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Rehabilitation of back pain with laser associated with negative or positive pressure massage in workers: A randomized controlled trial

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ABSTRACT

Background and purpose: Work-related musculoskeletal disorders (WMSDs) are an array of conditions affecting the human locomotor system, such as muscles, tendons, nerves, bones, and joints. It is related to physiological, kinesiological and biomechanical changes which result in pain, paresthesia, inflammation, weakness, tiredness, heaviness in limbs, fatigue, reduced range of motion and/or compression of peripheral nerves. The aim of this study was to investigate the therapeutic effects of positive (massage gum) or negative pressure (vacuum therapy) combined with laser on the health of workers with back pain, investigating pain intensity, shoulder mobility, spinal flexibility, life quality, and well-being.

Methods: Twenty-one workers (female and male) aged between 20 and 60 years and who had medical referral for pain complaint in low back, neck and shoulders due to WMSDs participated in this study and were randomized into 3 groups: (1) Positive Pressure plus Laser Group (PPL): positive pressure using a massage gun was applied after the laser; (2) Negative Pressure plus Laser Group (NPL): negative pressure by vacuum was applied together with the laser and; (3) Control group (CG): without positive and negative pressure treatments or laser therapy. All workers received an educational booklet with postural orientation and suggestions focused on stretching exercises. Anamnesis, visual analogue scale (VAS) to assess pain intensity, and functional tests to assess spine flexibility and shoulders mobility were performed. Quality of life and well-being also were evaluated. The regions of lumbar, thoracic and cervical spine were treated once a week, totaling seven sessions.

Results: The main result was a reduced pain and an increased spinal flexibility, shoulders mobility, and quality of life in the PPL and NPL groups compared to the CG ($p < 0.05$). Furthermore, NPL showed better results compared to PPL ($p < 0.05$) for lumbar and cervical pain, as well as for right shoulder mobility.

Conclusion: Therefore, laser combined with negative pressure massage was more effective in reducing lumbar and cervical pain and increasing shoulder mobility compared to positive pressure massage in workers.

1. Introduction

Work-related musculoskeletal disorders (WMSDs) are an array of conditions affecting the human locomotor system, such as muscles, tendons, nerves, bones, and joints (Tang, 2022). It is related to physiological, kinesiological and biomechanical changes which result in pain, paresthesia, inflammation, weakness, tiredness, heaviness in limbs, fatigue, reduced range of motion and/or compression of peripheral nerves (Yassi, 2000). WMSDs are also related to the intensification of work, for example, due to a number of employees reduced or when they are absent, heavy workload, absence of break time, excessive working hours, and psychological factors (Brasil, 2001).

In world 2.78 million workers die per year due to work related illnesses and injuries (Ryder, 2017). Although the number of injuries is decreasing in developed countries, they are increasing in developing countries (Ryder, 2017). According to the Ministry of Health, in Brazil between 2007 and 2016, 67,599 cases of WMSD were reported (Brasil, 2019) and approximately 59% of these were from the Southeast Region

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(Minas Gerais, Rio de Janeiro and São Paulo) (Brasil, 2020). In parallel, approximately 80% of the world's population has or will experience back pain in at some time during their lives (Dunn et al., 2013). In this context, the work conditions can increase the risk factors for back pain. The WMSDs, especially back pain, lead to human suffering and global economic impact (Lundberg, 2015). Then, managing back pain is a challenge for heath occupational.

For WMSDs, some intervention includes work organization, furniture design, psychosocial education, multifaceted actions (Sepehrian et al., 2024), seminar on ergonomics and proper workstation practices with a demonstration of exercises (Grana et al., 2024), and worksite physical activity programs (Gutenbrunner et al., 2021).

The use of technology, such as laser, positive and negative pressure massage may be an important resource for worker health.

Photobiomodulation can be performed with laser equipment that emits red and infrared light, increasing the formation of adenosine triphosphate (ATP), which promotes analgesic and anti-inflammatory effects, as well as accelerating tissue repair (Karu et al., 2004; Cheng et al., 2021).

To obtain positive pressure, rigid means can be used, such as rollers, bamboo, fingers, and mechanical devices (i.e. a massage gun) (Santos et al., 2022; Ferreira et al., 2023). Negative pressure, characterized by suction of the skin and adjacent tissues, can be activated by a manual pump or vacuum camera. These systems based on positive or negative pressure allow myofascial release, muscle relaxation, pain reduction, greater range of motion and changes in pressure gradients to improve blood flow.

