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Laser acupuncture in musculoskeletal disorders: A systematic review of randomized clinical trials

Acupuntura a laser em distúrbios musculoesqueléticos: Uma revisão sistemática de ensaios clínicos randomizados

Acupuntura con láser en trastornos musculoesqueléticos: Una revisión sistemática de ensayos clínicos aleatorizados

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Abstract
Musculoskeletal disorders (MSDs) are typically characterized by pain (often persistent) and limitations in mobility, decrease in the level of functioning and reduction in the quality of life and alternative therapeutical interventions have been studied to manage symptomatology such as laser in acupuncture points (LA). The aim of this study is to systematically review the literature of the use of LA in MSDs in pain and functional capacity. PubMed and EMBASE were systematically searched using the following terms: low-level laser therapy (LLLT) and acupuncture and ten randomized clinical trials (RCTs) that used LA in MSDs were selected. All the studies used the near-infrared PBMT irradiation, with an energy per point from 1J to 72J, power from 30 mW to 400 mW, number of sessions from 4 to 24 and application at acupuncture points according to each MSDs. Most studies have shown a significant decrease in pain and symptoms, and an increase of functionality, strength, and mobility after treatment with LA. This review demonstrates that LA produced positive effects in pain and functionality of patients with MSDs, although the evidence does not determine an effective dosage window for LA, the possible range of application adjusted and designed to fit specific musculoskeletal conditions.
Keywords: Musculoskeletal Diseases, Low-Level Light Therapy, Acupuncture, Pain.

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Resumo

Os distúrbios musculoesqueléticos (DME) são tipicamente caracterizados por dor (frequentemente persistente), limitações na mobilidade, redução no nível de funcionamento e diminuição na qualidade de vida. Intervenções terapêuticas alternativas têm sido estudadas para o manejo da sintomatologia, como o uso do laser em pontos de acupuntura (LA). O objetivo deste estudo é revisar sistematicamente a literatura sobre o uso do LA nos DME em relação à dor e à capacidade funcional. Uma busca sistemática foi realizada nas bases de dados PubMed e EMBASE utilizando os seguintes termos: terapia a laser de baixa intensidade (LLLT) e acupuntura, sendo selecionados dez ensaios clínicos randomizados (ECR) que utilizaram LA em DME. Todos os estudos utilizaram irradiação PBMT no espectro do infravermelho próximo, com energia por ponto variando de 1J a 72J, potência de 30 mW a 400 mW, número de sessões entre 4 e 24, e aplicação em pontos de acupuntura conforme a condição musculoesquelética estudada. A maioria dos estudos demonstrou uma redução significativa na dor e nos sintomas, além do aumento da funcionalidade, força e mobilidade após o tratamento com LA. Esta revisão demonstra que o LA produziu efeitos positivos na dor e funcionalidade de pacientes com DME. No entanto, embora as evidências sugiram benefícios, ainda não há uma determinação clara de uma faixa de dosagem eficaz para o LA, sendo necessário ajustar e projetar a aplicação para condições musculoesqueléticas específicas.

Palavras-chave: Doenças Musculoesqueléticas, Terapia com Luz de Baixa Intensidade, Acupuntura, Dor.

Resumen

Los trastornos musculoesqueléticos (TME) se caracterizan típicamente por dolor (a menudo persistente), limitaciones en la movilidad, reducción del nivel de funcionamiento y disminución de la calidad de vida. Se han estudiado intervenciones terapéuticas alternativas para el manejo de la sintomatología, como el uso del láser en puntos de acupuntura (LA). El objetivo de este estudio es revisar sistemáticamente la literatura sobre el uso del LA en los TME en relación con el dolor y la capacidad funcional. Se realizó una búsqueda sistemática en las bases de datos PubMed y EMBASE utilizando los siguientes términos: terapia láser de baja intensidad (LLLT) y acupuntura, seleccionándose diez ensayos clínicos aleatorizados (ECA) que emplearon LA en TME. Todos los estudios utilizaron irradiación PBMT en el espectro del infrarrojo cercano, con una energía por punto de 1J a 72J, potencia de 30 mW a 400 mW, número de sesiones entre 4 y 24, y aplicación en puntos de acupuntura según la condición musculoesquelética estudiada. La mayoría de los estudios mostraron una reducción significativa del dolor y los síntomas, así como un aumento en la funcionalidad, la fuerza y la movilidad después del tratamiento con LA. Esta revisión demuestra que el LA produjo efectos positivos en el dolor y la funcionalidad de los pacientes con TME. Sin embargo, aunque la evidencia sugiere beneficios, aún no se ha determinado una ventana de dosificación efectiva para el LA, por lo que es necesario ajustar y diseñar la aplicación para condiciones musculoesqueléticas específicas.

Palabras clave: Enfermedades Musculoesqueléticas, Terapia por Luz de Baja Intensidad, Acupuntura, Dolor.

1. Introduction

Musculoskeletal Disorders (MSDs) have a major effect on disability, medical costs and quality of life, lagging due to the associated musculoskeletal pain (Yuan et al., 2016). MSDs comprise more than 150 conditions that affect the locomotor system of individuals, ranging from short-term diseases such as fractures to lifelong conditions associated with ongoing functioning limitations and disability2. MSDs conditions are typically characterized by pain (often persistent) and limitations in mobility, decrease in the level of functioning and reduction in the quality of life (Torres-Torrillas et al., 2019). A recent analysis of Global Burden of Disease data showed that approximately 1.71 billion people globally have musculoskeletal conditions (Briggs et al., 2016).

