FACULTY OF VETERINARY MEDICINE
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Hydrotherapy as a conservative therapy for canine hip dysplasia

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Preface

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List of abbreviations

AROM	Active Range Of Motion
BCS	Body Condition Score
CT	Computed Tomography
DJD	Degenerative Joint Disease
Fz	Vertical Force
GLS	Global Lameness Score
GRF	Ground Reaction Forces
HD	Hip Dysplasia
LOAD	Liverpool Osteoarthritis in Dogs owner questionnaire
MCS	Muscle Condition Score
MRI	Magnetic Resonance Imaging
MVF	Mean Vertical Force
PROM	Passive Range Of Motion
PFz	Peak Vertical Force
ROM	Range Of Motion
TPO	Triple Pelvic Osteotomy
UWTM	Under Water Treadmill
VI	Vertical Impulses

1. Abstract

Hydrotherapy is a rapidly growing discipline in veterinary medicine. On the one hand, this is because the demand and expectations of dog owners for rehabilitation methods have increased. On the other hand, it can be explained by the high perception of positive effects among veterinarians. The goal is to reduce pain, stiffness and discomfort, facilitate healing and improve muscle strength due to the advantageous inherent physical properties of water. The aim is to improve flexibility, strength, balance, mobility, speed and endurance. Hip dysplasia (HD) can be defined as an abnormal development of the hip joint. This results in coxofemoral laxity due to incongruity and ineffective soft tissue stabilization of the joint. It is the most common non-congenital polygenic and heritable developmental orthopedic condition in dogs that causes hind leg lameness in all breeds.

In this master thesis, we will evaluate the gait pattern of dogs which are diagnosed with bilateral hip dysplasia with a pressure plate before and after a series of hydrotherapy sessions on the underwater treadmill in order to assess their potential progress. The purpose of this study is to obtain objective evidence about the effects of hydrotherapy as a conservative treatment. In addition, the Liverpool Osteoarthritis in Dogs (LOAD) owner questionnaire for dogs with mobility problems will be used to support the objective results.

In this study we noticed that after a series of hydrotherapy sessions, the symmetry-index was decreased. The global lameness score (GLS score) was slightly decreased, even further under the lower border of 95% meaning that the dogs were still clinically limping. There were no significant changes in the values of mean vertical force (mean Fz) and peak vertical force (PFz). We can conclude that hydrotherapy has the potential to improve the gait pattern in dogs with bilateral hip dysplasia. The main improvement was seen in the reach of the hind legs, indicating an improvement in flexibility and in the range of motion of the coxofemoral joint. According to the owners, the dogs had an increased activity level and were suffering less from stiffness after lying down.

2. Samenvatting

Hydrotherapie is een snelgroeiende discipline binnen de diergeneeskunde. Dit komt enerzijds omdat er een toenemende vraag is van hondeneigenaren voor rehabilitatietechnieken. Anderzijds is dit te verklaren omdat dierenartsen zich steeds meer bewust zijn over de positieve effecten ervan. Het doel van hydrotherapie is om pijn te reduceren, stijfheid te verminderen en spiersterkte te doen toenemen met behulp van de positieve fysieke eigenschappen van water. Hydrotherapie kan zo de beweeglijkheid, kracht, balans, mobiliteit, snelheid en uithouding verbeteren. Heupdysplasie (HD) is een abnormale ontwikkeling van het heupgewricht. Dit leidt tot coxofemorale laxiteit door incongruentie van het gewricht en ineffectieve weke delen stabilisatie. Het is de meest voorkomende niet-congenitale polygenische en erfelijke ontwikkelingsstoornis die manken veroorzaakt bij honden.

In deze masterproef zullen we de evolutie opvolgen van honden gediagnosticeerd met bilaterale heupdysplasie voor en na een serie van hydrotherapiesessies op de onderwaterloopband. De opvolging zal gebeuren door het beoordelen van hun bewegingspatroon aan de hand van een drukplaat. Het doel van deze studie is om op objectieve wijze de effecten van hydrotherapie als een conservatieve therapie aan te tonen. Bijkomend zal ook de Liverpool Osteoarthritis in Dogs questionnaire (LOAD) voor eigenaars van honden met mobiliteitsproblemen gebruikt worden om de objectieve resultaten te staven.

In deze studie werd aangetoond dat na de hydrotherapiesessies, de symmetrie-index gedaald was. De globale mankheidsscore (GLS score) was licht gedaald, nog verder onder de ondergrens van 95% dat erop wijst dat de honden nog steeds klinisch manken. Er waren geen signifcante verschillen voor de waarden van gemiddelde verticale kracht (gemiddelde Fz) en piek verticale kracht (PFz). We kunnen concluderen dat hydrotherapie het potentieel heeft om het bewegingspatroon van honden met bilaterale heupdysplasie te verbeteren. De grootste verbetering werd gezien in het bereik van de achterpoten. Dit wijst op een verbetering in de flexibiliteit van het coxofemorale gewricht. Volgens de eigenaars hadden de honden ook een toegenomen activiteit en hadden ze minder last van stijfheid na het neerliggen.

3. Literature

3.1 Hydrotherapy

Physiotherapy is defined as the therapeutic use of physical agents and natural stimuli such as pressure, temperature, electricity, ultrasound, light, water or movements to stimulate the body or to stimulate a selective part of the body (Samoy, 2018). It can be used as a preventative or curative treatment or can be part of the rehabilitation after surgery. The general goal is to reduce pain, increase the range of motion (ROM) and to strengthen muscles (Prydie and Hewitt, 2015). Physiotherapy is divided into three therapeutic categories by Prydie and Hewitt (2015) namely: manual therapy, use of therapeutic modalities and therapeutic exercises. These categories can be used separately or as a combination of therapy, depending on the findings on physiotherapeutic assessment. Hydrotherapy or aquatic therapy belongs to the third category of therapeutic exercises with natural muscle stimulation. Those are active exercises which the dogs perform with their own muscle strength without assistance. The muscles are actively trained and the mobility of the joints will improve. The indications for hydrotherapy are legio and include postoperative rehabilitation, training, neurological conditions, chronic pain management, weight loss, gait and posture correction, supportive movement for elderly dogs, improve water confidence in puppies, gait reeducation, psychological wellbeing and wellness (McGowan, 2016). The aim of hydrotherapy is to improve flexibility, strength, balance, coordination, postural awareness, mobility, speed and endurance (Sharp, 2008; McGowan, 2016). The main contra-indications are severe cardiorespiratory diseases, active gastro-intestinal diseases, systemic compromise, dermatological diseases and open wounds or sutures (Prydie and Hewitt, 2015; McGowan, 2016). Hydrotherapy has been developed based on the theory of hydrodynamics. Due to the advantageous inherent physical properties of water such as viscosity, hydrostatic pressure, resistance, buoyancy, surface tension and relative density, hydrotherapy can be used as a preventive and curative therapy and is efficient for maintaining total fitness (Wong, 2011).

Hydrotherapy is a rapidly growing discipline in veterinary medicine. On the one hand, this is because the demand and expectations of dog owners for rehabilitation methods have increased. On the other hand, it can be explained by the high perception of positive effects among veterinarians. Physiotherapy has been used for over 2 decades but despite this, there are only little studies about the effect of physiotherapy and hydrotherapy, so there is a lack of evidence-based research (Waining et al., 2011).

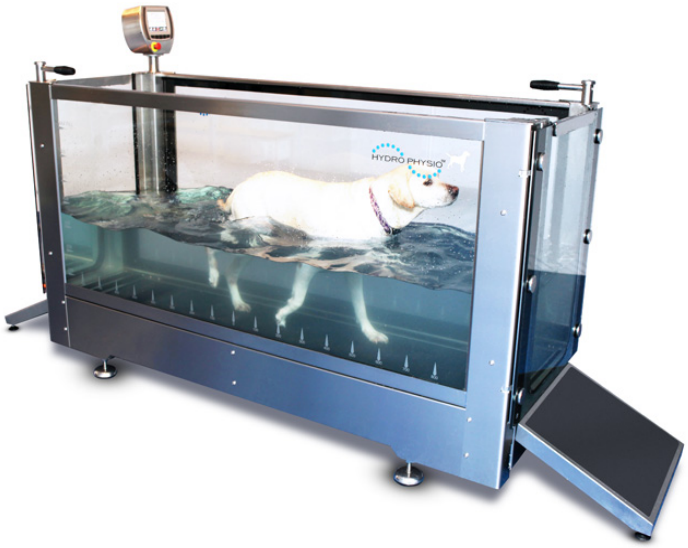


Fig 1: UWTM hydrophysio
(From: https://www.hydrophysio.com/canine/veterinary-hydrotherapy)

The application of hydrotherapy can either be as prehabilitation or as rehabilitation. Prehabilitation is a form of strength training with the aim of reducing the risk of injuring. When applying hydrotherapy as prehabilitation before an orthopedic surgery, the muscles can be strengthened and the recovery will be quickened because of the fact that the joints get more support from the surrounding soft tissue. Hydrotherapy can also be applied sole as a form of rehabilitation after orthopedic surgery or after an injury. In this case the aim of the therapy is to restore the lost function of the joints and muscles (Wong, 2011).

Hydrotherapy can be executed on an underwater treadmill (UWTM) or in a pool. There are advantages and disadvantages to each form of performing hydrotherapy. In a pool, the dog is swimming freely in the water and is fully supported by the water and the life vest. The physiotherapist is also in the water and can help with stimulating full movements of the joints. When swimming in a pool, the dogs must wear a life vest to float for safety reasons. By using the UWTM, the physiotherapist is more in control. The dog is still partially weight bearing in comparison to totally non-weight bearing when swimming in a therapeutic pool. Because the patient is weight bearing on the UWTM, the muscle build-up will be quicker because of walking movements and pushing the leg through the water rather than by only making swimming movements. There is an improved active range of motion (AROM) due to an increased step height on an UWTM (Dycus, 2017). In most UWTM's, there are side platforms which allows the physiotherapist to assist the dogs within the treadmill, offering the essential interaction for advanced treatment. The UWTM's have walls made out of glass which allows monitoring of the leg movements from all sides and an ease for the patient. The speed, inclination, water level and temperature can be adjusted for every patient on the UWTM to give individual training. The best results are achieved by adjusting the therapy to the individual needs and opportunities of every patient, keeping their individual problem, their ability to regain functionality and realistic outcome in mind. A treadmill can also be incorporated into a pool, combining the benefits from each form of performing hydrotherapy (Wong, 2011; Zink, 2013; Waining et al., 2011).

3.1.1 Physical properties of water

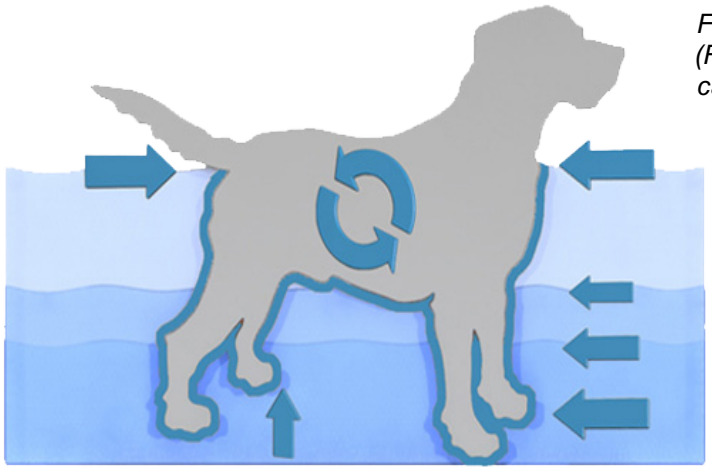


Fig 2: physical properties of water (From: https://www.hydrophysio.com/canine/veterinary/hydrotherapy)

3.1.1.1 Viscosity

The viscosity is an expression of the resistance to movement in a certain liquid, created by cohesiveness of fluid molecules. Moving in water has a higher resistance than moving in air because of the friction between water molecules and therefore hydrotherapy stimulates training of the muscles with increasing of muscle strength, endurance and muscle size (Wong, 2011). The viscosity helps patients to stand in water before they can stand or walk on land. The viscosity increases as water temperature decreases and this results in easier movement through warm water for weak dogs (McGowan, 2016).

