An Investigation into the Effects of a New Pulsed Electromagnetic Field Therapy Device on Kinetic and Kinematics in Dogs.

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Abstract

The investigation aims to appraise how Pulsed Electromagnetic Field Therapy (PEMFT) in the form of a KORA mat can influence kinetic (asymmetry of limb loading) and kinematic (stride length, protraction and retraction) parameters of dogs within walk and trot. Though PEMFT has been well documented in humans, limited studies exist in canine use, yet it is becoming extensively used within canine rehabilitation. A total of 6 greyhounds were recruited for the randomised, double blinded controlled trial which had kinetic measurements in the form of limb loading asymmetries, and kinematic measures such as SL, protraction and retraction recorded. Application of a PEMFT in the form of a KORA mat was applied for 30 minutes, either as a sham (switched off) or treatment (painkiller setting) after which all parameters were measured again. This process was repeat after a 2-week washout period, where sham or treatments were swapped so each dog had received one of each throughout the trial. Kinetic treatment group measures were all significant and one sham group ($P<0.05$). Hindlimb protraction and retraction significantly reduced ($P<0.05$) and the remaining protraction and retraction were insignificant ($P>0.05$). The SL reduced significantly after treatment ($P<0.05$) however, SL was not significantly different ($P>0.05$) between SL before and after for the sham group, nor the treatment group versus the change for the sham group. Due to the dogs being of a particular breed these results may not be applicable to the entire canine population and the dogs lying down may have influenced the movement post sham and treatment, therefore influencing results. Further studies could incorporate pain measurements pre and post treatment through an algometer and muscle usage through an electromyography device to further assess the influence of PEMFT. The PEMFT KORA mat improved the dogs' asymmetry therefore increased equal limb loading which, according to research, could suggest reduced pain levels. This study suggests that PEMFT can improve canine locomotion and so positively influencing musculoskeletal health. Therefore, PEMFT is a useful tool for canine rehabilitation. Key words: PEMFT, KORA, kinetics, kinematics.

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List of Abbreviations

A/m²	Amperes per metre squared.
Ca2+	Calcium.
Cm	Centimetre.
Hz	Hertz.
IVDD	Intervertebral Disc Disease.
GRF	Ground reaction force.
Kg	Kilogram.
K+	Potassium.
M.	Metres.
mT	Mega Tesla.
mV	Millivolt.
N.	Newtons.
Na+	Sodium.
NO	Nitric Oxide.
NSAID	Non-Steroidal Anti-Inflammatory Drug.
OA	Osteoarthritis.
PEMFT	Pulsed Electromagnetic Field Therapy.
PPS.	Pulses per second.
QL	Quality of life.
SL	Stride length.
TGF-ß	Transforming Growth Factor.
TSS	Tekscan Stride Way System.

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1 Introduction

The canine industry is currently growing in the UK with an estimated 8 million population in 2018 (Anderson *et al.*, 2018). As the canine population grows, so does the demand for veterinary care with certain pathologies also increasing, such as osteoarthritis (OA) (Anderson *et al.*, 2018; Summers *et al.*, 2019). OA is a degenerative disease which can cause inflammatory joint pain that currently has no cure but only management (Anderson *et al.*, 2020). Treatments for OA can vary from Non-Steroidal Anti Inflammatory Drugs (NSAIDs) (Sullivan *et al.*, 2013) yet though veterinary medicine has advanced, these drugs still risk gastrointestinal and renal systems long term issues (Lees *et al.*, 2004; Bergh and Budsberg, 2005). The greyhound industry made up 0.6% of the canine population under veterinary care in the UK in 2019 and there was a high rate of injuries reported through racing (O'Neill *et al.*, 2019).

Pulsed Electromagnetic Field Therapy (PEMFT) is a non-invasive treatment which offers pain relief for such musculoskeletal issues including OA (Wang *et al.*, 2024). Veterinary Physiotherapists often use PEMFT for a varying number of issues as it can improve bone healing, neurological signalling and also offers a calming setting and can also be used in conjunction with other modalities and treatments (Gaynor *et al.*, 2018). There are several PEMFT devices such as handheld, blankets to cover the animal or mats for animals to lie on, however there is limited research into mat PEMFT applicators. Though PEMFT has been researched excessively within the human field, there is less research in the canine field.

Veterinary Physiotherapists assess animals through their biomechanics, typically by eye however equipment allows a more accurate measure of the animals limb cycle pattern (Lee and Pollo, 2001; Back and Clayton, 2013). Through such assessments, lameness can be established and lameness is also linked to pain (Dyson, 2014; Mohsina *et al.*, 2014) as it has been well documented that canines will load less weight onto a lame limb in order to reduce the pain sensation which also creates further compensations such as altered stride length (SL), protraction and retraction (Rumph *et al.*, 1995; Duberstein *et al.*, 2013; Back and Clayton, 2013; Reicher *et al.*, 2020). Therefore, kinetic and kinematic analysis could be measured to assess the influence of PEMFT treatment.

2 Aims

The investigation aims to appraise how PEMFT in the form of a KORA mat can influence kinetic and kinematic parameters of dogs within walk and trot. Parameters involve limb loading of forelimbs and hindlimbs along with protraction and retraction of all limbs in walk and trot. Comparison of these results to sham treatments will be made to assess whether the PEMFT specifically elicited any responses found.

2.1 Objectives

1. Investigate whether the symmetry of limb loading when walking and trotting on a 'Stride Way' platform changes, following PEMFT treatment from the KORA mat.
2. Investigate whether stride length and protraction and retraction of forelimbs and hindlimbs in walk and trot changes, following PEMFT treatment from the KORA mat.
3. Compare the results found from the above parameters from the application of the KORA mat in the form of the pain killer setting (treatment), to the same parameters following application of the KORA mat switched off (sham).
4. Use the above results to determine the effect of PEMFT on canine biomechanics.
5. Offer insights into how PEMFT can influence biomechanics to be more symmetrical through less asymmetry within limb loading, promoting a globally more symmetrical musculoskeletal system and therefore healthier individual less prone to compensations.

2.2 Hypotheses

Null Hypotheses (H0a):
There will not be a statistically significant difference in symmetry of limb loading before and after application of the PEMFT treatment via the KORA mat.

Null Hypotheses (H0b):

There will not be a statistically significant difference between the PEMFT treatment group and the sham treatment group in relation to symmetry of limb loading.

Null Hypotheses (H0c):

There will not be a statistically significant difference in limb kinematics (protraction, retraction and stride length) before and after application of the PEMFT treatment via the KORA mat.

Null Hypotheses (H0d):
There will not be a statistically significant difference between the PEMFT treatment group and the sham treatment group in relation to limb kinematics.

Hypotheses (H1a):
There will be a statistically significant difference in symmetry of limb loading before and after application of the PEMFT treatment via the KORA mat.

Hypotheses (H1b):
There will be a statistically significant difference between the PEMFT treatment group and the sham treatment group in relation to symmetry of limb loading.

Hypotheses (H1c):
There will be a statistically significant difference in limb kinematics (protraction, retraction and stride length) before and after application of the PEMFT treatment via the KORA mat.

Hypotheses (H1d):
There will be a statistically significant difference between the PEMFT treatment group and the sham treatment group in relation to limb kinematics.

3 A Review of The Literature Surrounding the Influence of Pulsed Electromagnetic field Therapy on Kinetic and Kinematic Parameters in Dogs

3.1 Pulsed Electromagnetic Field Therapy Influence

As PEMFT is a non-invasive and non-heating modality which, through varying wave forms, can penetrate a variety of tissues to impact cells, including skin and bone (Strauch *et al.*, 2009; Cristiano and Pratellesi, 2020). PEMFT has been vastly studied in humans (Yang *et al.*, 2020) however studies have suggested it to also be safe within animal use such as canines (Pinna *et al.*, 2013), yet there is limited research to support this.

The electrical and magnetic fields released by PEMFT influences cells (Wade, 2013) and in 1830, Michael Faraday proposed the 'Law of Induction' (see 'Figure 1). The 'Law of Induction' suggests how time varying or pulsing electrical fields can create further electrical fields to nearby conductors (Gaynor *et al.*, 2018). Such electrical fields were described by Faraday to be influenced through frequency, duration and amplitude; Hence, Faraday suggested the following equation:

$$\mathcal{E} = N\frac{d\Phi_B}{dt}$$

Figure 1: Michael Faraday's 'Law of Induction' Equation.

The technology of PEMFT has been used based on these principles since its medical use in Japan and Europe since 1960 (Markov, 2007) and is now available in many different device types including hand held devices, straps, blankets and mats with varying settings to target several tissue types (Gaynor *et al.*, 2018).

3.2 Pulsed Electromagnetic Field Therapy Cellular Influence

Cells are exposed to bio-physical forces such as electrokinetic phenomena, hydrostatic and osmotic pressure, which PEMFT can influence (Panagopoulos *et al.*, 2002). One the physical electromagnetic field reaches the cells plasma membrane it will stimulate a transient depolarisation which triggers the biophysical mechanism as a secondary response (Cristiano and Pratellesi, 2020). As PEMFT generates an electric and a magnetic field, this influences electrons therefore altering the polarity which creates ion movement towards the electrodes and so, influencing ion channels and therefore, cell function (Wade, 2013). Through influencing ions, the cells biophysical response can be altered, which depends on the type of ion as shown in 'Table 1'.

Table 1: A brief outline of ion influences on the cell (adapted from Wade, 2013).

Ion	**Function**
Calcium (Ca2+)	Muscle contraction, secondary messenger and facilitates neurotransmitters.
Sodium (Na2+), Potassium (K+) and Chloride (Cl-)	Generates action potential

Voltage gated channels, such as Calcium (Ca2+) channels, are affected by changes in electromagnetic fields. Ion influx into and out of these cells cause the opening and closing of these channels. Alteration in ion content influence the voltage gradient, hence causing movement of the ions along the channels (Panagopoulos et al., 2002). Free ion movement, such as Potassium (K+), Sodium (Na+), Chlorine (Cl-), Ca2+, influences cell volume, transduction and magnetic field intensity (Alberts et al., 2002). Due to the body having voltage gated channels, such as Calcium (Ca2+), such electromagnetic fields can be influential upon the cells of the body. The free movement of Ca2+ is important as this can bind to calmodulin which can trigger cytoplasmic nitric oxide synthase, leading to nitric oxide (NO) release; see 'Figure 2' (Gaynor et al., 2018; Cristiano and Pratellesi, 2020). Panagopoulos *et al.,* (2002) also suggested that the cell membranes electrochemical balance can be disturbed through oscillating ions which can influence gated channel proteins, through NO release, several biological pathways are triggered, instigating the release of Cyclic Guanosine Monophosphate which is influential upon growth factor and protein synthesis, further impacting homeostasis which can reduce inflammation (Serhan and Savill, 2005; Kubat *et al.*, 2015). Electromagnetic fields, which hyperpolarises cells from -70 millivolt (mV) to -90mV, allows blocking of pain transmitters. Release of NO has been further suggested to create pain relief, particularly to patients with OA (Hancock and Riegger-Krugh, 2008).

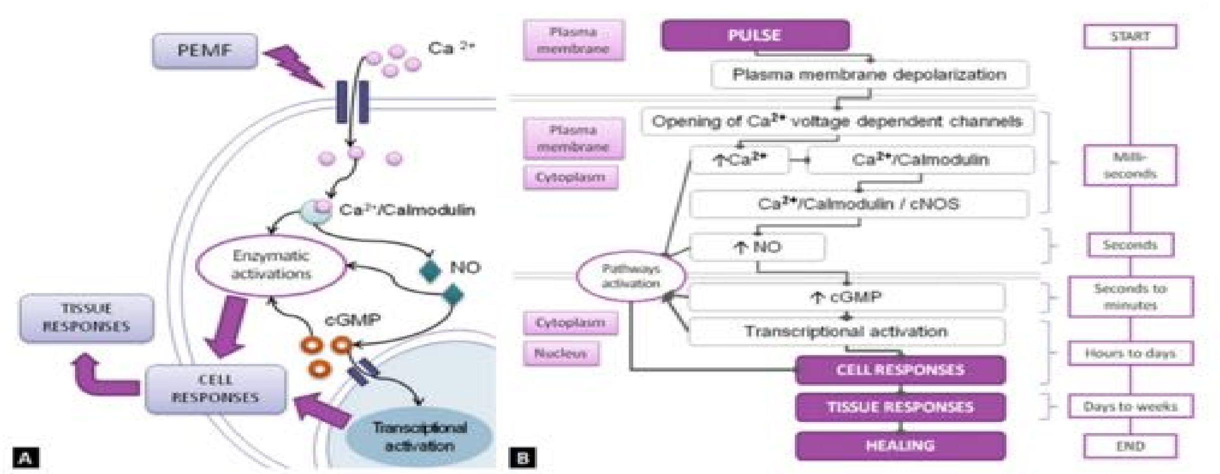

Figure 2: The influence PEMFT has on cells (A) and pathway activation occurrences with a time stamp (B). (Cristiano and Pratellesi, 2020).

