# High Intensity Laser Therapy (HILT):

## state of the art in sporting traumatology and pain therapy

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Research activities in the therapeutic and rehabilitative sector have always pursued the goal of maximum effectiveness and minimum invasiveness in the surgical, pharmacological and instrumental fields. This has led to the developing of a wide variety of electromedical devices, especially in the physical therapy sector, but over the years these have unfortunately resulted in being of no or very little use.
The main causes of the scarce effectiveness of instrumental therapy are to be found in the inadequacy of the old concept of instruments and the lack of serious clinical and laboratory research. There are in fact, various sources of energy used and physico-biological interactions exploited, often in the absence of suitable experimentation or a real therapeutic rationale.
The musculo-tendinous and minor articular pathology represents an extremely frequent event in numerous sporting disciplines.
Due to being invalidating, even after a certain amount of time, this calls for a timely, correct and equally effective therapeutic intervention.
On the other hand, the continual expansion of the playing of sports in increasingly wider circles of the population (especially over the last decade), apart from reaching a number of between 12 and 14 million players of sport, has also created a new series of problems for health operators in this sector. These range from accident-prevention to the rapid recovery of the person involved, whose temporary invalidity, apart from personal damage, also gives rise to significant effects on the labour force, with considerable social implications.
It is not the aim of this report to make an in-depth examination of this phenomenon.

In order to provide a correct picture better of this type of specific traumatology, it is worth pointing out that in the past there has been a great deal of research by specialists in this sector for outlining a pathological cause-and-effect profile, with particular emphasis on chronic lesions, that are now known by the term “athlopathies”, almost as though identifying the prevalent or exclusive aetiology of the athletic gesture.
Lately there has been the tendency of not considering sports pathologies as any “different” from those generally found in people who do not practice sports.
Over recent years the increased interest shown in the various sporting disciplines has forced health operators in this sector to use new therapeutic methods capable of accelerating the healing process of the different pathologies, with the resulting reduction in recovery times for the athlete. Included in this context is the work of Laser experimentation carried out by our team at the CONI FMSI Institute of Sports Medicine of Bologna.
Laser is a source of coherent electromagnetic radiation and is the acronym of Light Amplification by Stimulated Emission of Radiation.
It therefore defines a physical means that produces energy under the form of a light wave following a stimulated emission of radiation.
A Laser device is fundamentally system formed by three elements:
a) the active means,
b) the activation source,
c) the optic resonator [1].

a) the active means consists of solid, liquid or gaseous material which, when suitably stimulated, emits a radiation; it is responsible for the wevelength of the emission
b) the activation source, indispensable for triggering the reaction, supplies the active material that allows for the emission of the radiation
c) the optic resonator consists of a system of mirrors that allows for amplifying the electromagnetic waves of the Laser light

The parameters that have to be taken into consideration for defining the physical characteristics of the Laser are:
1) the wavelength,
2) the intensity,
3) the emission mode.
The various types of lasers used in the treatment the different pathologies of the locomotor system, are defined according to the active means, the wavelength and the intensity of the emission (soft-Laser, midlaser and power-Laser), of which the gallium arsenide and helio-neon are absolutely the most widespread and studied.
The *semiconductor* Laser is a solid Laser: the most common is the gallium arsenide Laser which emits in the infrared with average powers in the range of the mW: it is therefore equipped with good penetration but scarce power.
The *Helio-Neon* is a gas Laser that emits red light 632,8 nm in the visible spectrum with powers that vary from between 1 and 50 mW: it therefore has extremely low power and scarce penetration.
In literature there are many works on the effects of the soft and mid-lasers and the results of these studies are very contrasting.
For this purpose the study of Heleen Beckerman et al [2] is mentioned, in which she has grouped together and meta-analysed the literature on Laser in physical therapy, arriving at the conclusion that the methodologically most correct and comprehensive studies reported positive effects, without however underestimating the validity of several studies that instead denied the therapeutic effectiveness of lasers. As mentioned previously, the limits of Laser therapy up until several years ago were above all due to the low tissular penetration power and scarce intensity, in other words the scarce in-depth therapeutic effect [3].
Recently more widespread use has been made in physical therapy of high intensity Laser devices of surgical derivation, like the $CO^2$ and Neodymium YAG (Nd:YAG) lasers.
The $CO_2$ Laser is a gas Laser whose active material is carbon dioxide and it produced an invisible light in the far infrared with a lambda of 10600 nm and a high intensity: its radiation is also absorbed by water and