Treatments for MSDs are based mainly on medications and non-pharmacologic treatments available for relieving pain and the related inflammatory process (Sammaritano et al., 2020). Also, alternative therapeutical interventions are highly indicated to manage the symptomatology of MSDs such as physical interventions, manual therapies and acupuncture (Babatunde et al., 2017; Zhang & Wang, 2020).

Acupuncture is used for more than 3000 years as a therapeutic method and it is based on the insertion of needles into specific points on the body (acupuncture points), producing the restoration and maintenance of health by the stimulation of the central nervous system (Zhang & Wang, 2020). Recently, other approaches for acupuncture applications have been employed such as the use of photobiomodulation therapy (PBMT) and low-level laser therapy (LLLT) on acupuncture points (Mitova, 2020). Laser acupuncture (LA) can be defined as the stimulation of traditional acupuncture points with low power lasers, with no thermal effect and applied transcutaneously to a single, anatomically defined acupuncture point, many of which overlie the

course of peripheral nerves (Madani et al., 2020; Mitova, 2020).

In addition, LA is painless, easy to perform and is noninvasive (Madani et al., 2020). To date, some studies have demonstrated the effectiveness of LA for MSDs such as temporomandibular dysfunction (Madani et al., 2020), osteoarthritis (OA), myofascial pain and muscle pain (Huang et al., 2021). For example, in patients with OA in the knee, LA has been suggested to alleviate knee OA symptoms by increasing and decreasing serum beta-endorphin and substance P levels, respectively, demonstrating to be an effective modality for short-term pain relief and function improvement in these patients (Mohammed et al., 2018). Although all the positive evidences of the effects of this therapy in the improvement of some symptoms presented by MSDs, no systematic review have evaluated the effects of LA for this patients Thus, the aim of this study is to systematically review the literature of the use of LA in MSDs in pain and functional capacity evaluated by Visual Analog Scale (VAS), Lequesne index, Global Symptom Score (GSS), Shoulder Pain and Disability Index (SPADI) score and Saudi Knee Function Scale (SKFS) Moreover, goniometry, digital dynamometer, pressure algometry, electromyography (EMG) and nerve conduction study (NCS) and arm circumference were used to evaluate mobility and strength.

2. Methodology

2.1 Review protocol

The present systematic review was performed according to the orientations of Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) (Liberati et al., 2009). Medline via PubMed and EMBASE were systematically searched for articles about trials evaluating the effects of LA in MSDs.

Medical Subject Headings (MeSH) terms to search in all trials registers and databases were used: low-level laser therapy OR photobiomodulation OR phtotobiomodulation therapy AND acupuncture. The search runs from June to July 2021. Two reviewers (PGV and ABB) analysed independently the studies and selected the potential studies from inclusion and exclusion criteria. In addition, the same reviewers had access to selected studies.

Papers were selected based on the titles and abstracts meeting the eligibility criteria. This systematic review was registered by the online international prospective register of systematic reviews (PROSPERO) of the National Institute for Health Research (register: CRD42021273490). Furthermore, articles included in this review had their methodological quality assessed by the PEDro scale Physiotherapy Evidence Database.

2.2 Study selection

Two reviewers (ABB and PGV) analyzed independently the title and the abstract of the studies and selected the potential works according to the inclusion and the exclusion criteria. In addition, the same reviewers had access to the selected studies and the disagreements were discussed. Moreover, 2 reviewers evaluated the RTCs with the PEDRO scale (ABB and PGV).

2.3 Inclusion criteria

The inclusion criteria of this systematic review were:

1. Clinical trials written only in English.
2. Clinical trials published between 2012 to 2022.
3. Clinical trials that used acupuncture points in MSDs.
4. As MSDs, conditions that can affect muscles, joints, tendons, ligaments, nerves and bones were considered.

2.4 Exclusion criteria

The exclusion criteria of this systematic review were:

1. *In vitro* and *in vivo* studies, systematic reviews and meta-analysis, case reports and experimental studies.
2. Articles that have not studied MSDs.
3. Follow-up of previously published trials.
4. Conference abstract.

2.5 Data extraction

Data was extracted from included studies by 2 reviewers (ABB and PGV). The study database included basic characteristics of the studies (first author, published date, country), characteristics of the subjects (number of participants, age, gender, other relevant characteristics), interventions (treated group, control group or other treatment group and analyses), parameters of LA (wavelength (λ), mode, power, energy density, application area, total of applications). The outcomes comprised the improvement of the symptoms evaluated after the treatment.