3.3 Nociceptive Influence on Cells

Through influencing the cells as mentioned, PEMFT can reduce inflammation, pain and oedema, along with an increase in tissue proliferation (MARKOV *et al.*, 2006; Zou *et al.*, 2017). Within human literature, knee OA patients were found to have decrease pain levels after a month of PEMFT treatment within a randomised, double blinded and placebo controlled study (Bagnato *et al.*, 2016). A further randomised, double blinded and placebo controlled study however, found that PEMFT did not influence pain levels in human patients (Thamsborg *et al.*, 2005) yet Bagnato *et al.,* (2016) had a much higher daily treatment duration (12 hours) of PEMFT in comparison to Thamsborg *et al.,* (2005) (2 hours), indicating that PEMFT can be influential on pain but is dose duration dependent. Contrary to this, a further placebo controlled, double blinded study found PEMFT to not only reduced pain levels but also increased mobility range, however it utilised a different PEMFT device ('Magcell Arthro') which delivered different doses to that used in Bagnato *et al.,* (2016) and Thamsborg *et al.,* (2005) studies (Wuschech *et al.*, 2015). Conversely, other studies however have found PEMFT to have no significant influence on OA human patients (Pipitone and Scott, 2001) however did suggest some form of pain relief to be induced. A further study found differing results, whereby within group analysis found relief from stiffness in OA knees, but pain and improvement of daily activities to not significantly improve (Thamsborg *et al.*, 2005). Each of these studies utilised PEMFT at low frequencies (3-50 hertz (Hz)) and long durations (3-10 hours per week) and studies that have used PEMFT at higher frequencies for shorter durations have found similar results, with one study finding no significant differences between PEMFT and sham placebo groups, but only anecdotal reports that pain was reduced during the PEMFT application periods (Klaber Moffett *et al.*, 1996). A further study with similar settings with short wave PEMFT found similar results in that PEMFT did not influence pain scores but some alleviation of ‘stiffness’ was reported (Laufer *et al.*, 2005). These results may be due to lower frequencies being useful for osteoblast stimulation useful for fracture healing (Öztürk *et al.*, 2020), whereas higher frequencies such as 200Hz is linked to pain relief (Multanen *et al.*, 2018; Jie Tong *et al.*, 2022; Flatscher *et al.*, 2023). There are several studies which also suggest that PEMFT did not have an analgesic affect in humans (Özdemir *et al.*, 2021; Hochsprung *et al.*, 2021), therefore further research could conclude these conflicting results.

Within canine studies PEMFT was found to reduce pain; one study found an improvement in post-surgical wounds due to PEMFT and pain reduction through significantly less owners administering pain medication in comparison to the control group (Alvarez *et al.*, 2019). Though this study was a double blind, randomised placebo controlled clinical trial, the study still gained owner information post-surgery which may not have been subjective to the owners’ perception of pain. A similar study found that PEMFT did have an analgesic effect on post ovariohysterectomy dogs (Shafford *et al.*, 2002), however no objective measure was taken therefore the study recommended dogs further research In summary, the studies all suggest that PEMFT reduced pain in all species mentioned, however there is still lacking research to verify this within the canine field.

3.4 Impact of Reduced Nociception in Canines

As mentioned, PEMFT has been suggested to have the ability to reduce pain within many species and though pain plays an important role in preserving injured areas from further trauma (Zhang *et al.*, 2015), pain can impact a dogs quality of life (QL) (Belshaw *et al.*, 2015; Belshaw and Yeates, 2018). Though QL has more recently become regarded as an important scale for animal welfare and has been associated to euthanasia decision making due to its link with pain (Davies *et al.*, 2020; Rodger *et al.*, 2021; Davies *et al.*, 2024), it is still not entirely defined due to its subjectivity (Belshaw *et al.*, 2015). Therefore, methods of pain relief are an important for improved QL of dogs, such as PEMFT which has been proven to be safe and effective for most cases a discussed.

Many pathologies exist within the canine population including hip dysplasia, patella and cruciate ligament issues which have a high incidence rate in UK canines (Levine *et al.*, 2002; James *et al.*, 2020). Such issues can be difficult to treat due to complex and deep structure involvement, however a PEMFT field could target this depth (Polk, 1991). Such issues have been linked to OA and there is currently a high population that suffers from chronic and degenerative OA, which remains without a cure (Serra and Soler, 2019), affecting around 2.5% of the canine population in the UK (Anderson *et al.*, 2018). Non-surgical treatments include pain management drugs such as NSAIDs (Sullivan *et al.*, 2013) however these can negatively impact the gastrointestinal and renal systems long term (Lees *et al.*, 2004; Bergh and Budsberg, 2005). Other treatments such as PEMF are therefore a potential pain management alternative, which could be less invasive than long term medication. This therefore suggests that further research on the influence of PEMFT into canines is necessary to verify whether the treatment could provide analgesia for such conditions.

3.5 Bone Cell Healing

There are claims that PEMFT influences bone metabolism, for example PEMFT influence on bio-physical forces stimulates chondrocytes which are influential upon cartilage (Ciombor *et al.*, 2002). Human studies have found that PEMFT increased collagen type I levels, anti-inflammatory prostaglandins and 'Vascular Endothelial Growth Factor' (VGEF) which are suggested to increase both proliferation and vascularisation (Wuschech *et al.*, 2015) through delivering 105 Megatesla (mT) with a penetrating depth of 1cm, predisposing the tissue to 10 Amperes per metres squared (A/m^2) which has been further found in other studies (Schimmelpfeng and Dertinger, 1997). The study by Wuschech *et al.,* (2015) is highly reliable due to its double blinded and placebo-controlled study design however, used a PEMFT on patients with knee OA therefore the results may only be relevant to patients with OA related pathologies. Wuschech *et al.,* (2015) also used PEMFT device twice daily for 5 minutes for 18 days whereas the study by Schimmelpfeng *et al.,* (1997) used the device once for 60 minutes therefore suggesting a range of times that the PEMFT device can start to have an impact upon tissue. Also, Schimmelpfeng *et al.,* (1997) studied tissue in-vitro on mouse fibroblasts and human HL-60 promyelocytes, however Wuschech *et al.,* (2015) studied live patients therefore influencing result comparability yet suggesting PEMFT can be utilised on a range of tissue types of both human and animal. Influence of PEMFT on anabolic influence in chondrocytes within cartilage and joints was recorded (Ongaro *et al.*, 2011) however, this study used a PEMFT device with coils of copper wire whereas the study by Wuschech *et al.,* (2015) used discs to generate the magnetic field, which could have influenced the results of the studies but also suggests the viability of both device types through their positive results. Furthermore, anabolic increase of chondrocytes and chondroprotective influence on cartilage was also found in further studies (Fini *et al.*, 2008) however this study was conducted in guinea pigs that were exposed to PEMFT for 6 hours per day over 6 months whereas other studies have found similar results with 4 hour daily application for 60 days (Benazzo *et al.*, 2008). The study by Benazzo *et al.,* (2008) also commented on how PEMFT reduced pain and was robust through its prospective, double blinded and randomised study design however, due to being conducted within a long-term study, the human patients were given devices to apply the PEMFT treatment themselves therefore varying the timings of application. Catabolic effects were also found in which IL-1b levels were reduced through PEMFT application to rabbits for one hour daily over six weeks (Boopalan *et al.*, 2011) however the rabbits were housed with the PEMFT device surrounding the enclosure whereas previously mentioned devices were frequently applied, however the study by Ongaro *et al.,* (2011) also found catabolic influences on tissue when PEMFT was applied. These studies all suggest that PEMFT influences cells in varying species therefore it can be assumed that canine reactions would be similar to the device, further reasoning for the requirement to investigate PEMFT influence in canines.

Further human studies found that through PEMFT influencing the Ca2+ voltage gateways, through increasing both Ca2+ and cytoskeletal calmodulin therefore allowing improved bone healing (Brighton *et al.*, 2001). Also, PEMFT has also been found to increase 'Transforming Growth Factor' (TGF-ß) release which can influence fracture healing (Boopalan *et al.*, 2009). Once activated, TGF-ß binds to specific serine/threonine kinase through signalling across the plasma membrane (Attisano and Wrana, 2002) and has further been found to recruit progenitor cells that can stimulate bone remodelling (Xu and Cao, 2020). However, some studies suggest that TGF-ß has been associated with inhibit cell proliferation which may not benefit bone healing (Javelaud and Mauviel, 2004). Due to the binding previously mentioned it has been found that TGF-ß creates a downstream release of proteins including bone morphogenic proteins (BMP's) which care influential on strengthening bone structure (Ten Dijke *et al.*, 2002). Therefore, PEMF creating these biological responses suggests it is an effective tool for healing damaged bone tissue, which could be further investigated within the canine field.

Several studies suggest that PEMFT can specifically replicate processes that occur during limb weight bearing, such as anabolic pathways (De Mattei *et al.*, 2003). Mechanical loading influences bone density according to Wolff which can lead to formation of new bone or bone degeneration depending on the load applied (Wolff, 1870). Through exercise, mechanical loading occurs which has been found to reduce osteoblast apoptosis in mice (Fonseca *et al.*, 2011) and a further human study corroborated these results (Mann *et al.*, 2006), however both of these studies were conducted in vitro therefore may have slight variations in the results compared to live tissue. Within human literature it has been recorded that those who exercised had healthier bone tissue (higher bone mineral density) compared to those who did not (Liu-Ambrose *et al.*, 2004; Weaver *et al.*, 2016). Within other studies, results showed an increase in extra cellular matrix formation, such as proteoglycan and glycosaminoglycan deposits, due to PEMFT application (Liu *et al.*, 1996). The study by Liu *et al.,* (1996) however used chick embryos which were subject to PEMF for 3 hours per day across 48 hours which due to species difference and high PEMF doses, may not be transferrable to canine results. Similarly, the study by De Mattei *et al.,* (2003) also tested in vitro samples therefore the PEMF influence may not transfer to live canines. However, on average the results suggest that PEMFT can create a similar response within bone that bone loading does within humans, but this is yet to be researched within the canine field.

3.6 Orthopaedic Cellular Disfunction and Associated Pathologies

Bone healing is an important topic due to orthopaedic issues within the canine population such as humeral condyle fractures which make up 50% of humeral fractures so are suggested to be of high prevalence (Bardet *et al.*, 1983). A study found humeral condyle fractures in skeletally immature dogs to have higher prevalence in breeds such as English Springer Spaniels and French Bulldog; both very popular breeds in the UK particularly French Bulldogs (Smith *et al.*, 2020). The study by Smith (2020) was retrospective therefore may include bias results through interpretations, however a similar study also suggested these breeds to be higher risk of the disorder (Sanchez Villamil *et al.*, 2020). Application of PEMFT to such fractures could provide beneficial bone healing and therefore be an important part of the rehabilitation justifying the need for it to be further investigated in canine populations.

3.7 Neural Response to Pulsed Electromagnetic Field Therapy

It has been suggested that electrical stimulation can encourage certain nervous pathways, as the pulses create action potentials which influences neuromuscular junctions, stimulating a muscle contraction (Avramut, 2022). As PEMFT can promote a similar response, it was found to improve neurological health with one study finding advanced proprioception in post spinal surgery canine cases receiving PEMFT (Zidan *et al.*, 2018). This study was robust through its randomised and placebo-controlled study design, however the study suggested further research with higher sample sizes are necessary for further verification. Other studies suggest PEMFT can encourage nerve regeneration and cerebral ischemia (Scardino *et al.*, 1998) which was also found within in-vitro studies where PEMFT increased axon count significantly in comparison to controls, with 50Hz at 1 hour daily being the dose that created the highest regeneration levels (Hei *et al.*, 2016). These studies suggest that PEMFT can be beneficial to those with neurological issues and even to maintain neurological health.

There are vast neurological canine disorders that can lead to paralysis or paresis including ‘Intervertebral disc disease’ (IVDD) which is very common in the canine population, however PEMFT has been a useful tool for its rehabilitation (Alvarez *et al.*, 2019). Rats that underwent a disc herniation were found that the affected hindlimb regained movement through PEMFT therapy (Chan *et al.*, 2021), which demonstrates how PEMFT can influence neurological function. The study by Chan *et al.,* (2021) however this study used specialised treadmills to measure the movement yet other studies have shown treadmills can create movement (Minassian and Hofstoetter, 2016), therefore the PEMFT may not have created the limb movement, but the treadmill.

Based on the studies mentioned, there is evidence to support cellular responses occurring due to PEMFT application. However, a systematic review concluded that there are no long term studies into the side effects of PEMFT (Hug and Röösli, 2012) suggesting PEMFT to not be entirely safe to use, yet other studies have suggested that there are no immediate negative impacts caused through the modality (Wuschech *et al.*, 2015).

3.8 Pulsed Electromagnetic Field Therapy Biomechanical Influence

3.8.1 Kinematic Parameters

Kinematics are based on joint movements within a gait which can be recorded as angulation of joints stride length (SL) and other movement parameters that exclude forces (Sandberg *et al.*, 2023). Range of motion (ROM) is the measure of flexion and extension of a joint (Hady *et al.*, 2015) which can also be recorded through kinematics (Sandberg *et al.*, 2023) but also impacts other parameters such as SL which is also dependent on the protraction and retraction of the limbs (Kopec *et al.*, 2018; Knights and Williams, 2021).

Such kinematic parameters can assess the symmetry of a gait which has been linked to lameness diagnosis which are typically linked to musculoskeletal pathologies (Gillette and Angle, 2008; Jarvis *et al.*, 2013). Assessing movement of canine joints is important as this has been linked to certain pathologies for example OA which can limit joint ROM, however if the joint continues to not have full ROM the health will deteriorate through less synovial fluid and mobility will also worsen further (Bland, 2015). Therefore, detection of joint restrictions could impact the prognosis of issues, highlighting the importance of kinematic assessments.