3.1.1.2 Hydrostatic and hydrodynamic pressure

Hydrostatic pressure expresses the pressure the water puts equally on all the body parts depending on how deep the body is immersed in the water. The deeper the body is submerged under water, the higher the hydrostatic pressure and the more there is a swaddling effect (Wong, 2011). The hydrostatic pressure causes an extra pressure on the thorax which will improve the general physical condition by stimulating the muscles used for breathing (McGowan, 2016). The hydrostatic pressure stimulates the sensory skin receptors which decreases the hypersensitivity of the skin, allowing increased movement with less pain sensation. The hydrostatic pressure also has an effect on swelling and congestion in arthritic joints. It helps to reduce peripheral oedema, reduces the heart rate and assists the arterial circulation and pressure in deep and superficial tissues (Dycus, 2017). The lymphatic drainage is increased by the hydrostatic pressure. The hydrodynamic pressure is determined by water currents and include laminal flow, frontal resistance and drag. It can be increased by using water jets (McGowan, 2016).

3.1.1.3 Resistance

The resistance needed to move through the water helps to strengthen weak muscles and improve endurance. The joint flexion is increased in UWTM walking in comparison to walking on ground (Dycus, 2017). The resistance can be increased by using water jets. Swaggering gait, such as seen in dogs with hip dysplasia, can be corrected and stabilized by using the resistance of the water (McGowan, 2016).

3.1.1.4 Buoyancy

The buoyancy is the upward thrust acting on an object that creates an apparent decrease in the weight of a body while immersed and is equal to the weight of the displaced fluid (Hecox et al., 1994). The more the body is immersed in water, the more the weight bearing decreases causing less pressure on the joints. It diminishes the effects of gravity and supports the body in the water (McGowan, 2016). The buoyancy enables weightless exercises, especially for weak and unstable patients who will benefit the most from moving freely in the water because of the reduced load on the joints and muscles. It also improves core stability and flexibility. Due to the buoyancy, the passive range of motion (PROM) is greater in water than on land (Thein et al. 1992).

3.1.1.5 Surface tension

The resistance is slightly higher on the surface of the water due to the specific surface tension. This is caused by the water molecules that have the tendency to adhere at the surface. The surface tension helps to strengthen muscles and improve balance. Due to the surface tension, unsteady patients have a greater reaction time during the exercises but it is harder to lift a limb out of the water (McGowan, 2016).

3.1.1.6 Relative density

The relative density is the ratio of the weight of an object, relative to the weight of an equal amount of water and determines whether an object will float or sink (Haralson, 1986). Densities of specific substances are defined by the specific gravity. If the ratio of the specific gravity of an object is more than one, the object will have the tendency to sink. Objects with a specific gravity less than one, will more likely float. The specific gravity also shows which part off an object will submerged in the water. If the specific gravity of the object is 0,85, then 85% will be under water and 15% will float above the surface (Hexoc et al., 1994; McGowan, 2016).

Because of the relative density and specific gravity, an obese dog will more likely float than a patient with lean muscle or heavily muscled animals who will have the tendency to sink faster. As a result of the relative density, heavily muscled animals and lean animals will have to swim harder to float (Wong, 2011).

3.1.2 Parameters

3.1.2.1 Water temperature

The temperature should range between 28 and 32°C. The warmth of the water allows the blood supply to be increased which has positive effects on pain and relaxation. Warm water provides muscle-relaxation and aids comfort by pain relief due to the increased circulation (Pyrdie and Hewitt, 2015). The temperature of the water also has an impact on the sensory stimulation. If the water is too cold, the blood vessels will constrict and this will contribute to stiffness. Cold water will also result quicker in muscle acidification and tiredness. It is important to keep an eye on the patient during the sessions of hydrotherapy because hyperthermia is a potential risk, especially in brachycephalic dogs (Zink, 2013; McGowan, 2016).

3.1.2.2 Depth

The depth can be individually adjusted on a UWTM, depending on the individual needs of the patient. The higher the water level and the more the body is submerged by water, the more stress is taken off the joints. With water to the greater trochanter, dogs are supporting only 38% of their body weight (Dycus, 2017). This allows the patient to exercise longer and with less pain. Dogs with stability problems will benefit from higher water levels because of the extra support from the water. The depth for training dogs with hip dysplasia is usually midway the shoulder and elbow and with the trochanter major just covered by the water. This provides the most benefits from buoyancy. When the dogs become stronger, it may be considered to lower the depth to increase the resistance and the intensity of the training (Zink, 2013).

3.1.2.3 Speed and duration

By alternating the speed and duration, the intensity of the training can be adjusted to individual needs. Initially many dogs can only tolerate up to 5 minutes of training but will train to perform a hydrotherapy session up to 30 minutes, with or without rest. The speed of the belt of the UWTM is a comfortable walk or trotting speed, different for each individual dog (Zink, 2013).

3.1.2.4 Resistance

The resistance is mainly controlled by the speed the dogs move in the water. Jets may be used in the pool to increase the resistance in the water and the level of difficulty of the exercises. The higher the resistance, the more the muscles will be trained and the endurance will increase. The resistance can be increased by managing the tread speed on the UWTM (Wong, 2011).

3.1.2.5 Massaging and spa

Massaging or manual therapy, especially in a spa system, before and after a hydrotherapy session may benefit the muscles. The spa can be used as a warming-up and relaxation of the muscles before entering the pool or UWTM and before the exercises start. It also has a function in the end of a hydrotherapy session when used to cool down (Wong, 2011). Manual therapy benefits the passive range of motion (PROM) as is described by Ruoti et al. (1997) and it shows that the PROM is more improved in water than compared to on land.

3.1.2.6 Materials

A selection of floatation life vests and harnesses are required to perform hydrotherapy. A life vest is obligatory when swimming in a pool for safety reasons. When the dogs are trained and have a decent swimming technique, a harness can be sufficient. Harnesses are mostly used for practical reasons for the physiotherapist to guide the dogs movements. It is important that the life vest or harnesses do not compromises the complete motion and movement of the dogs. The intensity of a hydrotherapy session can be increased by using balance equipment and leg weights (Zink, 2013).

Fig 3: pug with life vest on UWTM
(From: http://www.veterinairquadrantdenderleeuw.be)

The leg weights are effective for additional muscle build-up and for proprioceptive improvement. The specific gravity of an animal will increase because of the leg weights and this will cause that they need to put more effort into keeping their head above water. Toys and treats can be used to motivate the dogs and to increase owner interaction. For the dogs comfort, head wraps may be used to prevent water from entering the ear canals and to reduce head shaking (Zink, 2013).

3.1.3 Goals of treatment

The main goal of a conservative therapy is to maintain pain control and to prevent further progression of the joint disease (Dycus, 2017). It is known that hydrotherapy has an effect on all kinds of tissue. The main effects are seen on the muscles, tendons, ligaments, cartilage and joint capsule (Millis and Levine, 2014). The goal of hydrotherapy is to reduce pain, stiffness and discomfort, facilitate healing, improve muscle strength and general condition, improving tendon elasticity, relive muscle spasm, maintain cartilage nutrition, restore normal osteokinematic and artrokinematic movements of joints and restore normal functionality (Levine et al., 2005; Sharp, 2008). It is also used for gait and posture re-education, core-stability and to improve proprioception. Hydrotherapy has also a positive effect on the cardiovascular and respiratory function. By applying hydrotherapy, the range of motion, endurance, balance, flexibility and stability can also be increased. The range of motion of the hind limb and the individual flexion of the joints can be increased while swimming (Drum et al., 2015). The stress and normal load on the joints are decreased while training underwater. Low impact exercises such as hydrotherapy can avoid worsening of osteoarthritis. Lastly, education and awareness for the owners about how the body weight needs to be managed is necessary (Bland, 2009; Robertson, 2003). This is primordial because obesity is a risk factor for developing hip dysplasia and degenerative joint disease (Kirkby, 2012). If the dogs keep a normal body condition score (BCS) there is less weight-bearing stress on the joint in comparison with obese dogs (Raghuvir et al., 2013). According to Bland et al. (2009) 32% of the dogs diagnosed with hip dysplasia, have a BCS of 4 or 5 out of 5 and are categorized as obese. Obese dogs will more likely be less active and exercise less than a dog with a normal BCS, contributing to the obesity even more. This again has a great impact on the mobility and global lameness score (GLS) of the dog.

The main problem in dogs with hip dysplasia is laxity of the joint capsule. Conservative management focusses on maintaining pain control and comfort while improving hip range of motion in extension and muscle mass (Dycus et al., 2017). The aim of hydrotherapy as a conservative therapy for hip dysplasia is to restore the normal function of the coxofemoral joint by increasing muscle strength, muscle size, balance and the flexibility of the joint capsule to stabilize the hip joint (Levine et al., 2005).

The positive effects of a conservative therapy are already documented in older literature. According to Barr et al. (1987), conservative therapy consisting of exercise restriction, weight management, analgesics, NSAIDs and physiotherapy can benefit dogs with moderate to severe radiographic signs of hip dysplasia. 76% of 50 dogs had no hindlimb gait abnormality or only a slight abnormality when evaluated by their owners. When they were re-evaluated by veterinary surgeons, 38% of 50 dogs showed no gait abnormality or only a slight pelvic swaying movement. 79% had normal range of motion and 72% had normal exercise tolerance. Smith (1992) describes that young dogs with joint laxity and pain have a 72% probability after 18 months of age to restore to a functional and comfortable state with conservative treatment alone. In a study of Lipowitz (1993) conservative therapy was applied in 68 dogs diagnosed with hip dysplasia when they were immature. This study demonstrated minimal clinical signs of osteoarthrosis after a period of more than 4years. But as conservative management does not cure hip dysplasia, secondary osteoarthrosis may still develop. Due to the unpredictable progression of hip dysplasia, signs of pain and lameness can occur chronically in some dysplastic dogs. In a contrast to the previous studies, Farell (2007) reported that 66% of 74 dogs diagnosed with hip dysplasia and kept on a conservative management, were clinically affected and required NSAIDS on a daily basis according to their owners. The dogs were re-assessed by a veterinary surgeon and there was a high incidence of restricted hip motion, pelvic limb muscle atrophy and pain on hip extension. However, in this study 33% of the dogs had other significant pelvic limb abnormalities (Anderson, 2011). A study of Nganvongpanit (2014) showed that dogs with osteoarthritis secondary to hip disease who had session of hydrotherapy twice weekly for 8 weeks, improved in their lameness, joint mobility, weight-bearing ability, had less pain on palpation and had reduced pain sensitivity in general. This was also confirmed in a study of Henderson (2015).

