Veterinary Research Communications (2025) 49:360
https://doi.org/10.1007/s11259-025-10939-x

BRIEF REPORT

Pulsed electromagnetic field therapy for pain control in dogs with hip osteoarthritis: A randomized clinical study

Luís Felipe Kühl[1] · Fabiano Montiani-Ferreira[1] · Jennifer Hummel[2] · Gustavo Vicente[3] · Gilberto Serighelli-Júnior[1] · Ricardo Guilherme D' Otaviano Castro Vilani[1] · Soraia Figueiredo de Souza[1]

Received: 22 July 2025 / Accepted: 29 September 2025

Abstract

Canine hip osteoarthritis (OA) is a common orthopedic disorder that leads to chronic pain, reduced mobility, and impaired quality of life. Pulsed electromagnetic field (PEMF) therapy has been proposed as a non-invasive adjunct for managing musculoskeletal pain, but clinical evidence in dogs remains limited. This randomized clinical trial evaluated PEMF as a standalone analgesic intervention in dogs with radiographically confirmed OA. Twenty client-owned dogs were randomly assigned to receive either active PEMF treatment (50 Hz, 40 Gauss, 30 min/session, twice weekly for 5 weeks; PEMF group, $n=10$) or no intervention (Control group, $n=10$). Pain was assessed using pressure algometry and two validated instruments: the Helsinki Chronic Pain Index and the Canine Brief Pain Inventory (CBPI). Goniometry and thigh circumference measurements were evaluated. Dogs in the PEMF group exhibited significant pain reduction from the first session, with CBPI scores improving markedly between sessions 1 and 10 ($P=0.01$) and Helsinki scores showing similar progress ($P=0.05$). In contrast, no significant differences in joint range of motion or thigh circumference were detected between groups throughout the study ($P>0.05$). These findings suggest that PEMF therapy is a safe, non-invasive, and effective approach to alleviate chronic pain in dogs with hip OA, representing a potential complement or alternative to long-term pharmacotherapy.

Keywords Analgesia · Canine osteoarthritis · Chronic pain · Pulsed electromagnetic field therapy

Introduction

Osteoarthrits (OA), secondary to hip dysplasia (HD), is a common condition in veterinary practice, often associated with chronic pain and locomotor impairment (Okamoto-Okubo et al. 2021). In the context of progressive joint degeneration and nociceptive sensitization, selecting an effective and safe therapeutic strategy becomes essential, especially in geriatric patients who frequently present with comorbidities that may contraindicate conventional pharmacological treatments (Mille et al. 2023). In this scenario, veterinary physiotherapy has emerged as a valuable, non-invasive approach capable of alleviating clinical signs in dogs with HD without exposing them to systemic adverse effects (Dycus et al. 2022).

Among the rehabilitation modalities available, pulsed electromagnetic field (PEMF) therapy has gained increasing recognition. By emitting pulsed magnetic fields, PEMF has been shown to reduce pain and improve overall comfort and quality of life in affected dogs (Sullivan et al. 2013; Zidan et al. 2018; Alvarez et al. 2019). Although PEMF therapy has demonstrated potential benefits in managing orthopedic pain in dogs, evidence regarding its effectiveness as a standalone treatment for chronic pain associated with OA remains limited.

Therefore, the aim of this study was to evaluate the efficacy of PEMF therapy, when used as a sole treatment, in reducing pain and improving quality of life in dogs with hip osteoarthritis. We hypothesized that PEMF therapy would significantly reduce pain scores in dogs diagnosed with hip osteoarthritis.

✉ Soraia Figueiredo de Souza
soraiasouza@ufpr.br

1 Department of Veterinary Medicine, Federal University of Paraná (UFPR), Curitiba, Paraná, Brazil

2 Department of Health Sciences, University of Southern Santa Catarina (UNISUL), Tubarão, Santa Catarina, Brazil

3 Independent Veterinary Practitioner, Porto Alegre, Brazil

Published online: 20 October 2025

Materials and methods

Animals

A priori sample size estimation was performed using G*Power (G*Power, version 3.1 (Heinrich Heine University Düsseldorf, Düsseldorf, Germany) to determine the minimum number of dogs required per group to detect a statistically significant reduction in chronic pain scores using the Helsinki Chronic Pain Index (HCPI) as the primary outcome. Based on previous studies, a clinically meaningful difference of 2.0 points on the HCPI was assumed, with an estimated standard deviation of 1.5. Considering a two-tailed t-test, an alpha level of 0.05, and a power of 80% (1 – $\beta = 0.80$), the minimum required sample size was calculated to be 10 dogs per group (Cohen's $d = 1.33$), totaling 20 animals.