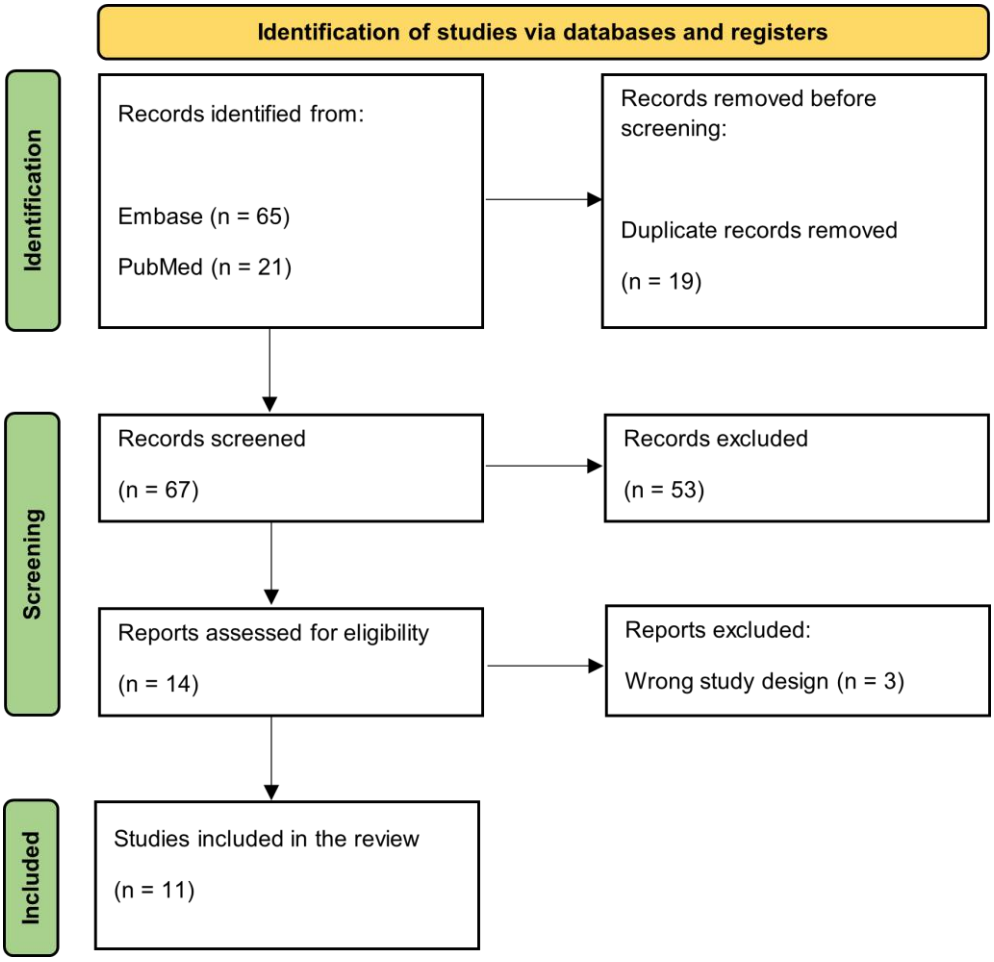
2.6 Types of Reported Results

Due to the heterogeneity of the primary studies, it was not possible to perform a meta-analysis. Quality of the body of evidence was determined using the GRADE approach, which analyses the following domains: trial design limitations due to risk of bias (utilizing the PEDro score), inconsistency of results, indirectness, imprecision of results, and publication bias.

3. Results

Eighty-five studies were retrieved from 2 electronic databases (PubMed: 21; Embase: 65). A total of 19 studies were excluded due to duplication. After title and abstract screening, a total of 53 studies were defined as ineligible. Three studies were excluded after screening the inclusion criteria. The final number of studies was 11 RCTs (Al Rashoud et al., 2014; Chang et al., 2019; Chang et al., 2021; Ferreira et al., 2013; Helianthi et al., 2016; Huang et al., 2021; Juan et al., 2019; Kibar et al., 2016; Liao et al., 2020; Madani et al., 2020; Salgueiro et al., 2021) after reading full texts. Figure 1 shows the flow diagram according to PRISMA guidelines (Liberati et al., 2009).

Figure 1 - Flow diagram of the different phases of the systematic review (PRISMA).



Source: Authors.

Table 1 shows the general characteristics of patients, experimental groups and analyses. The age of the volunteers varied from 6 (Salgueiro et al., 2021) to 71 years (Madani et al., 2020). One study recruited only children (Salgueiro et al., 2021), one study recruited only female volunteers (Ferreira et al., 2013) and eight studies recruited male and female volunteers (Al Rashoud et al., 2014; Chang et al., 2019; Chang et al., 2021; Helianthi et al., 2016; Huang et al., 2021; Juan et al., 2019; Kibar et al., 2016; Liao et al., 2020; Madani et al., 2020).

The findings of the studies were temporomandibular disorders (Ferreira et al., 2013; Madani et al., 2020), carpal tunnel syndrome (Juan et al., 2019), knee OA (Al Rashoud et al., 2014; Helianthi et al., 2016; Liao et al., 2020), subacromial impingement syndrome (Kibar et al., 2016), total knee replacement (Huang et al., 2021), sleep bruxism (Salgueiro et al., 2021), cervical myofascial pain syndrome (MPS) (Chang et al., 2021) and Delayed Onset Muscle Soreness (Chang et al., 2019).

All studies used LA as an intervention group, four studies included a control group without any intervention (Ferreira et al., 2013; Huang et al., 2021; Kibar et al., 2016; Salgueiro et al., 2021), seven studies used a placebo group (Al Rashoud et al., 2014; Chang et al., 2019; Helianthi et al., 2016; Juan et al., 2019; Liao et al., 2020; Madani et al., 2020). Other interventions were occlusal splint (OS) (Ferreira et al., 2013; Salgueiro et al., 2021), trigger point therapy (Chang et al., 2021) and PBMT at other points than acupuncture (Madani et al., 2020).

The analyses used for the authors were the Visual Analogue Scale (VAS) (Al Rashoud et al., 2014; Chang et al., 2019; Chang et al., 2021; Ferreira et al., 2013; Helianthi et al., 2016; Kibar et al., 2016; Liao et al., 2020; Madani et al., 2020), goniometry (Chang et al., 2021; Huang et al., 2021), digital dynamometer (Chang et al., 2019; Salgueiro et al., 2021), pressure algometry (Chang et al., 2019; Chang et al., 2021; Liao et al., 2020), Lequesne Index (Helianthi et al., 2016; Liao et al., 2020)

and Global Symptom Score (GSS) (Juan et al., 2019). Moreover, one study used Shoulder Pain and Disability Index (SPADI) score (Kibar et al., 2016), one study used Saudi Knee Function Scale (SKFS), one study used electromyography (EMG) and nerve conduction study (NCS) and one study used arm circumference with tape measure (Chang et al., 2019).