Optical (Saleh, 2024; Oliveira et al., 2024) or mechanical (Prasetyo et al., 2024; Zhang et al., 2024) technologies are widely used for treatment of pain-related musculoskeletal disorders, including back pain. However, to the best of our knowledge, the combined therapy has not been used in the workplace. Then, this novel approach which combines optical and mechanical devices must be investigated for evidence-based practice.

The aim of this study was to investigate the therapeutic effects of positive (massage gum) or negative pressure (vacuum therapy) combined with laser on the health of workers. The specific aims were to investigate the response to back pain intensity, shoulder mobility, spinal flexibility, life quality and, well-being. The hypotheses were that the proposed treatments which combine positive or negative pressure with laser reduce workers' pain, improving shoulder mobility, spinal flexibility, life quality and, well-being compared to control group without treatment.

2. Methodological procedures

The current study was approved by the Ethics Committee of the State University of Minas Gerais (UEMG), Passos, Minas Gerais, Brazil (approval no. 5.378.868). The current study is registered in ClinicalTrials.gov (NCT06245863). All volunteers signed written informed consents before their participation in the clinical trial. The study was carried out in the Laboratory of Kinanthropometry and Exercise Physiology from UEMG.

A longitudinal, randomized and controlled trial was conducted. Workers with back pain from Passos City, Minas Gerais in Brazil were asked to participate in the clinical trial using the media (websites, newspapers and e-mails). Thirty-six workers were invited for the study, however, the sample size was smaller, due to the inclusion and exclusion criteria (excluded; n = 6) as well as due to lack of free time to participate in the study, transportation difficulties, and did not complete the evaluation forms (lost to follow up; n = 9).

The inclusion criteria were volunteers (female and male) aged between 20 and 60 years and who had medical referral for pain complaint in low back, neck and shoulders due to WMSDs. The exclusion criteria were psychiatric illnesses, endocrinopathies, heart diseases, neurological diseases, osteoporosis, cancer, and analgesic, anti-inflammatory or muscle relaxant drugs in the last four weeks.

Twenty-one workers (n = 21) participated in this study (7 per group). The block randomization method was designed to randomize volunteers into groups that result in equal sample sizes. For randomization, a computer program was used (https://www.randomizer.org/). The groups investigated were: (1) Positive Pressure plus Laser Group (PPL): positive pressure using a massage gun was applied after the laser; (2) Negative Pressure plus Laser Group (NPL): negative pressure by vacuum was applied together with the laser and; (3) Control group (CG): without positive and negative pressure treatments or laser therapy. All workers received an educational booklet with postural orientation and suggestions focused on stretching exercises.

The clinical characteristics of the workers were obtained through anamnesis, anthropometric assessments to determine the body mass index [BMI = mass (kg)/height^2 (m)] and the waist-hip ratio [WHR = waist (cm)/hips (cm)]. Body composition also was performed to evaluate the hydration and the body fat percentage using bipolar bioimpedance (OMRON®, Kyoto, Japan) (Paolillo et al., 2019).

To investigate the effects of 7 treatment sessions with positive or negative pressure combined with laser, the data were collected before and immediately after the last session. The evaluations carried out were:

To evaluate the pain intensity, visual analogue scale (VAS) was performed. The volunteer was instructed to give a score for pain intensity between 0 (no pain) and 10 (worst imaginable pain) (Paolillo et al., 2021);

To evaluate shoulder mobility, bilateral range of motion was assessed, combining internal rotation with shoulder adduction and external rotation with abduction of the other shoulder, placing the hand on the central axis of the body in the thoracic region (Cuesta-Vargas et al., 2011). Three distance measurements were obtained on both sides between the third fingers of the right and left hands to calculate the average.

To evaluate the flexibility of the spine, fingertip-to-floor test was carried out. In upright standing position with knees joint fully extended, the volunteers were instructed to bend forward and attempt to reach for the floor with their fingertips. The distance between the patient's right long finger and the floor were measured using a measuring tape (Perret et al., 2001). Three measurements were taken to calculate the average value.

Quality of life and well-Being were measured, respectively, using the World Health Organization Quality of Life-Abbreviated form (WHO-QOL-BREF) and the Subjective Well-Being Scale (EBES) (Paolillo et al., 2023).

2.1. Protocol for treatment of back pain with positive pressure plus laser

The Phoenix A2® Professional massage gun (Phoenix, China) was applied to generate positive pressure in the back muscle from spine region. Twin Laser® (MMOptics, São Carlos, SP, Brazil) was applied immediately after massage gun.