Kinematic parameters can be recorded through various software's and devices, including Quintic which can offer measures of markers and track their linear movement within a gait (Sandberg *et al.*, 2023). A limitation to this measure however is any medial or lateral rotations will not be recorded due to the linear ability of 2D software, however 3D software also exists which is labelled as 'gold standard' (Fischer *et al.*, 2018; Dienes *et al.*, 2022). In order to minimise skewing 2D results, correct data collection is required which can be established through recording being conducted with correct camera alignment and use of a tripod for stabilisation and consistency (Kirtley, 2006; Sandberg *et al.*, 2020). Marker placement can also influence results of kinematics, therefore these should be placed correctly and securely as skin marker displacement is a recognised potential limitation (Sha *et al.*, 2004). Overall, kinematic analysis could benefit studies through allowing representation of the stride cycle which may correspond to kinetic results, therefore an important aspect of biomechanical analysis to assess for lameness and general ambulation.

3.8.2 Kinetic Parameters

Kinetics involve the measure of forces incurred through different gaits (DeCamp, 1997) and can be measured through force plates which are seen as the 'gold standard', however these are limited due to their expense and ability to capture one limb at a time (Quinn *et al.*, 2007; Carr *et al.*, 2016). Pressure walkways such as the 'Stride Way' system can capture multiple simultaneous temporospatial data through a runway system, providing more data from the gait cycle (Kozlovich *et al.*, 2022; Kieves, 2022).

Measurement of forces within a gait cycle can provide lameness analysis as if any limbs have less force than others, the dog may not be loading a particular limb/s due to pain through lameness (Lascelles *et al.*, 2006). Dogs natural bear approximately 40% of their weight on their forelimbs and 60% on their hindlimbs (Ben-Amotz *et al.*, 2020; Linder *et al.*, 2021), however variances of this have been found in lame dogs (Fischer *et al.*, 2013) which could be detected through kinetic analysis using the 'Stride Way' system.

Kinetic data recording are suggested to be a good lameness measure (Fanchon and Grandjean, 2007) as a lame dog will weight bear less on the lame limb (Quinn *et al.*, 2007). Studies concluded that subjective lameness measures between clinicians' were poor (Waxman *et al.*, 2008), therefore a more reliable analysis of biomechanical markers would improve lameness analysis. Slower quadruped gaits such as walk and trot are symmetrical, whereas faster gaits an unsymmetrical, therefore the paired limbs should have the same duty factor due to this symmetry (Alexander, 1980; Alexander, 1984). However symmetries can be influenced by lameness within quadruped species such as horses (Hardeman *et al.*, 2022) and similar studies suggest asymmetries due to lameness influenced weight bearing which further influenced the thoracolumbar angular motion and vertical movement of the pelvis (Hicks and Millis, 2014) which could be highlighted through kinetic and kinematic measures. Based on these suggestions, kinetics would be a valuable tool to assess limb loading through equipment such as the 'Stride Way' system.

3.8.3 Measuring Kinetic and Kinematic Parameters

If PEMFT does induce a difference to the dog, it could be observed through such kinetic and kinematic measures. There are several biomechanical measurement device on the market as previously suggested; one being the ‘Tekscan Stride Way System’ (TSS) which consists of a ‘Cyber Physical System’ that can record spatiotemporal data through ambulation across the mat (Arafsha *et al.*, 2018). Pressure mats when unloaded have a high resistance and when loaded their resistance reduces, therefore differences can be calculated and converted into biomechanical data (Besancon *et al.*, 2003). The TSS was first released in 2017 and based on a pressure mat consisting of one panel (MatScan) which was found to have ‘moderate to good’ reliability within human studies (Zammit *et al.*, 2010) however the participants in this study were not blinded and there no control was used. A further study however suggested that a pressure mats are a reliable record human gait measures when compared to similar technology results (Stöggl and Martiner, 2017). This suggests that the TSS system would be reliable, as it typically consists of 6 pressure mats, of which 4 have thousands of embedded sensors to detect force across 4m² area (Besancon *et al.*, 2003; Arafsha *et al.*, 2018), therefore more beneficial to capturing canine quadruped ambulation. Gait analysis has been suggested to be the best method of assessing outcome on limb function (Evans *et al.*, 2003), however this study utilised force plates to record the ground reaction forces (GRF) which are the ‘gold standard’ of kinetic measurement, yet the TSS records forces, although GRF can be calculated from this.

Other similar technologies consist of force plates, which ware seen as the ‘gold standard’ for limb force recording(Patterson *et al.*, 2016; Badby *et al.*, 2022) however a TSS would allow multiple limb recordings at once whereas force plates can only record one limb at a time, therefore this would not provide an accurate measure of canine locomotion(Lascelles *et al.*, 2006). In addition to this, studies have found that the TSS is a viable alternative to force plates (Besancon *et al.*, 2003) however the results showed significant differences between the peak vertical forces of both measurement systems, however this was suggested to be due to varying calibration influences.

Kinetic and kinematic technologies can therefore provide gait analysis which can determine correct stride parameters as lameness can create incorrect patterns. Gait analysis recording before and after PEMFT application would demonstrate whether the device has had an impact on the dog’s ambulation potentially due to lameness or pain reduction as lameness would be detected through gait asymmetries vs less lameness with reduced asymmetries. Studies have recruited ROM previously in order to assess the influence of PEMFT on locomotion (Ryang We *et al.*, 2013), however no significant difference was found which suggests either the PEMFT did not have an influence or ROM was the wrong parameter to assess , suggesting further research is required to verify the influence of PEMFT on canine movement.

3.9 Pulsed Electromagnetic Field Therapy Modalities

There are several different application methods of PEMFT depending on the device, which all have varying settings depending on the coils and apparatus set up (Gaynor *et al.*, 2018). A study investigated varying PEMFT device types such as, hand held devices held (shown in 'Figure 3') to the patient and electromagnetic fields delivered through the transducer and other PEMFT devices that have straps/harnesses to keep the PEMFT being delivered to a specific area (Waldorff *et al.*, 2017).

Figure 3: Several PEMFT devices that can be directly strapped to an area to provide targeted tissue responses. (a) Orthofix Inc Physio-Stim®. (b) ITO Co, LTD. Osteotron IV LIPUS. (c) Ossatec Othropulse II(d)GEA® ClinicalBiophisicsBiostim®SPT(Daish et al., 2018).

These applications however were designed for people and due to the nature of dogs, a specific harness location could easily become moved through the dog's movement or sensitivity to such a device. Therefore, it could be assumed that these applicator styles may not be the most suitable for canine rehabilitation as if the dog moved the device off the target area. The efficiency of the treatment may be influenced.

Devices to apply PEMFT to animals can vary from a handheld large pad to circular hand head devices (see ‘Figure 4’) or blankets to cover the body. For small animals including canines, PEMFT mats are also available. As physiotherapists typically apply devices during treatment times, the application window for PEMFT is very narrow and therefore may not be as effective and gain the results seen within the studies previously mentioned. Devices can be left with owners however due to anatomical knowledge requirements, not all owners will be confident in where to apply devices to their animal.

Figure 4: A ‘Westville’ Biomag 2e PEMFT device with applicator pad.

One human study found that a PEMFT mat that the patients laid on for 30 minutes 3 times a day was effective at reducing pain and increasing ROM (Sutbeyaz *et al.*, 2006), however this was conducted for 30 minutes 3 times a day which could be excessive to apply manually, therefore a bed would be easier to apply to a dog within its home environment. This suggests that a mat would be most suitable for a canine as they can lie on it in their usual sleeping area of the home and the owner can switch the device on for the set durations prescribed by the physiotherapist to access the most effective tissue response. There are several brands of mats available for application, including ‘KORA’ which utilises sturdy and durable mats (see ‘Figure 5’), which can withstand everyday use with a dog and has been designed to be safe and, based on the study by Sutbeyaz *et al.,* (2006), should effectively influence pain and ROM of dogs.

Figure 5: KORA PEMFT Mat with remote. (KORA, 2024).

3.9.1 Further Modalities

Laser has been suggested to have similar results to PEMFT such as pain reduction and healing through increasing type I and III procollagen 'messenger ribose nucleic acid' (mRNA) synthesis (Abergel *et al.*, 1984), though this study is now dated and was conducted in vivo therefore may not be entirely relevant to live canines. A more recent study found that PEMFT had better pain scores and mobility function in human patients with OA in comparison to those who received laser treatment (Elboim-Gabyzon and Nahhas, 2023). Though this study suggests was conducted in humans the tissue is likely to act similarly in canine and humans, but they did not investigate medications taken by the subjects which could have influenced pain scores and therefore mobility. However more papers suggest PEMF to be the better modality for pain than laser, such as one study that suggested PEMFT was a better modality for bone healing (Refai *et al.*, 2014). Though there are several studies comparing PEMFT with laser, laser has evolved from Chinese medicine and has become increasingly studied regarding its influence on animals over the past 20 years (Schofield, 2008). Therefore, due to more research being available on laser in animals, PEMFT requires further investigation.

Studies have compared analgesia induced through Transcutaneous Electrical Nerve Therapy (TENS) with PEMFT as TENS is a similar nonpharmaceutical modality. One study found TENS and PEMFT to provide similar levels of pain relief (Rajkumar *et al.*, 2023). Applications of TENS with higher frequencies can target the ‘pain gate’, where by noxious stimulus such as C Fibres are blocked (Coutaux, 2017), however this is not typically well tolerated in dogs. Opioid responses can also be triggered through TENS at lower frequencies (Sluka and Walsh, 2003), which is more accepted in dogs. However, studies found that PEMFT treatment was superior to TENS at relieving pain (Fergany *et al.*, 2017) and other studies have suggested that TENS would bring no additional analgesic effect (Paolucci *et al.*, 2020). In other studies, TENS was found to have no impact on pain relief (Rutjes *et al.*, 2009), therefore PEMFT appears the more viable modality to research.

4 Materials and Methods

4.1 Study Design

The study was a double blinded randomised controlled cross over trial, with a two-week washout period.

4.2 Materials

Kinetics were measured through a 'Stride Way' system (version 7.8) and crates set up with a KORA PEMF (180x110x50 centimetre (cm)) where the treatment mat would be switched on and the sham mat would be switched off. The KORA mat that was switched on would be set to 'pain killer' setting which is 19Hz and 19 pulses per second (PPS). An iPhone 12 was used to record videos and markers were placed on the dogs using double sided tape and retroreflective markers placed on the dorsal scapula spine, 5th forelimb digit, iliac crest and 5th hindlimb digit, as shown in 'Figure 6'.

Figure 6: A participant fitted with the retroreflective markers.

4.3 Sample

The sample consisted of 3 male and 3 female healthy ex-racing Greyhounds with a mean age 3.83 years old (3.8333 ± 0.75277 years) and 30.375kg (30.375 ± 4.17478kg) average weight, shown in ‘Table 2’. The sample size was calculated through the one-way ANOVA resource calculation as follows- E = N – k, according to (Arifin and Zahiruddin, 2017). Through the sample size calculation, a sample of 6 would be adequate for this trial.

Table 2: Details of canine participants within sample.

Dog	Age (years)	Weight (kg)	Sex
1	3	33.8	Male
2	4	28.5	Female
3	4	27.5	Female
4	5	36.5	Male
5	4	30.45	Female
6	3	25.15	Male

Before commencing the trial on both days, none of the dogs displayed any abnormal behaviours or illnesses throughout the duration of the trial.

4.4 Methodology

Before commencing the study, the Writtle Ethics Committee granted approval (ethics number 1717). The study was conducted on two days; 22nd November 2023 and 6th December 2023, with a two week washout period and on day one, all dogs were weighed and held in crates with normal beds.

Once the dog had markers fitted, they were walked up and down the stride way 3 times in walk and 3 times in trot whilst being recorded on the iPhone and ‘Stride Way’ system. The iPhone recorded the markers previously mentioned in order to gather the protraction, retraction and SL data, whereas the ‘Stride Way’ gathered the limb loading data through measuring forces.

The dogs were walked and trotted up the entire length of the ‘Stride Way’, shown in ‘Figure 7’. The same handler was used whilst walking and trotting the dogs up on the stride way and the same person was used to place the anatomical markers.

Figure 7: The ‘Stride Way’ system lay out.

Each dog was walked on their own collar and lead; collars were specifically greyhound collars as shown in 'Figure 8'. This rules out any new equipment that could influence the dogs way of going such as a harness (Williams *et al.*, 2023).

Figure 8: The collar and lead style used on each dog.

Upon having kinetic and kinematic data recorded, the dog was then placed in one of two crates; a sham with a KORA mat switched off or a treatment crate with a KORA mat switched on. The dog remained in here for 30 minutes on the pain setting according to the KORA guidelines, whilst another dog started the same procedure. After the sham or treatment had taken place within the 30 minutes, the dog repeated the 'Stride Way' walk for kinetic measurements and recorded with the markers still in place (left on during the treatment) for the kinematic measures.

Two weeks later, the same procedure occurred but with sham dogs receiving treatments and vice versa. A two week washout period was incorporated to allow enough time for the participants to be safely away from the PEMFT and to ensure that the results of the PEMFT were being recorded (Harvey et al., 2021). The washout period also allowed each dog to act as its own control to increase the adequacy of the study design (Charness *et al.*, 2012). During the second day after the washout period was complete, the trial was repeated in the same order but those dogs that had received a treatment on day 1 would now have a sham and those who had the sham on day 1 would have the treatment for the same duration and at the same setting as previously used.