The study included 20 client-owned dogs of either sex, aged 2 to 12 years, of medium to large breeds. Inclusion criteria consisted of clinical signs of lameness, a radiographic diagnosis of hip osteoarthritis for at least six months, and the absence of continuous pharmacological pain therapy. Dogs exhibiting acute exacerbation of pain during the study were withdrawn and received rescue analgesia for 7 consecutive days, consisting of carprofen (2.2 mg/kg, orally, twice daily; Carproflan® 25 mg, São Paulo, Brazil) in combination with dipyrone (25 mg/kg, orally, twice daily; EMS® 500 mg, Brazil). Exclusion criteria included concurrent orthopedic disorders that could independently affect gait or pain assessment (e.g., patellar luxation, cranial cruciate ligament rupture), systemic diseases likely to interfere with general health or treatment response (e.g., cardiac disease, endocrinopathies, neoplasia), and obesity, defined as a body condition score (BCS) $\geq 7/9$. Dogs presenting with severe pain (i.e., inability to walk or persistent vocalization) were also excluded, as well as those lacking at least one of the following clinical signs reported by the owner: difficulty walking, difficulty rising, difficulty trotting, and/or lameness.

All owners provided written informed consent, were blinded to group allocation, and were permitted to withdraw their dogs at any stage of the study.

Study design

This is a prospective, randomized, controlled clinical trial. Animals were randomly assigned to two equal-sized groups using block randomization (www.random.org), the Pulsed Electromagnetic Field group (PEMF group, $n = 10$) and the Control group ($n = 10$). Each dog underwent ten treatment sessions lasting 30 min, performed twice weekly over a five-week period, while positioned in either lateral or sternal recumbency.

In the PEMF Group, therapy was administered using the Magnum® device (Magnum®, VetHealth, São Paulo, Brazil). Coils were placed bilaterally over the lateral aspects of the hip joints. The treatment protocol consisted of a continuous pulsed electromagnetic field at 50 Hz and 40 Gauss. Dogs in the Control Group underwent the same procedures; however, the coils remained disconnected throughout the sessions. To maintain owner blinding, the device was covered with opaque fabric, preventing any visual indication of coil activity.

Clinical and functional assessments

All evaluations were performed immediately prior to the first, fifth, and tenth therapy sessions. Body weight (kg) was recorded. Joint range of motion (ROM) was assessed for the tarsal, stifle, and hip joints of both pelvic limbs using a universal goniometer (MFL Indústria de Produtos Ortopédicos Ltda., São Paulo, Brazil) (Formenton et al. 2019). Thigh circumference was measured with a flexible measuring tape while the dog was standing (McCarthy et al. 2018).

Mechanical nociceptive threshold (MNT) was quantified using a handheld pressure algometer (ProDPlus; Topcat Metrology, Ely, UK) equipped with a 2-mm diameter hemispherical tip. The rate of force application was maintained at 2 N/s with a built-in feedback system that signaled deviations greater than 0.5 N/s. Assessments were performed by a single investigator to ensure procedural consistency (Harris et al. 2018; Krystalli et al. 2023). MNT was recorded at four anatomical sites (cranial and caudal to the greater trochanter bilaterally) with dogs positioned in lateral recumbency and the tested limb placed dorsally. At each site, the probe was applied perpendicularly to the skin until a behavioral response (limb withdrawal or vocalization) was elicited, and the corresponding force (N) displayed on the algometer was recorded as the threshold. One cranial and one caudal measurement were obtained on each side, and mean values from the right and left limbs were used for analysis. Measurements were obtained before the first session and after the fifth and tenth sessions.

Pain and life quality evaluation

Pain and life quality were assessed using two validated owner-completed questionnaires: the Helsinki Chronic Pain Index (HCPI) (Hielm-Björkman et al. 2003) and the Canine Brief Pain Inventory (CBPI) (Brown et al. 2007). Both questionnaires were completed by the same owner at each evaluation session to ensure consistency.