To myofascial release on paravertebral muscles, the vertebrae were palpated with the fingers for anatomical location, next, the massage gun at speed 1 with U-shaped tip was carefully applied on sides of the spine, preventing the risk of fractures. The pressure exerted was moderate. The up-and-down movement was performed 5 times. To myofascial release on upper portion of the trapezius (between the neck and shoulders), a gun was also used at speed 1 with U-shaped tip, exerting moderate pressure. The equipment was also carefully applied to not to reach bones, such as proximal humerus, scapula and clavicle. The movement between the neck and each shoulder was performed 5 times. To myofascial release on the lumbar and thoracic regions, a gun was used at speed 1 with a smaller spherical tip, exerting moderate pressure. The up-and-down movement was carried out 5 times. The U-shaped tip was used on the dotted line and the spherical tip was used on the dashed line, as shown in Fig. 1.

After massage gun, the infrared laser (808 nm) with 100 mW power,

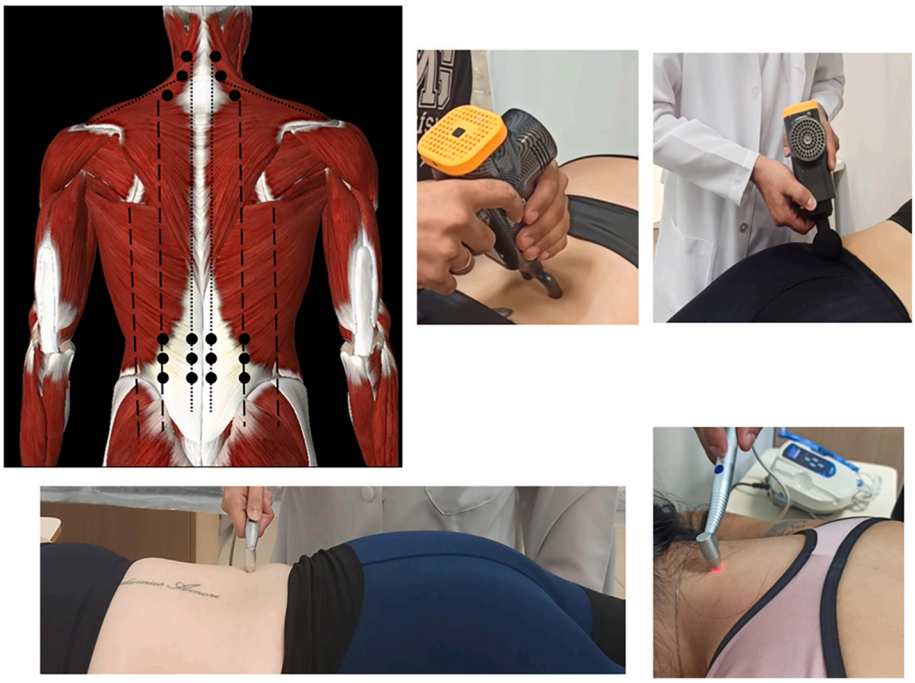


Fig. 1. Treatment with positive pressure plus laser (PPL Group).

in contact mode was applied during 40 s per point, leading to fluence of 100 J/cm^2. The 18 application points (6 points on the right side and 6 points on the left side of the lumbar spine as well as 3 points on the right side and 3 points on the left side of the cervical spine and upper portion of the trapezius) can be seen in Fig. 1.

2.2. Protocol for treatment of back pain with negative pressure plus laser

The Vacumlaser® (MMOptics, São Carlos, SP) is composed of 6 diode lasers (3 red lasers and 3 infrared lasers] arranged around the orifice of the vacuum chamber. The parameters of laser were: red (660 nm) and infrared (808 nm) lasers, continuous mode, 100 mW per laser. The parameters of vacuum therapy were: a 60 mm suction cup, pulsed mode (MP9, 50 pulsations per minute) and pressure of −150 at −350 mbar. The treatment was carried out during 1 min per point in stationary mode on the lumbar, thoracic and cervical spine regions, totaling 10 min, as well as 5 min on each side of the spine, totaling 10 min, in scanning mode following the dotted lines as shown in Fig. 2.

2.3. Statistical analysis

The data were expressed as mean ± standard deviation.