3.2 Hip dysplasia

Hip dysplasia (HD) can be defined as an abnormal development of the hip joint, resulting in coxofemoral laxity due to incongruity and ineffective soft tissue stabilization of the joint (Demko & McLaughlin, 2005; Lopez, 2012). The laxity causes lateralization of the femoral head and will cause a reduction of the degree that the femoral head is positioned in the acetabulum (Zink, 2013; Kirkby 2012). The increased laxity causes stretching of the joint capsule with increased traction and cartilage erosion (Kirkby, 2012). Pain and limping are associated with microfractures of the acetabular rim and with periosteal lesions (Barr et al., 1987; Ginja, 2009; Harper, 2017). The condition can progress into degenerative changes, subluxation, osteoarthritis, subchondral bone fracture and deformation of the hip joint (Zink, 2013).

Hip dysplasia is common in both young dogs with problems of laxity and in older dogs with symptoms due to osteoarthrosis. It is the most common non-congenital polygenic and heritable developmental orthopedic condition in dogs that causes hind leg lameness in all breeds (Zink, 2013). Because of the ethiology, breeding with dogs affected by hip dysplasia is contraindicated. The cause is multifactorial and is mainly influenced by a genetic aspect, nutrition, exercise and growth speed (Tano, 1998; Dycus, 2017; Van Ryssen, 2018). The prevalence of hip dysplasia is still very high, despite efforts from selective breeding programs to eradicate hip dysplasia (Ginja, 2009).

Clinical symptoms can be minimal or very severe and include swaggering gait, sitting down more than the dog used to do, limping, restricted activity, muscle atrophy, a decreased range of motion and stiffness (Harper, 2017). The dogs often show a bunny-hoping gait and a decreased activity with reluctance to jump (King, 2017). Dogs affected with hip dysplasia often have well-developed muscles in the forelimbs due to overcompensation. They relieve pressure and pain in the hindquarters by shifting their weight to the forelimbs (Tano, 1998). The dogs get caught up in a vicious cycle of progressive muscle loss, pain due to the increased stress on the joints and instability (Harper, 2017).

The diagnosis of hip dysplasia is based on anamneses, orthopedic examination including palpation, evaluation of the ROM and gait analysis but most important are radiographic images with extended hips, the PennHip method or distraction-stress radiographs (Zink, 2013). Based on radiographic findings such as hip laxity and signs of osteoarthritis with osteophyte formation, sclerosis and joint remodelling, the affected dogs can be divided into categories from A to E. The degree of hip laxity can be suspected on a radiograph but to have a better assessment, the hip laxity should be examined on a stress radiograph (Butler, 2017). With the Ortolani test, the passive hip laxity can be palpated. The degree of subluxation can be evaluated using the Norberg angle and femoral overlap method (Butler, 2017). Other diagnostic techniques are Computed Tomography (CT), diagnostic arthroscopy, Magnetic Resonance Imaging (MRI) and ultrasound (Van Ryssen, 2018).

Fig 4: hip dysplasia with laxity on ventrodorsal radiograph (From: http://www.causus.be)

Fig 5: severe osteoarthrosis in a dog with hip dysplasia (From: http://www.causus.be)

The treatment can be either conservative with non-steroidal inflammatory drugs, weight management and physiotherapy or chirurgical. According to an evaluation of the status of canine hydrotherapy in the UK, hip dysplasia is one of the most commonly encountered conditions referred to hydrotherapy centers for rehabilitation (Waining et al., 2011). As an addition to the conservative therapy, nutritional advisement is necessary (Harper, 2017). There are several surgical procedures possible, such as double pelvic osteotomy, juvenile pelvic symphysiodesis, triple pelvic osteotomy, total hip replacement or femoral head and neck ostectomy (Lust, 1993; Van Ryssen, 2018).

The prognosis for canine hip dysplasia depends upon the progression of the disease. The prognosis is good to reserved in cases where severe secondary osteoarthrosis has occurred. Management of the disease is possible with specific treatment where the main goal is to reduce symptoms, prolong the quality of life and the risk of secondary degenerative changes. Curing the disease with conservative treatment is highly unlikely. However, spontaneous improvement is possible, especially in younger dogs (Harper, 2017). The improvement is due to healing of microfractures in the acetabular rim. This can be the case when there is improvement of the joint congruity and stability secondary to remodeling and thickening of the joint capsula. The spontaneous improvement is less likely in older dogs, because of the higher prevalence of secondary osteoarthritis (Harper, 2017).

3.3 Evaluation of canine limb functionality

3.3.1 Pressure plate and gait analysis

Visual gait examination is a subjective diagnostic test with a lot of intra-observer variation and a high risk of bias. Gait analysis with a pressure plate is a noninvasive, valuable, reasonably priced and quick method to measure limb load and to obtain objective quantitative data about the gait pattern of dogs (McLaughlin, 2001). It is used to evaluate the results of treatments for orthopedic and neurological conditions, both conservative as surgical, for study purposes, for the diagnosis of orthopedic conditions or to evaluate disease progression. By using a pressure plate, minimal deviations that are unlikely to be noticed by individuals can be detectable and can be used as markers of subclinical pathology (Ladha, 2017). According to Voss (2007), the ability to differentiate lame and normal dogs using a pressure plate to analyze the gait increases with the severity of the lameness. Dogs normally carry 60% of their body weight on the forelimbs and 40% on their hind limbs but there is no difference in weight bearing between left and right limbs in normal dogs (Tano, 1998).

Fig 6: pressure plate
(From: www2.vet.cornell.edu)

A gait consists of individual strides and each stride is divided into a swing phase where the paw is lifted in the air and a stance phase where the paw has contact with the ground (McLaughlin, 2001; Gordon-Evans, 2012). An individual step therefore consists of a breaking phase, a rolling phase and a propulsions phase which forms an M-shaped curve. The forces resulting from paw impact during the stance phase of a limb are called ground reaction forces (GRF). These forces can be divided into three orthogonal vectors namely vertical (Fz), craniocaudal (Fy) and mediolateral (Fx) forces (Carr, 2016). When the dogs walk over the pressure plate, piezoelectric signals that corresponds with the GRF will be created and stored in a computer system for analyzing it with specific software (Vooijs, 2010).

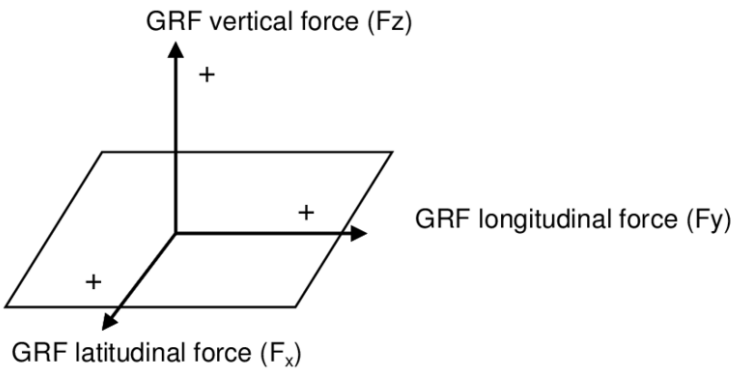


Fig 7: schematic representation of the ground reaction forces
(From : www.researchgate.net)

Pressure plates are used to obtain ground reaction forces (GRF) which are generated when the dogs walk across the measurement region incorporated in the floor surface. These measurements are kinetic-based. (Ladha, 2017). The kinetic gait analysis can be used as a parameter for weight bearing, limb loading and limb functionality. The stance analysis is a parameter for the willingness and ability to place complete weight on a painful limb (Voss, 2007). Asymmetry indices of the peak vertical force, the paw contact area and the vertical impulse determined via gait analysis of pressure plate measurements can be used as reliable indicators for the diagnosis of clinical unilateral hind limb lameness in dogs (Oosterlinck, 2011).

In a study of Tano (1998), data obtained with a force plate revealed that there was a significant increase in peak vertical force (PFz) and mean vertical force over stance (MVF) in a hindlimb that underwent triple pelvic osteotomy (TPO) as a surgical treatment for hip dysplasia compared to bilaterally dysplastic dogs that didn't receive any treatment and normal dogs. An increase in PFz is a sign of more weight bearing and better performance of the affected limb while MVF is used as an indicator of coxofermoral joint function and hind limb loading. In this case the data of the force plate were used to determine the long-term outcome of a surgical approach upon dogs treated for bilateral hip dysplasia and showed that the dogs had greater forces and weight bearing through the TPO corrected limb compared to the unoperated limb. In dogs with bilateral hip dysplasia with minimal clinical signs, the hip that was more affected with a higher mean degenerative joint disease (DJD) and more instability showed a higher mean peak vertical force and a higher MVF (Tano, 1998).

Ground reaction forces obtained with force plate gait analysis are influenced by many variables such as body weight, morphology of the dog and dog breed, gait velocity, acceleration, deceleration, habituation of dogs to the surrounding and trial repetitions, dog handlers and starting distance (Vooijs, 2010; Voss, 2007). Gross differences in gait mechanics between different breeds of dogs have been described in a study where dogs with different conformations were walked on a treadmill with a force plate to assess kinematic parameters (Vilar, 2016). Obtaining results with a pressure plate can only be executed in an instrumented environment, which may be stressful for a dog resulting in unnatural gait. It is important to give the dog the opportunity to familiarize with the room and surface where the measurements will take place (Ladha, 2017). Standardization of ground reaction forces is needed due to the large variation of normal GRF between different dogs or dog groups which makes is more difficult to do a direct comparison. GRF is highly dependent on the velocity and therefore the dog velocities should be kept in the same ranges. Body weight and peak vertical force have a negative correlation while body weight and vertical impulses (VI) have a positive correlation at walking gait. Heavier dogs appear to have a smaller PVG and larger VI but this rather related to differences in relative dog velocity comparing to a smaller dog. When the body weight was used to normalize the GRF, the correlation was significantly reduced but remained positive for VI (Voss, 2010). To compare force plate data between animals, it is important to keep the dog velocity, accelerations and decelerations within a narrow range so the dogs move in the same dynamic status and the parameters should be normalized to the body weight (Vilar, 2016). When the velocity in increased, the peak vertical forces will also be increased and the stance times will be decreased (McLaughlin, 2001).

Dogs with a hindlimb lameness will redistribute their body weight and will shift the position of the center of body mass alter the loading of the limbs. This compensatory strategy to cope with partial loss of limb function will cause deviations in the physiological gait pattern and have an influence on kinematic parameters and the ground reaction forces (Fischer, 2013).

Dogs with asymmetric weight bearing of the pelvic limbs show a greater pelvis vertical motion on the side with a greater peak vertical force and a greater thoracolumbar lateral angular motion towards the side with a lower peak vertical force. This is caused by the compensatory gait pattern due to asymmetry between the left and right pelvic limb and is valuable to evaluate dogs with subtle weight bearing asymmetry in the pelvic limbs (Hicks, 2014).

According to a study of Voss (2007) investigating the accuracy of the force plate gait analysis, the trotting gait was more sensitive and accurate than the walking gait for the differentiation of normal dogs from dogs with a low-grade hindlimb lameness due to stifle or hip joint problems. The gait velocity has a particular effect on the ground reaction forces but in general the two symmetric gaits, trot and walking, are useful to obtain ground reaction forces. There was a significant correlation found between measurements at walk and trot so both gait velocities can be used to differentiate lame dogs from dogs with hindlimb lameness. The evaluation of the peak vertical forces alone however is not sufficient for discriminating normal dogs from lame dogs. A multivariate analysis of ground reaction forces is needed to elevate the accuracy. The kinetic gait analysis does not give any information about the dog in motion and this is the reason why a clinically lame dog can produce normal ground reaction forces (Voss, 2007).

