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Key words: Laser safety; Reflected laser radiation; Ocular hazard; Surface reflectance; Specular and diffuse reflection; Clinical settings.

Ocular hazards from reflected laser radiation in clinical settings: practical implications of surface reflectance for healthcare operators.

Giacomo Insero[1,2,*] and Giovanni Romano[1]

[1] Department of Experimental and Clinical Biomedical Sciences "Mario Serio", University of Florence, FI, Italy

[2] CNR-INO– Istituto Nazionale di Ottica, Sesto Fiorentino FI, Italy

* giacomo.insero@unifi.it

In the last few decades, we have witnessed a wide diffusion of intense optical sources such as lasers or LEDs (Light Emitting Diodes) [1]. These devices are now present not only in hospitals and research environments, but are now routinely deployed in non-hospital settings, including private outpatient clinics, such as dermatology and dental offices, aesthetic medical clinics, physiotherapy clinics, as well as veterinary practices. Depending on the specific therapeutic procedures, these light sources operate over wavelengths spanning from the UV (ultraviolet) to the mid-IR (mid-infrared) region.

Such diffusion exposes patients and operators to risks from artificial optical radiation, that must be properly assessed in the occupational safety framework [2]. Risk management must be robust not only in controlled operating theatres but also in smaller and decentralized clinical rooms, as less frequent use of these technologies may result in operators having limited experience with laser-based procedures, thereby increasing the likelihood of accidents or unsafe practices. In the veterinary context, laser sources may be used directly in the field, further complicating the implementation of standard risk-minimization measures. Training pathways commonly address these issues under workplace safety programs and are aligned with normative references and guidance documents: Directive 2006/25/EC (artificial optical radiation), ICNIRP exposure-limit guidelines (180 nm–1,000 µm) [3], and device standards for medical laser equipment (e.g., EN 60601-2-22). These frameworks provide essential foundations for hazard identification, classification, and selection of controls and personal protective equipment (PPE).

However, in day-to-day clinical practice, training and checklists often emphasize prevention of **direct-beam** exposure and unexpected events, such as misalignment, accidental light-induced firing or device malfunction. A less underlined risk is connected to the **reflected radiation generated during normal treatment**, which can represent an important ocular hazard even when procedures are performed correctly. In this work, we underline the risks related to reflected laser radiation during routine treatments rather than exceptional or accidental events.

The light reflection

A common assumption in laser safety is that "if the primary beam is controlled (and everyone wears appropriate eyewear), residual risks are negligible", but this is not necessarily true.

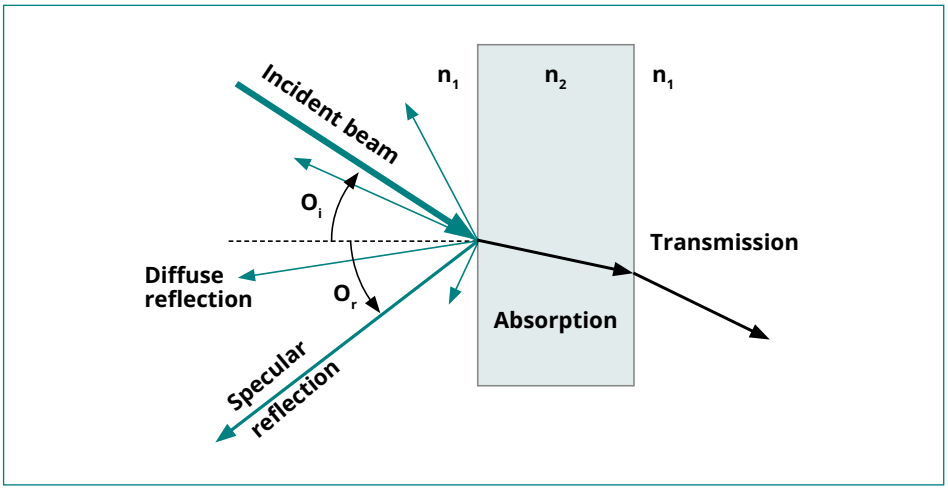

Fig. 1 Scheme depicting the presence of both diffuse and specular reflected radiation.

When an optical beam impinges on the interface between two media with refractive indices n_1 and n_2 — for instance, air and a solid, liquid, or a tissue (Figure 1) — a fraction of the incident radiant power is always reflected due to the refractive-index mismatch [4]. The remaining fraction enters the second medium (e.g. the tissue), where it may be attenuated by absorption and (in most cases) also by scattering. If the medium is not optically opaque at the wavelength of interest and the geometry allows it, a portion of the radiation can traverse the material and exit into air on the opposite side as transmitted radiation.

For a given wavelength λ, these processes can be described by the spectral reflectance $R(\lambda)$, transmittance $T(\lambda)$, and absorptance $A(\lambda)$, which satisfy the energy balance

$$R(\lambda) + T(\lambda) + A(\lambda) = 1,$$

where each quantity is defined as the ratio of reflected, transmitted, or absorbed radiant power to the incident radiant power, respectively. Therefore, they are dimensionless, ranging from 0 (for example $R = 0$ means no reflected radiation) to 1 (for example $R = 1$ means all the incident power is reflected).

Depending on the surface characteristics, reflection may be sub-divided into:

- **Specular reflection**: directional, mirror-like; the reflected angle equals the incidence angle. This component corresponds to a secondary beam able to propagate over long distances and potentially maintaining the majority of incident beam energy, according to the value of R.

- **Diffuse reflection**: scattered into many directions. In strongly scattering surfaces, typically approximated as Lambertian, the specular reflection is strongly reduced, and the total reflected energy is distributed over a large solid angle.

Following this division, the total reflectance $R(\lambda) = R_{tot}(\lambda)lambda)$ can also be split as

$$R_{Tot}(\lambda) = R_S(\lambda) + R_D(\lambda)$$

where $R_S(\lambda)$ *and* $R_D(\lambda)$ represent the specular and diffusive reflectance components, respectively. As $R_S(\lambda)$ depends on the incidence angle of the light, we have decided to focus our discussion on $R_S^{45°}(\lambda)$, corresponding to the specular reflectance at the exemplary incidence angle of 45°. This angle is representative of many practical situations and is also easily measurable with simple and inexpensive setups. Following our work on [5], we can identify a simple parameter that immediately indicates whether a surface mainly exhibits specular or diffusive characteristics, and we call it the Lambertian parameter $L_{Lamb}(\lambda)$ defined as

$$L_{Lamb}(\lambda) = 100 \cdot \left[\frac{(R_S^{45°}(\lambda)}{R_S^{45°}(\lambda) + R_D(\lambda)} \right]$$

For most of the materials, L_{Lamb} ranges between 1 and 100: low values indicate predominantly diffusing materials, while higher values indicate specular behavior. Since L_{Lamb} depends on the wavelength, the same material can have a predominantly diffusive or rather specular behavior according to the wavelength or wavelength range considered. In fact, the reflective characteristic of a material depends on its microstructure and the ratio between the characteristic **surface roughness and λ**. Surfaces that are smooth on the scale of λ tend toward specular reflection; increasing roughness promotes scattering and diffuse behavior. Importantly, a surface may appear "non-shiny" in visible light yet behave more specularly at longer wavelengths where the same roughness becomes small relative to λ. Especially in the NIR range, **one cannot reliably infer infrared reflectance behavior from visible appearance**.

A frequent oversimplification in laser safety is to equate "diffuse" with "safe" due to the reduced irradiance in any single direction compared with a specular reflection, but **diffuse reflection can still pose risks** when incident powers are high, and distances surface-to-eye are short. Risks associated to specular reflection could be underestimated because they extend ocular hazard beyond what would be intuitively expected for "indirect exposure."

In realistic geometries in clinical settings, the beam frequently encounters several different surfaces: the patient's tissue, surgical drapes, plastic accessories, metallic instruments, endoscope components, dental mirrors, or smooth polymer housings. These interactions, which include multi-bounce paths, can create non-negligible reflected, and often uncontrolled, components that may enter an operator's visual field.

In the following, we show reflectance and Lambertian parameters of materials commonly found in biomedical/clinical environments, measured over a broad spectral range (250 nm to 25 µm), explicitly separating **specular** and **diffuse** components [5].

Clinically relevant materials: metals, textiles, plastic and polymers

- **Metals (e.g., stainless steel clinical instruments):**

Metallic instruments are ubiquitous in procedural fields. They can be both "polished" or satin finished.

Polished surface are mirror-like and they have high-specular reflectance as high as almost 100 %, as expected; nevertheless, also brushed or satin metals can exhibit **specular reflection in the visible range up to few tens of percentage**, which is not negligible considering high-power sources.
In the mid-infrared (2.4–25 μm), reflectance measurements showed that brushed metals can exhibit higher reflectance in the **10–25 μm range compared to the visible range up to** several tens of percentage points. This is particularly relevant to **CO_2 lasers (~10.6 μm)** and other NIR systems, as also shown by the Lambert parameter plot [5].
Operational implication: where possible, minimize exposed metallic surfaces in the illuminated field; prefer matte/blackened tools or use non-reflective covers when compatible with sterility and procedure constraints.

