Zurich, Vetsuisse Faculty 2009:88.

(11) Ondreka N, Amort KH, Stock KF, Tellhelm B, Klumpp SW, Kramer M, et al. Skeletal morphology and morphometry of the lumbosacral junction in German shepherd dogs and an evaluation of the possible genetic basis for radiographic findings. Vet J 2013;196(1):64-70.

(12) Scharf G, Steffen F, Grunenfelder F, Morgan JP, Fluckiger M. The lumbosacral junction in working german shepherd dogs -- neurological and radiological evaluation. J Vet Med A Physiol Pathol Clin Med 2004;51(1):27-32.

(13) Godde T, Steffen F. Surgical treatment of lumbosacral foraminal stenosis using a lateral approach in twenty dogs with degenerative lumbosacral stenosis. Vet Surg 2007;36(7):705-713.

(14) Danielsson F, Sjostrom L. Surgical treatment of degenerative lumbosacral stenosis in dogs. Vet Surg 1999;28(2):91-98.

(15) Steffen F, Hunold K, Scharf G, Roos M, Fluckiger M. A follow-up study of neurologic and radiographic findings in working German Shepherd Dogs with and without degenerative lumbosacral stenosis. J Am Vet Med Assoc 2007;231(10):1529-1533.

(16) Bergknut N, Rutges JP, Kranenburg HJ, Smolders LA, Hagman R, Smidt HJ, et al. The dog as an animal model for intervertebral disc degeneration? Spine (Phila Pa 1976) 2012 Mar 1;37(5):351-358.

(17) Suwankong N, Voorhout G, Hazewinkel HA, Meij BP. Agreement between computed tomography, magnetic resonance imaging, and surgical findings in dogs with degenerative lumbosacral stenosis. J Am Vet Med Assoc 2006;229(12):1924-1929.

(18) D'Anastasi M, Birkenmaier C, Schmidt GP, Wegener B, Reiser MF, Baur-Melnyk A. Correlation between vacuum phenomenon on CT and fluid on MRI in degenerative disks. AJR Am J Roentgenol 2011;197(5):1182-1189.

(19) Axlund TW, Hudson JA. Computed tomography of the normal lumbosacral intervertebral disc in 22 dogs. Vet Radiol Ultrasound 2003;44(6):630-634.

(20) Jones JC, Banfield CM, Ward DL. Association between postoperative outcome and results of magnetic resonance imaging and computed tomography in working dogs with degenerative lumbosacral stenosis. J Am Vet Med Assoc 2000;216(11):1769-1774.

(21) Jones JC, Shires PK, Inzana KD, Sponenberg DP, Massicotte C, Renberg W, et al. Evaluation of canine lumbosacral stenosis using intravenous contrast-enhanced computed tomography. Vet Radiol Ultrasound 1999;40(2):108-114.

(22) Mayhew PD, Kapatkin AS, Wortman JA, Vite CH. Association of cauda equina compression on magnetic resonance images and clinical signs in dogs with degenerative lumbosacral stenosis. J Am Anim Hosp Assoc 2002;38(6):555-562.

(23) Amort KH, Ondreka N, Rudorf H, Stock KF, Distl O, Tellhelm B, et al. MR-imaging of lumbosacral intervertebral disc degeneration in clinically sound German shepherd dogs compared to other breeds. Vet Radiol Ultrasound 2012;53(3):289-295.

(24) Patel PR, Lauerman WC. The use of magnetic resonance imaging in the diagnosis of lumbar disc disease. Radiology Review Orthopaedic Nursing 1997;16(1):59-65.

(25) De Decker S, Wawrzenski LA, Volk HA. Clinical signs and outcome of dogs treated medically for degenerative lumbosacral stenosis: 98 cases (2004-2012). J Am Vet Med Assoc 2014;245(4):408-413.