3.3.2 LOAD survey

The Liverpool Osteoarthritis in Dogs (LOAD) owner questionnaire for dogs with mobility problems is a survey written by the University of Liverpool and is a clinical metrology instrument used to assess canine articular disorders. The application of LOAD includes identification of osteoarthritis, to assess the severity of disease or to assess the response to treatment. It is used to determine a repeatable, reliable and sensitive scoring for osteoarthritis. The owners must complete the questionnaire and respond to general questions about the dog's history, his lifestyle, his mobility and level of exercise. The LOAD survey will be used as a scoring system and will be filled in by the owners of dogs that got diagnosed with a form of hip dysplasia at the department of orthopaedics at the Faculty of Veterinary Medicine in Ghent. The individual question scores are summed to provide a LOAD score suggestive of the dog's diseases severity. The scores will also determine whether the dogs had a return to functionality depending on their activities of daily living. A score in between 0 and 10 is indicative for a mild severity, while a score from 11 to 20 is moderate severity. Severely affected dogs will have a score in between 21 and 30. Extremely affected dogs will have a score above 31. The LOAD survey has received peer reviewed validation and it has a good correlation with ground reaction forces of the force-plate data (Hercock 2009; Walton, 2013). The LOAD survey is added as attachement 1 to this master thesis.

3.3.3 Muscle size and range of motion

An indicator for improving limb strength and regaining function is the increase in muscle size. We can use the global muscle condition score (MCS) to evaluate the muscle gain. This evaluation consists of a visual examination and palpation. The muscle size can also be measured using a Gulick or girthometer. It is a tape measure with a spring-loaded tension device. The muscle size can then be measured by taking the circumference of the thigh at a set place and tension (Prydie and Hewitt, 2015).

The girthometer has its use by standardizing the way we get data and get more repeatable results but still, the muscle size is not an objective parameter. When measuring the muscle mass, it is important to use a repeatable place and preferably by the same person but still, we face a lack of repeatability in this indicator.

Fig 8: use of girthometer
(From: www.veteriankey.com)

Fig 9: use of goniometer
(From: www.veteriankey.com)

The range of motion of a joint is the degree of motion that a joint can reach by comprising. It can be determined by using a goniometer on specific bony landmarks. The fixed arm of a goniometer is set on the proximal bony landmark, in the case of the hip joint on the ilium. The fulcrum is placed over the joint axis. In the case of measuring the ROM of the hip, this point is the greater trochanter. Finally, the moving arm is placed on the distal bony landmark, the lateral femoral epicondyle. To measure the degrees of motion, the operator then moves the joint by flexing and extending it (Pyrdie and Hewitt, 2015). Just like the muscle size, the ROM is not a fully objective parameter because of its variables like the person executing the measurement and the cooperation of the dog. Because of the lack of repeatability, these parameters will not be used.

4. Research question and purpose

Very few studies have investigated the long-term results of conservative management or compared hydrotherapy as a conservative therapy to classical approach of hip dysplasia treatment (Waining et al., 2011). Experimentally, vets agree that a lot of dogs function better and have benefited from hydrotherapy as a conservative therapy to cure, to reduce symptoms and progression of joint disease or to postpone surgery. Hydrotherapy is usually combined with medicinal treatment as a multimodal approach consisting activity modification, weight reduction through dietary control and pain management. (Harper, 2017; Kirkby, 2012; Dycus, 2017). In this research, we want to verify the effects of hydrotherapy as a non-surgical treatment for hip dysplasia to determine the benefits it may create on a short term.

In this master thesis, we will use dogs which are diagnosed with light, moderate and severe hip dysplasia. The gait pattern will be evaluated with a pressure plate before and after a series of hydrotherapy sessions on the underwater treadmill in order to put their potential progress in place. The purpose of this study is to obtain objective evidence about the effect of hydrotherapy as a conservative treatment on different grades of hip dysplasia on a short term. We will record the potential progress by pressure plate examination and gait analysis. In addition, the Liverpool Osteoarthritis in Dogs (LOAD) owner questionnaire for dogs with mobility problems will be used to support the objective results. The LOAD survey contains questions about the dog's lifestyle and mobility and the owners are asked to grade their dog's activity, exercise levels, stiffness, lameness or any other changes. By using the LOAD survey, a score that rates the level of disease severity can be determined and be used throughout the conservative treatment program.

The null-hypothesis is that there would be no difference between applying hydrotherapy or not. If the dogs improve, the null-hypothesis will be rejected.

5. Research: hydrotherapy as a conservative therapy for canine hip dysplasia

5.1 Materials and methods

5.1.1 Study population and study design

The population in the following study consists of client-owned dogs who got diagnosed with light, moderate or severe hip dysplasia at the faculty of Veterinary medicine in Ghent from October 2018 to May 2019 and where the owners chose for conservative treatment. The conservative treatment consists of sessions on the UWTM. The dogs are not selected on breed or sexes nor on their body weight so any breed, any sex, intact or neutered, of any age and with any body condition score, can participate to the study.

A pressure plate embedded in a linear track runway on a hard, non-slip surface that is marked out using tape was used to collect data. The dogs were kept on a leash and walked over the pressure plate guided by their owners who were all instructed by the same investigator. The dogs must perform a continuous walking gait without trotting at a mean gate velocity of 2m/s at walk with no acceleration or deceleration. The velocity was determined by videotaping the trials with a camera frontally and laterally. Five valid trails are needed for data analysis of the thoracic and pelvic limbs and the rounds were performed both clockwise and anti-clockwise. The pressure plate is connected to a converter, which interfaced with a computer that stored the samples. Recordings were started and stopped by photoelectric switches. In this study, we will compare the data collected with a pressure plate before and after 10 sessions of hydrotherapy on an underwater treadmill. We will compare the reach, peak vertical force (PFz), the mean force in Z-direction (mean Fz), the symmetry index and the global lameness score (GLS) which is expressed by a color code. The forces are measured in Newtons and then normalized to the dog's body weight which results in data expressed in a static newton force for analysis.

5.1.2 Data analysis

The data in this study is processed and analysed using Microsoft Excel. All data is collected in a table and added as attachment 2 to this master thesis.

5.2 Results and conclusion

Seven dogs started the study but there were only three dogs where we obtained all necessary data. One dog got euthanised after the fourth session of hydrotherapy because the dog was also diagnosed with severe bilateral elbow dysplasia. Three dogs never finished the final session of hydrotherapy and therefore no pressure plate data was collected after the series of hydrotherapy. All dogs that participated are diagnosed with bilateral hip dysplasia. The ages varied from 9 months old to 3,5 years old with an average age of 17 months $\pm$ 10,94 months. The ratio female/male was 3 to 4 and the ratio intact over castrated was also 3 to 4. Different breeds have participated to the study: three Bernese Mountain dogs, one King Charles Spaniel, one English Cocker Spaniel, one Labrador Retriever and one German shepherd. The three dogs where we obtained all data are a Kind Charles Spaniel, an English Cocker Spaniel and a Bernese mountain dog. Some dogs had other orthopaedic problems such as bilateral valgus, medial coronoid disease or bilateral patellar luxation but there was no treatment started for the additional orthopaedic condition.

An overview of the current diet, feeding supplements and medication at the start of the sessions of hydrotherapy is listed in table 1. The body condition score of the dogs where all data was collected varied from 4 to 6 out of 9. It is important to make the owners aware about the fact that obesity is a risk factor so the body weight needs to be controlled throughout the dogs life. The current diet of all dogs was Hill´s Prescription Diet Canine J/D Joint Care or Royal Canin Joint Care. Additionally, a feeding supplement of Flexadin Advanced was given to all dogs. One dog also got an extra supplement of glucosamine and chondroitin. Meloxicam 0,1 mg/kg SID was given to one dog when the clinical complaints were worse. The two other dogs were given a therapy with cimicoxib 2mg/kg SID or robenacocib 2mg/kg SID for 3 weeks, starting from the first session of hydrotherapy.

Table 1: dataset current diet, supplements and medication of dogs where all data was collected

	Breed	**Age**	**BCS**	**Current diet**	**Feeding supplement**	**Medication**
Case 1	King Charles Spaniel	1y 10m	4/9	Hill´s Prescription Diet Canine J/D ®	Flexadin Advanced (Vétoquinol SA)	Meloxicam (Metacam, Boehringer Ingelheim Vetmedica GmbH) 0,1 mg/kg SID
Case 2	English Cocker Spaniel	3y 6m	5/9	Royal Canin Joint Care ®	Flexadin Advanced (Vétoquinol SA)	Robenacocib (Onsior, Elanco GmbH) 2mg/kg SID – 3w
Case 3	Bernese mountain dog	12m	6/9	Hill´s Prescription Diet Canine J/D ®	Aplazyl ® (glucosamine and chondroitin) + Flexadin Advanced (Vétoquinol SA)	Cimicoxib (cimalgex, Vétoquinol SA) 2mg/kg SID – 3w

All dogs had severe complaints of limping, difficulty with jumping and laying down more often. On orthopaedic examination, all dogs showed muscle atrophy on both hind legs and instability, tested with the Barden or Ortolani test. Some dogs showed pain when flexing and extending the hips or showed decreased range of motion. Most of the dogs also showed a waddling gait or bunny hopping gait. In 33% of the cases exercise is limited by the owners, and in the remaining 67% exercise is limited by the dog itself.

The ventrodorsal hip-extended radiographs to diagnose hip dysplasia were all taken under sedation. The dogs were placed in a dorsal recumbency with their hind limbs extended caudally while slightly endorotating the femurs. On the radiographs of the dogs that were selected in this study, the position of the dogs could have been better, especially in the first dog. All three dogs were diagnosed with bilateral hip dysplasia of which the right side was more affected than the left side.

Fig 10: ventrodorsal hip-extended radiograph of case 1

On the radiograph of the dog of case 1, the centre of the femoral head is clearly lateral to the dorsal acetabular edge, indicating subluxation of the coxofemoral joint. The acetabulum is shallow and there is mild smooth new bone production lateral to the dorsal acetabular edge. This dog was diagnosed with moderate bilateral hip dysplasia with mild subluxation of the right coxofemoral joint. A slight difference in muscle size is noticeable when comparing the right, more affected side to the left side. This dog was also diagnosed with bilateral genu valgum and associated bilateral medial patellar luxation grade 4.