- **Surgical textiles and field drapes**

Blue/green surgical clothing and coverings are often assumed to be "safe" if irradiated because they don't show a perceivable specular reflectance (generally less than 4% in the **250–2500 nm range**). Nevertheless, these textiles can have **high total reflectance**: in the 0.7-2.5 um range, many tested fabrics showed total reflectance typically **~60% to nearly 90%** depending on fabric type and composition. The average Lambertian parameter over 400–1100 nm is generally lower than 10, confirming the strongly **diffusive reflective** nature of these materials.

Operational implication: diffuse does not mean irrelevant. Close-range scattering from high-power systems can still pose ocular concerns if eyewear is absent or not properly chosen or if scattered beam reaches the eye through lateral gaps.

- **Plastics and polymers (device housings, disposables, etc**

Polymers such as **plexiglass (PMMA)**, **polycarbonate**, **PVC**, and **PTFE** are common in clinical settings (protective shields, device enclosures, tubing, disposable accessories, positioning tools) and exhibit generally diffuse reflective behavior, but if polished can have a high specular reflection. The average Lambertian parameter in the range 250 nm -2.5 μm can be higher than 80 for polished PVC, plexiglass or polycarbonate, indicating a high specular reflectance component against a total reflectance of approx. 10-20%. Indeed, PTFE components show diffusive behavior, $L_{Lamb}\ (\lambda) \sim 2$. While generally less hazardous than polished metals, these materials can still reflect a substantial fraction of incident radiation.

Operational implication: smooth polymer and transparent plastic surfaces can present a reflection that, while possibly modest in absolute terms, is **highly specular in character**—hence potentially hazardous.

Beam properties matter: collimated versus focused emission

A further practical point is that reflection hazards cannot be assessed based solely on surface type; they must be coupled to the **spatial properties of the employed laser beam**:

- **Collimated beams** (low divergence): a specular reflection tends to remain collimated, preserving radiant exposure over long distances. In this case, a secondary specular reflection can behave as a "mirror-generated beam" that remains hazardous even far from the reflection point.
- **Focused beams**: the hazard depends strongly on where the focus is relative to reflective surfaces and human eye. A specular reflection from a surface near the focal region may still carry high irradiance, while reflections far from focus may be less intense due to divergence—yet can remain non-negligible for high-power settings.

Operational implication: the risk from specular reflection is not governed only by "how shiny" a surface is; it depends on the laser's divergence, spot size, and working distance as well. Therefore, device-specific information (beam diameter, divergence, focusing optics, delivery system) should be explicitly included in the clinical risk assessment.
These considerations reinforce the importance of appropriate personal protective equipment. Laser safety eyewear should provide adequate attenuation at the operating wavelength and ensure full coverage, including lateral protection. In addition, unnecessary metallic or plastic objects should be removed from the illuminated field whenever possible.

CONCLUDING REMARKS

Reflected radiation should be treated as a first-order element of clinical laser safety, not as a residual concern limited to mishaps. Reflected laser radiation represents a tangible ocular hazard in clinical environments, even during routine and correct use of medical laser devices. While diffuse reflections are generally less dangerous than specular ones, their contribution cannot be

neglected, particularly at nearinfrared wavelengths.

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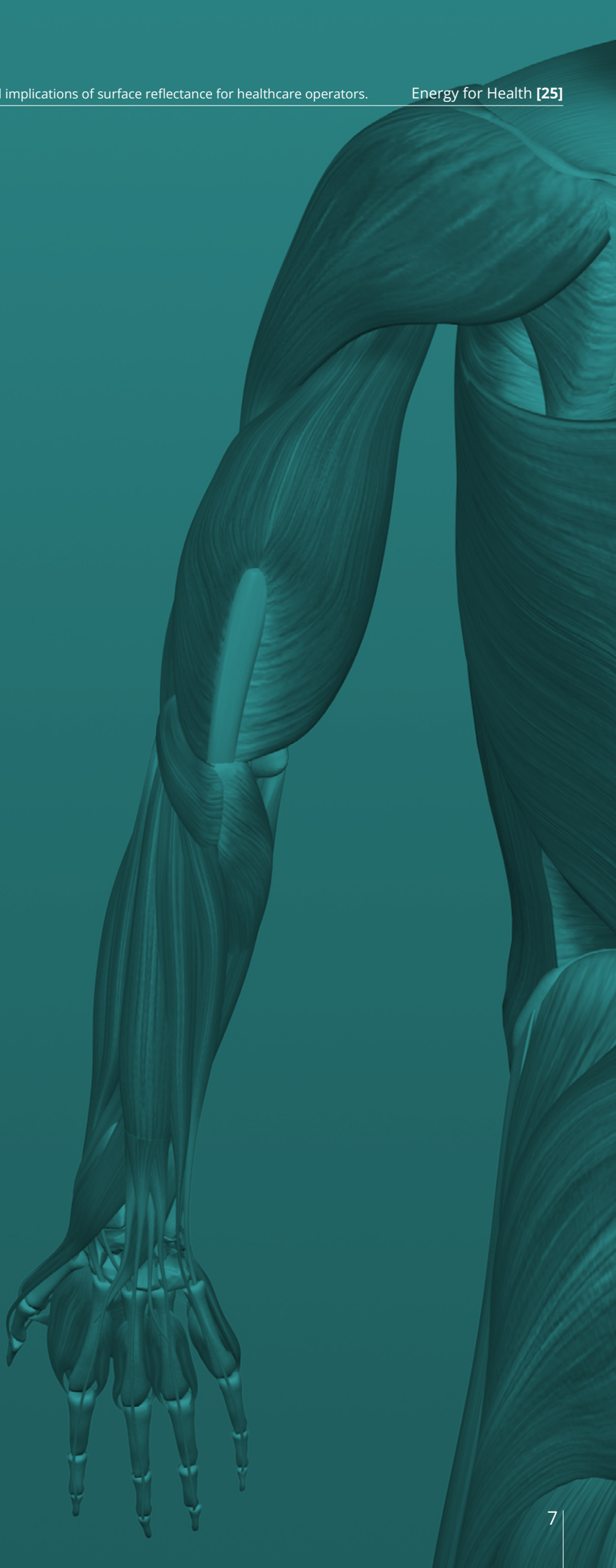

Clinical and ultrasound-monitored outcomes after MLS® M-Hi laser therapy in tendinous and bursal disorders: an observational case series

Luca Barni, PT, PhD

Department of Physical Therapy and Rehabilitation, University of Florence, Florence, Italy;
PhD in Human Health Sciences, University of Malaga, Spain;
Private Practice, Montecatini Terme, Italy.

ABSTRACT

Background: Tendinous and bursal disorders are frequent sources of musculoskeletal pain and functional impairment. High-power laser therapy (HPLT) is used in rehabilitation settings for its analgesic, anti-inflammatory and biostimulatory effects, which may contribute to tissue repair.

Objective: To evaluate changes in pain, function and ultrasound-documented tissue morphology following laser therapy in patients with tendinous or bursal lesions.

Methods: Five outpatients with ultrasound-confirmed musculoskeletal soft-tissue pathology (mid-portion Achilles tendinopathy, supraspinatus tendinopathy with or without subacromial bursitis, lateral epicondylalgia with partial lesion of the common extensor tendon, and lateral collateral ligament sprain) underwent ten sessions of MLS® M-Hi laser therapy. Pain intensity (VAS), condition-specific functional scores and ultrasound characteristics were assessed before and after treatment.

Results: Mean pain intensity decreased by 67% (VAS −4 points), and functional scores improved in all cases. Follow-up ultrasound showed reduced tendon or ligament thickness when previously increased, more regular fibrillar alignment, reduction or disappearance of hypoechoic areas, and reduction or resolution of bursal effusion and pathological vascularity. No adverse events were reported.

Conclusions: In this observational case series, MLS® M-Hi laser therapy, used as part of a rehabilitation program, was followed by reductions in pain, improvements in patient-reported function and ultrasound changes compatible with tissue repair in tendinous and bursal lesions. Larger controlled studies are required to confirm these findings and to define optimal treatment parameters.

Keywords: High-power laser therapy; Musculoskeletal rehabilitation; Ultrasound imaging; Tissue remodeling; Pain management.

INTRODUCTION

Tendinopathies, enthesopathies and bursal disorders are common causes of pain and functional limitation in musculoskeletal practice. These conditions are often characterized by impaired healing, low-grade inflammation and progressive structural disorganization that may delay recovery [1].

Current management typically combines therapeutic exercise, manual therapy, pharmacological interventions and physical modalities within a multimodal rehabilitation approach [2]. Among these, laser therapy is widely used to modulate pain and inflammation, support tissue repair and facilitate functional restoration, particularly when integrated with targeted exercise programs [3].

Despite its extensive clinical adoption, evidence specifically documenting the structural effects of laser therapy on tendons, ligaments and bursae is still limited. Ultrasound imaging, with its ability to assess tendon thickness, fibrillar alignment, vascularity and peritendinous changes, is an essential tool to relate symptom variation to measurable tissue remodeling [4].

Clinical reports that integrate pain and functional outcomes with ultrasound-monitored structural changes may help clarify the potential contribution of photobiomodulation to tendon, ligament and bursal healing in daily rehabilitation practice.

This case series presents five patients with tendinous or bursal disorders treated with laser therapy, focusing on changes in pain, function and ultrasound appearance. Particular attention is given to the description of MLS® M-Hi treatment parameters, in order to facilitate replication of the protocols.