4.5 Data Collection

Within the trial there were two researchers: 'Researcher 1' (the author) and 'Researcher 2'. Researcher 1 collected data on kinetics through the 'Stride Way' system in the form of force data (Newtons- N). From this data collection, a symmetry index was calculated to detect how symmetrical the dogs were and therefore any uneven limb loading. Symmetry index was recalculated using a commonly used formula within quadruped literature by Kano *et al.*, (2016), see 'Appendix 1' for the calculation. Researcher 2 collected kinematic data which included protraction and retraction of forelimbs and hindlimbs in both walk and trot, plus kinetics through limb forces to the fore and hindlimbs in walk and trot. Researcher 2 send this data to 'Researcher 1' for SL, protraction and retraction analysis.

4.6 Data Analysis

Once all the data was completed, it was uploaded into Excel tables and organised into categories including walk and trot before and after treatment and before and after sham plus walk and trot difference parameters (calculated through the difference divided by the original multiplied by 100). These numbers were used initially to calculate descriptive statistics and preliminary analysis of the data.

The data was then imported to SPSS (Version 28). Through SPSS, a Shapiro Wilk Test was ran for normality, where if the result was more than 0.05 it was classified as 'normal' (parametric), if less than 0.05 then this was classed as 'not normal' (non-parametric). All data was parametric therefore a Paired T Test was conducted for all variables where the significance of the data was analysed based on a P value of 0.05. This was conducted for walk, trot, forelimb, hindlimbs and total for both kinetic and kinematic data.

5 Results

5.1 Kinetics

5.1.1 Forelimb Left Versus Right Symmetry

Data collected using the 'Stride Way' walkway was analysed to assess the forelimb symmetry index for the sample of dogs in walk and trot, before and after the treatment and before and after the sham. A symmetry index of zero indicates even forelimb loading and any deviation from zero indicates asymmetrical forelimb loading, with the severity of asymmetry increasing linearly.

5.1.1.1 Walk Left Versus Right Symmetry of Forelimb

Descriptive statistics were carried out to assess whether the KORA mat intervention (treatment) changed the forelimb symmetry index in walk, as compared to the sham intervention and found that the mean forelimb symmetry index reduced from 8.9 to 2.0 for the treatment group but remained largely the same for the sham group (10.1 to 10.2).

A paired-samples t-test was then used to determine whether there was a statistically significant mean difference in forelimb symmetry index in dogs before and after receiving treatment. Data are mean ± standard deviation, unless otherwise stated. The assumption of normality was not violated, as assessed by Shapiro-Wilk's test ($p > 0.05$). Dogs had a reduced forelimb symmetry index after treatment (1.9933 ± 1.75925) when compared with before treatment (8.8783 ± 4.43637N), showing a statistically significant improvement in forelimb loading symmetry $t(5) = 5.678$, $p= 0.002$.

A paired-samples t-test was also ran to determine whether there was a statistically significant mean difference in forelimb symmetry index in dogs before and after a sham procedure to rule out a placebo effect. Data are mean ± standard deviation, unless otherwise stated. The assumption of normality was not violated, as assessed by Shapiro-Wilk's test ($p > 0.05$). Dogs had a unchanged / increased / slightly reduced forelimb symmetry index after sham (10.1500 ± 3.33629N) when compared with before sham (10.0500 ± 3.88538N) showing a non-statistically significant change in forelimb loading symmetry, $t(5) = -0.111$, $p =0.916$.

Finally, a paired-samples t-test was ran to determine whether the change in forelimb symmetry index seen after the treatment was a statistically significant mean difference compared to the change in forelimb symmetry index after the sham. The assumption of normality was not violated, as assessed by Shapiro-Wilk's test ($p > 0.05$). The difference in forelimb symmetry index after treatment (-0.82434654 ± 0.134139392N) when compared to after sham (0.150661501 ±

0.525365644N), was statistically significant $t(5) = -3.858$, $p = 0.012$, showing a statistical impact of the KORA mat on forelimb loading in walk.

5.1.1.2 Trot Left Versus Right Symmetry of Forelimb

Descriptive statistics were carried out to assess whether the KORA mat intervention (treatment) changed the forelimb symmetry index in trot, as compared to the sham intervention and found that the mean forelimb symmetry index reduced from 9.1N to 1.8N for the treatment group but remained largely the same for the sham group (9.9N to 8.9N).

A paired-samples t-test was then used to determine whether there was a statistically significant mean difference in forelimb symmetry index in trot before and after receiving treatment. Data are mean ± standard deviation, unless otherwise stated. The assumption of normality was not violated, as assessed by Shapiro-Wilk's test ($p > 0.05$). Dogs had a reduced forelimb symmetry index after treatment (1.8267 ± 1.33907) when compared with before treatment (9.1100 ± 3.90318), showing a statistically significant improvement in forelimb loading symmetry $t(5) = 5.456$, $p = 0.003$.

A paired-samples t-test was also ran to determine whether there was a statistically significant mean difference in forelimb symmetry index in dogs before and after a sham procedure to rule out a placebo effect. Data are mean ± standard deviation, unless otherwise stated. The assumption of normality was not violated, as assessed by Shapiro-Wilk's test ($p > 0.05$). Dogs had a slightly reduced forelimb symmetry index after sham 8.9160 ± 2.00010N when compared with before sham 9.9467 ± 3.04790N showing a non-statistically significant change in forelimb loading symmetry, $t(5) = 1.395$, $p = 0.222$.

Finally, a paired-samples t-test was ran to determine whether the change in forelimb symmetry index seen after the treatment was a statistically significant mean difference compared to the change in forelimb symmetry index after the sham. The assumption of normality was not violated, as assessed by Shapiro-Wilk's test ($p > 0.05$). The difference in forelimb symmetry index after treatment -0.80183306± 0.90904098N when compared to after sham -0.06567190 ± 0.195310318N, was statistically significant $t(5) = -7.831$, $p =< 0.001$, showing a statistical impact of the KORA mat on forelimb loading in trot. A summary of the average findings can be seen in 'Figure 9', outlining the significant impact PEMFT had on symmetry index of the forelimb versus sham.

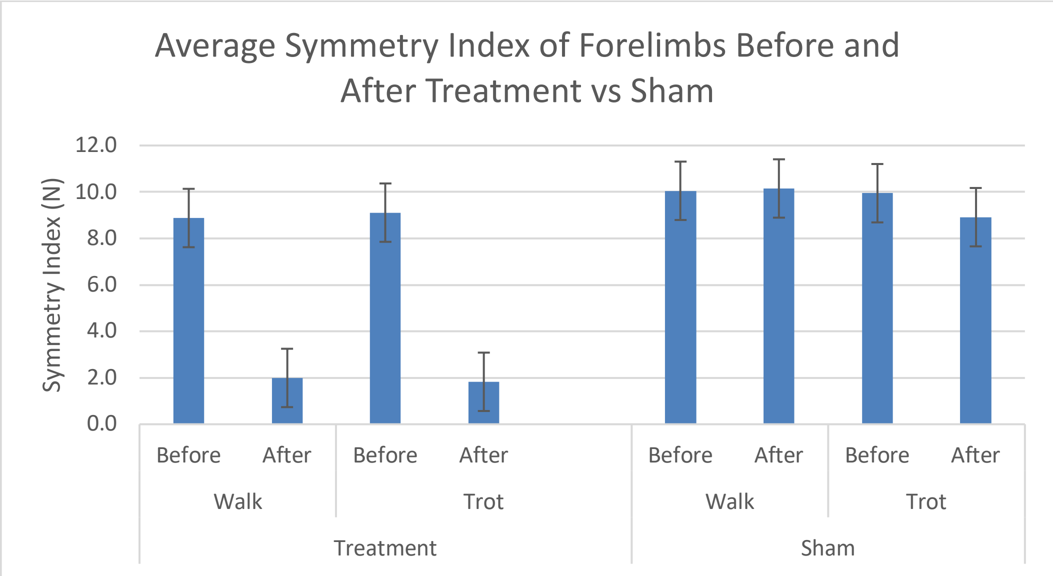

Figure 9: Average forelimb symmetry index for sample dogs before and after either treatment or sham, in walk and trot.

5.1.2 Hindlimb Left Versus Right Symmetry

Data collected using the 'Stride Way' walkway was analysed to assess the hindlimb symmetry index for the sample of dogs in walk and trot, before and after the treatment and before and after the sham. A symmetry index of zero indicates even limb loading and any deviation from zero indicates asymmetrical limb loading, with the severity of asymmetry increasing linearly.

5.1.2.1 Walk Left Versus Right Symmetry of Hindlimb

Descriptive statistics were carried out to assess whether the KORA mat intervention (treatment) changed the hindlimb symmetry index in walk, as compared to the sham intervention and found that the mean hindlimb symmetry index reduced from 10.9 to 0.9N for the treatment group but slightly reduced for the sham group (11.5 to 9.5N).

A paired-samples t-test was then conducted to determine whether there was a statistically significant mean difference in hindlimb symmetry index in walk before and after receiving treatment. Data are mean ± standard deviation, unless otherwise stated. The assumption of normality was not violated, as assessed by Shapiro-Wilk's test ($p > 0.05$). Dogs had a reduced hindlimb symmetry index after treatment (0.9383 ± 0.82925N) when compared with before treatment (10.8517 ± 4.00848N), showing a statistically significant improvement in hindlimb loading symmetry $t(5) = 6.948$, $p = <0.001$.

A paired-samples t-test was also ran to determine whether there was a statistically significant mean difference in hindlimb symmetry index in walk before and after a sham procedure to rule out a placebo effect. Data are mean ± standard deviation, unless otherwise stated. The assumption of normality was not violated, as assessed by Shapiro-Wilk's test ($p > 0.05$). Dogs had a slightly reduced hindlimb symmetry index after sham 9.4633 ± 2.57220N when compared with before sham 11.5117 ± 4.59683N showing a statistically insignificant change in hindlimb symmetry, $t(5) = 1.361$, $p = 0.232$.

Finally, a paired-samples t-test was ran to determine whether the change in hindlimb symmetry index seen after the treatment was a statistically significant mean difference compared to the change in symmetry index after the sham. The assumption of normality was not violated, as assessed by Shapiro-Wilk's test ($p > 0.05$). The difference in hindlimb symmetry index after treatment -0.92315290 ± 0.064016071N when compared to after sham -0.11659448 ± 0.225721740N, was statistically significant $t(5) = -7.518$, $p =< 0.001$, showing a statistical impact of the KORA mat on hindlimb loading in walk.

5.1.2.2 Trot Left Versus Right Symmetry of Hindlimb

Descriptive statistics were carried out to assess whether the KORA mat intervention (treatment) changed the hindlimb symmetry index in trot, as compared to the sham intervention and found that the mean hindlimb symmetry index reduced from 10.0 to 1.1N for the treatment group but remained largely the same for the sham group (10.6 to 9.3N).

A paired-samples t-test was then used to determine whether there was a statistically significant mean difference in hindlimb symmetry index in trot before and after receiving treatment. Data are mean ± standard deviation, unless otherwise stated. The assumption of normality was not violated, as assessed by Shapiro-Wilk's test ($p > 0.05$). Dogs had a reduced symmetry index after treatment (1.1250 ± 0.88951N) when compared with before treatment (10.0067 ± 4.02624N), showing a statistically significant improvement in symmetry $t(5) = 6.527$, $p = 0.001$.

A paired-samples t-test was also ran to determine whether there was a statistically significant mean difference in hindlimb symmetry index in trot before and after a sham procedure to rule out a placebo effect. Data are mean ± standard deviation, unless otherwise stated. The assumption of normality was not violated, as assessed by Shapiro-Wilk's test ($p > 0.05$). Dogs had a slightly reduced hindlimb symmetry index after sham 9.2717 ± 4.05911N when compared with before sham 10.6033 ± 4.96310N showing a statistically significant change in hindlimb loading symmetry, $t(5) = 3.261$, $p = 0.022$.

Finally, a paired-samples t-test was ran to determine whether the change in hindlimb symmetry index seen after the treatment was a statistically significant mean difference compared to the change in hindlimb symmetry index after the sham. The assumption of normality was not violated, as assessed by Shapiro-Wilk's test ($p > 0.05$). The difference in hindlimb symmetry index after treatment -0.90102091± 0.059683486N when compared to after sham -0.10514533 ± 0.091386624N, was statistically significant $t(5) = -15.121$, p =<0.001, showing a statistical impact of the KORA mat on hindlimb loading in trot. A clear visual representation of the significance of the PEMFT impact in comparison to the sham can clearly be seen in 'Figure 10'.