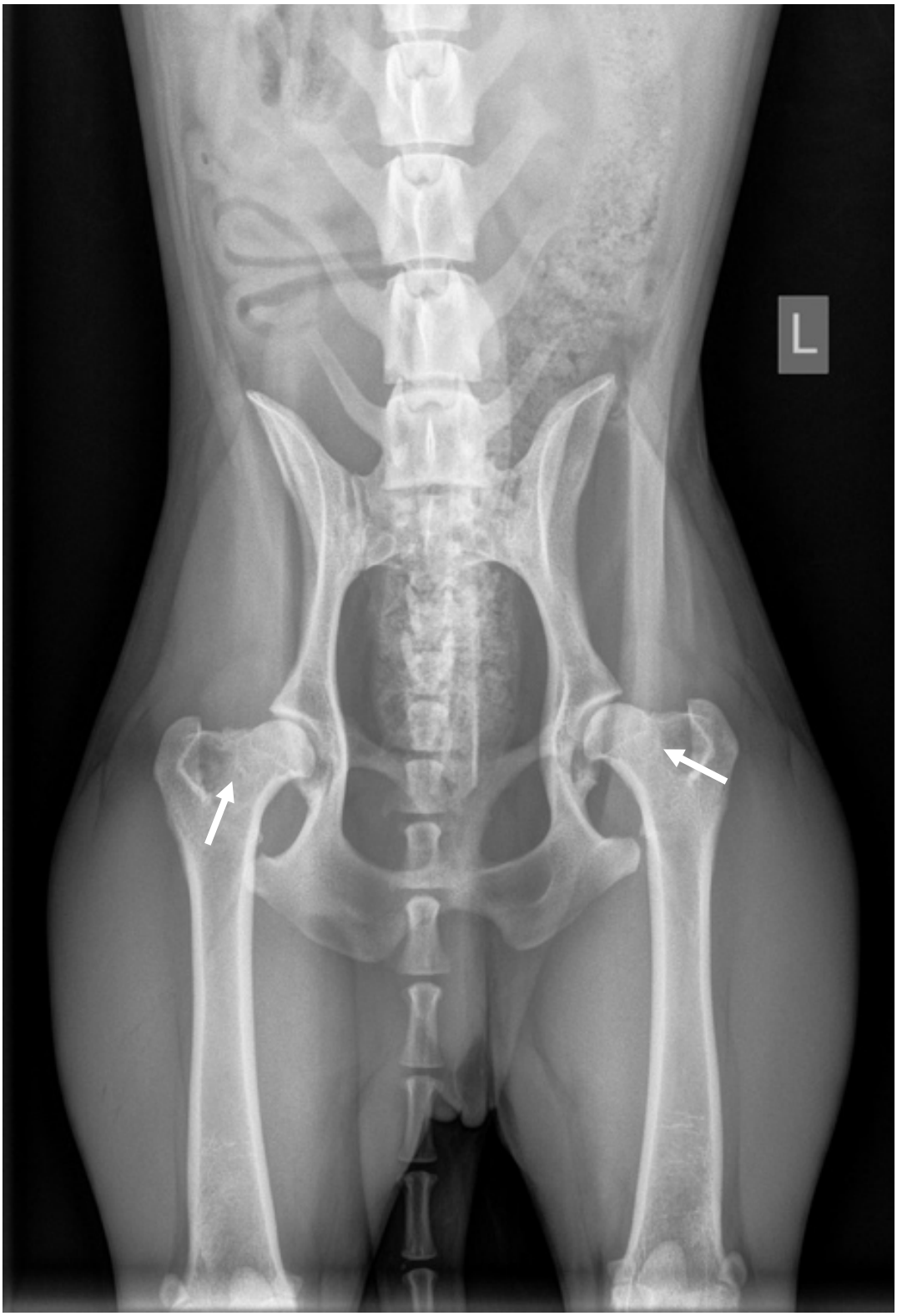


Fig 11: ventrodorsal hip-extended radiograph of case 2

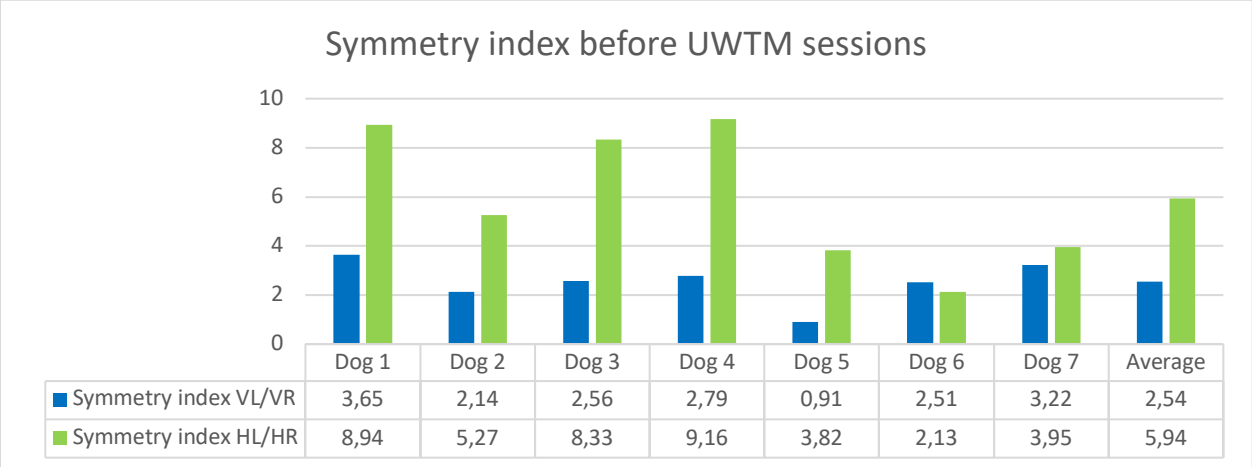
On the radiograph of the dog of case 2, slight flattening of the femoral head is seen. The centre of the femoral head is lateral to the dorsal acetabular edge. There is mild subchondral sclerosis of the craniodorsal acetabulum. An early radiographic sign of osteophytosis is the Morgan line (white arrows). This is a caudocurvilinear enthesophyte in the caudolateral aspect of the femoral neck. There are circumferential osteophytes around the femoral head. This dog is diagnosed with moderate bilateral hip dysplasia with mild sclerosis.

Fig 12: ventrodorsal hip-extended radiograph of case 3

On the radiograph of the dog of case 3, the acetabulum is shallow and barely covering the femoral head. There is severe subluxation of the coxofemoral joint. There is mild smooth new bone formation at the cranial edge of the acetabulum and surrounding the femoral head. The dog is diagnosed with severe bilateral hip dysplasia with secondary subluxation and mild osteoarthritis of the coxofemoral joint.

The UWTM sessions were individualized to each patient's needs. The English Cocker Spaniel was diagnosed with hip dysplasia at the faculty of veterinary medicine in Ghent. He followed the series of hydrotherapy in a local center for physiotherapy but was rechecked at the faculty of veterinary medicine in Ghent after the conservative treatment. The dog had one session of hydrotherapy every week for a period of 10 weeks. The Bernese Mountain dog and king Charles Spaniel had one session of hydrotherapy every week for a period of 10 weeks at the faculty of veterinary medicine in Ghent. Each session lasted 20 minutes. The water level for the Bernese Mountain dog was kept at 450mm and at 225mm for the king Charles Spaniel. The speed was gradually increased from 22 to 35 meter per minute for the Bernese Mountain dog and from 18 to 25 meter per minute for the king Charles Spaniel. When the dogs would have showed worsening of the clinical signs after a session or when the pain medication would have been changed, the sessions would be kept less intensive. In the case of these 2 dogs, there was no worsening of the clinical signs after a session of hydrotherapy.

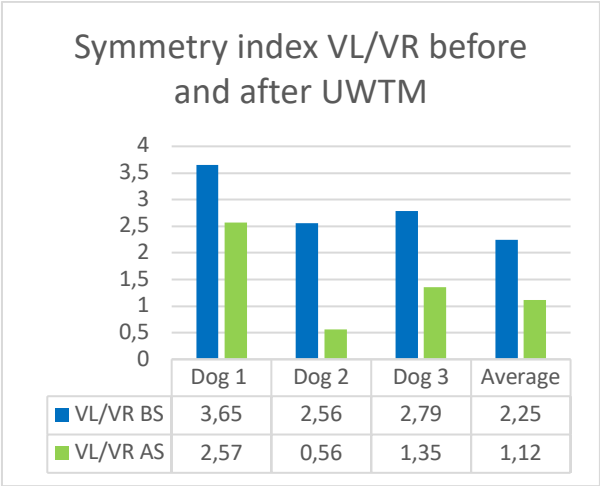
The most significant parameter in the pressure plate examinations before the dogs started the sessions of hydrotherapy was the symmetry index. It is a value to evaluate the asymmetry in the gait of dogs (Volstad, 2017). Ideally the symmetry-index should be 0% but can be normal till 3%. Total asymmetry will be presented when the value is 100%. There is a clinical aspect of asymmetry from a value of 6% or above. All dogs were diagnosed with bilateral hip dysplasia and showed a significant higher symmetry index of the hind legs. This means that there was asymmetric weight bearing of the pelvic limbs and one limb was more affected than the other one.



	Dog 1	Dog 2	Dog 3	Dog 4	Dog 5	Dog 6	Dog 7	Average
Symmetry index VL/VR	3,65	2,14	2,56	2,79	0,91	2,51	3,22	2,54
Symmetry index HL/HR	8,94	5,27	8,33	9,16	3,82	2,13	3,95	5,94

Chart 1: symmetry index of front leg left over front leg right (VL/VR) and hindleg left over hindleg right (HL/HR) before UWTM sessions

After the series of hydrotherapy, the dogs showed a lower symmetry index of the hind legs with an average of 7,20 in comparison with an average of 8,81, only taking the 3 dogs in account that completed all sessions. The asymmetry in the gait pattern of the dogs is decreased but is still above 6%. This means that the asymmetry still has a clinical value.



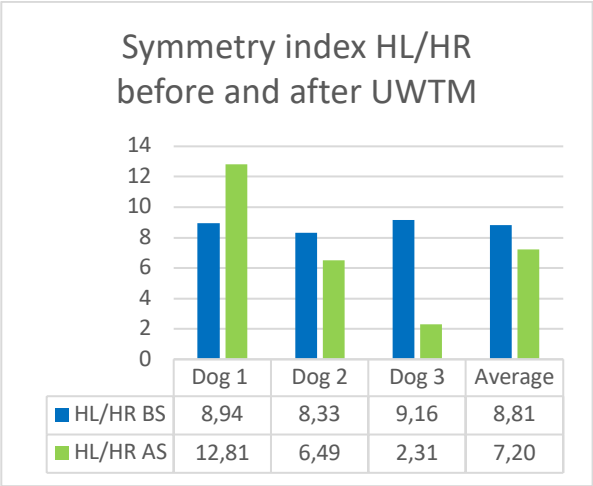
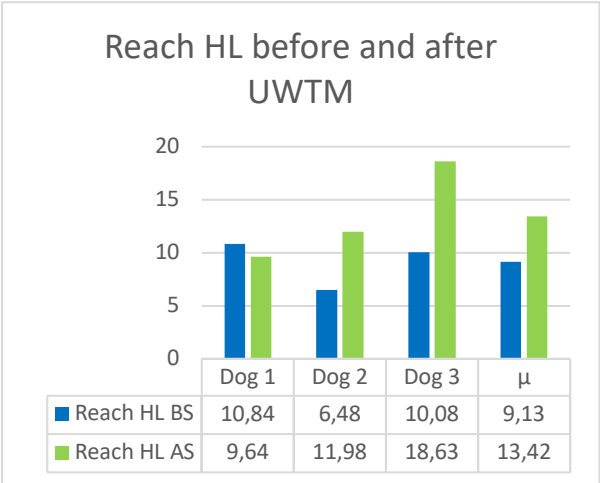


Chart 2 and 3: symmetry index of front leg left over front leg right (VL/VR) and hindleg left over hindleg right (HL/HR) before and after UWTM sessions

The reach is described as the distance in between the centers of two steps from ipsilateral limbs (Carr, 2016). The hypothesis is that when a dog is presented with hip dysplasia, they will not be able to flex the hip joints as much as normal dogs so this will have an influence on the reach. The reach of the dogs has bilaterally increased after the sessions of hydrotherapy from an average of 9,13 and 9,76 to an average of 13,42 and 13,07 respectively on the left hindleg and on the right hindleg.