Statistical analysis

Data distribution was first assessed for normality using the Shapiro–Wilk test. Variables with normal distribution (algometry, goniometry, thigh circumference, and body mass) were analyzed using repeated-measures ANOVA, followed by post hoc tests when appropriate. Between-group comparisons of HCPI scores were performed using unpaired t-tests. Because CBPI data are ordinal and not normally distributed, they were analyzed using the chi-square test, which is appropriate for categorical or ordinal data. Statistical significance was defined as $P \leq 0.05$. All analyses were conducted using MedCalc Statistical Software version 20.015 (MedCalc Software Ltd, Ostend, Belgium).

Results

All enrolled dogs completed the treatment sessions without adverse effects. Sessions were well tolerated and no discomfort or behavioral signs of pain were observed during sessions.

Nineteen dogs presented bilateral hip osteoarthritis, and one dog in the PEMF group had unilateral disease. One subject in the CG was withdrawn from the study following session six due to the need for analgesic rescue.

The cohort included 10 Golden Retrievers (50%), 3 mixed-breed dogs (15%), 2 Labrador Retrievers (10%), 2 German Shepherds (10%), 2 Pitbulls (10%), and 1 Rottweiler (5%). The mean age and body weight in the Control group were 5.9 ± 2.47 years and 38.4 ± 7.4 kg, respectively, and 6.1 ± 1.79 years and 39.5 ± 5.4 kg in the PEMF group.

Regarding sex distribution, 65% (13/20) of the dogs were male, and 35% (7/20) were female. Neutered status was balanced across groups: 76.9% of males and 57.1% of females were neutered. Group distribution by sex was homogeneous ($P > 0.05$).

No significant differences were detected between groups for body weight or thigh circumference over the course of treatment ($P > 0.05$) Table 1. Likewise, goniometric outcomes (tarsal, stifle, and hip joints of both pelvic limbs) showed no significant between-group differences at any time point and no within-group changes over time; no treatment, time, or treatment × time interaction effects were identified. Consequently, overall range of motion (ROM) did not differ between the Control and PEMF groups throughout the protocol.

The analysis of CBPI scores demonstrated that pain severity (PSS) and pain interference (PIS) decreased significantly in the PEMF group between sessions 1 and 10 (P 0.0083 and P = < 0.0001, respectively), while no significant changes were observed in the Control group. HCPI scores in the PEMF group also showed a reduction 1 by session 10, although reaching statistical significance ($P < 0.0001$). Between-group comparisons indicated that PEMF-treated dogs consistently presented lower pain scores at later sessions compared with controls (Table 2). Quality of life, assessed through the CBPI quality-of-life question, did not differ significantly between sessions ($P = 0.1753$), but showed a descriptive trend toward improvement.

MNT measurements demonstrated a progressive positive response to PEMF therapy. A significant increase in pain tolerance was observed over time, as reflected by progressively higher-pressure values tolerated before and after treatment. In the left hind limb (LHL), significant improvements were detected between pre-session 1 and pre-session 5 ($P = 0.0128$), pre-session 1 and pre-session 10 ($P = 0.0005$), and between pre-session 5 and post-session 5

Table 1 Goniometric angles of joint extension, flexion, and range of motion (ROM) of the tarsus, stifle, and hip in control and PEMF-treated dogs across the study period (mean ± SD)