MATERIALS AND METHODS

All subjects completed a therapeutic cycle of ten sessions over five weeks, performed with the M-Hi laser device (ASA S.r.l., Arcugnano, Italy), a Class IV high-power system of the MLS® (Multiwave Locked System) family. The device emits synchronized 808 nm (continuous or frequency-modulated) and 905 nm (super-pulsed) wavelengths, with a maximum peak power of 270 W and up to 3.3 W average output, and offers different emission modalities that can be adapted to tissue characteristics.

Treatments were administered using manual scanning or fixed-point techniques, selected according to lesion type and anatomical region. All applications employed a 2-cm diameter handpiece (≈3 cm^2 spot area). Suggested clinical protocols available in the device software were customized for each patient, and one or more parameter sets could be applied within the same session.

When clinically indicated, laser therapy was combined with a home-based exercise program tailored to the underlying condition.

No additional pharmacological therapies were introduced during the treatment period.

Pain intensity was recorded using a 0–10 VAS before and after each session. Functional outcomes were measured with validated, condition-specific questionnaires (VISA-A, QuickDASH, PRTEE, KOOS). A musculoskeletal ultrasound examination was performed before the first session and after completing the treatment cycle by the same experienced radiologist, using standardized protocols. Ultrasound assessment focused on tendon or ligament thickness, echogenicity, fibrillar alignment, vascularity, and bursal or periosteal alterations.

All participants provided informed consent for the use of anonymized clinical and imaging data for research and publication purposes.

CASE PRESENTATION

CASE 1 – CHRONIC MID-PORTION ACHILLES TENDINOPATHY (M, 71)

Clinical Baseline

A 71-year-old male recreational runner presented with chronic pain and swelling of the right Achilles tendon, persisting for several months despite rest, topical treatments and a short course of anti-inflammatory drugs prescribed by his physician.

Baseline ultrasound showed fusiform thickening of the mid-portion of the tendon (7.8 mm, versus 6.0 mm on the contralateral side), loss of the normal fibrillar pattern, hypoechoic intrasubstance areas and mild peritendinous effusion, consistent with Achilles tendinopathy. The paratenon was thickened but continuous, and no partial tear was observed.

Treatment

Laser therapy was delivered twice per week for five weeks, with approximately 48 hours between sessions. The treatment targeted the mid-portion and insertion of the Achilles tendon with fixed-point applications (10 points), combined with scanning along the course of the tendon (80 cm^2) and over the calf region (100 cm^2) corresponding to the main areas of referred pain during work and sports activities. Each session lasted approximately 5–11 minutes (mean ≈ 9 minutes) and delivered a total energy of about 660–1270 J (mean ≈ 1040 J). Considering all scanning and point-by-point applications within each session, the mean session dose was approximately 4.6 J/cm^2 (range 4.0–5.1 J/cm^2). The Achilles tendon region was treated using predefined "Tendinopathy" protocols at 700 Hz or with CPW emission, with intensity between 80% and 100% of maximal output in both scanning and fixed-point modalities. From the fifth session onward, an additional "Myalgia/contracture" scanning program at 1500 Hz and 80% power was applied over the calf.

Laser therapy was integrated with a non-supervised home-based exercise program designed for mid-portion Achilles tendinopathy. The program included concentric and eccentric heel-rise exercises with both legs and then with one leg, progressing to single-leg eccentric heel rises using both legs to return to the starting position. Exercises were performed daily, following a progressive loading schedule of 3 × 10 repetitions for the first two weeks and 3 × 15 repetitions for the last three weeks. Continuation of the exercises was recommended if pain remained ≤ 5/10, discomfort subsided after completion, did not persist the following morning and did not progressively increase over subsequent weeks.

Outcomes

Clinical. Pain intensity on the VAS decreased from 7/10 at baseline to 2/10 at the end of the treatment cycle.

Functional. The VISA-A (Victorian Institute of Sport Assessment–Achilles) score increased from 25.5 to 51 (0–100 scale, higher scores indicating better tendon-related function).

Ultrasound. Follow-up ultrasound showed a reduction of tendon thickness to 7.0 mm, reappearance of a more regular parallel fibrillar echotexture and disappearance of peritendinous effusion.

CASE 2 – LEFT SUPRASPINATUS TENDINOPATHY WITH SUBACROMIAL BURSITIS (M, 44)

Clinical baseline

A 44-year-old male amateur rugby player reported chronic left-shoulder pain and restricted range of motion.

Baseline ultrasound revealed three main findings: multiple punctate hyperechoic microlesions arranged in series at the enthesis of the anterior bundle of the supraspinatus tendon (up to 0.5 mm in size), periosteal irregularities involving the humeral trochiter and extensive subacromial–deltoid bursitis with hyperechoic internal strands causing coracohumeral impingement during abduction, without hypervascularization of the bursal walls.

Treatment

Given the extent of subacromial bursitis, treatment included fixed-point applications along the deltoid to address the bursa, involving the tissue planes between the anterior deltoid and the long head of the biceps tendon (LHBT). Additional scanning was performed along the bursal region and the supraspinatus tendon, moving from caudal to cranial with gentle manual pressure to facilitate fluid drainage towards the axillary lymph nodes. Ten sessions were completed over approximately five weeks. Each session lasted about 6–12 minutes (mean ≈ 10 minutes) and delivered a total energy between 500 and 950 J (mean ≈ 735 J). Considering all scanning and point-by-point applications, the mean session dose was approximately 4.7 J/cm^2 (range 4.5–4.9 J/cm^2). Fixed-point and scanning applications over the deltoid, subacromial bursa and supraspinatus tendon were delivered using predefined "Bursitis" and "Tendinopathy" protocols with FPW emission, generally at 700 Hz for the tendon and 900 Hz for the bursa, with power at 40% for fixed points and 70–80% for scanning.

Laser therapy was combined with a rehabilitation program focused on scapular stabilizers (serratus anterior, middle and lower trapezius) and rotator cuff strengthening, in line with the University Hospitals recommendations for rotator cuff rehabilitation.

Outcomes

Clinical. Pain intensity on the VAS decreased from 6/10 to 2/10 at the end of treatment.

Functional. The QuickDASH score decreased from 23 to 14. The work and performing-arts/sports modules improved from 25 to 0 and from 50 to 6, respectively, indicating less interference of pain with daily and sports activities.

Ultrasound. Follow-up ultrasound demonstrated resolution of the supraspinatus microlesions and remodeling of the humeral trochiter periosteal irregularities. The subacromial–deltoid bursitis was still present but reduced in size (23 × 6.4 mm versus 30 × 8.5 mm at baseline). Clinically, the patient recovered full active abduction and external rotation without pain and progressively returned to sports.

CASE 3 – SUPRASPINATUS TENDINOPATHY WITH SUBACROMIAL OSTEOPHYTE AND LHB TENOSYNOVITIS (F, 69)

Clinical baseline

A 69-year-old female presented with chronic left-shoulder pain and nocturnal discomfort limiting daily activities.

Baseline ultrasound showed a small partial-thickness tear of the anterior bundle of the supraspinatus tendon (deep layers IV and V), approximately 2 × 1.5 mm, with minimal subacromial–deltoid bursitis. A marked transudate within the sheath of the LHB was visible, with the tendon continuous along its course. No cortical irregularities or acute lesions were detected.

Treatment

Laser therapy was delivered using a combined scanning and fixed-point modality targeting both the supraspinatus and the long head of the biceps regions. The patient completed ten sessions over approximately seven weeks, with variable intervals resulting in an average frequency of about two sessions per week. Treatment focused on fixed-point applications over the LHB tendon sheath (14 points) and in the area of supraspinatus microcalcifications (14 points), combined with scanning along the course of the supraspinatus tendon (50 cm^2) and over the deltoid region (50 cm^2) corresponding to referred pain. Each session lasted approximately 7–14 minutes (mean ≈ 11 minutes) and delivered a total energy between about 670 and 1320 J (mean ≈ 1060 J). Across all scanning and point-by-point applications, the mean session dose was approximately 4.0 J/cm^2 (range 2.9–4.5 J/cm^2). All applications used a predefined "Myalgia/contracture" program with FPW emission at 1500 Hz and intensity between 60% and 90%, adjusted according to tolerance and clinical response.

Outcomes

Clinical. Pain intensity decreased from VAS 7/10 at baseline to 3/10 after the treatment cycle.

Functional. The QuickDASH score improved from 86 to 2.3, with resto-

ration of shoulder mobility and daily functional performance.

Ultrasound. Follow-up ultrasound showed no residual supraspinatus tendon lesion, a reduction in LHB tendon sheath effusion and a more homogeneous fibrillar pattern. The patient regained full range of motion and reported the ability to sleep on the affected side without discomfort.

CASE 4 – LATERAL EPICONDYLITIS WITH PARTIAL LESION OF THE COMMON EXTENSOR TENDON (M, 43)

Clinical baseline

A 43-year-old male factory worker, performing repetitive upper-limb tasks with moderate loads, presented with persistent lateral elbow pain exacerbated by resisted wrist extension.

Baseline ultrasound revealed an anechoic area of approximately 2 × 3 mm, compatible with a partial-thickness lesion of the common extensor tendon at the enthesis, associated with a 6 × 3 mm hypoechoic region bordered by a rim of hypervascularization on power Doppler, consistent with chronic tendinosis.