Table 1 - General characteristics of patients, experimental groups and analyses.

Authors	N. of participants/ Gender	Age	Characteristics of patients	Intervention group	Control or other treatment group	Analyses
Chang et al. 2021	100/ male and female	20 - 65 y	Cervical MPS	LA group n=25	Control group (n=25) Trigger point therapy (n=25) Trigger point control (n=25)	VAS; pressure algometry, and cervical ROM
Huang et al. 2021	82/male and female	≥60y	Diagnosed knee OA; TKR; unilateral	LA group n=39	Control group n=40	Goniometry (joint flexion); subscale of joint stiffness
Salgueiro et al. 2020	76/ children	6-12y	SB; First molars in Angle Class I occlusion; absence of dental caries and of physical motor impairment.	LA group n=19	OS group (n=19); Placebo group (n=19); Control group without SB (n=19)	Digital dynamometer (bite force) and saliva analysis
Liao et al. 2020	33/ male and female	>50y	OA patients' severity above Level II (Kellgren–Lawrence grading scale); pain more than six months.	LA group n = 16	Placebo group (n = 17)	VAS; Pressure algometry and Lequesne index
Juan et al. 2019	84/male and female	20-65y	Idiopathic mild-to-moderate CTS; Positive Phalen's test and/or Tinel's sign	LA group n=43	Placebo group (n=41)	EMG/NCS; Self-reported Assessments
Madani et al. 2019	45/male and female	15-71y	TMD muscular disturbance (class Ia, Ib) or arthralgia (class IIIa)	LA group n=15	PBMT group (n=15) Placebo group (n=15)	VAS; mouth opening (digital caliper); horizontal distance.
Chang et al. 2019	40/male and female	Avera ge 20y	Delayed Onset Muscle Soreness of college students; healthy individuals.	LA group n=20	Placebo group (n=20)	Pressure algometer; VAS; Arm Circumference (tape measure); dynamometer (Muscle Strength and Proprioception)
Kibar et al. 2017	73/male and female	18-70y	Neer and Hawkins-Kennedy impingement tests (stage I or stage II)	LA group n=36	Control group (n=37)	SPADI, digital inclinometer; Self-reported Assessments (VAS)
Helianthi et al. 2016	62/male and female	>60y	Kellgren-Lawrence grading scale (grade 2, 3); VAS (40 on a 100-mm)	LA group n=31	Placebo group (n=31)	VAS, Lequesne index
Al Rashoud et al. 2014	49/male and female	N/A	Knee OA; VAS (pain intensity of ≥3)	LA group n = 26	Placebo laser group (n=23)	SKFS; VAS
Ferreira et al. 2013	40/female	20-40y	Temporomandibular disorders and arthralgia	LA group n=20	Placebo group (n=20)	VAS

MPS: myofascial pain syndrome; ROM: range of motion; Acupuncture with low-level laser therapy (ALLLT); total knee replacement (TKR); occlusal splint =OS; laser acupuncture (LA); sleep bruxism (SB); Temporomandibular disorder (TMD); low-level laser therapy (LLLT); Visual analogue scale (VAS); CTS = carpal tunnel syndrome; Boston carpal tunnel questionnaire (BCTQ); pressure pain threshold (PPT); subacromial impingement syndrome=SAIS; Shoulder Pain and Disability Index (SPADI); Saudi Knee Function Scale (SKFS); carpal tunnel syndrome (CTS); Electromyography (EMG); nerve conduction study (NCS); N/A: Not available. Source: Authors.

Table 2 demonstrates the LA protocols used in the studies. All the studies applied the near-infrared irradiation wavelength, in a range from 780 nm (Ferreira et al., 2013; Liao et al., 2020) to 850 nm (Kibar et al., 2016). The power output varied from a minimum of 30 mW (Al Rashoud et al., 2014; Liao et al., 2020) to a maximum of 400mW (Juan et al., 2019). In addition, the energy density varied from 2 J/cm² (Chang et al., 2021) to 112.5 J/cm^2 (Ferreira et al., 2013). The lowest energy per point was 1 J (Salgueiro et al., 2021) and the highest energy per point was 32 J (Liao et al., 2020). Furthermore, the number of acupuncture points varied from 3 (Liao et al., 2020; Madani et al., 2020) to 12 (Salgueiro et al., 2021).

The lowest total energy per session was 6 J (Al Rashoud et al., 2014) and the highest total energy per session was 216 J (Liao et al., 2020) and the number of sessions varied from 1 (Chang et al., 2021) to 24 sessions (Salgueiro et al., 2021).

Table 2 - LA protocols and parameters used by the studies.