Days	Extension		Flexion		Range of Motion (ROM)	
	Control	**PEMF**	**Control**	**PEMF**	**Control**	**PEMF**
TARSUS						
1 days	154.4° ± 4.38	154.1° ± 3.57	47.3° ± 1.16	46.3° ± 1.42	107.1° ± 2.77	107.8° ± 2.49
5 days	155° ± 4.14	154.6° ± 3.02	46.7° ± 1.16	46.4° ± 1.26	108.3° ± 2.65	108.2° ± 2.14
10 days	154.44° ± 4.21	156.3° ± 2.87	46.44° ± 2.01	47.4° ± 0.84	108° ± 3.11	108.9° ± 1.85
STIFLE						
1 days	153.8° ± 2.44	152.4° ± 4.45	38.8° ± 1.55	37.8° ± 1.23	115° ± 1.99	114.6° ± 3.22
5 days	152.4° ± 1.95	153.6° ± 4.53	38.1° ± 0.99	39° ± 0.47	114.3° ± 1.21	114.6° ± 2.87
10 days	152.44° ± 2.07	154.5° ± 3.72	38° ± 1.12	39.5° ± 0.97	114.44° ± 2.24	115° ± 2.60
HIP						
1 days	146.6° ± 2.95	144.1° ± 3.03	36.1° ± 2.13	34.9° ± 1.66	110.5° ± 2.54	109.2° ± 2.78
5 days	147.3° ± 3.37	146.6° ± 2.84	35.8° ± 1.87	35.8° ± 1.32	111.5° ± 2.62	110.8° ± 2.08
10 days	146.3° ± 4.21	148.6° ± 4.9	35.55° ± 2.35	36.1° ± 1.59	110.75° ± 3.28	112.5° ± 3.24

Values are presented as mean ± standard deviation for each joint at days 1, 5, and 10 in both groups. No significant differences were detected between groups or within groups over time for any joint measurement (P >0.05). ROM was calculated as the difference between maximum extension and flexion angles.

Table 2 Changes in canine brief pain inventory (CBPI) pain severity score (PSS), pain interference score (PIS), and Helsinki chronic pain index (HCPI) in control and PEMF-treated dogs on days 1, 5, and 10

Days	CBPI PSS		*p* (value)	CBPI PIS		*p* (value)	Helsinke		*p* (value)
	Control	PEMF		Control	PEMF		Control	PEMF	
1 days	2.90±1.75*	4.4±2.34* a	0.0017	1.86±1.06*	3.11±2.24*	0.0010	20.10±1.4	19.90±2.1a	0.8239
5 days	3.12±1.81	3.05±2.11 b	0.8652	2.00±1.19	2.61±1.86	0.0857	20.45±2.1	17.20±1.4	0.6243
10 days	2.60±2.09*	1.85±1.27* c	0.0468	2.20±1.45*	1.22±1.02*	0.0027	21.44±2.4	14.70±1.4b	0.0651
p (value)	n/s	1/5<0.0001 1/10=0.0083 5/10=0.0029		n/s	1/5<0.0001 1/10<0.0001 5/10<0.0001		n/s	1/10<0.0001	

The CBPI Pain Severity Score (PSS) represents the mean ± SD of questions 1–4, while the CBPI Pain Interference Score (PIS) represents the mean ± SD of questions 5–10.

Statistical comparisons between treatment groups and across time points within each group were performed using Student's *t*-test, with significance set at $p < 0.05$.

Different superscript letters within the same column denote significant differences.An asterisk (*) indicates significant differences between treatments at the same time point, while different lowercase superscript letters within the same column denote significant differences across time points within each group.

($P = 0.0128$), indicating a sustained increase in nociceptive threshold. In the right hind limb (RHL), statistically significant differences were observed between pre-session 1 and post-session 1 ($P = 0.0231$), pre-session 1 and post-session 5 ($P = 0.0244$), pre-session 1 and pre-session 10 ($P = 0.0145$), and pre-session 10 and post-session 10 ($P = 0.0567$) (Fig. 1). In contrast, the control group (CG) showed no significant differences at any time point ($P > 0.05$), confirming the absence of a therapeutic effect.

Although not all comparisons between pre- and post-session data reached statistical significance, the PEMF group demonstrated consistently higher MNT values and lower pain scores across all evaluation time points, supporting a cumulative analgesic effect over time.

Discussion

The present study suggests promising results, highlighting the effectiveness of PEMF therapy in the management of chronic pain in dogs with hip dysplasia (HD). The application of this technique provided significant improvements in pain control and in the animals' quality of life, reinforcing its viability as a non-invasive and effective therapeutic alternative. The positive response observed in the treated dogs, without the need for additional medication, further emphasizes the potential of PEMF in treating chronic pain associated with OA.