Treatment

The patient completed ten sessions over approximately four weeks, with intervals of about 2–3 days between applications. Laser applications focused on the tendinous component of the common extensor origin and on selected myofascial trigger points in the extensor compartment of the forearm. In the initial sessions, treatment mainly consisted of scanning applications combined with trigger-point irradiation over the most symptomatic myofascial areas, according to the referred pain pattern. Each session lasted approximately 4–10 minutes (mean ≈ 6 minutes) and delivered a total energy between about 430 and 1030 J (mean ≈ 590 J). Considering all scanning, fixed-point and trigger-point applications, the mean session dose was approximately 3.7 J/cm² (range 3.0–4.5 J/cm²). All laser applications used a predefined "Myalgia/contracture" program with FPW emission, at 1500 Hz, and intensity mainly between 60% and 80% of maximal output for scanning and fixed-point applications. Early trigger-point applications were delivered at 10 Hz and 15% intensity. Parameters were adjusted according to pain provocation and tissue irritability.

Laser therapy was combined with a progressive strengthening program for the forearm extensor muscles, including concentric and eccentric exercises with gradual load exposure and isometric holds of about 5 seconds per repetition. The patient presented with a marked neuropathic pain component; therefore, in addition to laser therapy, neuromodulation with low-frequency electrical stimulation (2 Hz, high-intensity microcurrent in the microampere range, 250 µs pulse duration) was applied along the course of the radial nerve, targeting both its sensorimotor component and the purely motor component via stimulation of the posterior interosseous nerve identified under ultrasound guidance. The combination of neuromodulation and laser therapy yielded the best clinical effect in this patient.

Outcomes

Clinical. At follow-up, pain intensity decreased from VAS 6/10 to 1/10.

Functional. The PRTEE score improved from 57 to 1.

Ultrasound. Follow-up ultrasound showed restoration of the fibrillar tendon architecture at the enthesis, disappearance of the previously observed anechoic defect and absence of vascular signal at the enthesis.

CASE 5 – LATERAL COLLATERAL LIGAMENT INJURY (RIGHT KNEE) (F, 64)

Clinical baseline

A 64-year-old female sustained a grade I sprain of the lateral collateral ligament (LCL) of the right knee following a twisting injury.

Baseline ultrasound revealed a partial tear of the external collateral ligament, approximately 3.8 × 2 mm, located above the meniscal region. Mild peri-ligamentous edema was present, without joint effusion or other ligamentous abnormalities.

Treatment

The patient completed ten laser therapy sessions over approximately six weeks. Sessions were generally scheduled twice per week, with rest intervals ranging from 2 to 6 days. In the initial sessions, the patient reported pain irradiating along the iliotibial band and tensor fasciae latae region; treatment therefore focused on scanning applications combined with trigger-point irradiation in these areas. After this irradiated pain pattern resolved (after the first four sessions), therapy was shifted to fixed-point applications and scanning along the entire course of the lateral collateral ligament. Each session lasted approximately 9–20 minutes (mean ≈ 16 minutes) and delivered a total energy between about 600 and 1025 J (mean ≈ 920 J). Considering all scanning, fixed-point and trigger-point applications within each session, the mean session dose was approximately 3.5 J/cm² (range 3.0–4.3 J/cm²), corresponding to an overall mean therapeutic dose per individual application of about

3.43 J/cm². All laser applications were delivered using a predefined "Distortion/contusion" program with FPW emission at 700 Hz, with intensity typically between 50% and 70% of maximal output for scanning (100 c) and fixed-point applications (14 points). Early trigger-point applications were delivered at 10 Hz and 15% intensity, with parameters adjusted according to pain provocation and tissue response.

Outcomes

Clinical. Pain intensity decreased from VAS 5/10 at baseline to 2/10 after the treatment cycle.

Functional. KOOS subscales improved across all domains for symptoms, pain and function.

Ultrasound. Post-treatment ultrasound showed continuity of LCL fibers in the area of the previous lesion, resolution of peri-ligamentous edema and absence of hypervascularization. The patient returned to daily activities and light recreational exercise without symptom recurrence.

SUMMARY OF RESULTS

All five patients completed the treatment cycle without adverse events or laser-related complications. Pain intensity decreased consistently across cases. Baseline VAS scores (at rest or during activity, depending on the case) ranged from 5 to 7 and decreased to 1–3. The mean VAS decreased from 6.0 ± 0.6 to 2.0 ± 0.6, corresponding to a mean reduction of 4 points (≈ 67 ± 9%).

Functional scores improved in all patients. Condition-specific questionnaires (VISA-A, QuickDASH with sport module, PRTEE, KOOS) showed better values at follow-up, with percentage changes relative to baseline ranging from approximately 39% to almost 100%, depending on the initial impairment and the instrument used.

Ultrasound examinations after the treatment cycle documented structural changes in each case, including reductions in increased tendon or ligament thickness, restoration of fibrillar alignment, decreased hypoechogenicity, reduction or resolution of bursitis and reduction or normalization of vascular signals. In three patients, tendon or ligament echotexture approached normal appearance in the region of the previous lesion. In one case, a small residual subacromial–deltoid bursitis was still present despite healing of the primary tendon lesion, without associated clinical worsening.

Individual clinical, functional and ultrasound outcomes are summarized in Table 1.

DISCUSSION

The findings of this Case Series show improvements in pain, function and ultrasound-monitored tissue structure in patients with different musculoskeletal soft-tissue disorders treated with MLS® laser therapy using the M-Hi device. The mean 67% reduction in VAS scores, combined with better functional questionnaire results (VISA-A, QuickDASH, PRTEE, KOOS), indicates a consistent change in symptoms and disability over the treatment period. These clinical changes were accompanied by ultrasound evidence of tissue modification, suggesting that the intervention may have contributed to both symptom modulation and structural evolution, within the limits of an uncontrolled design.

Analgesic and Anti-inflammatory Effects

Photobiomodulation therapy (PBMT) has well-described analgesic and anti-inflammatory actions supported by preclinical and clinical literature. Dual-wavelength protocols combining near-infrared continuous and super-pulsed emission, such as those used in MLS® systems, have been reported to modulate nociceptive pathways, reduce COX-2 expression, decrease prostaglandin synthesis and attenuate neurogenic inflammation [3,5]. Studies have also documented increased microcirculation and improved lymphatic drainage, which may promote edema resorption and metabolic clearance in injured tissues [6].

In the present series, the delivered dose per application (generally between 3 and 5 J/cm², depending on tissue depth and lesion location) falls within ranges associated with analgesic and anti-inflammatory effects in tendinopathies and ligament injuries [7,8]. The progressive pain reduction observed across the treatment cycles is compatible with the temporal dynamics of PBMT-mediated modulation of peripheral sensitization, although causality cannot be demonstrated in this design.

Structural and Reparative Outcomes

A notable element of this series is the consistent documentation of structural changes on ultrasound, including normalization of fibrillar alignment, reductions in tendon or ligament thickness when previously increased, resolution of hypoechoic areas, disappearance or reduction of pathological vascular signals and absence of ultrasound-detectable defects in regions of previous partial lesions. These observations are in line with clinical reports suggesting that PBMT can influence tendon morphology and extracellular matrix remodeling.

In Achilles and patellar tendinopathy, studies have described reduced tendon thickness, improved fibrillar

organization and smaller hypoechoic regions after PBMT, as assessed by diagnostic ultrasound [8; 9]. Similar structural changes have been reported in lateral epicondylalgia and supraspinatus tendinopathy when PBMT is combined with exercise [10]. Experimental work on MLS® and similar protocols provides mechanistic support for these findings. PBMT has been shown to stimulate fibroblast proliferation, promote collagen I synthesis, regulate metalloproteinases and enhance fibroblast migration [11]. In muscle and nerve models, MLS® irradiation modulates oxidative stress, increases ATP production and promotes cytoskeletal reorganization [12-14]. Taken together, these effects are compatible with the structural changes observed in this small series.

Integration with Exercise Therapy

Laser therapy was combined with condition-specific exercise programs in several cases, such as eccentric loading for Achilles tendinopathy, scapular and rotator cuff strengthening for shoulder disorders, and extensor muscle rehabilitation for lateral epicondylitis. The rationale for this integration is that mechanical loading promotes tendon remodeling, while PBMT may improve tolerance to load, reduce pain during rehabilitation and support matrix reorganization [2, 6].
In some cases where exercise could not be immediately intensified due to pain or neuropathic components, PBMT was used initially with or without neuromodulation and allowed subsequent progression of active rehabilitation. This suggests a potential role for high-power MLS® laser therapy as a component of multimodal care, including phases when loading strategies must be temporized.

Clinical Implications

The reproducibility of improvements across different anatomical regions in this series suggests that high-power MLS® laser protocols can be applied to a range of tendinous and ligamentous lesions within musculoskeletal rehabilitation. Ultrasound confirmation of tissue changes adds objective information beyond symptom reports and may help clinicians monitor the evolution of lesions and adjust treatment parameters.
The ability to record treatment parameters session by session, as available in the M-Hi system, facilitated precise reporting of the protocols used in these cases and may be useful in future studies aimed at protocol standardization and quality assurance.