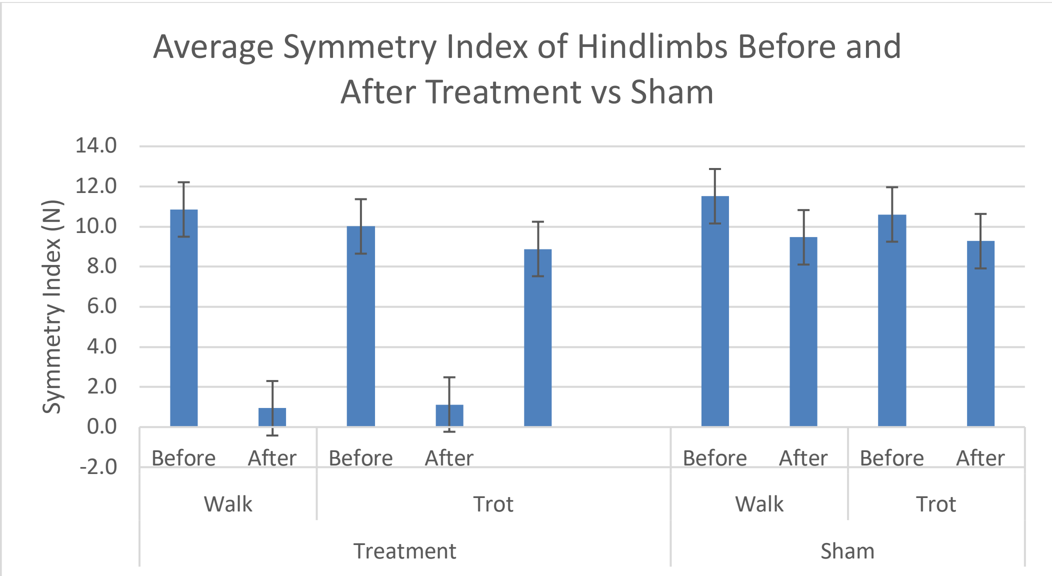

Figure 10: Average hindlimb symmetry index for sample dogs before and after either treatment or sham, in walk and trot.

5.1.3 Total left vs right symmetry

Data collected using the 'Stride Way' walkway was analysed to assess the symmetry index for the sample of dogs in walk and trot, before and after the treatment and before and after the sham. A symmetry index of zero indicates even limb loading and any deviation from zero indicates asymmetrical limb loading, with the severity of asymmetry increasing linearly.

5.1.3.1 Walk Total Left Versus Right Symmetry

Descriptive statistics were carried out to assess whether the KORA mat intervention (treatment) changed the symmetry index in walk, as compared to the sham intervention and found that the mean symmetry index reduced from 7.3N to 1.8N for the treatment group but remained largely the same for the sham group (8.0N to 8.5N).

A paired-samples t-test was then used to determine whether there was a statistically significant mean difference in left versus right symmetry index in walk before and after receiving treatment. Data are mean ± standard deviation, unless otherwise stated. The assumption of normality was not violated, as assessed by Shapiro-Wilk's test ($p > 0.05$). Dogs had a reduced left versus right symmetry index after treatment (1.75000 ± 1.39196) when compared with before treatment (7.3000 ± 3.64609), showing a statistically significant improvement in left versus right symmetry $t(5) = 4.947$, $p = 0.004$.

A paired-samples t-test was also ran to determine whether there was a statistically significant mean difference in left versus right symmetry index in dogs before and after a sham procedure to rule out a placebo effect. Data are mean ± standard deviation, unless otherwise stated. The assumption of normality was not violated, as assessed by Shapiro-Wilk's test ($p > 0.05$). Dogs left versus right symmetry index after sham 8.5 ± 3.72027N did not largely differ when compared with before sham 8.0067 ± 4.12873 showing a non-statistically significant change in left versus symmetry, $t(5) = -0.565$, $p = 0.597$.

Finally, a paired-samples t-test was ran to determine whether the change in left versus right symmetry index seen after the treatment was a statistically significant mean difference compared to the change in left versus right symmetry index after the sham. The assumption of normality was not violated, as assessed by Shapiro-Wilk's test ($p > 0.05$). The difference in symmetry index after treatment -0.79413897± 0.180148661N when compared to after sham 0.318275558 ± 0.686389110N, was statistically significant $t(5) = -3.411$, $p = 0.019$, showing a statistical impact of the KORA mat on left versus right limb loading symmetry in walk.

5.1.3.2 Trot Total Left Versus Right Symmetry

Descriptive statistics were carried out to assess whether the KORA mat intervention (treatment) changed the left versus right symmetry index in trot, as compared to the sham intervention and found that the mean left versus right symmetry index reduced from 8.2N to 1.7N for the treatment group but remained largely the same for the sham group (8.9N to 7.7N).

A paired-samples t-test was then used to determine whether there was a statistically significant mean difference in left versus right symmetry index in trot before and after receiving treatment. Data are mean ± standard deviation, unless otherwise stated. The assumption of normality was not violated, as assessed by Shapiro-Wilk's test ($p > 0.05$). Dogs had a reduced left versus right symmetry index after treatment (1.7267 ± 0.69278) when compared with before treatment (8.1617 ± 1.89095), showing a statistically significant improvement in left versus right symmetry $t(5) = 7.917$, $p = <0.001$.

A paired-samples t-test was also ran to determine whether there was a statistically significant mean difference in left versus right symmetry index in trot before and after a sham procedure to rule out a placebo effect. Data are mean ± standard deviation, unless otherwise stated. The assumption of normality was not violated, as assessed by Shapiro-Wilk's test ($p > 0.05$). Dogs had a slightly reduced left versus right symmetry index after sham 7.66 ± 1.43832N when compared with before sham 8.8967 ± 2.31919 showing a non-statistically significant change in symmetry, $t(5) = 1.548$, $p = 0.182$.

Finally, a paired-samples t-test was ran to determine whether the change in symmetry index seen after the treatment was a statistically significant mean difference compared to the change in symmetry index after the sham. The assumption of normality was not violated, as assessed by Shapiro-Wilk's test ($p > 0.05$). The difference in symmetry index after treatment -0.78231965± 0.094647601N when compared to after sham -0.11478232 ± 0.153373668N, was statistically significant $t(5) = -12.918$, $p =< 0.001$, showing a statistical impact of the KORA mat. The walk and trot total symmetry index are displayed in in 'Figure 11', which clearly indicates the improvement PEMFT makes within the treatment group compared to the sham group.

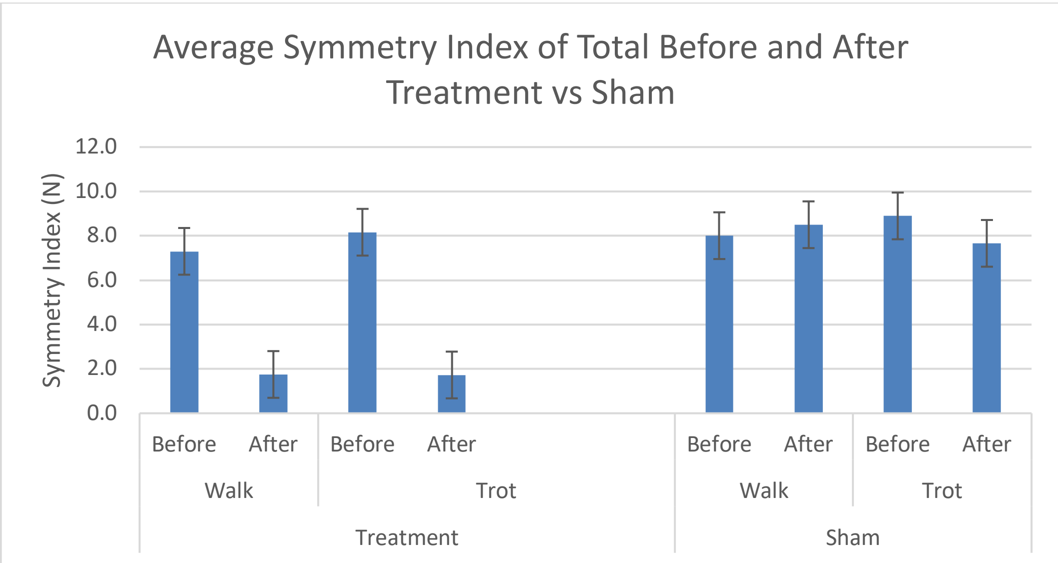

Figure 11: Average total symmetry index for sample dogs before and after either treatment or sham, in walk and trot.

5.2 Kinematics

5.2.1 Forelimb Protraction

5.2.1.1 Walk Forelimb Protraction

Descriptive statistics were carried out to assess whether the KORA mat intervention (treatment) changed the kinematics including protraction of the forelimbs walk, as compared to the sham intervention and found that the mean protraction increased from 17.8° to 18.7° for the treatment group but decreased for the sham group (18.0° to 16.9°).

A paired-samples t-test was then used to determine whether there was a statistically significant mean difference in protraction in walk of the dogs' forelimbs before and after receiving treatment. Data are mean ± standard deviation, unless otherwise stated. The assumption of normality was not violated, as assessed by Shapiro-Wilk's test ($p > 0.05$). Dogs had an increased forelimb protraction after treatment (18.6550° ± 5.75145°) when compared with before treatment (17.8083° ± 2.26783°), showing a statistically significant improvement in protraction $t(5) = -.336$, $p= 0.750$.

A paired-samples t-test was also ran to determine whether there was a statistically significant mean difference in protraction in walk of the dogs' forelimbs before and after a sham procedure to rule out a placebo effect. Data are mean ± standard deviation, unless otherwise stated. The assumption of normality was not violated, as assessed by Shapiro-Wilk's test ($p > 0.05$). Dogs had a slightly reduced forelimb protraction after sham 16.8900° ± 3.20535° when compared with before sham 17.9850° ± 2.40260° showing a statistically insignificant change in forelimb protraction, $t(5) = 2.565$, $p =0.05$.

Finally, a paired-samples t-test was ran to determine whether the change in forelimb protraction in walk seen after the treatment was a statistically significant mean difference compared to the change in forelimb protraction after the sham. The assumption of normality was not violated, as assessed by Shapiro-Wilk's test ($p > 0.05$). The difference in forelimb protraction after treatment 0.06° ± 0.332° when compared to after sham -0.7° ± 0.71°, was statistically insignificant $t(5) = 0.933$, $p =<0.394$.

5.2.1.2 Trot Forelimb Protraction

Descriptive statistics were carried out to assess whether the KORA mat intervention (treatment) changed the kinematics including protraction of the forelimbs in trot as compared to the sham intervention and found that the mean protraction increased from 17.6° to 21.9° for the treatment group but decreased for the sham group (18.0° to 17.8°).

A paired-samples t-test was then used to determine whether there was a statistically significant mean difference in protraction of the dogs' forelimbs in trot before and after receiving treatment. Data are mean ± standard deviation, unless otherwise stated. The assumption of normality was not violated, as assessed by Shapiro-Wilk's test ($p > 0.05$). Dogs had an increased forelimb protraction after treatment (22.2250° ± 9.48743°) when compared with before treatment (17.5983° ± 1.90478°), showing a statistically insignificant improvement in protraction $t(5) = -1.182$, $p= 0.290$.

A paired-samples t-test was also ran to determine whether there was a statistically significant mean difference in symmetry index in dogs before and after a sham procedure to rule out a placebo effect. Data are mean ± standard deviation, unless otherwise stated. The assumption of normality was not violated, as assessed by Shapiro-Wilk's test ($p > 0.05$). Dogs had a slightly reduced symmetry index after sham 17.8250° ± 2.14766° when compared with before sham 18.0067° ± 1.81761° showing a statistically insignificant change in symmetry, $t(5) = 0.655$, $p =0.542$.

Finally, a paired-samples t-test was ran to determine whether the change in forelimb protraction in trot seen after the treatment was a statistically significant mean difference compared to the change in forelimb protraction after the sham. The assumption of normality was not violated, as assessed by Shapiro-Wilk's test ($p > 0.05$). The difference in forelimb protraction in trot after treatment 0.27° ± 0.597° when compared to after sham -0.01° ± 0.041N=°, was statistically insignificant $t(5) = 1.116$, $p =0.315$. A summary of the average findings can be seen in 'Figure 12', outlining the impact PEMFT had on forelimb protraction versus sham and highlighting how a bigger influence occurred in trot within the treatment group post treatment.

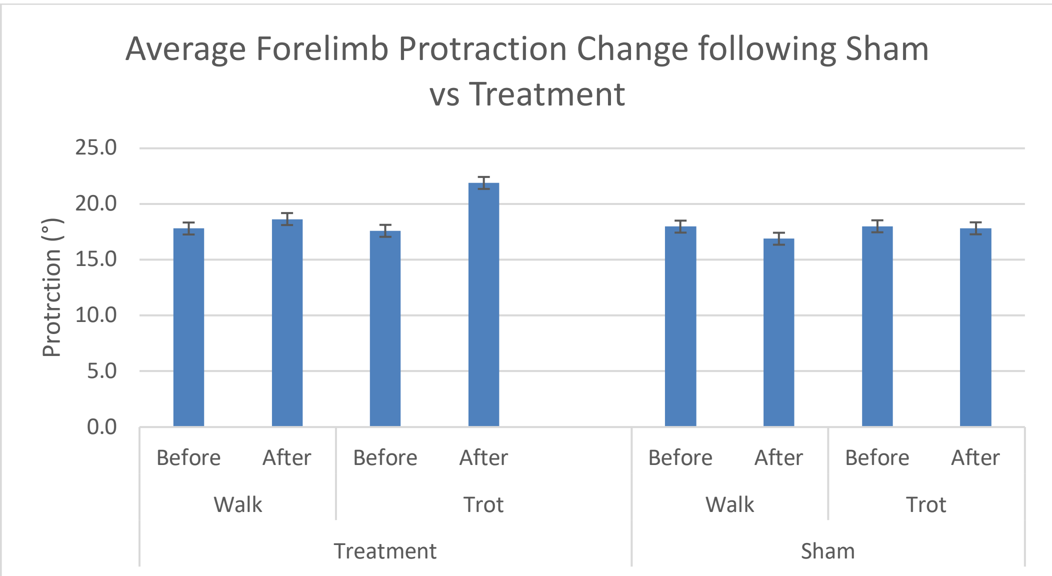

Figure 12: A graph to show the protraction of the forelimbs in walk and trot before and after treatment and sham conditions.