(26) Janssens L, Beosier Y, Daems R. Lumbosacral degenerative stenosis in the dog. The results of epidural infiltration with methylprednisolone acetate: a retrospective study. Vet Comp Orthop Traumatol 2009;22(6):486-491.

(27) Meij BP, Suwankong N, Van der Veen AJ, Hazewinkel HA. Biomechanical flexion-extension forces in normal canine lumbosacral cadaver specimens before and after dorsal laminectomy-discectomy and pedicle screw-rod fixation. Vet Surg 2007;36(8):742-751.

(28) Suwankong N, Meij BP, Voorhout G, de Boer AH, Hazewinkel HA. Review and retrospective analysis of degenerative lumbosacral stenosis in 156 dogs treated by dorsal laminectomy. Vet Comp Orthop Traumatol 2008;21(3):285-293.

(29) De Risio L, Sharp NJ, Olby NJ, Munana KR, Thomas WB. Predictors of outcome after dorsal decompressive laminectomy for degenerative lumbosacral stenosis in dogs: 69 cases (1987-1997). J Am Vet Med Assoc 2001;219(5):624-628.

(30) Smolders LA, Voorhout G, van de Ven R, Bergknut N, Grinwis GC, Hazewinkel HA, et al. Pedicle screw-rod fixation of the canine lumbosacral junction. Vet Surg 2012;41(6):720-732.

(31) Hankin EJ, Jerram RM, Walker AM, King MD, Warman CG. Transarticular facet screw stabilization and dorsal laminectomy in 26 dogs with degenerative lumbosacral stenosis with instability. Vet Surg 2012;41(5):611-619.

(32) Golini L, Kircher PR, Lewis FI, Steffen F. Transarticular fixation with cortical screws combined with dorsal laminectomy and partial discectomy as surgical treatment of degenerative lumbosacral stenosis in 17 dogs: clinical and computed tomography follow-up. Vet Surg 2014;43(4):405-413.

(33) van Klaveren NJ, Suwankong N, De Boer S, van den Brom WE, Voorhout G, Hazewinkel HA, et al. Force plate analysis before and after dorsal decompression for treatment of degenerative lumbosacral stenosis in dogs. Vet Surg 2005;34(5):450-456.

(34) van de Veen EA, de Vet HC, Pool JJ, Schuller W, de Zoete A, Bouter LM. Variance in manual treatment of nonspecific low back pain between orthomanual physicians, manual therapists, and chiropractors. J Manipulative Physiol Ther 2005 Feb;28(2):108-116.

(35) Lascelles BD, Findley K, Correa M, Marcellin-Little D, Roe S. Kinetic evaluation of normal walking and jumping in cats, using a pressure-sensitive walkway. Vet Rec 2007;160(15):512-516.

(36) Lascelles BD, Roe SC, Smith E, Reynolds L, Markham J, Marcellin-Little D, et al. Evaluation of a pressure walkway system for measurement of vertical limb forces in clinically normal dogs. Am J Vet Res 2006;67(2):277-282.

(37) Oosterlinck M, Bosmans T, Gasthuys F, Polis I, Van Ryssen B, Dewulf J, et al. Accuracy of pressure plate kinetic asymmetry indices and their correlation with visual gait assessment scores in lame and nonlame dogs. Am J Vet Res 2011;72(6):820-825.

(38) Oosterlinck M, Pille F, Back W, Dewulf J, Gasthuys F. Use of a stand-alone pressure plate for the objective evaluation of forelimb symmetry in sound ponies at walk and trot. Vet J 2010;183(3):305-309.

(39) Meijer E, Bertholle CP, Oosterlinck M, van der Staay FJ, Back W, van Nes A. Pressure mat analysis of the longitudinal development of pig locomotion in growing pigs after weaning. BMC Vet Res 2014;10:37-6148-10-37.

(40) Meijer E, Oosterlinck M, van Nes A, Back W, van der Staay FJ. Pressure mat analysis of naturally occurring lameness in young pigs after weaning. BMC Vet Res 2014;10:193-014-0193-8.