Limitations and Future Directions

The main limitations of this study are the small sample size, the absence of a control group and the heterogeneity of anatomical regions and associated rehabilitation programs. These factors limit the generalizability of the results and prevent any firm conclusions on efficacy or on the specific contribution of laser therapy compared with exercise, neuromodulation or spontaneous recovery. Ultrasound assessments were performed by a single experienced operator, which supports internal consistency but does not allow evaluation of inter-observer variability.
Future research should include randomized controlled trials with adequate sample size, the use of quantitative ultrasound metrics such as elastography and power Doppler quantification, comparative studies evaluating PBMT alone versus PBMT combined with exercise, and standardized dosing studies for specific tissue types and stages of injury.
Despite these limitations, the convergence of subjective, functional and imaging findings in this series indicates that MLS® M-Hi therapy, used within a structured rehabilitation program, may influence both symptoms and the ultrasound appearance of tendinous and ligamentous lesions.

CONCLUSION

This case series describes the clinical course of five patients with tendinous or bursal disorders treated with MLS® M-Hi laser therapy integrated into individualized rehabilitation programs. Across cases, pain intensity decreased, functional scores improved and ultrasound findings evolved towards patterns compatible with tissue repair, including normalization of fibrillar architecture, reductions in pathological thickness, resolution of effusion and disappearance of partial-thickness lesions.
These observations suggest that high-power MLS® laser therapy may represent a useful adjunct in musculoskeletal rehabilitation for selected tendinous and ligamentous conditions. Controlled studies are needed to confirm these preliminary findings, to better define dose–response relationships and to refine treatment parameters for different tissues and stages of injury.

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CASE	ANATOMICAL AREA / DIAGNOSIS	VAS (PRE–POST PER SESSION)	VAS (START–END OF CYCLE)	ΔVAS CYCLE (%)	FUNCTIONAL OUTCOME (QUESTIONNAIRE)	ULTRASOUND FINDINGS (POST-TREATMENT)
1 (M, 71)	Right Achilles tendon – Chronic enthesopathy with osteophyte	5.3 → 2.6	6 → 2	−4 (−67 %)	VISA-A: 61.5 → 29 (+53 %)	Reduced tendon thickness (7.8 → 7 mm); osteophyte 4.5 → 3 mm; homogeneous fibrillar pattern
2 (M, 44)	Left shoulder – Partial supraspinatus lesion (PASTA) + subacromial bursitis	4.5 → 2.1	6 → 2	−4 (−67 %)	Quick-DASH: 23 → 14 (+39 %); Sport module: 50 → 6	Resolution of supraspinatus micro-lesions; restored periosteal contour; bursitis reduced (30×8.5 → 23×6.4 mm)
3 (F, 69)	Left shoulder – Deep partial supraspinatus tear + LHB tenosynovitis	5.7 → 3.2	7 → 3	−4 (−57 %)	Quick-DASH: 86 → 2.3 (+97 %)	Complete healing of supraspinatus tear; decreased LHB effusion; mild new subacromial-deltoid bursitis
4 (M, 43)	Right elbow – Partial enthesis lesion of extensors (epicondylitis)	5.0 → 2.8	6 → 1	−5 (−83 %)	PRTEE: 57 → 1 (+98 %)	Complete restitutio ad integrum; new echogenic fibers at enthesis; normal periosteum
5 (F, 64)	Left knee – Partial LCL lesion + periosteal irregularities	4.0 → 2.1	5 → 2	−3 (−60 %)	KOOS: 52 → 100 (+92 %)	Complete healing of LCL; resolution of periosteal notches; bursitis resolved

Table 1. Clinical, functional and ultrasound outcomes for the five patients treated with MLS® M-Hi laser therapy.

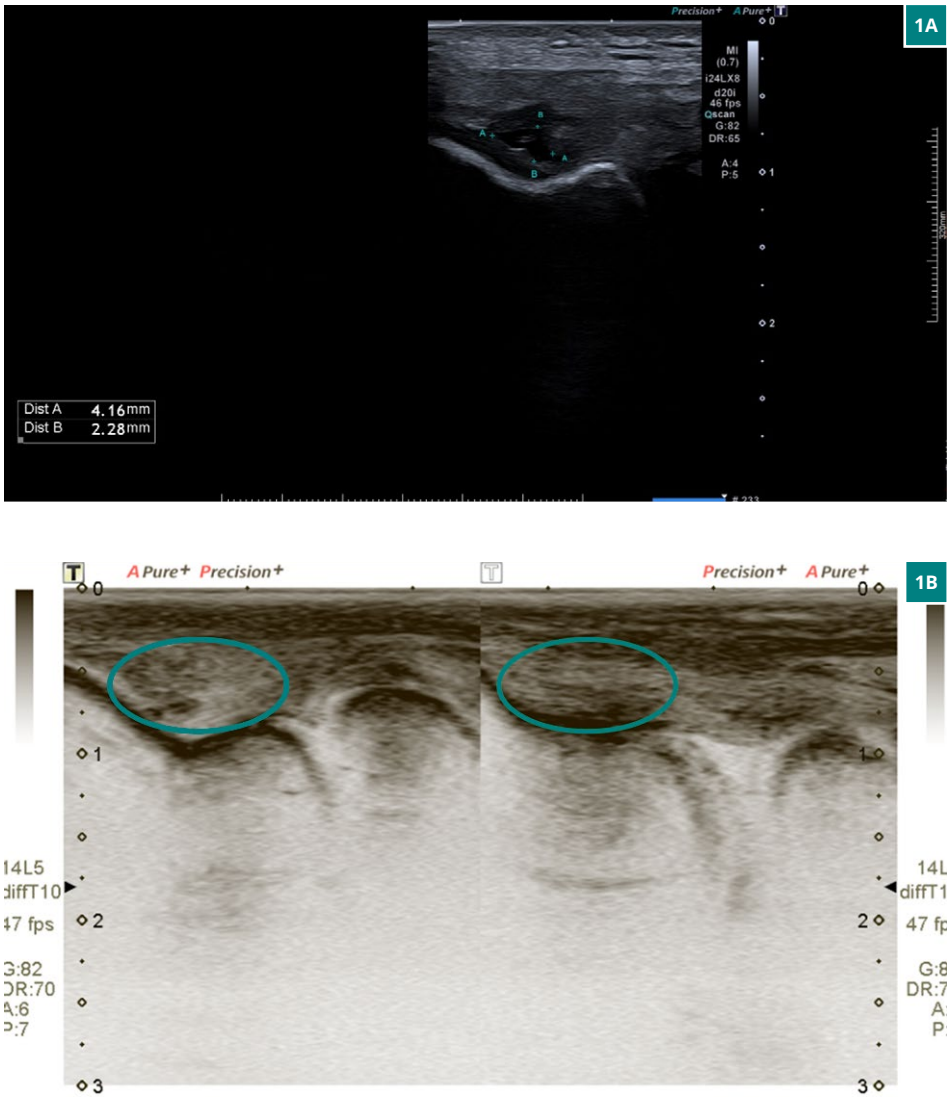

Figure 1. Longitudinal ultrasound images of the common extensor tendon enthesis at the lateral elbow.
(A) Baseline examination showing a focal anechoic area (~2 × 3 mm) at the tendon enthesis, consistent with a partial-thickness lesion and disruption of the normal fibrillar pattern.
(B) Post-treatment examination demonstrating resolution of the anechoic area and restoration of a homogeneous fibrillar architecture

Accelerated Recovery of a Pediatric Ischial Tuberosity Avulsion Fracture with Adjunctive Photobiomodulation: A Case Report

Cesar Puertolas[1], Jacqueline Puertolas[1]

[1] Belrose - Frenchs Forest Podiatry Centre - 9 Blackbutts Rd, Frenchs Forest NSW 2086, Australia

ABSTRACT

Background: Avulsion fractures of the ischial tuberosity are uncommon injuries in pediatric athletes that can significantly impair function. Conservative management is generally preferred when displacement is limited, but return to sport often requires several months.

Case presentation: We describe a 12-year-old male athlete who sustained an acute avulsion fracture of the right ischial tuberosity during an Australian Rules Football match. Initial management included protected weight-bearing and suspension from sports. Upon parental request, adjunctive photobiomodulation therapy (PBMT) was initiated using the MLS® Robotic M8 laser system. The seven-week protocol involved simultaneous treatment of the avulsion site and proximal hamstring with tailored parameters delivered by a handheld applicator and a robotic scanning head. MRI at week six demonstrated reattachment of the fragment with bridging callus formation and resolution of surrounding edema. Clinically, the patient had discontinued crutches, started jogging, and by week seven had returned to full participation in both soccer and AFL without pain or functional limitations. No adverse effects or physiotherapy were required, and surgery was definitively avoided.

Conclusion: This is, to our knowledge, the first documented case of a pediatric ischial tuberosity avulsion fracture managed with adjunctive PBMT. The therapy was well tolerated and associated with accelerated clinical and radiological recovery, enabling full return to sport in less than two months. These findings suggest that PBMT may be a safe and valuable adjunct to conservative management of apophyseal avulsions in young athletes, warranting further clinical investigation. Further controlled studies are needed to validate these findings and explore their applicability in pediatric sports medicine.