5.2.2 Forelimb Retraction

5.2.2.1 Walk Forelimb Retraction

Descriptive statistics were carried out to assess whether the KORA mat intervention (treatment) changed the kinematics including retraction of the forelimbs in walk, as compared to the sham intervention and found that the mean retraction increased from 26.5° to 27.9° for the treatment group but largely remained the same for the sham group (24.6° to 24.8°).

A paired-samples t-test was then used to determine whether there was a statistically significant mean difference in retraction of the forelimbs in walk before and after receiving treatment. Data are mean ± standard deviation, unless otherwise stated. The assumption of normality was not violated, as assessed by Shapiro-Wilk's test ($p > 0.05$). Dogs had an increased forelimb retraction after treatment (27.9150° ± 4.37160°) when compared with before treatment (26.4517° ± 6.23927°), showing a statistically insignificant improvement in forelimb retraction $t(5) = -.611$, $p = 0.568$.

A paired-samples t-test was also ran to determine whether there was a statistically significant mean difference in forelimb retraction in dogs in walk before and after a sham procedure to rule out a placebo effect. Data are mean ± standard deviation, unless otherwise stated. The assumption of normality was not violated, as assessed by Shapiro-Wilk's test ($p > 0.05$). Dogs had a slightly reduced forelimb retraction after sham 24.7633° ± 3.03146° when compared with before sham 24.6117° ± 2.86493° showing a non-statistically significant change in forelimb retraction, $t(5) = -0.684$, $p = 0.525$.

Finally, a paired-samples t-test was ran to determine whether the change in forelimb retraction in walk seen after the treatment was a statistically significant mean difference compared to the change in forelimb retraction in walk after the sham. The assumption of normality was not violated, as assessed by Shapiro-Wilk's test ($p > 0.05$). The difference in forelimb retraction after treatment 0.0817° ± 0.19426° when compared to after sham 0.0058° ± 0.02108°, was statistically insignificant $t(5) = 0.946$, $p = 0.387$.

5.2.2.2 Trot Forelimb Retraction

Descriptive statistics were carried out to assess whether the KORA mat intervention (treatment) changed the kinematics including retraction of the forelimbs trot, as compared to the sham intervention and found that the mean retraction increased from 22.4° to 31.0° for the treatment group but largely remained the same for the sham group (22.4° to 22.9°).

A paired-samples t-test was then used to determine whether there was a statistically significant mean difference in retraction of the dogs' forelimbs in trot before and after receiving treatment. Data are mean ± standard deviation, unless otherwise stated. The assumption of normality was not violated, as assessed by Shapiro-Wilk's test ($p > 0.05$). Dogs had an increased forelimb retraction after treatment (32.9733° ± 9.69662°) when compared with before treatment (22.4067° ± 2.37737°), showing a statistically insignificant improvement in retraction $t(5) = -2.370$, $p= 0.064$.

A paired-samples t-test was also ran to determine whether there was a statistically significant mean difference in retraction in the dogs' forelimbs in trot before and after a sham procedure to rule out a placebo effect. Data are mean ± standard deviation, unless otherwise stated. The assumption of normality was not violated, as assessed by Shapiro-Wilk's test ($p > 0.05$). Dogs retraction after sham 22.5267° ± 1.91589° did not differ much than before sham 22.3600° ± 2.26968° showing a statistical insignificant change in forelimb retraction in trot, $t(5) = -0.315$, $p =0.765$.

Finally, a paired-samples t-test was ran to determine whether the change in forelimb retraction in trot seen after the treatment was a statistically significant mean difference compared to the change in retraction after the sham. The assumption of normality was not violated, as assessed by Shapiro-Wilk's test ($p > 0.05$). The difference in forelimb retraction in trot after treatment 0.5017 ± 0.55658 when compared to after sham 0.0117° ± 0.06080°, was statistically insignificant $t(5) = 2.171°$, $p =0.082°$. The average results have been summarised in 'Figure 13', outlining the impact PEMFT had on forelimb retraction versus sham, similarly to forelimb protraction, retraction in trot within the treatment group post treatment had the biggest difference.

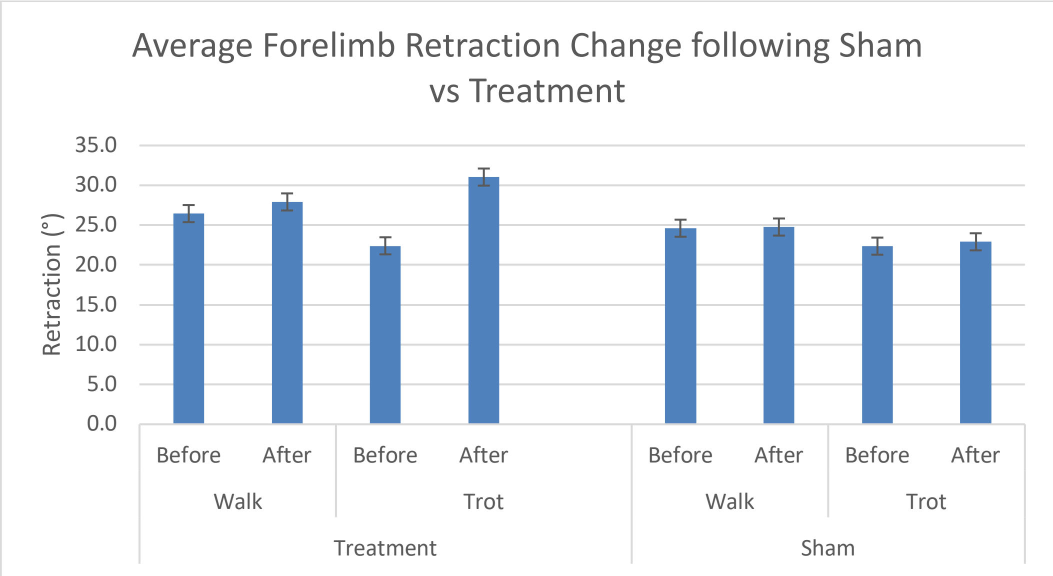

Figure 13: A graph to show the retraction of the forelimbs in walk and trot before and after treatment and sham conditions.

5.2.3 Hindlimb Protraction

5.2.3.1 Walk Hindlimb Protraction

Descriptive statistics were carried out to assess whether the KORA mat intervention (treatment) changed the kinematics including hindlimb protraction in walk, as compared to the sham intervention and found that the mean protraction decreased from 10.4° to 7.5° for the treatment group and decreased slightly for the sham group (8.6° to 7.5°).

A paired-samples t-test was then conducted to determine whether there was a statistically significant mean difference in protraction of the dogs hindlimbs in walk before and after receiving treatment. Data are mean ± standard deviation, unless otherwise stated. The assumption of normality was not violated, as assessed by Shapiro-Wilk's test ($p > 0.05$). Dogs had a reduced hindlimb protraction after treatment (7.5050° ± 2.35015°) when compared with before treatment (10.3617° ± 2.29610°), showing a statistically significant decrease in hindlimb protraction in walk (5) = 3.205, p= 0.024.

A paired-samples t-test was also ran to determine whether there was a statistically significant mean difference in hindlimb protraction in dogs in walk before and after a sham procedure to rule out a placebo effect. Data are mean ± standard deviation, unless otherwise stated. The assumption of normality was not violated, as assessed by Shapiro-Wilk's test ($p > 0.05$). Dogs had a slightly reduced protraction after sham 7.4583° ± 1.18884° when compared with before sham 8.6283° ± 1.71082° showing a statistically insignificant change in hindlimb protraction in walk, t(5) = 1.467, p =0.202.

Finally, a paired-samples t-test was ran to determine whether the change in hindlimb protraction in walk seen after the treatment was a statistically significant mean difference compared to the change in protraction after the sham. The assumption of normality was not violated, as assessed by Shapiro-Wilk's test (p > 0.05). The difference in hindlimb protraction after treatment -2.7 ± 0.188 when compared to after sham -0.11 ± 0.203, was statistically insignificant t(5) = -1.261, p =0.263.

5.2.3.2 Trot Hindlimb Protraction

Descriptive statistics were carried out to assess whether the KORA mat intervention (treatment) changed the kinematics including protraction of the hindlimbs in trot, as compared to the sham intervention and found that the mean hindlimb protraction decreased from 10.5° to 7.8° for the treatment group and decreased for the sham group (11.7° to 11.4°).

A paired-samples t-test was then used to determine whether there was a statistically significant mean difference in protraction of the dogs hindlimbs in trot before and after receiving treatment. Data are mean ± standard deviation, unless otherwise stated. The assumption of normality was not violated, as assessed by Shapiro-Wilk's test (p > 0.05). Dogs had a reduced hindlimb protraction after treatment (7.8100° ± 2.19041°) when compared with before treatment (10.4817° ± 1.85903°), showing a statistically significant improvement in hindlimb protraction t(5) = 3.348, p= 0.02.

A paired-samples t-test was also ran to determine whether there was a statistically significant mean difference in hindlimb trot protraction in dogs before and after a sham procedure to rule out a placebo effect. Data are mean ± standard deviation, unless otherwise stated. The assumption of normality was not violated, as assessed by Shapiro-Wilk's test (p > 0.05). Dogs had a decreased hindlimb protraction after sham 11.4367° ± 1.34716° when compared with before sham 11.6517° ± 1.51079° showing a statistically insignificant change in hindlimb protraction, t(5) = 0.698, p =0.516.

Finally, a paired-samples t-test was ran to determine whether the change in hindlimb trot protraction seen after the treatment was a statistically significant mean difference compared to the change in protraction after the sham. The assumption of normality was not violated, as assessed by Shapiro-Wilk's test (p > 0.05). The difference in protraction after treatment -2.5° ± 0.181° when compared to after sham -0.01° ± 0.066°, was statistically significant t(5) = -3.825, p

=0.012, showing a statistical impact of the KORA mat. A summary of the averages can be found in ‘Figure 14’, outlining the impact PEMFT had on hindlimb protraction versus sham.

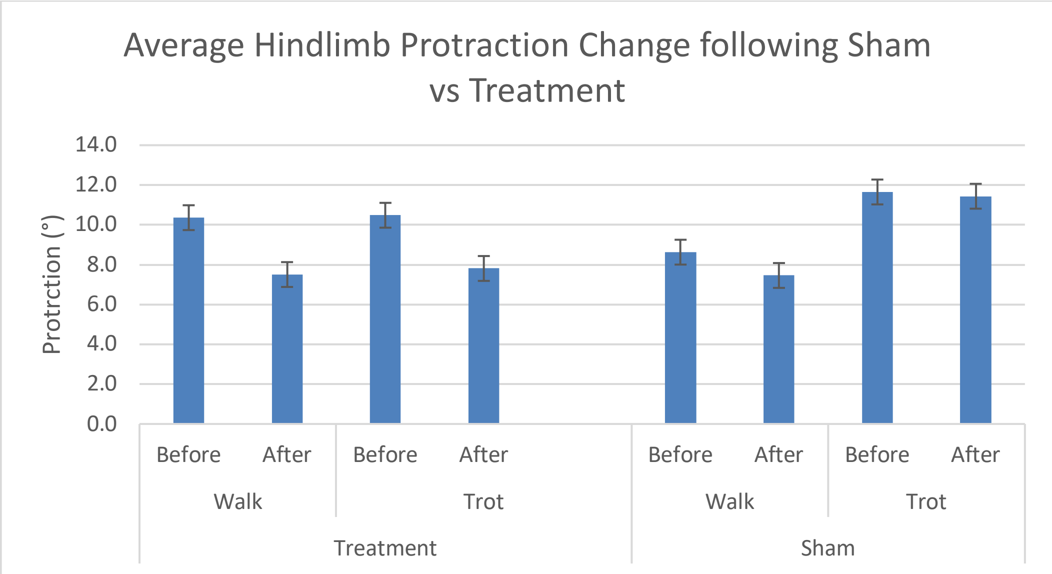

Figure 14: A graph to show the protraction of the hindlimbs in walk and trot before and after treatment and sham conditions.

5.2.4 Hindlimb Retraction

5.2.4.1 Walk Hindlimb Retraction

Descriptive statistics were carried out to assess whether the KORA mat intervention (treatment) changed the kinematics including hindlimb retraction in walk, as compared to the sham intervention and found that the mean hindlimb retraction increased from 25.1° to 31.2° for the treatment group but largely remained the same for the sham group (24° to 25.2°).

A paired-samples t-test was then used to determine whether there was a statistically significant mean difference in retraction of the dogs hindlimbs in walk before and after receiving treatment. Data are mean ± standard deviation, unless otherwise stated. The assumption of normality was not violated, as assessed by Shapiro-Wilk's test ($p > 0.05$). Dogs had an increased hindlimb retraction after treatment (32.6783° ± 12.55871°) when compared with before treatment (25.1083° ± 1.01889°), showing a statistically insignificant increase in retraction $t(5) = -1.507$, $p = 0.192$.