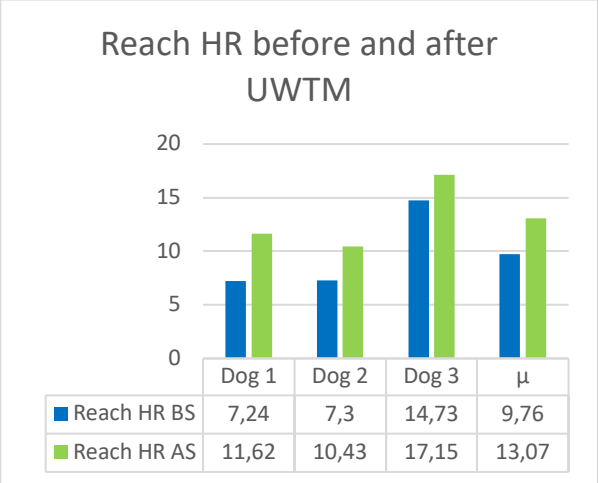
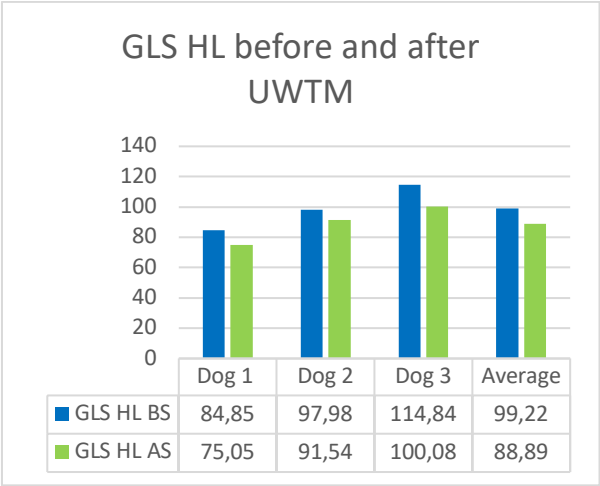


Chart 4 and 5: reach of left hindleg (HL) and right hindleg (HR), before (BS) and after (AS) sessions on the UWTM

The global lameness score is a score of the total pressure index which is mainly influenced by the mean Fz and the symmetry. When a dog has a normal kinetic gait, the GLS of the front limbs should be 30% of the body weight in normal load and the GLS of the hind limbs should be 20% of the body weight in normal load (Carr, 2016). The GLS derives the value of the total pressure index and normalizes them to 100% based on the body weight. When the score is lower than 95%, there is an underload. When the score is above 105%, the dogs show a compensatory overload.



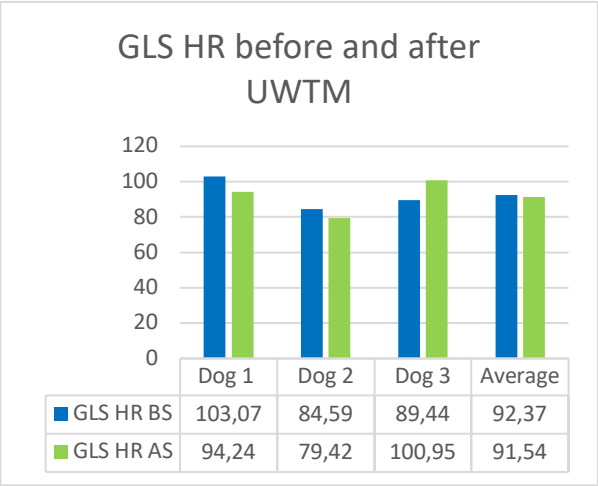
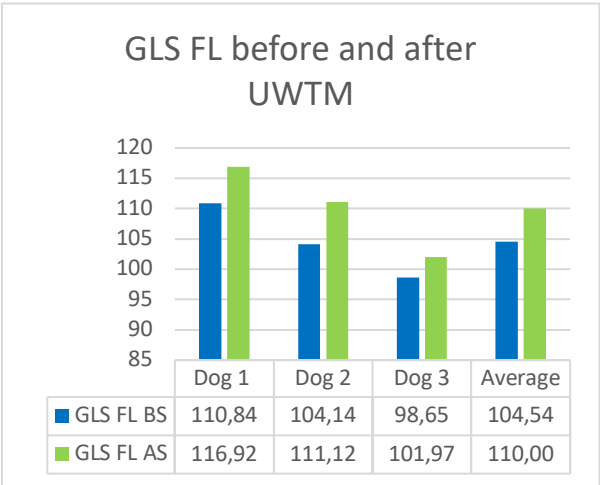


Chart 6 and 7: Global Lameness Score (GLS) of left hindleg (HL) and right hindleg (HR), before (BS) and after (AS) sessions on the UWTM

The global lameness score of the left hindleg after the sessions of hydrotherapy went from an average of 99,22% to 88,89% and the global lameness score of the right hingleg went from an average of 92,37% to 91,54%. These values are under the lower border of 95%, indicating that the dogs still undercompensate the hindlegs and are affected by their hip dysplasia. The dogs had an average GLS of the left frontleg of 104,54% and an average GLS of the right frontleg of 101,06% before the sessions of hydrotherapy. These results are still within the normal limitis of 95% to 105% and are not expected in dogs diagnosed with hip dysplasia. Due to the fact that these dogs undercompensate the hindlegs, we often see compensatory lameness and overcompensation of the frontlegs. After the sessions of hydrotherapy, the average GLS of the left frontleg increased to 110%, which is above the upper limit of 105%. The average GLS of the right frontleg increased to 103,05% but is still within the normal limits.



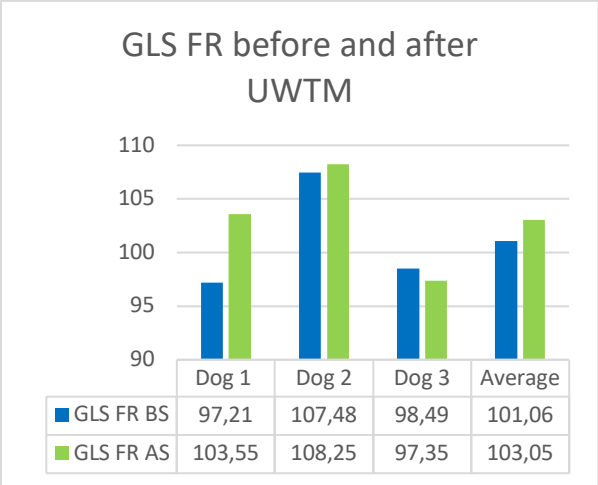
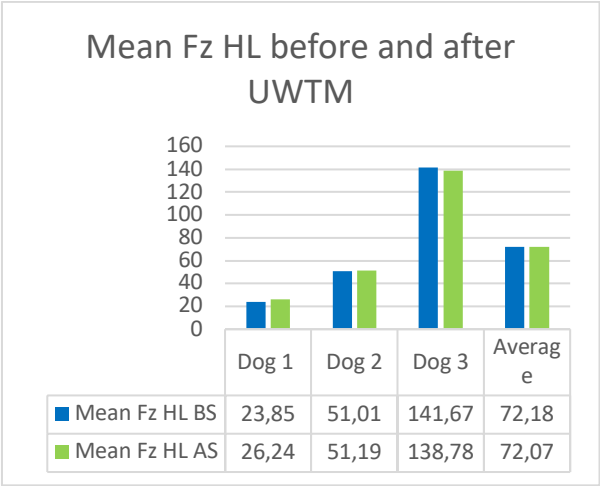


Chart 8 and 9: Global Lameness Score (GLS) of left frontleg (FL) and right frontleg (FR), before (BS) and after (AS) sessions on the UWTM

The mean vertical force (mean Fz) is the average value of all forces measured in the Z-direction and gives an overview of the total load (Carr, 2016). The mean Fz did not show significant changes after the sessions of hydrotherapy.



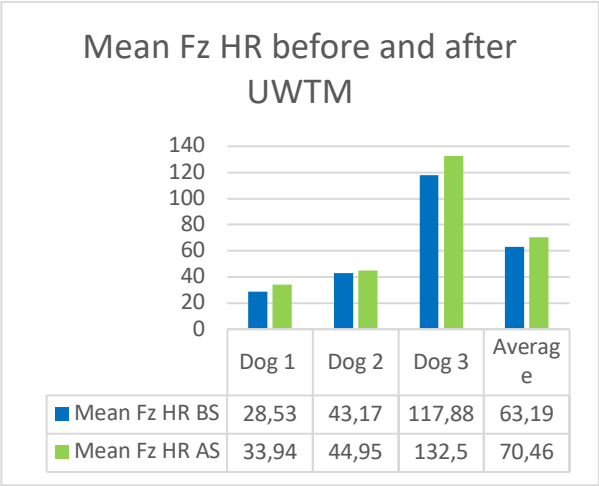
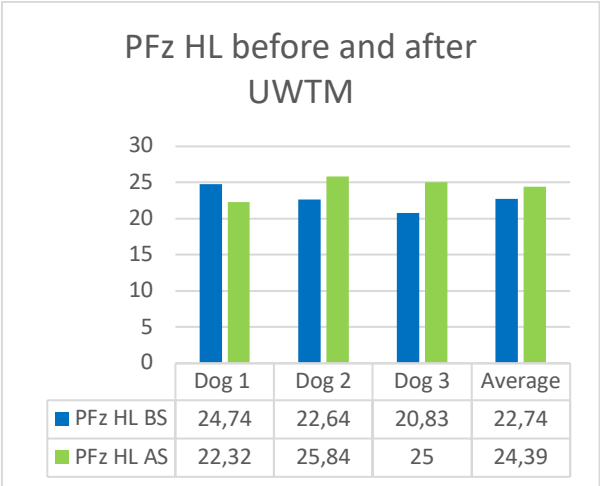


Chart 10 and 11: mean vertical force (Fz) of left hindleg (HL) and right hindleg (HR), before (BS) and after (AS) sessions on the UWTM

The average before hydrotherapy of the left hind leg was 72,18 and was similar after the hydrotherapy with a value of 72,07. The average value of the right hindleg was 63,19 and increased to 70,46 after the sessions of hydrotherapy.



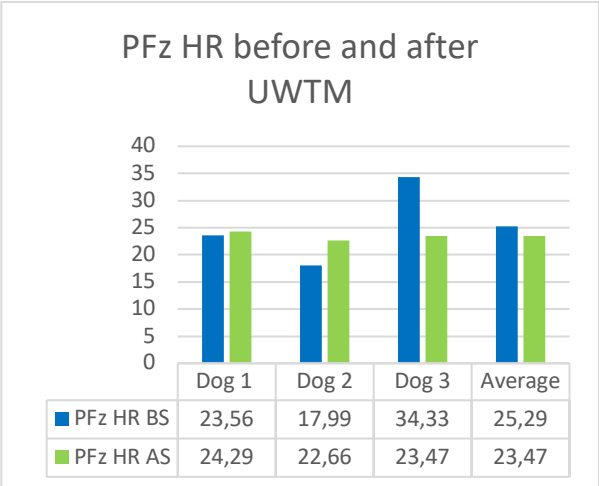


Chart 12 and 13: peak vertical force (PFz) of left hindleg (HL) and right hindleg (HR), before (BS) and after (AS) sessions on the UWTM

The peak vertical force is defined as the maximum force perpendicular to the surface during the stance phase where the paw has contact with the surface (Lascelles, 2006). The higher the velocity, the lower the average duration of the stance phase will be (McLaughlin, 2001).
The peak vertical force of the hindlegs also didn't showed significant changes before and after the hydrotherapy sessions. The average value of the left hind legs increased from 22,74 to 24,39 and the average value of the right hind legs decreased from 25,29 to 23,47 after the hydrotherapy sessions. The reference used at Ghent University for the hind legs is that the value should be lower than 35% of the time of the M-curve, which was the case before and after the hydrotherapy sessions. An increase in peak vertical force would be a sign of more weight bearing and better performance of the affected limb (McLaughlin, 2001).