(41) Denham SF, Staniar WB, Dascanio JJ, Phillips AB, Splan RK. Linear and Temporal Kinematics of the Walk in Warmblood Foals. J Equine Vet Sci 2012;32:112–115.

(42) Verdugo MR, Rahal SC, Agostinho FS, Govoni VM, Mamprim MJ, Monteiro FO. Kinetic and temporospatial parameters in male and female cats walking over a pressure sensing walkway. BMC Vet Res 2013;9:129.

(43) Gillette RL, Angle TC. Recent developments in canine locomotor analysis: a review. Vet J 2008;178(2):165-176.

(44) Keegan KG. Evidence-based lameness detection and quantification. Vet Clin North Am Equine Pract 2007;23(2):403-423.

(45) Waxman AS, Robinson DA, Evans RB, Hulse DA, Innes JF, Conzemius MG. Relationship between objective and subjective assessment of limb function in normal dogs with an experimentally induced lameness. Vet Surg 2008;37(3):241-246.

(46) Quinn MM, Keuler NS, Lu Y, Faria ML, Muir P, Markel MD. Evaluation of agreement between numerical rating scales, visual analogue scoring scales, and force plate gait analysis in dogs. Vet Surg 2007;36(4):360-367.

(47) Suwankong N, Meij BP, Van Klaveren NJ, Van Wees AM, Meijer E, Van den Brom WE, et al. Assessment of decompressive surgery in dogs with degenerative lumbosacral stenosis using force plate analysis and questionnaires. Vet Surg 2007;36(5):423-431.

(48) Gordon-Evans WJ, Evans RB, Conzemius MG. Accuracy of Spatiotemporal Variables in Gait Analysis of Neurologic Dogs. J Neurotrauma 2009;26:1055–1060.

(49). Evans R, Gordon W, Conzemius M. Effect of velocity on ground reaction forces in dogs with lameness attributable to tearing of the cranial cruciate ligament. Am J Vet Res 2003;64:1479–1481.

(50) Riggs C, DeCamp C, Soutas-Little R, Braden T, Richter M. Effects of subject velocity on force plate-measured ground reaction forces in healthy greyhounds at the trot. Am J Vet Res 1993;54:1523–1526.

(51) Fanchon L, Grandjean D. Accuracy of asymmetry indices of ground reaction forces for diagnosis of hind limb lameness in dogs. Am J Vet Res 2007;68(10):1089-1094.

(52) Cho SH, Park JM, Kwon OY. Gender differences in three dimensional gait analysis data from 98 healthy Korean adults. Clin Biomech (Bristol, Avon) 2004;19(2):145-152.

(53) Ferber R, Davis IM, Williams DS,3rd. Gender differences in lower extremity mechanics during running. Clin Biomech (Bristol, Avon) 2003;18(4):350-357.

(54) Keebaugh AE, Redman-Bentley D, Griffon DJ. Influence of leash side and handlers on pressure mat analysis of gait characteristics in small-breed dogs. J Am Vet Med Assoc 2015;246(11):1215-1221.

(55) Abdelhadi J, Wefstaedt P, Galindo-Zamora V, Anders A, Nolte I, Schilling N. Load redistribution in walking and trotting Beagles with induced forelimb lameness. Am J Vet Res 2013;74(1):34-39.

(56) Voss K, Galeandro L, Wiestner T, Haessig M, Montavon PM. Relationships of body weight, body size, subject velocity, and vertical ground reaction forces in trotting dogs. Vet Surg 2010;39:963-969.

(57) Hof AL. Scaling gait data to body size. Gait Posture 1996;4:222–223.

(58) Voss K, Imhof J, Kaestner S, Montavon PM. Force plate gait analysis at the walk and trot in dogs with low-grade hindlimb lameness. Vet Comp Orthop Traumatol 2007;20(4):299-304.