A paired-samples t-test was also ran to determine whether there was a statistically significant mean difference in hindlimb retraction in dogs in walk before and after a sham procedure to rule out a placebo effect. Data are mean ± standard deviation, unless otherwise stated. The assumption of normality was not violated, as assessed by Shapiro-Wilk's test ($p > 0.05$). Dogs had a slightly increased hindlimb retraction after sham 25.2350 ° ± 0.64565° when compared with before sham 23.9517° ± 2.01057° showing a non-statistically significant change in hindlimb retraction in walk, $t(5) = -2.211$, $p = 0.078$.

Finally, a paired-samples t-test was ran to determine whether the change in hindlimb retraction in walk seen after the treatment was a statistically significant mean difference compared to the change in retraction after the sham. The assumption of normality was not violated, as assessed by Shapiro-Wilk's test ($p > 0.05$). The difference in hindlimb retraction after treatment 0.3° ± 0.482° when compared to after sham 0.6° ± 0.065°, was statistically insignificant $t(5) = 1.192$, $p = 0.287$, showing an non statistical impact of the KORA mat on hindlimb retraction in walk.

5.2.4.2 Trot Hindlimb Retraction

Descriptive statistics were carried out to assess whether the KORA mat intervention (treatment) changed the kinematics including retraction of the hindlimbs in trot, as compared to the sham intervention and found that the mean retraction increased from 24.1° to 28.5° for the treatment group but largely remained the same for the sham group (24.2° to 25.2°).

A paired-samples t-test was then used to determine whether there was a statistically significant mean difference in retraction of the dogs hindlimbs in trot before and after receiving treatment. Data are mean ± standard deviation, unless otherwise stated. The assumption of normality was not violated, as assessed by Shapiro-Wilk's test ($p > 0.05$). Dogs had an increased hindlimb retraction after treatment (28.4600° ± 10.77554°) when compared with before treatment (24.0933° ± 1.56443°), showing a statistically insignificant difference in hindlimb retraction $t(5) = -1.005$, $p = 0.361$.

A paired-samples t-test was also ran to determine whether there was a statistically significant mean difference in hindlimb trot retraction in dogs before and after a sham procedure to rule out a placebo effect. Data are mean ± standard deviation, unless otherwise stated. The assumption of normality was not violated, as assessed by Shapiro-Wilk's test ($p > 0.05$). Dogs had a slightly increased hindlimb retraction after sham 25.1983° ± 1.68679° when compared with before sham 24.1850° ± 1.85296° showing a statistically insignificant change in hindlimb retraction, $t(5) = -1.171$, $p = 0.294$.

Finally, a paired-samples t-test was ran to determine whether the change in hindlimb trot retraction seen after the treatment was a statistically significant mean difference compared to the change in retraction after the sham. The assumption of normality was not violated, as assessed by Shapiro-Wilk's test ($p > 0.05$). The difference in retraction after treatment 0.18° ±

0.438° when compared to after sham 0.05° ± 0.086°, was statistically insignificant t(5) = 0.752, p =0.486, showing no statistical impact of the KORA mat on hindlimb retraction in trot. A summary of the mean values can be seen in 'Figure 15', outlining the impact PEMFT had on hindlimb retraction versus sham.

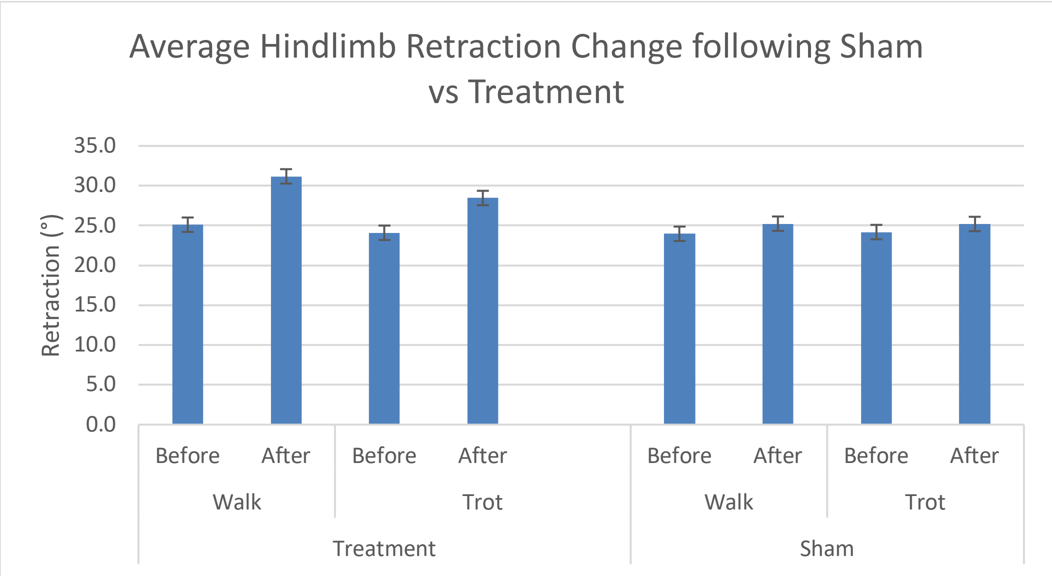

Figure 15: A graph to show the retraction of the hindlimbs in walk and trot before and after treatment and sham conditions.

5.2.5 Stride Length

5.2.5.1 Walk Stride Length

Descriptive statistics were carried out to assess whether the KORA mat intervention (treatment) changed the kinematics including average forelimb SL (left and right) in walk, as compared to the sham intervention and found that the mean forelimb SL remained the same for treatment and sham at walk (0.8metres (m)).

A paired-samples t-test was then used to determine whether there was a statistically significant mean difference in average forelimb SL of the dogs at walk before and after receiving treatment. Data are mean ± standard deviation, unless otherwise stated. The assumption of normality was not violated, as assessed by Shapiro-Wilk's test ($p > 0.05$). Dogs had a reduced average forelimb SL after treatment (0.7517m ± 0.13152m) when compared with before treatment (0.8150m ± 0.09894m), showing a statistically significant reduction in forelimb SL at walk t(5) = 2.698, p= 0.043.

A paired-samples t-test was also ran to determine whether there was a statistically significant mean difference in average forelimb SL in dogs at walk before and after a sham procedure to rule out a placebo effect. Data are mean ± standard deviation, unless otherwise stated. The assumption of normality was not violated, as assessed by Shapiro-Wilk's test ($p > 0.05$). Dogs had an overall decreased forelimb SL after sham 0.7700m ± 0.17889m when compared with before sham 0.8283m ± 0.10304m showing a statistically insignificant change in forelimb SL at walk, $t(5) = 1.736$, $p = 0.143$.

Finally, a paired-samples t-test was ran to determine whether the change in average forelimb SL at walk seen after the treatment was a statistically significant mean difference compared to the change in forelimb SL after the sham. The assumption of normality was not violated, as assessed by Shapiro-Wilk's test ($p > 0.05$). The difference in forelimb SL after treatment -0.833m ± 0.07285m when compared to after sham -0.0800m ± 0.10752m, was statistically insignificant $t(5) = -0.51$, $p = 0.961$. The SL results are summarised in 'Figure 16', clearly demonstrating the significant impact PEMFT had on SL decrease.

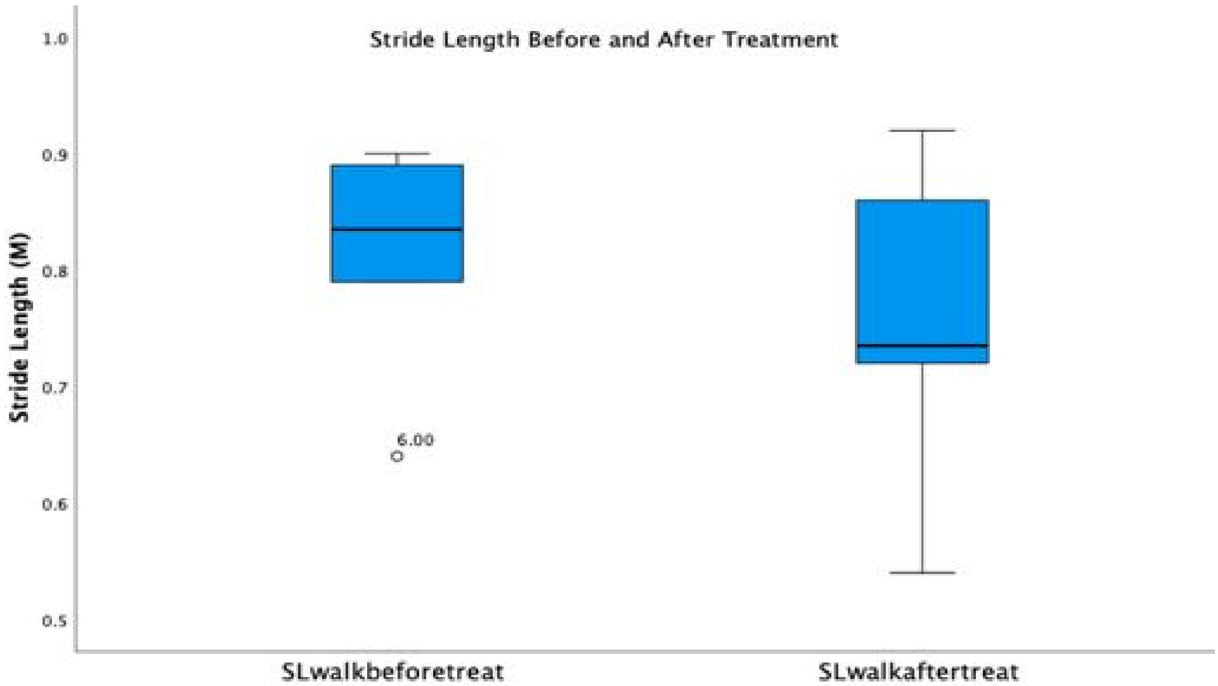

Figure 16: Box plot highlighting the mean stride length decrease post treatment.

6 Discussion

The intent of this study was to assess the influence of a PEMFT application to canine kinetic and kinematics. The trial was based on the KORA PEMFT mat specifically.

6.1 Findings

6.1.1 Kinetics

The study reported statistically significant reductions in the asymmetries of the dogs that received the PEMFT treatment had significant increases in forelimb and hindlimb loading symmetry ($P<0.05$), indicating less uneven limb loading. Therefore, the hypothesis was accepted as the null hypothesis was rejected. These findings suggest that the dogs displayed less asymmetrically gaits post PEMFT treatment, (further discussed in **3.7**) that outlines how gait asymmetries can relate to canine pain. Although every treatment group had a significant increase in symmetry, the forelimb trot treatment group had the most significant statistically ($P<0.001$), suggesting that the PEMFT had the most influence on the trot in the forelimbs. This may be due to potential cranial loading of dogs with undiagnosed pathologies (for example old racing injuries leading to OA). As racing greyhounds incur cyclic loading (Muir *et al.*, 1999; Johnson *et al.*, 2000) which has been linked to pelvic limb issues such as fractures in human athletes (Eisele and Sammarco, 1993; Kiss *et al.*, 1993), racehorses (Norrdin *et al.*, 1998) and greyhounds; particularly the central tarsal bone (Boudrieau *et al.*, 1984; Tomlin *et al.*, 2000). Studies have suggested that dogs typically hide pain as a defence mechanism, therefore if the greyhounds did have any underlying pain from racing injuries this may initially be undetectable without a full veterinary assessment (Lush and Ijichi, 2018). Therefore, if there were any undiagnosed pelvic limb issues in the greyhounds, they would have been cranially loading to relieve the area of any pain or discomfort being caused by the potential racing linked issue, causing higher forelimb loading. If the KORA PEMFT did reduce pain, as discussed in **3.3**, then this could reason why the forelimb trot result was the most significant, as naturally dogs will carry 60% on their forelimbs and 40% behind (Lee *et al.*, 2004; Abdelhadi *et al.*, 2013). However, studies have found this to be less in dogs with pelvic limb pathologies, therefore by minimising pain in the pelvic region, the asymmetrical limb loading of the forelimbs is likely to be reduced, especially in trot where GRF would be higher due to trot being a more propulsive gait (Fischer *et al.*, 2013).

The was also consistently significant increases in limb loading symmetry between the treatment and sham group differences for forelimb, hindlimb, protraction and retraction ($P<0.05$). This suggests that not only were both forelimb and hindlimb symmetry index results improved, but the difference between the treatment and sham group also significantly different. This suggests that the PEMFT had a large effect on the dogs' limb loading, further suggesting that it had an analgesic effect to elicit this response (as discussed in **3.7**).

There was also however a significant increase in limb loading symmetry within hindlimb trot measures. This result could suggest that the bed had influence on the limb loading symmetry, as most of the dogs slept on the mats in each condition. Sleep has been associated with release of Local IGF-1 which can reduce inflammation and muscle recovery (Chennaoui *et al.*, 2021), therefore the sleep may have provided analgesia and therefore better limb symmetry and not the PEMFT. However, this was one sham group and all other sham groups were insignificant whereas all of the treatment groups all had significant improvements, suggesting the PEMFT is likely to have caused this change.

6.2 Kinematics

6.2.1 Protraction and Retraction

Within the entire forelimb kinematic results there were no significant differences (P>0.05) between protraction before and after for the sham group, and there was no significant difference (P>0.05) when comparing the change in protraction for the treatment group versus the change for the sham group, resulting in failure to reject the null hypothesis (H0d). There were also no significant differences (P>0.05) between retraction before and after for the sham group, and there was no significant difference (P>0.05) when comparing the change in retraction for the treatment group versus the change for the sham group, resulting in failure to reject the null hypothesis (H0d).