therefore it has a scarce penetration power.
The *Nd:YAG Laser* is a solid lade whose active means is a yttrium-aluminium-granate crystal drugged with neodymium that emits light with a wavelength of 1064 nm with a good penetration power [4]. Up until some time ago these devices were lacking in manageability as due to the elevated heat effect they were capable of causing tissular damage.
The last generation Laser devices offer certain technical features that distinguish them in a substantial manner from the previous versions.
More specifically, the Laser we used in this study was a last generation Nd:YAG Laser which combines penetration power with a high peak intensity and energy density. Being a Laser light with an electromagnetic wave that passes through a dys-homogeneous means (like the biological substrata) it is important to keep in mind the general features of the passage of light through tissues. The electromagnetic wave in part passes through the tissues unmodified thanks to the "transmission" phenomenon which is observed with greater prevalence in the red and infrared due to the scarce cellular "absorption" at these wavelengths, and is in part "diffused" due to the heterogeneity of the tissues, in both a back-scattering direction and via a simple change in direction of the "deviation" radius [5].
The interaction between the non-ionised electromagnetic radiation (Laser) and the biological tissues is generally determined by physical processes that govern the granting of energy by the radiation at the substrate and by the biological response of the tissues themselves. The intensity of the biological reactions of the tissues radiated will therefore depend on the characteristics of the tissue that is able to absorb, transmit or reflect the energy, on the wavelength, on the power density and on the emission mode. There are a multitude of hypotheses regarding the real interactions of the Laser radiation with the cellular substrate: the most accredited postulate the "biostimulant" or "catalysed Laser reaction" effect [6, 7] that would result in either the stimulation or inhibition of the biochemical, physiological and proliferating activities. In fact, for sometime now it has been well-known that the cells are sensitive to specific wavelengths [8].

The in-vitro cells (culture) communicate by means of ionic messengers, thus generating electromagnetic energy and influencing metabolic and catabolic processes. Under conditions of imbalance or pathologies, the energetic status of the cells modifies just as they alter as a result of intercellular communication processes. The Laser radiation determines an increase in the "energetic status", activating the repair mechanisms and overcoming the damaging ones. One of the most accredited theories is that of the photochemical effect for which the absorption of the Laser radiation takes place thanks to specific chromophores [9] identified in enzymes, cellular membranes and/or other intra and extra-cellular substances whose activation or inactivation seems to be responsible for the main Laser effects, that is, the antalgic, anti-phlogistic, anti-oedemigenic and biostimulating action.
The extent of these effects seems to be in relation to the wavelength, dosage and emission mode of the Laser radiation [10].
The *wavelength* depends on the active means used, is found between 180 and 10,600 nm, and influences the penetration power of the ray: the ultraviolet rays (200-350 nm) are absorbed by the proteins and the nucleic acids [11]; the frequencies of the visible spectrum included between 400 and 750 nm are absorbed by the melanin and by the tetrapyrrolic compounds; for the frequencies found between 800 and 1400 nm (therefore in the near infrared) there is the so-called "therapeutic window" [4] in which the Laser radiations are not absorbed electively by a specific elements and as a result they have a greater penetration power.
The *dosage* is responsible for the extent of the effect and the volumetric tissuta involvement. As far as the power (watts) of the various lasers is concerned, it is necessary to make a distinction between the peak power (maximum emission power for each pulse) and the average power, recorded at the tip in one second.
It is therefore necessary to compare the irradiated surface with the output (power density in watt/cm$^2$) or with the energy released (energy density in J/cm$^2$).
As far as the *emission mode* is concerned the Laser may be continuous, pulsed (repeated pulses at more or less high frequencies), flash or

Q-switched (brief emissions at high peak intensity).
The pulsed emission represents an additional possibility for modulating the Laser effects, as demonstrated by the studies of Coche [12]. In fact, different frequencies and pulsations have different effects on the substrate, in particular, with equal lambda and powers, the lower the frequency the greater the interaction with the conduction structures and vice-versa.
Irrespective of the origin, be it direct trauma, functional overload, and/or acute or chronic evolution, in the majority of these affections the symptoms of "pain" and "functio lesa" dominate the clinical picture and the three following pathogenic events are evident as the common denominator:

1. acute or chronic phlogosis;
2. micro and/or macro-circulatory alterations;
3. lesions of the fibres and connective tissue.