The animals' body weights remained stable throughout the study. Thigh circumference also did not show significant variation between sessions in either the Control or PEMF group, indicating that no substantial muscle mass changes occurred during the evaluation period. This result was expected, as no therapeutic modalities specifically aimed at promoting hypertrophy were included. The effects of PEMF are primarily attributed to its analgesic, anti-inflammatory, and tissue-healing properties (Sullivan et al. 2013; Zidan et al. 2018; Rajalekshmi and Agrawal 2024). Analgesia is thought to result from modulation of nociceptive signaling via altered calcium and sodium ion channel activity, leading to reduced neuronal excitability (Zidan et al. 2018; Rajalekshmi and Agrawal 2024). Anti-inflammatory effects are associated with downregulation of pro-inflammatory mediators such as IL-1β, TNF-α, PGE_2, and COX-2, alongside increased expression of anti-inflammatory cytokines. Tissue-healing benefits have been linked to enhanced local blood flow, angiogenesis, and stimulation of fibroblasts, chondrocytes, and osteoblasts, promoting extracellular matrix synthesis and growth factor release (e.g., VEGF, TGF-β) (Strauch et al. 2009; Zidan et al. 2018). In the present study, all dogs in the PEMF group achieved adequate pain control without requiring rescue medication, which supports an effective analgesic response and aligns with these mechanisms.

Regarding joint range of motion (ROM), no significant differences were detected either between groups or across time points. This finding was consistent with expectations, as dogs with hip osteoarthritis typically present reductions in hip extension rather than alterations in flexion (Dycus et al. 2022). Therefore, PEMF therapy alone did not modify ROM in the evaluated joints during the treatment period. To achieve clinically meaningful improvements in joint mobility, PEMF may need to be combined with additional interventions, such as passive range of motion exercises and stretching (Dycus et al. 2022) or swimming (Nganvongpanit et al. 2014), which have shown benefits in enhancing ROM in dogs with hip OA.

To increase data reliability and reduce bias, caretakers were blinded to group allocation. Consequently, the HCPI revealed significant reductions in pain perception, as reported by owners, between the first and tenth sessions in the PEMF Group, indicating a progressive improvement