There was a significant decrease in the hindlimb protraction (P<0.05) in walk and trot within the treatment group therefore the hypotheses was accepted (H1d) and the null hypotheses was rejected. There was also significant decrease in the hindlimb protraction (P<0.05) in the change in hindlimb protraction for the treatment group versus the change for the sham group in therefore the hypotheses was accepted (H1d) and the null hypotheses was rejected. There was no significant difference (P>0.05) between hindlimb protraction in walk and trot before and after for the sham group, and there was no significant difference (P>0.05) when comparing the change in hindlimb protraction for the treatment group versus the change for the sham group in walk, resulting in failure to reject the null hypothesis (H0d).

There was no significant difference (P>0.05) between hindlimb retraction in walk and trot before and after for the sham group, and there was no significant difference (P>0.05) when comparing the change in hindlimb retraction for the treatment group versus the change for the sham group in walk and tot, resulting in failure to reject the null hypothesis (H0d).

Within equine studies, lameness did not alter the protraction or retraction angles (Alvarez *et al.*, 2008), therefore if the dogs did have any lameness this may not have been detected through the influence of PEMFT. Conversely to Alvarez *et al.,* (2008), a similar study found lameness to induce subtle limb alterations which is similar to the findings in this study as there were higher changes within the descriptive results between the treatment and sham group, however not all significant, for example the forelimb retraction in trot had increased within the mean data (22.4°-31°) whereas the sham largely remained the same (22.4°-22.9°). This suggests that the PEMFT did have an influence on the retraction however due to the nature of lameness the differences were not large enough to be significant.

6.2.2 Stride Length

There as a significant decrease in the SL ($P<0.05$) within the treatment group therefore the hypotheses was accepted (H1d) and the null hypotheses was rejected. There was no significant difference ($P>0.05$) between SL before and after for the sham group, and there was no significant difference ($P>0.05$) when comparing the change in SL for the treatment group versus the change for the sham group, resulting in failure to reject the null hypothesis (H0d).

Within equine literature, SL has been found to increase due to PEMFT therapy (Rostad, 2022) however this result was concluded through a prospective study through owner opinion which may have led to biased results. A further study found by Rostad found SL was not influenced by PEMFT immediately after treatment but did increase 8 hours post treatment and the quality of the walk post PEMFT reduced which was concluded to be due to PEMFT creating relaxation (Rostad *et al.*, 2023). The study by Rostad *et al.,* (2023) however used a low frequency of 5Hz but for a long duration of 30 minutes which in comparison to a pain setting of 200 Hz for 20 mins several times a day (Tingting Tong *et al.*, 2022; Flatscher *et al.*, 2023) seems relatively low, therefore higher settings may have had a different outcome within the results.

Within human literature, PEMFT had no influence on SL in one randomised placebo controlled trial which utilised 15-30Hz PEMFT for 45 minutes 5 times per week through a full body PEMFT mat (Granja-Domínguez *et al.*, 2022), similar to that of the KORA mat but designed for humans. This study also used a relatively low Hz measurement as previously discussed, considering the patients were prone to fractures and neurological issues which typically require 50 Hz (Multanen *et al.*, 2018; Jie Tong *et al.*, 2022; Flatscher *et al.*, 2023). A similar study found that PEMFT had no influence on SL but did increase gait speed (Giusti *et al.*, 2013), suggesting PEMFT to not have an impact on SL overall.

Within rats PEMFT was found to initially decrease SL within a group that received PEMFT for 1 hour but a group that received PEMFT for 3 hours had an increased SL but 6 weeks after

(Huegel *et al.*, 2020). This study utilised rats with Achilles tendon damage, therefore the increased SL could have been due to natural healing of soft tissues rather than the PEMFT. However, in relation to the KORA mat, this could explain the results found as PEMFT increases SL but not immediately according to the equine and rat studies mentioned, therefore if measurements were taken at a later date post KORA PEMFT application, a further impact on SL may have been seen.

Some studies have suggested that in dogs with OA, getting up after a period of lying down can induce stiffness (Sharkey, 2013). Based on these findings, it could be concluded that the stride length was not increased as the dog was allowed to rest in sham and treatment conditions, allowing the muscle fibres to return to their resting status. In human studies, movement post recumbency has shown to increase blood and fluid movement as the body tries to redirect its flow to all extremities (Maw *et al.*, 1995; Wagle *et al.*, 2017) and as muscles require blood flow for oxygen to produce ATP for kinetic energy to move (González-Alonso *et al.*, 2002), this could be influential upon the SL ability of the dog.

6.2.3 Parameter Comparison

Through analysing several streams of data, it allows comparisons to be made to explain certain data patterns. Within hindlimb retraction, ‘Dog 2’ had a large increase in angulation post treatment of around 55% in walk and 51% in trot whereas in comparison the majority of other dogs had a low increase of under 10% and some had decreased values. This means ‘Dog 2’ could be classed as an outlier as this was not a typical increase in comparison to the other dogs’ data, however ‘Dog 2’ had similar increases in forelimb retraction pre and post treatment. Also, ‘Dog 2’ had similar results to the other dogs within the asymmetry and SL results. Therefore, the PEMFT had individual responded from each dog, suggesting ‘Dog 2’ may have had a pathology that responded well to the treatment.

6.3 Relevance to Industry

The canine industry is rapidly expanding and with the increase of breeding and desires for particular breeds such as dachshunds (O’Neill *et al.*, 2023), yet these breeds have been linked to certain pathologies and IVDD (Dorn and Seath, 2018) suggesting an increase in pain relief for these cases. Non-invasive treatments such as PEMFT has been found to be beneficial for these cases (Zidan *et al.*, 2018), however application can come in several device types (Gaynor *et al.*, 2018) each requiring anatomical knowledge of where to apply the device and time consumption to apply the device. However, a device such as the KORA mat requires no anatomical knowledge as the dog lies on the mat which also means there is no time consumption required to apply a handheld device. As PEMFT is advised to be applied several times per day (Gaynor *et al.*, 2018), the amount of time saved through using a KORA mat is very beneficial to the owner who may not be able to dedicate time to PEMFT applications which could hinder the rehabilitation and QL of the dog.

Alternative pain relief exists in the form of NSAIDS however recent studies have linked the prescription of such medication with adverse events in patients (Hunt *et al.*, 2015; Belshaw *et al.*, 2016). Therefore, PEMFT could be an alternative as it reduced uneven limb loading in this trial and uneven limb loading has been associated with pain (Anil *et al.*, 2002; Barwick *et al.*, 2018). The current veterinary climate is also labelled as 'expensive' according to UK owners (Rhys-Davies and Ogden, 2020) and as pets are a 'luxury', owners may not be in a position to afford veterinary bills which could influence the wellbeing of pets including dogs. Surveys in America found owners to be unable to afford veterinary bills or suggest that bills seemed too high (American Veterinary Medical Association, 2022) and other studies suggest owners to be sceptical of veterinarians suggestions with the mindset that veterinarians may offer expensive routes of care (Coe *et al.*, 2007). Therefore, if PEMFT can gain the results suggested, it could be a cheaper alternative to such veterinary treatments as a PEMFT device could be a large outgoing for a lifetime of pain relief.

6.4 Limitations

Though every effort was made to provide a robust trial through its randomised controlled trial design, there were some limitations. One limitation is the sample as, though the sample was calculated using the one way ANOVA equation (Arifin and Wan Mohammad, 2017), 6 dogs would not be representative to the wider canine population and more so due to them all being one breed who have all had a racing career therefore are quite niche in comparison to a pet dog without a discipline. Due to the nature of racing some of the dogs may have undiagnosed issues which may have influenced the cell response to the PEMFT, therefore future studies could not only involve larger sample sizes to provide more statistically significant results, but also samples with healthy and unhealthy dogs could provide insights into optimal treatment times or variance of treatment responses.

During the trial, there was a 14-day washout period which was necessary for reasons previously stated, however during that time the dogs' daily routine could have entirely varied which could have influenced the results rather than the PEMFT. The KORA mat was also applied to the sample in a strange environment; therefore, the dogs may have reacted differently than if they were in their usual residence. As the dogs are usually housed in kennels, it is unknown what type of bed or flooring the dogs are usually on and surfaces can influence GRF and therefore limb loading which may have also influenced the change in the dog's locomotion.

Kinematic data allows the movement of the joint to be assessed, as discussed in **3.7**, however studies have found that ROM can differ between breeds and neuter status can also influence ROM measurements (Hady *et al.*, 2015), therefore results of the greyhounds may not be applicable to the entire canine population.

6.5 Future Study Recommendations

Though variables were controlled such as the same handler, the assumption that reduced asymmetry is linked to less pain or discomfort could have been further verified with a measurement of pain. For example, an algometer reading could have been taken in order to assess the dogs' pain before and after the PEMFT device which could have verified whether the asymmetry of the dog reduced due to PEMFT providing pain relief or not.

The PEMFT was only applied to each dog for 30 minutes, which is minimal compared to other studies. Therefore, to assess the impact of PEMFT if used in a rehabilitation setting, the device would need to be applied for longer. Future studies could utilise the PEMFT as it would be prescribed by a Veterinary Physiotherapist to assess its influence over a certain period within a rehabilitation plan.

Kinematic results were less significant that kinetic results, as outlined. Due to the SL finding being inconsistent with the hypotheses, future research could also include a SL measurement later to see the long-term influence of the PEMFT. Protraction was the only significant parameter in both walk and trot of the hindlimb and retraction in hindlimbs requires muscles groups such as the hamstrings including the *semimembranosus*, *semitendinosus* and *biceps femoris* to contract in order to extend the hip, stifle and hock (Budras, 2008). Therefore, in future studies, a measure of muscle usage through electro myelography or thermotherapy could highlight which muscles the PEMFT is influencing which could explain the results found in this study further. In order to more accurately assess kinematic data in future, the dogs should be walked around for x number of laps in order to allow blood flow to reach all extremities to allow a true representation of their movement to be recorded.

As this trial had two researchers, there may be a limitation to the assurance of the quality of the data collection which would have significantly influenced the results. Therefore, in future only one researcher should collect the data but checks and measures could be put in place to minimise the chance of human error.

7 Conclusion

The investigation appraised how PEMFT in the form of a KORA mat influenced kinetic and kinematic parameters of dogs within walk and trot. The KORA PEMFT mat significantly influenced all limb loading asymmetries of forelimbs and hindlimbs along and some protraction and retraction of all limbs in walk and trot. Comparison of these results to sham treatments suggested that the PEMFT did elicit a response to the kinetics and kinematics of the dog however, more significantly to the asymmetry responses.

The results showed that PEMFT had a significant influence on reduce asymmetry within both walk and trot within forelimbs and hindlimbs, therefore PEMFT influenced limb loading symmetry and therefore assumptions were made that it influenced pain levels to achieve these results, as limb loading, lameness and pain have been associated to each other within literature. However, PEMFT did not have as consistent results within the kinematic parameters, for example the protraction and retraction results did not all have significance unlike the kinetic results. This could have been due to alterations in the dog's movement, for example dogs will naturally shift more weight onto the forelimbs and typically hind limb injuries are more common in greyhounds, therefore results could represent how the greyhounds are not utilising their limbs differently due to reduced pain. where some results suggested that SL was reduced which has been recorded in the presence of lameness in previous studies. However due to several factors including the dogs sleeping on the KORA mat during sham and treatment groups, this could have influenced the dogs' mobility afterwards hence the reduced SL within the results.

Future studies could include varying dog breeds to allow the results to be more representable to the entire canine population, along with different groups such as healthy, unhealthy and controls. The study design could also incorporate different PEMFT style applicators and application more in line with that prescribed by a Veterinary Physiotherapist regarding the frequency and duration of application. The use of PEMFT long term has not been studied, which could also be incorporated into future studies to assess any long-term side effects, but also to follow up on any musculoskeletal or global influences long term.

Overall, this study has highlighted how PEMFT can be influential in the form of better symmetry within the dogs' movement which long term would improve muscle symmetry and allow a healthier overall dog. Therefore, PEMFT is recommended for Veterinary Physiotherapists and other such practitioners to utilise, case dependent.

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9 Appendices

Appendix i. Calculation of symmetry index

Right vs Left: Symmetry of both right limbs to both left limbs. Calculated as the total of the values for the two right limbs minus the total of the values for the two left limbs, with this difference divided by the average of total right limb values and total left limb values. This is a signed index where a positive SI indicates the right limbs have higher values and a negative SI indicates the left limbs have higher values.

Right vs Left SI = ([(XRF + XRH) - (XLF + XLH)] / [0.5 * (XRF + XLF + XRH + XLH)]) * 100%

Right vs Left Front: Symmetry of contralateral front limbs. Calculated as the difference between right and left front values divided by the average of right and left front values. This is a signed index where a positive SI indicates the right limbs have higher values and a negative SI indicates the left limbs have higher values.

Right vs Left Front SI = ((XRF - XLF) / [0.5 * (XRF + XLF)]) * 100%

Right vs Left Hind: Symmetry between contralateral hind limbs. Calculated as the difference between right and left hind values divided by the average of right and left hind values. This is a signed index where a positive SI indicates the right limbs have higher values and a negative SI indicates the left limbs have higher values.

Right vs Left Front SI = ((XRH - XLH) / [0.5 * (XRH + XLH)]) * 100%

Adapted from Kano *et al.*, (2016) and Blake (2024).