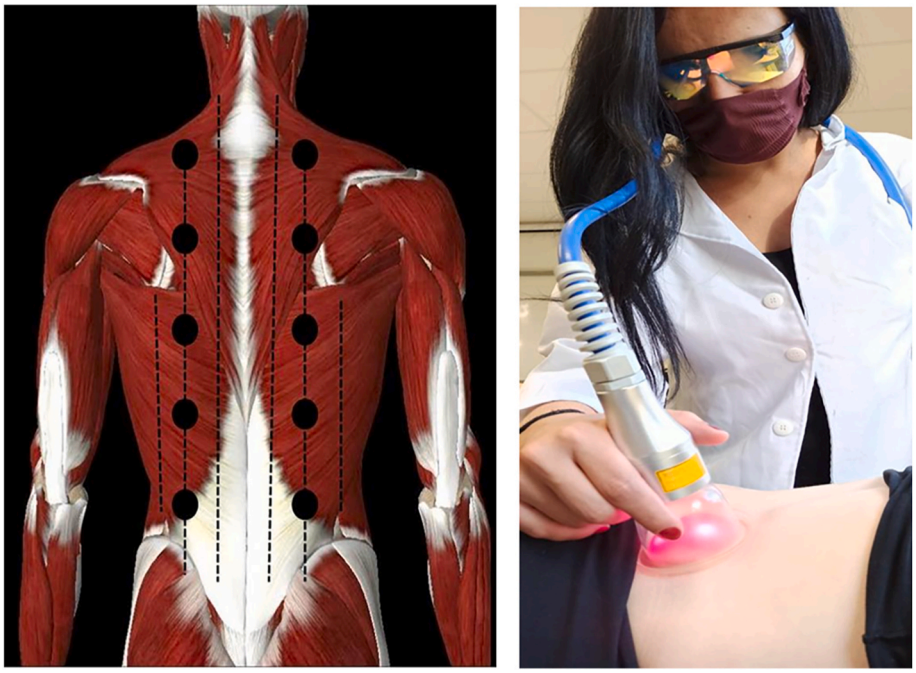


Fig. 2. Treatment with negative pressure plus laser (NPL Group).

Shapiro–Wilk was used to verify the data normality. The Mann–Whitney test was used to compare to differences for clinical characteristics of the workers. The Wilcoxon test was used to compare changes between baseline and 7 sessions of treatment. The delta (Δ = post - pre) between the situations before and after the treatment was used to compare groups using a Mann–Whitney test. The significance level was set at 5 % ($p < 0.05$). For the statistical analysis, Statistica for Windows 7 (Statsoft Inc., Tulsa, OK) was used.

3. Results

The workers who participated in this study are artisans (n = 1); trader (n = 1), teacher (n = 2); nursing technician (n = 1); lawyer (n = 2), receptionist (n = 1), librarian (n = 1) and those in the administrative sector, which includes analyst, secretary, technician and administrative assistant (n = 12). Only one worker was male. The clinical characteristics of the workers are listed in Table 1. There was no significant difference between the groups ($p \geq 0.05$).

The statistical results of the pain intensity, shoulder mobility and spine flexibility can be seen in Table 2. There was a significant reduction in pain intensity for the low back, neck and shoulder in the two treated groups ($p < 0.05$), while the control group showed an increase in low back pain ($p < 0.05$). A significant reduction in the distance between the fingers across the back was also found, indicating improved mobility of the right and left shoulder ($p < 0.05$). In addition, there was also a significant reduction in the distance between the finger and the floor during trunk flexion ($p < 0.05$), indicating better flexibility in the treated groups. For the CG, no significant difference was found for shoulder mobility and spinal flexibility ($p \geq 0.05$) Regarding the delta data, NPL showed better results than PPL for the lumbar ($p = 0.04$) and neck ($p = 0.02$) pain relief (Fig. 3) and, the right shoulder mobility ($p = 0.04$) (Fig. 4). There was improved life quality and affect positive for NPL ($p = 0.01$) and PPL ($p = 0.01$) compared to CG (Fig. 5).

4. Discussion

This is the first study carried out with workers that showed the clinical features and the effectiveness of treatments for back pain. The main finding was greater pain relief and shoulder mobility for the workers who received laser combined with vacuum therapy.

Table 1
Clinical features of workers.