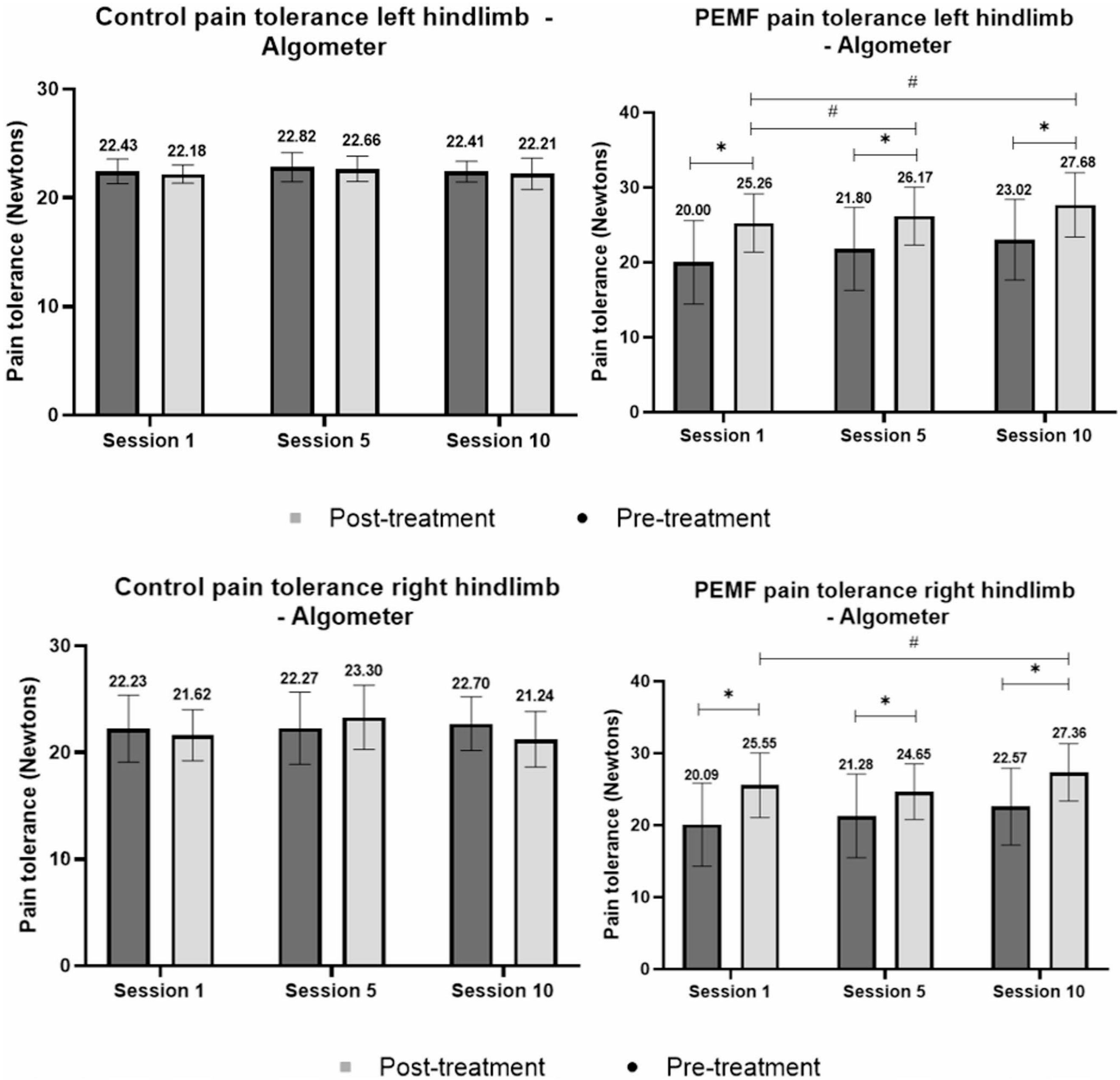

Fig. 1 Variation in mechanical nociceptive threshold (MNT) assessed by algometry in the right hind limb (RHL) and left hind limb (LHL) of dogs undergoing pulsed electromagnetic field (PEMF) therapy. Evaluations were performed at sessions 1, 5, and 10, and values are presented as pre- and post-session measurements. Statistically significant differences between the control and PEMF groups are indicated by corresponding p-values. Note Asterisks (*) indicate time points at which differences between treatments within the same session were statistically significant ($P<0.05$). Hash symbols (#) indicate significant differences between sessions within the same treatment group

over the course of therapy. CBPI confirmed a significant enhancement in the quality of life of dogs in the PEMF Group. These results validate the sensitivity of both scales in identifying initial discomfort associated with hip OA and monitoring clinical improvement, emphasizing the importance of owner input in assessing chronic pain in dogs.

Algometry was particularly useful and effective in quantifying the response to PEMF therapy. In the PEMF Group, a significant reduction in pain perception was observed both immediately after each session and when comparing the first, fifth, and tenth sessions for both hind limbs. These findings are supported by the study of Pinna et al. (2013), which demonstrated that pulsed electromagnetic field (PEMF) therapy is a safe and effective approach for pain management in dogs with OA. Besides being a non-invasive and non-pharmacological method, the study showed that the benefits provided by PEMF are maintained over prolonged periods, exhibiting effects that are superior and longer-lasting compared to conventional treatment with non-steroidal anti-inflammatory drugs (NSAIDs). Thus, PEMF emerges as a promising alternative to improve the quality of life of patients, especially those who have contraindications to prolonged drug use.

In a systematic review and meta-analysis, Yang et al. (2020) demonstrated that PEMF application can relieve pain, reduce stiffness, and improve physical function in human patients with OA. The authors included 16 studies in the systematic review and 15 in the meta-analysis, incorporating various protocols and time intervals. The results indicate that PEMF is significantly effective in short-term studies, which supports the findings of the present study, where despite the species difference, significant pain reduction was observed in dogs undergoing PEMF therapy, confirmed by algometry and behavioral pain scales.

Furthermore, Gaynor et al. (2018) highlight that PEMF has been studied across cellular, animal, and human models, with evidence supporting its biological activity in pain relief, inflammation reduction, and tissue repair. It is approved by the FDA for clinical use, further reinforcing its safety and utility as a primary or adjunctive therapeutic tool in veterinary medicine.

Leung et al. (2024) found no significant analgesic effect after a single 15-minute PEMF session at 200 Hz in dogs with osteoarthritis. Contrastingly, the current study suggests that PEMF therapy, delivered at 50 Hz and 40 Gauss for 30 min, may provide statistically significant pain relief from the first application. Although the initial analgesic effect may be subtle, it appears to accumulate and intensify with successive sessions, highlighting PEMF's potential as a cumulative and sustainable pain management modality.