On the basis of the type of pathology treated, the method and doses employed, Laser radiation seems capable of acting by raising the threshold of the perception of pain via the direct action on by stimulating the releasing of endorphins "in loco" and in the liquor [14]. Moreover, induced active Laser hyperaemia [15] and macrophagic activation [16], reducing the ischemia and local stasis of the algogenic substances, would seem to exclude other possible causes of the onset of pain and inflammation [17]. The reintegration of the cellular membrane potential seems finally to contribute towards the interruption of the contractive–vasoconstrictive-pain triad and the resolution of the inflammation [18]. As far as the tissular lesion is concerned, various experimental results have demonstrated the regenerative biological stimulus determined by Laser radiation.
On the basis of the above pulsed Nd:Yag Laser has been used over a period of seven years at the department of Instrumental Physical Therapy and Rehabilitation of the Institute, both for the purposes of research and experimentation, and also for treatment of over 1500 patients.
The equipment used was an Nd:YAG Laser supplied in collaboration with the company DEKA MELA of Calenzano (FI) which emits coherent light with a wavelength of 1064 nm with a peak intensity of 750 W, an

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| ***No. 118 DEGENERATIVE PATHOLOGIES*** <br> *RESULTS (86 Excellent, 11 fair, 21 negative)* |
| ***No. 5 SUDECK SYNDROMES*** <br> *(3 E, 0 F, 2 N)* |
| ***No. 45 ARTHROSIS OF THE SPINE LUMBAR-SACRAL SECTION*** <br> *(35 E, 3 F, 7 N)* |
| ***No. 32 ARTHROSIS OF THE SPINE CERVICAL-DORSAL SECTION*** <br> *(22 E, 3 F, 7 N)* |
| ***No. 35 ARTHROSIS OF THE TIBIAL-FEMORAL ARTICULATION*** <br> *(25 E, 5 F, 5 N)* |
| ***No. 1 HUMERAL ARTHROSIS*** <br> *(1 E, 0 F, 0 N)* |

***Table 1.***

adjustable emission frequency of between 10 and 40 Hz, adjustable pulse energy between 30 and 150 mJ and an adjustable average power of between 0.3 and 6 Watts. In this study we present a selected case history (405 cases with an age of between 11 and 73 years (mean age 37.5) obtained by gathering together various groups from different investigation works. The objective is that of offering a representative overview of the various most-frequently observed clinical and anatomo-pathological situations (table 1). A protocol was applied to each subject treated, standardised according to the type, intensity and extension of the pathological process in progress, and broken down into daily sessions with a maximum of 12 and a minimum of 5, with an average of 10 sessions per case.

The densities of the power administered varied from between 8,7 and 9,5 W/cm$^2$ for 7 sec. of punctiform applications and between 13.7 and 15.8 W/cm$^2$ for 40/60 seconds of the manual scanner application adapting the amount of energy administered on the basis of the somatic characteristics of the subject in relation to the irradiation area.

The assessment of the subjects was performed according to the clinical analysis before and after the application with the Laser, using objective and subjective assessment tests.

In 88% of the cases, in order to obtain confirmation of the diagnosis post-clinically, the assessment was also performed via imaging with instrumental diagnostic methods: echotomography, C.A.T. scans or N.M.R., X-rays and isokinetic ergometry.

We used the clinical evaluation criteria described to group the results of the cases treated on the basis of the results of the therapy with the following criteria:

- EXCELLENT, with the disappearance of the painful symptomatology and any functional and/or articulation deficits and a rapid resuming of the activity;
- FAIR, with a moderate regression of the symptomatology and a reduction and/or disappearance of the deficits and resuming of the activity;
- NEGATIVE, with scarce or no variation in the symptomatology after the treatment.

| Symptomatological regression with disappearance or reduction of any functional deficit | Attenuation of the symptomatology and functional deficit | Persisting of the symptomatology and/or functional deficit |
|---|---|---|
| **Excellent** | **Fair** | **Negative** |
| 294 subjects (72.6%) | 60 subjects (14.8%) | 51 subjects (12.6%) |

***Table 2.***

Each subject was assessed a second time at least 10 days after the end of the treatment without the onset of any relevant negative modifications of the clinical situation present at the end of therapy test.
It is evident from the results shown in table 2 that the treatment with HILT is highly successful with regard to the clinical-symptomatological situation. We wish to stress however one fact that merges from the NMR and/or X-ray, and ultrasound assessment of the patient, and namely, that in a high percent of cases there was a surprising improvement in the anatomo-pathological situation especially in the phlogistical alterations and the chondral lesions. This only further reaffirms the postulated metabolic stimulation effects of high intensity Laser.

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