Authors	Laser model	λ	Power output	Energy density	Energy per point	Number of irradiated points	Total energy per session	Total application
Chang et al. 2021	LaserPen Expert	810 nm	150mW	2 J/cm²	N/A	4	8 J/cm^2	1 session
Huang et al. 2021	TRANS Laser Phototherapy Infrared GaAlAs	808 nm	≤ 300 mW	N/A	3 J	7	21 J	6 sessions
Salgueiro et al. 2020	Therapy EC DMC	786,94 nm	70 mW	33.5 J/cm²	1 J	12	12 J	24 sessions
Liao et al. 2020	Multband laser TI-816-2	780 nm 808 nm	50 mW 30 mW	N/A	72 J	3	216 J	12 sessions
Juan et al. 2019	RJ-Laser LLLT	810 nm	400 mW	24 J/cm²	N/A	2	N/A	20 sessions
Madani et al. 2019	DD2 – LLLT GaAlAs	810 nm	200 mW	21 J/cm²	6 J	3	18 J	10 sessions
Chang et al. 2019	Painless Light PL-830	830 nm	60 mW	9.7 J/cm²	18 J	2	36 J	4 sessions
Kibar et al. 2017	GaAlAs Continuous wave laser	850 nm	100 mW	4 J/cm²	4 J	11	44 J	15 sessions
Helianthi et al. 2016	Handylaser Trion RJ – Laser GaAlAs	785 nm	50 mW	N/A	4 J	5	20 J	10 sessions
Al Rashoud et al. 2014	Endolaser 476 GaAlAs	830 nm	30 mW	4 J/cm²	1,2 J	5	6 J	9 sessions
Ferreira et al. 2013	Twin Flex II Infrared	780 nm	50 mW	112.5 J/cm²	4,5 J	8	36 J	12 sessions

λ: wavelength; Nm: nanometers; mW: miliWatts; J: Joules; J/cm^2: Joules per square centimeter; N/A: not available. Source: Authors.

Table 3 shows the minimum, maximum, mean and median of power, energy density, energy per point and total energy of studies analyzed. Studies demonstrated a window of power output of 30 mW (Al Rashoud et al., 2014; Liao et al., 2020) to 400 mW (Juan et al., 2019) and the mean of 132.72 mW. In addition, different values of energy density were presented, with a mean of 26.33 J/cm². The energy per point remained within a window of 1 J (Salgueiro et al., 2021) to 32 J (Liao et al., 2020) and mean of 8.18 J. Total energy demonstrated a window of 6 J (Al Rashoud et al., 2014) to 216 J (Liao et al., 2020) and a mean of 45.44 J.

Table 3 - Minimum, maximum, mean and median of power, energy density, energy per point and total energy of studies analyzed.

	Power output (mW)	Energy density (J/cm^2)	Energy per point (J)	Total energy (J)
Minimum	30	4	1	6
Maximum	400	112.5	32	216
Mean	132.72	26.33	8.18	45.44
Median	60	21	4	21

Source: Authors.

Table 4 demonstrates the results and outcomes presented by the articles included in this review. After analysis, all the authors demonstrated that LA treatment has produced positive effects in the symptoms related to MSDs (Al Rashoud et al., 2014; Chang et al., 2019; Ferreira et al., 2013; Helianthi et al., 2016; Huang et al., 2021; Juan et al., 2019; Kibar et al., 2016; Liao et al., 2020; Madani et al., 2020; Salgueiro et al., 2021).

Furthermore, VAS scores demonstrated a significant improvement in the LA groups in patients with knee OA (Al Rashoud et al., 2014; Ferreira et al., 2013; Helianthi et al., 2016; Liao et al., 2020), TMD (Ferreira et al., 2013; Madani et al., 2020), Delayed Onset Muscle Soreness of the Biceps Brachii (Chang et al., 2019) and subacromial impingement syndrome (Kibar et al., 2016) compared to placebo or control group. A statistically significant decrease was observed in the Lequesne index in patients with knee OA (Helianthi et al., 2016; Liao et al., 2020).

One study used the Saudi Knee Function Scale (SKFS) and observed a significant improvement in the laser group compared with the placebo group post- intervention in patients with knee OA (Al Rashoud et al., 2014). The same study evaluated active range of motion of knee flexion and demonstrated a statistically significant improvement for the LA group (Al Rashoud et al., 2014).

Only one study including patients with sleep bruxism showed that LA was effective in improving the level of pain related to headaches (Salgueiro et al., 2021). Three studies showed significant changes in pressure pain threshold in patients with knee OA (Liao et al., 2020), Delayed Onset Muscle Soreness of the Biceps Brachii Muscle (Chang et al., 2019) and TMD (Ferreira et al., 2013).

One study demonstrated that LA was effective in decreasing the pain intensity, pain degree of masticatory muscles and temporomandibular joints and amount of lateral excursive and protrusive movements in TMD patients (Madani et al., 2020). Moreover, a decrease in the global symptom score was observed and a significant improvement in paresthesia, numbness, and nocturnal awakening assessment in tunnel carpal syndrome patients (Juan et al., 2019). Also, Huang et al., demonstrated a significant improvement in the joint stiffness score and knee flexion angle in patients with knee OA after total knee replacement.

Table 4 - Outcomes and results after intervention.

Authors	MSDs	Outcomes	Results after intervention
Chang et al. 2021	Cervical MPS	LA No efficiency on 1 session	Trigger point therapy improves myofascial pain and cervical ROM limitations, while the LA group did not.
Huang et al. 2021	Knee OA after total knee replacement	LA efficiency	LA group: significant improvements in the knee flexion angle and joint stiffness score on days 2 and 3.