A significative limitation of this study is that the same veterinarian performed both the clinical assessments and the therapeutic sessions, which may have introduced observer bias. Although algometry findings were corroborated by blinded owner-reported scores, the potential for assessor bias cannot be fully excluded. Another relevant limitation is that dogs in the PEMF group exhibited significantly higher baseline pain scores (PSS and PIS from the CBPI) compared with controls, which may have affected the magnitude of the treatment response. The relatively small sample size, despite an a priori calculation indicating adequate power, may also limit the generalizability of the findings. In addition, blood biomarkers related to inflammation or cartilage metabolism were not measured, and pain and quality of life were assessed exclusively with HCPI and CBPI. Complementary tools such as the VetMetrica index, parasympathetic tone activity, kinematic gait analysis or infrared thermography could have provided additional insight. Another limitation is the lack of baseline assessment of OA severity, which may have influenced pain perception and treatment response. Future studies with larger cohorts, extended follow-up, double blinding, balanced baseline pain distributions, and multimodal outcome measures are warranted to confirm and extend these results.

Conclusions

PEMF represents a safe, low-risk alternative to pharmacological therapies in the management of chronic pain in HD dogs. The application of PEMF at 50 Hz and 40 Gauss, twice weekly for 30 min, proved effective in relieving pain, as demonstrated by behavioral scales and algometry. These findings support further investigation into optimizing PEMF protocols and combining this modality with other therapeutic strategies to maximize the clinical benefits in dogs with chronic musculoskeletal disorders.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s11259-025-10939-x.

Acknowledgements We would like to thank Vet Health® for providing the pulsed electromagnetic field equipment used in the study.

Author contributions JH and GV proposed the PEMF protocol in the study design, read the paper for accuracy, and provided the PEMF device. FM-F was involved in the data analysis. RGDV was involved in the study design, SFS participated in the conceptualization, writing review, and editing of the manuscript, LFK was primarily responsible for the execution of the PEMF sessions, evaluations, wrote the initial drafts of the paper, and participated in the editing and GSJ participated in the conceptualization, writing review, and editing of the manuscript.

Funding We would like to thank Vet Health® for providing the pulsed electromagnetic field equipment used in the study.

Data availability The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval The study was submitted and approved by the Ethics Committee of Universidade Federal do Paraná (nº 039/2023).

Competing interests The authors LFK, FMF, RGDV, GSJ and SFS declare that they have no financial interests. The authors JH and GV assisted in the development of the therapeutic protocol and are co-owners of Vet Health, the company responsible for providing the electromagnetic field equipment used in the study.

References

Alvarez LX, McCue J, Lam NK, Askin G, Fox PR (2019) Effect of target pulsed electromagnetic field therapy on canine postoperative hemilaminectomy: a double-blind, randomized, placebo-controlled clinical trial. J Am Anim Hosp Assoc 55(2):83–91. https://doi.org/10.5326/JAAHA-MS-6798

Brown DC, Boston RC, Coyne JC, Farrar JT (2007) Development and psychometric testing of an instrument designed to measure chronic pain in dogs with osteoarthritis. Am J Vet Res 68(6):631–637. https://doi.org/10.2460/ajvr.68.6.631

Dycus DL, Levine D, Ratsch BE, Marcellin-Little DJ (2022) Physical rehabilitation for the management of canine hip Dysplasia. The veterinary clinics of North America. J Small Anim Pract 52(3):719–747. https://doi.org/10.1292/jvms.20-0730

Formenton MR, de Lima LG, Vassalo FG, Joaquim JGF, Rosseto LP, Fantoni DT (2019) Goniometric assessment in French bulldogs. Front Vet Sci 6:424. https://doi.org/10.3389/fvets.2019.00424

Gaynor JS, Hagberg S, Gurfein BT (2018) Veterinary applications of pulsed electromagnetic field therapy. Res Vet Sci 119:1–8. https://doi.org/10.1016/j.rvsc.2018.05.005

Harris LK, Whay HR, Murrell JC (2018) An investigation of mechanical nociceptive thresholds in dogs with hind limb joint pain compared to healthy control dogs. Vet J 234:85–90. https://doi.org/10.1016/j.tvjl.2017.12.012