The LOAD-score from the dogs before the sessions of hydrotherapy varied from 15 to 27 with an average of 20 $\pm$ 5,10**.** This score is used to assess the severity of disease at the outset of treatment. The clinical signs are classified as mild when the LOAD-score is in between 0 and 10 and moderate from 11 to 20. When the LOAD-score is in the range of 21 to 30, the dogs show severe signs of osteoarthritis and when the LOAD-score is above 31, the dogs still have extreme clinical signs. The LOAD-score from the dogs after the sessions of hydrotherapy varied from 9 to 23 with an average of 15,66 $\pm$ 5,73**.** This indicates that the dogs still had moderate to severe clinical signs of osteoarthritis after the hydrotherapy sessions. An overview of the breed, sex, age, body condition score, additional orthopaedic condition that was diagnosed and LOAD-scores are listed in table 1.

Table 2: dataset LOAD score

	Breed	**Sex**	**Age**	**BCS**	**Additional orthopaedic condition**	**LOAD score before UWTM**	**LOAD score after UWTM**
Case 1	King Charles Spaniel	FC	1y 10m	4/9	Bilateral patellar luxation grade 4	27	23
Case 2	English Cocker Spaniel	MC	3y 6m	5/9	-	15	9
Case 3	Bernese mountain dog	F	12m	6/9	Suspicion of medial coronoid disease	18	15
Case 4	Labrador retriever	MC	10m	5/9	Suspicion of medial coronoid disease	-	-
Case 5	German Sherperd	MC	9m	4/9	Bilateral fragmented anconeal process	-	-
Case 6	Bernese mountain dog	M	12m	7/9	Bilateral mild valgus	-	-
Case 7	Bernese mountain dog	F	12m	5/9	-	-	-

The dog of case 1 has shown a great improvement in the level of exercise. The dog used to go for a walk of 2 to 3 km a day and one big walk of 8 km during the weekend. Now the dog goes for a walk of 2 to 3 km twice a day and a big hike up to 18 km during the weekend. The dog had a moderate activity level and is now more active, according to the owners. After lying down, the dog showed some moderate stiffness which has improved to a mild stiffness after the sessions of hydrotherapy. During exercise the dog frequently sat down to rest but after the sessions of hydrotherapy, this improved to occasionally. The owners still believe that the hip dysplasia has a moderate effect on the ability to exercise of the dog, despite an improvement in the level of exercise.

The level of exercise stayed similar before and after the sessions of hydrotherapy in the case of dog 2. The dog goes for walks of 1 to 2 km twice a day. After lying down, the dog showed moderate stiffness before the sessions of hydrotherapy which improved to mild stiffness after the sessions of hydrotherapy. During exercise the dog hardly ever sat down to rest but after the sessions of hydrotherapy, this was never seen again. The dog still had a mild effect of his hip dysplasia on his ability to do exercise, ever after the conservative therapy. But the owners described the dog to be more active and more playful.

The dog of case 3 showed an increased level of exercise after the sessions of hydrotherapy. She went for walks of 1 to 2 km twice a day to walks of 1 to 2 km four times a day. The dog went from fairly active to very active, according to the owners. She showed moderate stiffness after lying down and her hip dysplasia had a moderate effect on her ability to exercise. These two parameters didn't change after the sessions of hydrotherapy. During exercise, the dog still occasionally sits down to rest, which also hasn't changed after the sessions of hydrotherapy.

6. Discussion

In this study we wanted to evaluate the effect of hydrotherapy sessions on the UWTM as a non-surgical conservative treatment for canine hip dysplasia using pressure plate gait analysis.

An improvement was noticed in the symmetry index of the hind legs. All dogs were diagnosed with bilateral hip dysplasia and showed a significant higher symmetry index of the hind legs. Meaning there was asymmetric weight bearing of the pelvic limbs and one limb was more affected than the other. Voss (2007) described a load redistribution from the affected limb to the contralateral limb that occurs with chronic hindlimb lameness. The results from this study confirm Voss' findings. After the series of hydrotherapy, the dogs showed a lower symmetry index but is still above 6%. This means that the asymmetry still has a clinical value. The slight improvement can be explained by the fact that the hydrotherapy potentially resulted in an increase in muscle strength in the hind limbs and an increase in general core stability.

A second parameter that improved was the reach of the hind legs. This can be explained by the theory that the dogs are able to take bigger steps because they are less disabled by their hip dysplasia. The dogs are able to place the hind limbs more cranially when walking. The improved reach is objective evidence that the dogs have an increased joint flexibility and an improved range of motion of the coxofemoral joint.

The global lameness score (GLS) of the hind legs didn't show significant changes after the sessions of hydrotherapy. The values were still under the lower border of 95%, indicating that the dogs still undercompensate the hindlegs and are affected by their hip dysplasia. Values under 95% indicate underload. The GLS of the front legs slightly worsened after the sessions of hydrotherapy. Due to the fact that dogs with hip dysplasia undercompensate the hindlegs, we often see compensatory lameness and overcompensation of the frontlegs. In this study, the GLS before the therapy was still within normal limits. This can be explained by the fact that the dogs in this population also got diagnosed with a second orthopeadic condition that could have an influence on the gait pattern. The mean vertical force and peak vertical force didn't show significant changes after the conservative therapy.

The LOAD-score of all three dogs decreased after the conservative treatment with hydrotherapy. The activity level of the dogs increased. The stiffness after a lie-down period decreased and the dogs had to rest less during exercise. This means that a clinical improvement is seen, although most dogs still had a mild effect of their hip dysplasia on their ability to do exercise.

A study of Nganvongpanit (2014) showed that dogs with osteoarthritis secondary to hip disease who had session of hydrotherapy twice weekly for 8 weeks, improved in their lameness, joint mobility, weight-bearing ability, had less pain on palpation and had reduced pain sensitivity in general. The range of motion of both extension and flexion of the hip joint was found to be significantly improved with 5% after 8 weeks of hydrotherapy. These results are confirmed in this study. The dogs had hydrotherapy once a week for 10 weeks and improved their joint mobility, range of motion and weight-bearing ability.

Nganvongpanit (2012) described that hydrotherapy can give pain relief because the water takes pressure off the joints, bones and muscles. Pain on palpation was significantly improved at week 6 during the study of Nganvongpanit (2014). The dogs in this master thesis experienced less pain after the conservative treatment and had an increased activity level according to the owners. Therefore hydrotherapy can be used as a nonpharmaceutical component in a multimodal pain management approach for canine hip dysplasia.

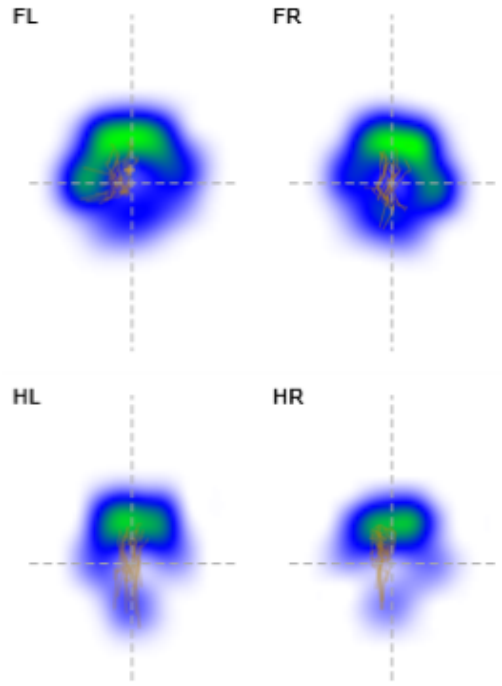


Fig 13 : Mean contact areas and dynamic pressure distribution of a dog diagnosed with moderate bilateral hip dysplasia before sessions of hydrotherapy

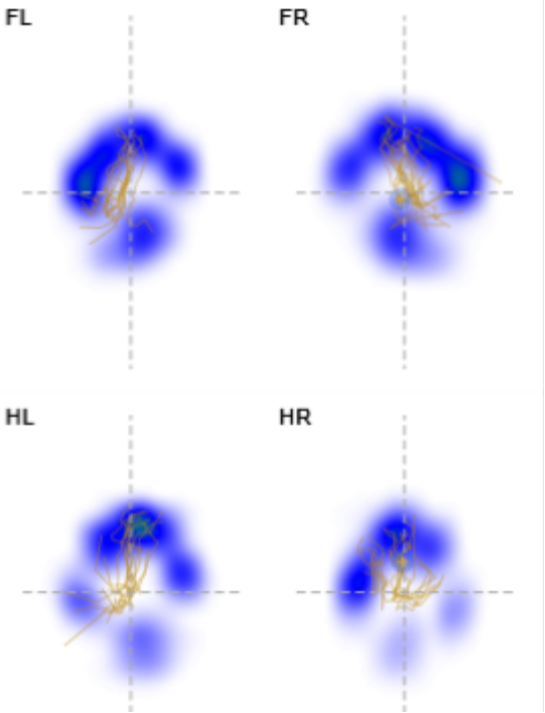


Fig 14 : Mean contact areas and dynamic pressure distribution of a dog diagnosed with moderate bilateral hip dysplasia after sessions of hydrotherapy

When observing dogs with hindlimb lameness, we can see that their weight is shifted cranially. This load redistribution is called compensatory lameness and is a coping strategy to relieve pressure from the hindquarters and spare the painfull limbs (Butler, 2017). The forelimbs are usually placed more caudally and the head and neck are often extended and lowered to help offset weight. Dogs diagnosed with hip dyplasia often show a bunny hopping gait and a hip hike in which the hip of the unaffected side appears lower than the affected hip when observing the gait from behind. This is caused by an increased vertical motion of the hip on the lame side (Carr, 2016). On the illustrating figure of a dog with hip dysplasia before the sessions of hydrotherapy, we can clearly see that there is more pressure being put on the frontlimbs causing an increased density of the distribution pattern in the frontlimbs. There is a more even distribution pattern of the mean contact area and dynamic pressure distribution after the sessions of hydrotherapy. This can be explained by the improvement in the symmetry index caused by a potential increase in muscle strength in the hind limbs and an increase in general core stability.

We cannot deny that the acquisition of applying hydrotherapy as a conservative therapy has its limitations. In dogs with a mild form of hip dysplasia, especially before they have clinical complaints, hydrotherapy is useful to gain core stability, to improve muscle strength and to increase joint flexibility. In the case of dogs with severe bilateral hip dysplasia, a surgery is inevitable but hydrotherapy can have its value to gain muscle strength pre-operatively. It is very important to select the right type of patients that are suited to have conservative therapy for hip dysplasia. Conservative therapy is mainly advised for dogs that show mild clinical signs and that don't have severe degenerative changes on medical imaging. The dogs also have variations in individual training. All dogs in this study had a training scheme personalized to their ability and their motivation to perform the hydrotherapy.

The results of this master thesis were not entirely as expected. Based on the existing literature a more significant improvement was expected after the series of hydrotherapy. This can be explained by the fact that dogs included in this study had a quiet severe grade of hip dysplasia. This illustrates the importance of selecting the patients where conservative treatment can result in an equal or even better outcome than surgical intervention. A more significant improvement can be expected in the dogs diagnosed with mild to moderate hip dysplasia. Another factor that had an influence on the results is the presence of additional orthopedic conditions in the patients included in this study. This could disguise overcompensation of the forelimbs or worsening of the gait pattern of the hindlimbs.