Salgueiro et al. 2020	Sleep bruxism	LA efficiency	*Bite force:* in the LA group the children had lower bite force on both sides compared to the other groups. *Headache*: statistically significant difference was found between the frequency of children with headache before and after treatment in LA group and occlusal splint therapy group.
Liao et al. 2020	Knee OA	LA efficiency	*Lequesne index:* statistically significant decreases in the 1st, 2nd, 3rd, and 4th weeks after treatment. *VAS:* Statistically significant decreases, 4 weeks after treatment for moving knee and resting knee. *Pes Anserinus Tendon Pain pressure threshold:* increase was noted in the LA group compared with the PG.
Juan et al. 2019	Carpal tunnel syndrome	LA efficiency	*Global symptom score:* significantly greater reduction in the LA group than in the PG in weeks 2 and 4. *Pain, paresthesia, numbness and nocturnal awakening assessment:* LA group showed significant improvement at weeks 2 and 4. *Nerve conduction studies:* no significant difference between the two groups.
Madani et al. 2019	Temporomandibular disorders	LA efficiency	*Maximum pain-free mouth opening and maximum possible mouth opening:* no significant differences between the groups at any of the assessment intervals. *Amount of lateral excursive and protrusive movements:* significantly greater in laser and LA groups than the PG at some intervals. *Overall pain intensity and pain degree at masticatory muscles (except temporal muscle) and temporomandibular joints:* significantly lower in both experimental groups than the PG at most intervals after therapy.
Chang et al. 2019	Delayed Onset Muscle Soreness of the Biceps Brachii Muscle	LA No efficiency in DOMS prevention	Significant changes in the VAS, pressure pain threshold, normalized arm circumference, and normalized muscle strength were observed within the groups over time, but there were no significant differences between the two groups.
Kibar et al. 2017	Subacromial impingement syndrome	LA efficiency	Significant improvement was observed in all parameters in the treatment group post-treatment. All parameters of pain and functional status in the treatment group were significantly better than those in the control group post-treatment.
Helianthi et al. 2016	Knee OA	LA efficiency	*VAS scores:* statistically significant improvement for the LA group after four sessions, nine sessions and at 2 weeks post intervention (mean difference 0.39, 37.48, and 39.15, respectively) compared to the PG. *Lequesne index:* improved significantly after four sessions, nine sessions and at 2 weeks post intervention for the LA group (mean difference 4.68, 5.90, and 6.48 respectively) compared to the PG.
Al Rashoud et al. 2014	Knee OA	LA efficiency	*VAS scores:* significant improvement in the LA group compared with the PG at 6 weeks post intervention (mean difference −1.3) and 6 months post intervention (mean difference −1.8). *SKFS scores:* significant improvement in the LA group compared with the PG at the last treatment session (median difference −15) and 6 months post intervention (median difference −21). *Active range of motion (knee flexion):* statistically significant improvement for the LA group 6 months post intervention.
Ferreira et al. 2013	Temporomandibular dysfunction	LA efficiency	*Symptom reduction:* significant in both groups (LA group: VAS=0, n=20; PG: VAS between 2 and 4, n=18). Most of the patients in the LA group (n≥16) achieved total remission of symptoms after the treatment in some structures. *Assessment by palpation of structures:* average pain intensity smaller than 0.5 as indicated by VAS.

MPS: myofascial pain syndrome; VAS: Visual Analogical Scale; PG: Placebo group; SKFS: Saudi Knee Function Scale. Source: Authors.

Table 5 shows methodological evaluation of the studies with technical specifications by PEDro scale. Most of the articles were classified as moderate to high methodological quality (≥ 6/9) score. The three PEDro scale criteria that were not clearly satisfied in most of the studies were the blinding of all physiotherapists who administered the therapy (Chang et al., 2021; Ferreira et al., 2013; Huang et al., 2021; Juan et al., 2019; Liao et al., 2020; Madani et al., 2020; Salgueiro et al., 2021) and none of the studies demonstrated precision and variability measurements. Thus, these studies showed the highest risk of bias in relation to gauging and categorical outcomes bias. Table 5 shows in detail the quality assessment of included studies.

Table 5 - Methodological evaluation of studies with technical specifications by Pedro scale.

Study	Random allocation	Blinded assessor	Similar prognosis	Blinded subjects	Blinded physiothe rapists	Blinded evaluators	≥85% completed protocol	Intention -to-treat analysis	Intergrou p analysis described	Precision & variability reported	Score
Chang et al. 2021	1	1	1	1	0	0	1	1	1	0	7
Huang et al. 2021	1	1	1	1	0	0	1	0	1	0	6
Salgueiro et al. 2020	1	0	1	0	0	0	1	0	1	0	4
Liao et al. 2020	1	1	1	0	0	0	1	0	1	0	5
Juan et al. 2019	1	1	1	0	0	1	1	1	1	0	7
Madani et al. 2019	1	1	1	1	0	1	1	0	1	0	7
Chang et al. 2019	1	1	0	1	1	1	1	0	1	0	7
Kibar et al. 2017	1	0	1	0	1	1	0	1	1	0	6
Helianthi et al. 2016	1	0	1	1	1	0	1	0	1	0	6
Al Rashoud et al. 2014	1	0	1	1	1	0	0	0	1	0	5
Ferreira et al. 2013	1	0	1	1	0	1	0	0	1	0	5

Source: Authors.

4. Discussion

The present study analyzed the effectiveness of LA for managing symptoms related to MSDs, being included in this review 11 studies, according to the inclusion criteria. All studies showed positive effects of LA in MSDs, including TMD (Ferreira et al., 2013; Madani et al., 2020), cervical MPS (Chang et al., 2021), carpal tunnel syndrome (Juan et al., 2019), knee OA (Al Rashoud et al., 2014; Huang et al., 2021; Liao et al., 2020) subacromial Impingement Syndrome (Kibar et al., 2016), knee OA after total knee replacement (Huang et al., 2021), sleep bruxism (Salgueiro et al., 2021) and Delayed Onset Muscle Soreness (Chang et al., 2019). Moreover, all the studies used near-infrared laser irradiation, with the energy per point varying from 1J to 32J, fluence ranging from 2 J/cm^2 to 112.5 J/cm^2 and number of treatment sessions from 1 to 24. All the protocols included the application of LA alone, furthermore some studies included LA placebo (Al Rashoud et al., 2014; Chang et al., 2019; Chang et al., 2021; Helianthi et al., 2016; Juan et al., 2019; Liao et al., 2020; Madani et al., 2020) and control groups without intervention (Ferreira et al., 2013; Huang et al., 2021; Kibar et al., 2016; Salgueiro et al., 2021).