Keywords: Ischial tuberosity avulsion; pediatric athlete; photobiomodulation therapy; MLS® laser; conservative management; early return to sport.

INTRODUCTION

Avulsion fractures of the ischial tuberosity are uncommon injuries that predominantly affect skeletally immature athletes. They usually occur during sports requiring sprinting, jumping, or forceful kicking, when a sudden eccentric contraction of the hamstrings avulses the unfused ischial apophysis [1,2]. Although rare in the general pediatric population, these lesions are not negligible in sports medicine: in the largest published series of pelvic apophyseal avulsions, the ischial tuberosity represented the most frequent site, accounting for more than half of the 203 cases collected in adolescent athletes [5].

Diagnosis can be challenging, as symptoms often mimic hamstring strain, and delayed recognition may result in prolonged pain, functional limitation, or even pseudarthrosis [5]. Standard imaging includes radiographs to assess fragment displacement and, when necessary, magnetic resonance imaging (MRI) to evaluate associated soft tissue injury [1].

Management depends primarily on the degree of displacement. Conservative treatment—consisting of rest, protected weight-bearing, and gradual rehabilitation—is recommended for displacements <15–20 mm, with expected return to sport in approximately 8–12 weeks [1,3]. Surgical fixation is generally indicated in cases of greater displacement, persistent pain, or delayed union [1]. Despite appropriate treatment, recovery may be prolonged, particularly when diagnosis is delayed or in athletes with underlying risk factors [3].

Adjunctive strategies aimed at enhancing recovery in conservatively managed cases have been explored.

These include ultrasound-guided percutaneous fenestration [5] and, more recently, extracorporeal shockwave therapy in young gymnasts [6]. Photobiomodulation therapy (PBMT) has also emerged as a promising option. Preclinical and clinical evidence indicates that PBMT can reduce inflammation, stimulate osteoblast proliferation, promote angiogenesis, and accelerate bone callus formation [7–9]. Meta-analyses of randomized controlled trials suggest potential benefits in pain reduction and functional recovery after fractures, although the certainty of evidence remains low and standardized protocols are lacking [7].

To date, however, no reports have described the use of PBMT in pediatric ischial tuberosity avulsion fractures. This case report presents the first documented instance of such an application, highlighting the potential role of PBMT as a safe and non-invasive adjunct to conventional management in young athletes.

CASE PRESENTATION

A 12-year-old male competitive athlete, active in both soccer and Australian Rules Football (AFL), with no relevant past medical history, sustained an acute injury during an AFL match. While performing a forceful kicking motion, he experienced sudden sharp pain in the right gluteal region accompanied by an audible "pop." He was immediately unable to bear weight on the affected limb and required assistance off the field. On clinical examination, marked tenderness was noted over the right ischial tuberosity, and the patient was completely unable to ambulate. Magnetic Resonance Imaging (MRI) performed the following day confirmed a complete avulsion of the right ischial tuberosity, with inferior and lateral displacement of the apophyseal fragment (Figure 1). The coronal STIR sequence demonstrated a well-defined osseous fragment surrounded by high-signal intensity, consistent with acute edema and hemorrhagic infiltration. Retraction of the hamstring tendon origin from the ischial base was also evident, resulting in loss of continuity between the fragment and the pelvis. No additional fractures, acetabular involvement, or hip joint abnormalities were detected, and the left hemipelvis appeared structurally normal. These findings confirmed a high-grade apophyseal avulsion injury, raising concern for possible surgical intervention should conservative management prove insufficient.

Initial orthopedic management included non-weight-bearing with crutches for six weeks, suspension from sporting activities for twelve weeks, analgesics as required, and a scheduled orthopedic review at week six.

In parallel with the orthopedic plan, and upon parental request, adjunctive photobiomodulation therapy (PBMT) was initiated using the Multiwave Locked System (MLS®) Robotic M8 device. The treatment protocol lasted seven weeks, with a total of 26 sessions. During the first week, therapy was delivered on five consecutive days, followed by three sessions per week for the subsequent six weeks. Each treatment included irradiation of both the avulsion site and the proximal hamstring muscle belly. For the avulsion site, a handheld applicator in scanning mode (beam spot ≈3 cm^2) was used to deliver localized energy. For the hamstring, a robotic multidiode scanning head (beam spot ≈20 cm^2) ensured uniform, hands-free irradiation of the musculotendinous region. Figure 2 illustrates this dual approach, which allows different anatomical regions to be treated simultaneously with distinct parameter settings. The dosimetric parameters applied throughout the treatment period are summarized in Table 1.

RESULTS

After the first week of PBMT, the patient reported mild pain reduction, good tolerance to therapy, and no adverse effects. Clinical improvement progressed steadily over the following weeks.

At the six-week follow-up, the patient had discontinued the use of crutches at home, although he still required them during school activities. The orthopedic specialist authorized the initiation of light jogging. Follow-up MRI at this time revealed clear evidence of anatomical and biological healing at the avulsion site. Compared with the baseline scan, which had shown a displaced fragment with surrounding edema, the week-six image demonstrated reapproximation of the fragment to its anatomical base, bridging callus formation, and resolution of peri-lesional edema (Figure 3). The hamstring origin appeared continuous, without signs of retraction or scarring, and no additional abnormalities were noted in the pelvis, hip joints, or surrounding musculature.

By the seventh week after injury, the patient had resumed full participation in both soccer and Australian Rules Football. He reported no residual pain, weakness, or functional limitation. Physiotherapy was not required, and surgical intervention—initially considered due to the degree of displacement—was definitively ruled out. The accelerated clinical and radiological recovery was further confirmed when the patient participated in his AFL grand final, playing without pain and scoring a goal, as reported by his mother.

Key words: Ischial tuberosity avulsion; pediatric athlete; photobiomodulation therapy; MLS® laser; conservative management; early return to sport.

DISCUSSION

Ischial tuberosity avulsion fractures are uncommon injuries in adolescent athletes, but they represent a clinically significant challenge due to their potential for delayed diagnosis and prolonged recovery. Current literature indicates that most cases can be managed conservatively with good outcomes, but the expected return-to-sport time is typically around 8–12 weeks, with reports of prolonged recovery up to 6–12 months in cases of delayed recognition or comorbidities such as endocrine disorders [3,5,12]. For instance, Meshram et al. described a gymnast with growth hormone deficiency who required 12 months to resume competitive activity after nonoperative treatment [12].

The present case demonstrates a markedly faster recovery, with return to full sport participation at 7 weeks, substantially shorter than the standard timelines reported in the literature [3,5]. Several factors may have contributed to this accelerated outcome, including strict adherence to the conservative protocol, early diagnosis, and the addition of photobiomodulation therapy (PBMT) as an adjuvant modality.

The biological rationale for PBMT in bone healing is well established. Experimental studies have demonstrated its capacity to stimulate osteoblast proliferation, angiogenesis, and callus mineralization, while modulating the inflammatory response [7,9,10]. Chauhan and Sarin, in one of the earliest randomized controlled trials, reported earlier pain resolution and faster return to ambulation in patients with tibial stress fractures treated with PBMT compared to placebo, although the study was underpowered to achieve statistical significance [7]. More recently, Lawrence et al. highlighted the potential of PBMT to enhance bone repair and emphasized the need for standardized clinical protocols [9].

In the muscular domain, the evidence is more heterogeneous. Animal studies consistently show beneficial effects of PBMT on muscle regeneration and reduction of fibrosis [9]. However, clinical trials have produced mixed results. For example, Medeiros et al., in a randomized controlled trial on hamstring strains, found no significant reduction in return-to-play time when PBMT was added to an exercise-based rehabilitation program, although both groups achieved full recovery [11]. This suggests that while PBMT may exert biological effects at the tissue level, its translation into clinically measurable acceleration of recovery remains dependent on treatment parameters, injury type, and patient characteristics.

The use of the Multiwave Locked

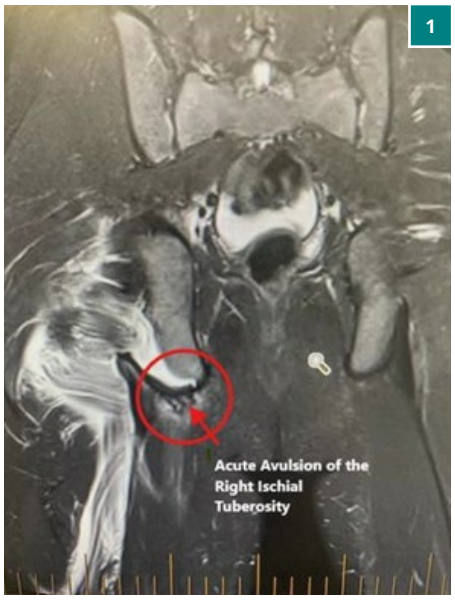

Figure 1. Baseline coronal STIR MRI of the right pelvis showing complete avulsion of the ischial tuberosity with inferior and lateral displacement of the apophyseal fragment, surrounding edema, and retraction of the hamstring origin.

Figure 2. Example of MLS® Robotic M8 laser therapy session. The handheld applicator (spot area ~3 cm^2) was applied over the ischial tuberosity, while the robotic scanning head (spot area ~20 cm^2) simultaneously treated the proximal hamstring, allowing distinct treatment protocols to be delivered in the same session.