According to a study of Voss (2007) investigating the accuracy of the force plate gait analysis, the trotting gait was more sensitive and accurate than the walking gait for the differentiation of normal dogs from dogs with a low-grade hindlimb lameness due to hip joint problems. The walking gait is preferable to the trotting gait for dogs with a sever lameness because they are more likely to be too lame to use the affected leg at a trot. For dogs with a low-grade lameness or in studies to examine treatment outcomes, the trot seems to be preferable to the walk because of the higher sensitivity and accuracy to differentiate normal dogs from lame dogs.
In this study, only the walking gait was used to obtain pressure plate data. This means that we used a technique with a lower sensitivity and accuracy but most dogs only get presented at the faculty when the owners notice that the dogs are clearly limping. In addition, Voss (2007) also described a significant correlation between measurements at walk and trot. The walking gait is therefore sufficient to diagnose a hindlimb lameness. The trotting gait would have been better to evaluate minimal differences, unlikely to be noticed by individuals, of gait improvement during the therapy. The trotting gait is therefore especially recommended in a study environment for dogs with a low-grade lameness to find minimal deviations.

The pressure plate definitely has its value to use in the future, especially when more investigation is done. It is a reliable and reproducible method to obtain objective data about limping when standardized collection protocols are used. It will mainly have a function as a specialized gait analysis technique enabling veterinarians to accurately diagnose subtle lameness, evaluate treatment protocols, for research purpose and to accurately select the right time for athletic dogs to return to exercise after an injury (McLaughlin, 2001).

It is important to acknowledge the limitations of this study. The population of dogs only consisted of seven dogs and we were only able to collect all necessary data in the case of three dogs. This population is too small to acknowledge the assumptions made in this study. To have a higher scientific value of the correlations, further investigation and expansion of the population is needed. Moreover, not all dogs in this study had the same grade of hip dysplasia. The study didn't include a control group of non-swimming group of dogs diagnosed with hip dysplasia. For ethical reasons, no dog should be deprived of pain relieve treatment. When comparing results from different studies that use pressure plate data, variables in data acquisition and patient material complicate a direct comparison of the obtained results (Voss, 2007). The population in this study included dogs with combined orthopedic issues where no treatment was started for the additional orthopedic issue. The values of the pressure plate data are possibly influenced by the additional shift in weight-bearing and potential limping caused by the additional orthopedic issue. Due the fact of the prospective nature of the study, there was no possibility to use existing records because there were no data of the pressure plate available prior to September 2018.

From this pilot-study we can conclude that hydrotherapy has the potential to improve the gait pattern in dogs with bilateral hip dysplasia. The main improvement was seen in the reach of the hind legs, indicating an improvement in the range of motion of the coxofemoral joint. Further investigation should be done to provide more information on the long-term result after hydrotherapy as a conservative treatment for hip dysplasia.

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8. Attachments

Attachment 1: LOAD survey

UNIVERSITY OF LIVERPOOL

Initial Visit

Liverpool Osteoarthritis in Dogs (LOAD)

Owner questionnaire for dogs with mobility problems

Dear Owner,

Thank you for agreeing to complete this questionnaire.

Your assistance in this endeavour will enable us to gather valuable information about your pet, and is a vital component in our ongoing quest to combat painful and debilitating diseases such as arthritis. It is important that all questions are answered to the best of your ability and if you have a question regarding the questionnaire, please contact a member of staff from your veterinary clinic.

Thank you again for your help.

Answering the questions

Most of the questions are fairly simple. It is important that you only tick one box per question except where otherwise requested (e.g. Question 4 under Lifestyle).

If you are in any doubt as to how to answer a particular question, please contact a member of staff for assistance.

Owner's name: Pet's name:

Owner's phone number: Client number: Today's date: YYYY-MM-DD

Breed of pet: Pet's age: Sex: M ○ F ○

For office use only Reference limb: LF ○ RF ○ LH ○ RH ○ Reset

Background

1. How long has your pet been suffering with his/her mobility problem?

○ Up to 6 months ○ 6–12 months ○ 12–24 months ○ 24–36 months ○ more than 36 months

2. Has your dog been diagnosed as suffering from any other problems in addition to his/her orthopaedic disease?

○ No ○ Yes Please list these if you can:

3. If you can, please list any medications that your pet is currently receiving, stating when he/she received the last dose of each:

Lifestyle

1. In the last week, on average, how far has your dog exercised each day?

- ○ 0–1 km (0–0.6 miles)
- ○ 1–2 km (0.6–1.2 miles)
- ○ 2–3 km (1.2–1.9 miles)
- ○ 3–4 km (1.9–2.5 miles)
- ○ more than 4 km (more than 2.5 miles)

2. In the last week, on average, how many walks has your dog had each day?

- ○ 0
- ○ 1
- ○ 2
- ○ 3
- ○ 4
- ○ more than 4

3. What type of exercise is this?

- ○ Always on lead
- ○ Mostly on lead
- ○ Mostly off lead
- ○ Always off lead
- ○ Working

4. Are there particular days of the week upon which your dog has significantly more exercise?
(Tick more than one box if necessary.)

- ○ Monday
- ○ Tuesday
- ○ Wednesday
- ○ Thursday
- ○ Friday
- ○ Saturday
- ○ Sunday

Reset

5. On what sort of terrain does your dog most often exercise?

- ○ On level grass
- ○ In woodland
- ○ On street
- ○ Over rough hill ground

6. At exercise, how is your dog handled?

- ○ Walk on lead
- ○ Walk off lead
- ○ Trot
- ○ Run freely

7. Who limits the extent to which your dog exercises?

- ○ You
- ○ Your dog

Mobility

For office use only

Generally

1. How is your dog's mobility in general?

○ Very good ○ Good ○ Fair ○ Poor ○ Very poor

0

2. How disabled is your dog by his/her lameness?

○ Not at all disabled ○ Slightly disabled ○ Moderately disabled ○ Severely disabled ○ Extremely disabled

0

3. How active is your dog?

○ Extremely active ○ Very active ○ Moderately active ○ Slightly active ○ Not at all active

0

4. What is the effect of cold, damp weather on your dog's lameness?

○ No effect ○ Mild effect ○ Moderate effect ○ Severe effect ○ Extreme effect

0

5. To what degree does your dog show stiffness in the affected leg after a 'lie down'?

○ No stiffness ○ Mild stiffness ○ Moderate stiffness ○ Severe stiffness ○ Extreme stiffness

0

At exercise

6. At exercise, how active is your dog?

○ Extremely active ○ Very active ○ Fairly active ○ Not very active ○ Not at all active

0

7. How keen to exercise is your dog?

○ Extremely keen ○ Very keen ○ Fairly keen ○ Not very keen ○ Not at all keen

0

8. How would you rate your dog's ability to exercise?

○ Very good ○ Good ○ Fair ○ Poor ○ Very poor

0

For office use only

9. What overall effect does exercise have on your dog's lameness?

○ No effect ○ Mild effect ○ Moderate effect ○ Severe effect ○ Extreme effect

0

10. How often does your dog rest (stop/sit down) during exercise?

○ Never ○ Hardly ever ○ Occasionally ○ Frequently ○ Very frequently

0

11. What is the effect of cold, damp weather on your pet's ability to exercise?

○ No effect ○ Mild effect ○ Moderate effect ○ Severe effect ○ Extreme effect

0

12. To what degree does your dog show stiffness in the affected leg after a 'lie down' following exercise?

○ No stiffness ○ Mild stiffness ○ Moderate stiffness ○ Severe stiffness ○ Extreme stiffness

0

13. What is the effect of your dog's lameness on his/her ability to exercise?

○ No effect ○ Mild effect ○ Moderate effect ○ Severe effect ○ Extreme effect

0

Thank you once again for completing this questionnaire.
Please return the form to a member of staff.

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Clicking LOAD Score will tabulate your score once.
Reset is not available for this function.

LOAD Score = 0

NOVARTIS ANIMAL HEALTH

Attachment 2: data

BEFORE UWTM	Reach HL	Reach HR	Symmetry index VL/VR	Symmetry index HL/HR	GLS FL	GLS FR	GLS HL	GLS HR
Dog 1	10,84	7,24	3,65	8,94	110,84	97,21	84,85	103,07
Dog 2	1,31	2,26	2,14	5,27	102,65	103,99	87,64	102,4
Dog 3	6,48	7,3	2,56	8,33	104,14	107,48	97,98	84,59
Dog 4	10,08	14,73	2,79	9,16	98,65	98,49	114,84	89,44
Dog 5	4,57	3,48	0,91	3,82	103,08	103,6	98,06	91,92
Dog 6	/	/	2,51	2,13	95,2	100,09	105,73	101,33
Dog 7	1,27	5,5	3,22	3,95	95,96	95,59	111,04	101,63
Average	*5,76*	*6,75*	*2,54*	*5,94*	*101,50*	*100,92*	*100,02*	*96,34*
Standard deviation	*3,79*	*4,01*	*0,81*	*2,63*	*5,02*	*3,94*	*10,45*	*6,97*

BEFORE UWTM	Mean Fz FL	Mean Fz FR	Mean Fz HL	Mean Fz HR	PFz FL	PFz FR	PFz HL	PFz HR
Dog 1	52,38	48,7	23,85	28,53	54,07	55,42	24,74	23,56
Dog 2	118,76	123,95	69,44	77,16	43,01	41,28	38,04	21,98
Dog 3	83,67	88,07	51,01	43,17	28,53	34,66	22,64	17,99
Dog 4	209,24	197,9	141,67	117,88	46,77	32,43	20,83	34,33
Dog 5	120,89	118,72	77,44	71,75	51,45	56,78	31,74	37,88
Dog 6	101,68	106,9	75,28	72,15	37,54	25,78	21,61	27,83
Dog 7	166,3	155,92	128,39	118,64	66,23	69,48	25,81	16,67
Average	*121,85*	*120,02*	*81,01*	*75,61*	*46,80*	*45,12*	*26,49*	*25,75*
Standard deviation	*48,28*	*44,16*	*38,31*	*31,48*	*11,25*	*14,61*	*5,80*	*7,43*

AFTER UWTM	Reach HL	Reach HR	Symmetry index VL/VR	Symmetry index HL/HR	GLS FL	GLS FR	GLS HL	GLS HR
Dog 1	9,64	11,62	2,57	12,81	116,92	103,55	75,05	94,24
Dog 2	11,98	10,43	0,56	6,49	111,12	108,25	91,54	79,42
Dog 3	18,63	17,15	1,35	2,31	101,97	97,35	100,08	100,95
Average	*13,42*	*13,07*	*1,49*	*7,20*	*110,00*	*103,05*	*88,89*	*91,54*
Standard deviation	*3,81*	*2,93*	*0,83*	*4,32*	*6,15*	*4,46*	*10,39*	*9,00*

AFTER UWTM	Mean Fz FL	Mean Fz FR	Mean Fz HL	Mean Fz HR	PFz FL	PFz FR	PFz HL	PFz HR
Dog 1	62,93	59,77	26,24	33,94	59,53	60,9	22,32	24,29
Dog 2	87,24	88,21	51,19	44,95	32,44	38,77	25,84	22,66
Dog 3	214,46	208,75	138,78	132,5	46,09	39,74	25	23,47
Average	*121,54*	*118,91*	*72,07*	*70,46*	*46,02*	*46,47*	*24,39*	*23,47*
Standard deviation	*66,45*	*64,58*	*48,26*	*44,10*	*11,06*	*10,21*	*1,50*	*0,67*