The World Health Organization (WHO) points out that MSDs lead to a reduction of general mobility, an increase of the level of pain and a decrease of the quality of life of the affected individuals (World Health Organization, 2020).

Acupuncture is commonly used for treating these symptoms (Ammendolia et al., 2008). The proposed mechanism of action suggests that stimulation of acupuncture points cause analgesia by releasing neuropeptides, producing vasodilation, and increasing local blood circulation (Cabýoglu et al., 2006; Cheng, 2014). Moreover, LA has become attractive in clinical practice, especially for patients with needle phobias, elderly people and children (Yang et al., 2020). A systematic review with meta-analysis published by Law et al. (2015) showed that LA is effective for long-term treatment of patients with pain related to musculoskeletal conditions. Wu et al. (2017) and Fernandes et al., (2017) concluded that LA therapy attenuates the signs and symptoms of TMD. In addition, Peres e Serra & Ashmawi, (2010) observed a release of local opioids after the application of LA, decreasing the level of pain in patients with knee OA.

In the present review, the studies evaluated different diseases affecting musculoskeletal tissues. Between them, knee OA (Al Rashoud et al., 2014; Helianthi et al., 2016; Huang et al., 2021; Liao et al., 2020) which is a degenerative joint deformity, caused by articular cartilage wear and damage to the peripheral soft tissues including the surrounding bursa, tendon, and ligament joint, in addition to causing pain and joint stiffness. Salgueiro et al. studied sleep bruxism which is characterized by repetitive or prolonged dental contact and/or squeezing or projecting the jaw. Children with sleep bruxism may have symptoms during the day, such as headache, earache and pain when chewing muscles. Carpal tunnel syndrome is a neuropathy of the median nerve of the wrist, which causes pain or paresthesia involving fingers innervated by the median nerve and weakness of thumb abduction (Juan et al., 2019). Madani et al., and Ferreira et al., studied TMD that affects orofacial muscles, temporomandibular joints, or both, and it is the most common reason for nondental pain around the orofacial region. Delayed Onset Muscle Soreness is a myogenic condition often caused after performing overload exercises, which includes pain, muscle tenderness and decreased range of motion, that improves over time (Chang et al., 2019). Kibar et al., studied patients with subacromial impingement syndrome, which is a disorder in the subacromial space and is characterized by shoulder pain, restricted range of motion and functional disability to performing daily activities.

Both genders were included in the studies (Al Rashoud et al., 2014; Chang et al., 2019; Chang et al., 2021; Helianthi et al., 2016; Huang et al., 2021; Juan et al., 2019; Kibar et al., 2016; Liao et al., 2020; Madani et al., 2020), only females were included in the study of Ferreira et al. and only children were included in the study of Salgueiro et al. Although gender differences in LA are under-reported, Hu et al. (2019) reported that sex affects the penetration of red-light (660 nm) through sites susceptible to a sports injury in lean tissues regardless of tissues thickness.

VAS was the most common scale used to evaluate pain levels after the treatments (Al Rashoud et al., 2014; Chang et al., 2019; Chang et al., 2021; Ferreira et al., 2013; Helianthi et al., 2016; Kibar et al., 2016; Liao et al., 2020; Madani et al., 2020). VAS, as a single-item instrument, is widely used among clinical research because it is easy to apply and low-cost, in addition shows a good reliability to be used in the evaluation of MSDs patients, mainly with chronic pain (Boonstra et al., 2008). Moreover, several other specifics questionnaires were also used such as the Lequesne index (Helianthi et al., 2016; Liao et al., 2020), Global Symptom Score (GSS) (Juan et al., 2019), Shoulder Pain and Disability Index (SPADI) score (Kibar et al., 2016), and Saudi Knee Function Scale (SKFS) (Al Rashoud et al., 2014). It is well known that patients with MSDs present an impairment of the functional capacity, which is related mainly to the episodes of pain (Wendt et al., 2017). In this context, it is essential to measure the effects of LA in the management of these symptoms. Moreover, goniometry was used by some authors and is considered an accurate method for evaluating articular angles in patients with MSDs (Hancock et al., 2018). The digital dynamometer is a reliable method and allows the evaluation of isometric strength (Romero-Franco et al., 2017). Pressure algometry is a method described to determine the minimal pressure when the patient feels a painful sensation and can be used to assess pain in MSDs, such as knee OA (Hinarejos et al., 2019). EMG and NCS are useful for clinical examination of the peripheral nervous system and striated skeletal muscle (Kane & Oware, 2012). Arm circumference is a measure of the sum of the muscle and subcutaneous fat in the arm and can be used as an indicator of body composition in adults and children (J.

Eaton-Evans, 2013). Although it is often used in studies with nutritional themes, Chang et al. used this method to assess edema caused by Delayed Onset Muscle Soreness of the Biceps Brachii.