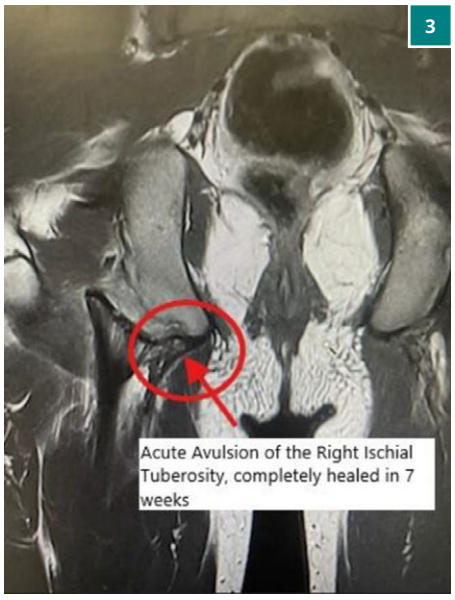

Figure 3. Coronal STIR MRI of the right pelvis at week six showing reattachment of the apophyseal fragment to its anatomical base, bridging callus formation, and marked resolution of surrounding edema.

System (MLS®) laser may represent a further innovation. By synchronizing continuous 808 nm and pulsed 905 nm emissions, MLS® therapy has been proposed to combine anti-inflammatory and biostimulatory effects, potentially leading to more consistent clinical outcomes. A recent systematic review using text-mining approaches confirmed an increasing number of publications supporting MLS® therapy in musculoskeletal pain and tissue healing, while highlighting the need for protocol standardization [13].

This case has several limitations. Being a single case report, it cannot establish causality, and the favorable outcome may have been influenced by patient compliance and individual biological variability. No direct comparator was available, and the lack of quantitative measures of bone healing, such as serial radiographic scoring or bone turnover markers, limits the ability to draw firm conclusions. Nevertheless, this remains the first documented case of a pediatric ischial tuberosity avulsion fracture successfully treated with PBMT as part of conservative management, suggesting that PBMT may play a valuable role in accelerating recovery and supporting safe return to sport.

CONCLUSIONS

This case report describes the successful management of an acute ischial tuberosity avulsion fracture in a pediatric athlete through conservative treatment complemented by adjunctive photobiomodulation therapy (PBMT). The integration of standard orthopedic care with a structured MLS® laser protocol was associated with rapid pain relief, early radiological signs of bone healing, and a full return to competitive sports within seven weeks—considerably earlier than the recovery timeframe typically expected with conservative treatment alone.

PBMT appears to be a safe, non-invasive, and well-tolerated therapeutic option that may enhance biological repair and functional recovery in apophyseal injuries. Although this case supports its potential role in accelerating healing and possibly reducing the need for surgery, larger prospective and controlled studies are warranted to confirm these findings and to define standardized treatment protocols for pediatric populations.

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ANATOMICAL ZONES TREATED	WEEKS	AREA COVERED (CM^2)	PROTOCOL	FREQUENCY (HZ)	INTENSITY (%)	DURATION (MIN:SEC)	ENERGY (J)	DOSE (J/CM^2)
Ischial Tuberosity	1–3	69	Anti-Edema	1500	100	12:00	477.30	6.92
	4-7	20	Bio-stimulation	1500	100	06:00	238.32	11.92
Hamstring	1-3	131	Anti-Edema	1500	100	12:00	1433.89	10.95
	4-7	150	Anti-Edema	1500	100	06:00	714.96	4.76

Table 1. Dosimetric parameters applied during PBMT protocol

Key words: Ischial tuberosity avulsion; pediatric athlete; photobiomodulation therapy; MLS® laser; conservative management; early return to sport.

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Neurological and Orthopedic Recovery in Dogs Treated with Pulsed Electromagnetic Fields: A Clinical Case Series

Sisti Valentina Maria, DVM

Responsible for Veterinary Rehabilitation, University Veterinary Teaching Hospital, Matelica, Italy

ABSTRACT

Pulsed electromagnetic fields (PEMFs) are increasingly applied in veterinary rehabilitation as non-invasive and safe adjuncts, but clinical case-based evidence remains limited. This article describes three canine patients in which PEMF was integrated into multimodal rehabilitation protocols. Scooter, a 16-year-old Jack Russell Terrier with suspected cervical spinal cord contusion, underwent a two-phase PEMF protocol and regained autonomous ambulation with near-complete cervical range of motion. Yago, an 8-year-old Labrador Retriever with acute non-compressive nucleus pulposus extrusion at C4–C5, improved from non-ambulatory tetraparesis to autonomous gait within one month, with only mild residual deficits after PEMF therapy during hospitalization and follow-up. Zoe, an adult mixed-breed female surgically treated for cranial cruciate ligament rupture, received seven PEMF sessions and showed increased quadriceps circumference and reduction of lameness from grade IV to grade I. All dogs tolerated PEMF well, and consistent functional improvements were observed. These cases suggest that PEMF is a safe and adaptable modality that may support neurological and orthopedic recovery in dogs, warranting further controlled studies to confirm efficacy and optimize treatment parameters.

Keywords: Pulsed electromagnetic fields; Veterinary rehabilitation; Dog; Neurological disorders; Orthopedic disorders; Case series.

INTRODUCTION

Pulsed electromagnetic fields (PEMFs) are increasingly employed in veterinary rehabilitation as safe, non-invasive adjuncts for neurological and orthopedic disorders. Their therapeutic rationale is supported by a solid body of *in vitro* and preclinical studies. At the cellular level, PEMFs enhance fibroblast proliferation and cytoskeletal remodeling while reducing pro-inflammatory cytokine release [1,2]. They also promote myoblast differentiation [3] and increase Schwann cell proliferation without altering phenotype [4], supporting both muscle regeneration and neuroprotection. Moreover, PEMFs activate repair-related intracellular pathways such as MAPKs [5].

Preclinical canine studies have shown accelerated bone healing after osteotomy [6] and improved cartilage integration with tissue-engineered constructs [7]. Clinically, PEMF has been associated with reduced pain and improved mobility in dogs with osteoarthritis [8] and functional recovery in severe traumatic or neurological cases [9]. In human medicine, meta-analyses confirm beneficial effects on function in osteoarthritis [10] and improvements in pain and disability in chronic low back pain [11].

Despite this growing evidence, veterinary clinical reports remain limited, particularly regarding PEMF use as part of multimodal rehabilitation. This article presents three canine cases—two neurological and one orthopedic—in which PEMF was integrated into rehabilitation protocols. The aim is to describe clinical outcomes and relate them to current biological and translational evidence.

MATERIALS AND METHODS

Treatments were carried out using the PMT QS device (ASA S.r.l, Arcugnano, Italy). The system allows the application of PEMFs through different applicators (Flexa and Cylinder), with adjustable parameters for intensity, frequency, magnetic flux density and treatment duration. Therapy was integrated into multimodal rehabilitation, including passive manual therapy, proprioceptive training and, when required, neuromuscular electrostimulation. Protocols lasted between four and

eight weeks and were tailored to each case.

CASE PRESENTATIONS

CASE 1 – SCOOTER

Scooter, a 16-year-old male Jack Russell Terrier, was admitted after a fall, arriving in cardiopulmonary arrest. He was resuscitated and stabilized, and clinical suspicion was of a cervical spinal cord contusion. At discharge, he exhibited non-ambulatory tetraparesis, more severe in the thoracic limbs. Rehabilitation was initiated with passive mobilizations, proprioceptive training, and pulsed electromagnetic fields (PEMF).

PEMF therapy followed two individualized protocols that were adjusted empirically according to Scooter's tolerance and neurological progress. The Flexa applicator was first employed in recumbency, and the Cylinder was later adopted as patient's condition stabilized. Details of the applied parameters are provided in Table 1. The patient was cooperative, which facilitated the protocol. After ten sessions, Scooter regained autonomous ambulation, cervical range of motion was nearly complete, and proprioception was restored, although mild thoracic limb deficits remained.

CASE 2 – YAGO

Yago, an 8-year-old male Labrador Retriever (43 kg), presented with acute tetraparesis following sudden vocalization. MRI confirmed an acute non-compressive nucleus pulposus extrusion (ANNPE) at C4–C5 with focal endomedullary myelopathy.

At presentation, he showed flaccid paraparesis, thoracic limb weakness, and cervical pain. Rehabilitation included pharmacological management, manual therapy, proprioceptive exercises, electrostimulation, and PEMF. During hospitalization, PEMF therapy was delivered using the Cylinder applicator through two sequential protocols. After discharge, sessions were performed weekly using the same settings, and subsequently at longer intervals, with the choice of applicator and parameters adjusted empirically according to clinical progress. Detailed parameters are reported in Table 1.

Although temperamentally lethargic, Yago tolerated the sessions well and allowed full completion of the rehabilitation program. By discharge, cervical pain and muscle tone had improved. At one month, he regained autonomous ambulation, with mild residual paraparesis and intermittent urinary incontinence. By two months, recovery had stabilized, and maintenance PEMF sessions were continued to support functional recovery.

CASE 3 – ZOE

Zoe, an adult mixed-breed female, presented with grade IV lameness of the right hindlimb after trauma. Orthopedic examination confirmed rupture of the cranial cruciate ligament, surgically stabilized with an extracapsular technique. Rehabilitation began two days post-surgery and included electrostimulation and PEMF.