Hielm-Björkman AK, Kuusela E, Liman A, Markkola A, Saarto E, Huttunen P, Leppäluoto J, Tulamo R, Raekallio M (2003) Evaluation of methods for assessment of pain associated with chronic osteoarthritis in dogs. J Am Vet Med Assoc 222(11):1552–1558. https://doi.org/10.2460/javma.2003.222.1552

Krystalli A, Sideri A, Kazakos GM, Anatolitou A, Prassinos NN (2023) Contribution to the study of perioperative factors affecting the restoration of dog's mobility after femoral head and neck excision: a clinical study in 30 dogs. Animals 13(14):2295. https://doi.org/10.3390/ani13142295

Leung G, Junnila J, Björkenheim T, Tiainen H, Hyytiäinen HK (2024) A prospective, randomised, controlled, double-blinded, crossover study on the effect of a single session of pulsed electromagnetic field therapy on signs of hip osteoarthritis in dogs. Acta Vet Scand 66:36. https://doi.org/10.1186/s13028-024-00754-w

McCarthy DA, Millis DL, Levine D, Weigel JP (2018) Variables affecting thigh girth measurement and observer reliability in dogs. Front Vet Sci 5:203. https://doi.org/10.3389/fvets.2018.00203

Mille MA, McClement J, Lauer S (2023) Physiotherapeutic strategies and their current evidence for canine osteoarthritis. Vet Sci 10(1):2. https://doi.org/10.3390/vetsci10010002

Nganvongpanit K, Tanvisut S, Yano T, Kongtawelert P (2014) Effect of swimming on clinical functional parameters and serum biomarkers in healthy and Osteoarthritic dogs. ISRN Vet Sci 9(2014):459809. https://doi.org/10.1155/2014/459809

Okamoto-Okubo CE, Cassu RN, Joaquim JGF, Mesquita LR, Rahal SC, Oliveira HSS, Takahira R, Arruda I, Maia L, Landim FC, Luna SPL (2021) Chronic pain and gait analysis in dogs with degenerative hip joint disease treated with repeated intra-articular injections of platelet-rich plasma or allogeneic adipose-derived stem cells. J Vet Med Sci 83(5):881–888. https://doi.org/10.1292/jvms.20-0730

Pinna SF, Landucci F, Tribuiani AM, Carli F, Venturini A (2013) The effects of pulsed electromagnetic field in the treatment of osteoarthritis in dogs: clinical study. Pak Vet J 33(1):96–100. https://www.pvj.com.pk/pdf-files/33_1/96-100.pdf

Rajalekshmi R, Agrawal DK (2024) Energizing healing with electromagnetic field therapy in musculoskeletal disorders. J Orthop Sports Phys Ther 6(2):89–106. https://doi.org/10.26502/josm.511500147

Strauch B, Herman C, Dabb R, Ignarro LJ, Pilla AA (2009) Evidence-based use of pulsed electromagnetic field therapy in clinical plastic surgery. Aesthet Surg J 29(2):135–143. https://doi.org/10.1016/j.asj.2009.02.001

Sullivan MO, Gordon-Evans WJ, Knap KE, Evans RB (2013) Randomized, controlled clinical trial evaluating the efficacy of pulsed signal therapy in dogs with osteoarthritis. Vet Surg 42(3):250–254. https://doi.org/10.1111/j.1532-950X.2012.01066.x

Yang X, He H, Ye W, Perry TA, He C (2020) Effects of pulsed electromagnetic field therapy on pain, stiffness, physical function, and quality of life in patients with osteoarthritis: a systematic review and meta-analysis of randomized placebo-controlled trials. Phys Ther 100(7):1118–1131. https://doi.org/10.1093/ptj/pzaa054

Zidan N, Fenn J, Griffith E, Early PJ, Mariani CL, Muñana KR, Guevar J, Olby NJ (2018) The effect of electromagnetic fields on Post-Operative pain and locomotor recovery in dogs with Acute, severe thoracolumbar intervertebral disc extrusion: A randomized Placebo-Controlled, prospective clinical trial. J Neurotrauma 35(15):1726–1736. https://doi.org/10.1089/neu.2017.548