About LA parameters, all the studies used the near-infrared wavelength for laser irradiation. Tsai & Hamblin (2017) showed that near-infrared wavelength can reach deeper tissues such as muscles, cartilage and bones, being more indicated to use for LA. Moreover, the effects of laser therapy on tissues are dependent, being necessary to offer a proper amount of energy to achieve an optimal tissue response (R Hamblin, 2017), including when using LA (Litscher, 2018). In this systematic review the energy per point varied from 1 J (Salgueiro et al., 2021) to 72 J (Liao et al., 2020). The recommendation of the World Association of Laser Therapy (Taylor et al., 2020) for treating knee OA, TMD, sleep bruxism and subacromial impingement syndrome is around 4 J per point in the local disease. It is also recommended 8 J per point for carpal tunnel syndrome and 6 J per point to Delayed Onset Muscle Soreness of the Biceps Brachii, but there are no specific guidelines developed for LA. Interestingly, Liao et al., used a higher dose compared to the recommendation of 4-8 J per point for patients with OA (Stausholm et al., 2019) and found statistically significant decreases in pain 4 weeks after the treatment. In addition, the power between the studies ranged from 30 mW (Al Rashoud et al., 2014; Liao et al., 2020) to 400 mW (Juan et al., 2019). Regardless of this power range, all studies showed statistically positive results in decreasing pain, corroborating with a systematic review of Baxter et al. (2008) showing moderate evidence of the use of a power of at least 10mW with 0.5 J for treating local pain related to MSDs, supporting the use of this therapy. Also, different values of energy density were applied by the different authors, without any consensus. A study of da Silva et al. (2012) with TMD patients tested two energy density values (52.5 J/cm² and 105 J/cm²) to identify the optimal clinical outcome and concluded that higher energy density (105 J/cm²) was statistically positive in pain reduction and increased of range of motion of temporomandibular joint. About the number of sessions, these varied between 1 and 24, and it is important to highlight that the studies that applied fewer sessions (1 and 4) were the studies that did not showed significant differences in its outcomes between the control/placebo groups and the group treated with LA in patients with cervical MPS (Chang et al., 2021) and Delayed Onset Muscle Soreness of the Biceps Brachii (Chang et al., 2019). These findings suggest that a longer period of treatment is necessary for inducing positive results.

In this review, 7 studies have shown a significant decrease in pain after treatment with LA compared to other groups (placebo or control) (Al Rashoud et al., 2014; Chang et al., 2019; Ferreira et al., 2013; Kibar et al., 2016; Liao et al., 2020; Madani et al., 2020). At the same time, Salgueiro et al. showed positive effects on bite force and on the improvement of headache symptoms in children with sleep bruxism. Other study significantly showed reduction on Global Symptom Score in tunnel carpal syndrome (Juan et al., 2019). Huang et al. presented a significant improvement in joint stiffness and knee flexion angle in patients with knee OA after total knee replacement. These findings corroborate with the experimental study of Erthal et al. (2016), which evaluated the effect of LA in the edema, inflammation and pain, symptoms commonly present in patients with MSDs, and showed positive and relevant effects. The stimulatory effects of LA on MSDs symptoms may be explained by the physiological modifications induced by laser therapy such as the release of anti-inflammatory cytokines and endogenous opioid neurotransmitter production, raising the threshold to pain level (Clijsen et al., 2017; Podogrodzki et al., 2016). Also, the modulation of the inflammatory processes, enhancement of local blood circulation and production of analgesic effects are observed after laser application (Chung et al., 2012).

This systematic review covered different musculoskeletal conditions, and each one may have required a distinct parameter and dosage regimen for clinical efficacy, as well as different application points according to the appropriate acupuncture points for each disorder. It is important to emphasize that the local of application is an important factor in parameter selection, such as each acupuncture point is specific to a particular pathology (Law et al., 2015). However, there is a

lack of studies regarding the effects of LA, as well as the absence of recommendations by the guidelines for this specific type of application.

Some studies and systematic reviews (Gendron & Hamblin, 2019; Hanna et al., 2021; Petrucci et al., 2011) have analyzed laser therapy in MSDs, but no other study has covered only the articles using this therapeutical intervention only at acupuncture points. According to the Litscher et al., the definition of LA is "Photonic stimulation of acupuncture points and areas to initiate therapeutic effects similar to that of needle acupuncture and related therapies together with the benefits of laser therapy". The mechanism of LA is like manual acupuncture in the treatment location as analgesia and vasodilation, in addition to chromophores in the skin (Hamblin et al., 2019). This therapeutic modality may be the preference for geriatric and pediatric patients because it is non-invasive, painless, and possibly associated with fewer adverse effects (Chon et al., 2019). Also, another advantage is that the duration of an individual treatment with LA is from 10 to 60 seconds per point, being shorter when compared to treatment with needles, which duration is from 10 to 30 minutes, significantly reducing treatment time (Hu et al., 2019).

Furthermore, it is important to highlight a limitation of the present study. The parameters and dosages varied among the studies in this review, what resulted in heterogeneity of findings and made it impossible to carry out a meta-analysis. However, the methodological quality of the studies included was classified as moderate to high methodological quality ($\geq 6/9$) score due to some of works being not double-blinded, the therapists and evaluators being aware of the intervention and groups.

5. Conclusion

In conclusion, this review demonstrates that LA produced positive effects in pain and functionality of patients with MSDs, although the evidence does not determine an effective dosage window for LA, the possible range of application adjusted and designed to fit specific musculoskeletal conditions. However, a longer period of treatment seems to be the most appropriate. To the development of clinical guidelines, future research should carefully define the study population and provide a consensus for the chosen LA parameters.

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