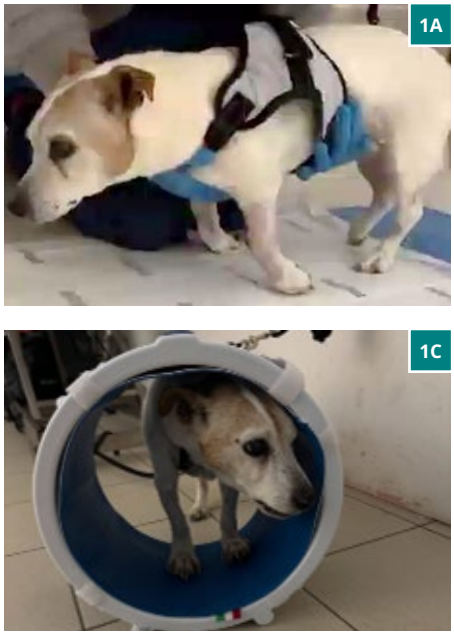

Figure 1A, 1B, 1C, 1D. Case 1 - SCOOTER

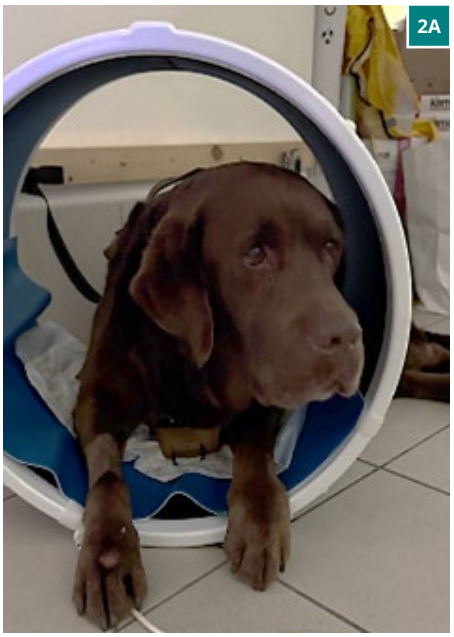

Figure 2A, 2B, 2C, 2D, 2E. Case 2 - YAGO

Because she tended to sit on the unaffected limb when positioned on the Flexa, PEMF was applied exclusively with the Cylinder. Each session consisted of three sequential protocols with varying frequencies (see Table 1).
Across seven sessions over six weeks, Zoe's quadriceps circumference increased by 1.2 cm, lameness improved from grade IV to grade I, and gait became autonomous. Therapy was discontinued prematurely for economic reasons, yet significant functional recovery had been achieved.


2B


2C

2D


2E

RESULTS

All three dogs completed the planned PEMF rehabilitation protocols without adverse effects, and overall compliance was good. The parameters applied, session schedules and applicators used are summarized in Table 1, which illustrates the progressive adaptation of treatment to each clinical condition. Clinically, consistent improvements were observed. Scooter regained autonomous ambulation with near-complete cervical range of motion, though mild deficits persisted in the thoracic limbs. Yago improved from acute non-ambulatory tetraparesis to autonomous gait within one month, with only mild residual paraparesis and intermittent urinary incontinence. Zoe recovered muscle mass and joint stability, with lameness improving from grade IV to grade I and restoration of autonomous gait, despite premature interruption of the program.
Across all cases, PEMF therapy appeared safe, well tolerated, and associated with meaningful neurological or orthopedic recovery when integrated into multimodal rehabilitation protocols.

DISCUSSION

The three cases described illustrate the role of pulsed electromagnetic fields (PEMFs) as supportive tools in multimodal rehabilitation of both neurological and orthopedic conditions in dogs. Despite differences in etiology and severity, PEMF was consistently associated with functional recovery, reinforcing its clinical value as a flexible and well-tolerated adjunct.
A key insight emerging from these cases is the importance of tailoring PEMF protocols to each patient's specific clinical conditions and therapeutic response. In the first two cases, the choice between the Fl-

exa applicator and the Cylinder was guided by the progression and localization of the pathology. In contrast, Zoe was treated exclusively with the Cylinder, as the animal's positioning in the lateral recumbency on the healthy side prevented the magnetic field of the Flexa from adequately reaching the operated limb. The Cylinder, by generating a uniform magnetic field throughout its interior, ensured consistent exposure to the target area. This adaptability highlights how PEMF therapy can be pragmatically integrated into multimodal rehabilitation program, effectively complementing manual therapy, proprioceptive training and electrostimulation.

The outcomes observed are consistent with mechanistic studies showing that PEMFs promote fibroblast activity and reduce inflammatory mediator release [1,2], stimulate myoblast differentiation [3], and support Schwann cell proliferation [4]. These cellular effects translate into improved tissue repair and neuroprotection, in line with our neurological cases. Clinically, Kimram et al. [9] reported recovery in a polytraumatized dog treated with PEMF, while Sisti et al. [8] demonstrated significant pain reduction and improved mobility in dogs with osteoarthritis, paralleling the improvements seen in Zoe. Preclinical canine models have also shown accelerated bone healing [6] and enhanced cartilage integration [7], supporting the orthopedic rationale. The translational relevance is further reinforced by human studies. A meta-analysis in knee osteoarthritis reported functional improvement with PEMF even when analgesic effects were inconsistent [10], while a systematic review in chronic low back pain confirmed significant reductions in pain and disability [11]. These findings suggest that functional benefits may represent the most robust clinical outcome of PEMF therapy across species.

Practical aspects also deserve consideration. All patients tolerated the therapy without adverse effects, and owner compliance was crucial in maintaining continuity. In Scooter and Yago, highly motivated owners supported prolonged treatment, while in Zoe economic limitations led to early discontinuation despite evident benefits. These real-world factors underline the importance of integrating PEMF into feasible, individualized protocols rather than rigid treatment schemes.

Taken together, these observations strengthen the view of PEMF as a safe, adaptable and biologically plausible adjunct in veterinary rehabilitation. Although improvements cannot be attributed to PEMF alone due to the multimodal approach, the convergence of positive outcomes across different pathologies, combined with supporting experimental and clinical evidence, provides a strong rationale for its use. Controlled studies remain necessary to better define optimal treatment parameters and indications.

CASE	PHASE	WEEKS	FREQUENCY (N° SESSIONS)	APPLICATOR	PROTOCOL	INTENSITY (%)	FREQUENCY (HZ)	FIELD STRENGTH (G)	DURATION (MIN)
Scooter	A	Week 1	Daily (5 sessions)	Flexa	1 + 2	85 + 85	10 + 100	32 + 17	30 + 10
	B	Week 2	Alternate days (3 sessions)	Flexa	1 + 2	85 + 85	10 + 100	32 + 17	30 + 10
	C	Week 3	Every two days (2 sessions)	Cylinder	3	70	5	50	35
Yago	A	Week 1	Daily (3 sessions)	Cylinder	1 + 2	100 + 50	50 + 100	60 + 20	35 + 15
	B	Weeks 2-4	Weekly (3 sessions)	Cylinder	1 + 2	100 + 50	50 + 100	60 + 20	35 + 15
	C	Weeks 5-7	Weekly (3 sessions)	Flexa	3	90	25	37	45
	D	Weeks 8-11	Every ten days (3 sessions)	Flexa	3	90	25	37	45
Zoe	A	Weeks 1-2	Twice weekly (4 sessions)	Cylinder	1 + 2 + 3	65 + 50 + 60	50 + 100 + 5	35 + 23 + 40	25 + 15 + 15
	B	Weeks 3-4	Weekly (2 sessions)	Cylinder	1 + 2 + 3	65 + 50 + 60	50 + 100 + 5	35 + 23 + 40	25 + 15 + 15
	C	Week 6	After 15 days (1 session)	Cylinder	1 + 2 + 3	65 + 50 + 60	50 + 100 + 5	35 + 23 + 40	25 + 15 + 15

Table1. Detailed PEMF rehabilitation protocols applied to the three canine cases.

CONCLUSIONS

In this series of three canine cases, pulsed electromagnetic field therapy was integrated into multimodal rehabilitation protocols and was consistently safe, well tolerated and associated with meaningful clinical improvements. Dogs affected by both neurological disorders (cervical contusion, ANNPE) and orthopedic condition (post-surgical cruciate ligament rupture) regained ambulation, improved proprioception, muscle trophism, with clear functional benefits despite differences in age, severity and treatment duration.

These observations reinforce the concept that PEMFs represent a versatile adjunct in veterinary physiotherapy, applicable across neurological and orthopedic domains. The ability to adapt protocols to the clinical condition and to patient compliance further highlights their practicality in daily practice.

While outcomes cannot be ascribed to PEMF alone due to the multimodal setting, the consistency of results, together with mechanistic plausibility and corroborating evidence from controlled studies, provides a solid rationale for its use. Further prospective trials are warranted to optimize parameters and establish clearer clinical guidelines for veterinary application.

Figure 3A, 3B, 3C, 3D. Case 3 - ZOE

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3. Gmünder FK, Cogoli A. Effect of space flight on lymphocyte function and immunity. In: Fregly MJ, Blatteis CM, eds. Handbook of Physiology. Oxford:University Press, 1996, vol. 2, pp 799-813.

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