	Positive Pressure and Laser Group (PPL)	Negative Pressure and Laser Group (NPL)	Control Group (CG)
Age (years)	35 ± 11	41 ± 13	38 ± 14
Body mass (Kg)	79 ± 9	77 ± 24	82 ± 21
Body Height (m)	1.66 ± 0.04	1.62 ± 0.05	1.61 ± 0.04
Body Mass Index (BMI)	31 ± 6	29 ± 8	31 ± 6
Fat percentage (%)	40 ± 9	41 ± 14	40 ± 15
Hydration Percentage (%)	41 ± 6	40 ± 9	39 ± 7
Waist (cm)	84 ± 10	91 ± 18	93 ± 13
Hip (cm)	113 ± 7	111 ± 15	110 ± 14
Waist and Hip Ratio	0.74 ± 0.08	0.82 ± 0.07	0.84 ± 0.03
Those who exercise (%)	50	40	65
Standing time (hours)	0.7 ± 1	0.5 ± 0.7	0.3 ± 0.5
Sitting time (hours)	8 ± 0.5	8 ± 0.8	8 ± 2
Right laterality (%)	100	100	100

No significant difference was found between the groups ($p \geq 0.05$, Mann-Whitney).

Table 2
Effects of the positive and negative pressure combined with laser.

	Positive Pressure and Laser Group (PPL)		Negative Pressure and Laser Group (NPL)		Control Group (CG)	
	Pre	Post	Pre	Post	Pre	Post
Pain Intensity						
Lumbar	5 ± 1	3 ± 1[a]	6 ± 2	2 ± 2[a]	3 ± 0.5	5 ± 1[a]
Cervical	6 ± 1	3 ± 1[a]	6 ± 2	1 ± 1[a]	3 ± 2	3 ± 3
Most Painful Shoulder	8 ± 0.5	3 ± 2[a]	6 ± 2	1 ± 1[a]	4 ± 2	5 ± 1
Mobility and Flexibility						
Right shoulder mobility (cm)	7 ± 4	2 ± 2[a]	10 ± 4	3 ± 2[a]	19 ± 3	20 ± 4
Left shoulder mobility (cm)	10 ± 6	4 ± 3[a]	9 ± 6	2 ± 2[a]	20 ± 4	20 ± 3
Spine Flexibility (cm)	11 ± 7	7 ± 4[a]	11 ± 6	6 ± 4[a]	12 ± 4	13 ± 3
World Health Organization Quality of Life-Abbreviated form (WHOQOL-BREF)						
Physical Factors	65 ± 15	73 ± 5[a]	60 ± 8	71 ± 6[a]	54 ± 20	50 ± 19
Psychological Factors	66 ± 18	68 ± 16	63 ± 10	68 ± 8	44 ± 12	45 ± 16
Social Relationships	72 ± 14	81 ± 12[a]	59 ± 16	69 ± 9[a]	58 ± 20	53 ± 17
Environmental Context	67 ± 13	70 ± 14	62 ± 10	66 ± 5	48 ± 8	47 ± 9
Total Score	68 ± 11	73 ± 7	61 ± 7	68 ± 5[a]	52 ± 8	50 ± 7
Subjective Well-Being Scale (SWBS)						
Positive Affect	3.3 ± 0.8	3.7 ± 0.4	3.1 ± 0.6	3.5 ± 0.6	3.2 ± 0.5	2.6 ± 0.5*
Negative Affect	2.5 ± 0.4	2.4 ± 0.3	1.8 ± 0.6	1.7 ± 0.5	3.2 ± 0.6	3.1 ± 0.5
Life Satisfaction	2.9 ± 0.1	3.1 ± 0.4	3.1 ± 0.3	3.3 ± 0.3	3.1 ± 0.2	3.2 ± 0.3
Total Score	2.9 ± 0.5	3.1 ± 0.2	2.6 ± 0.3	2.7 ± 0.2	3.2 ± 0.2	2.9 ± 0.3

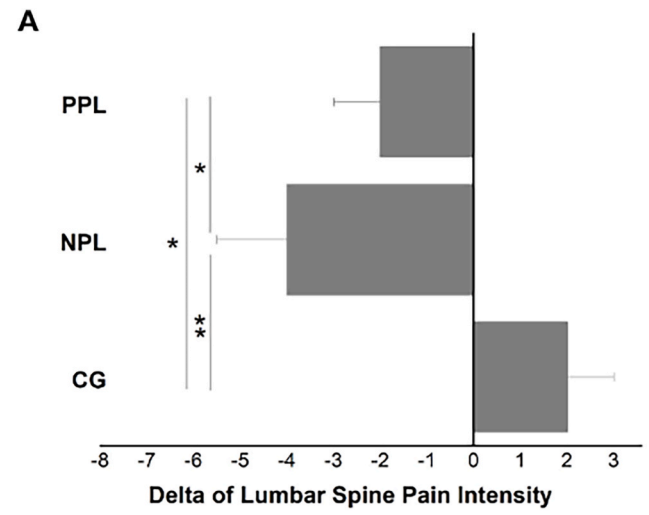
[a] Significant difference compared with the pre-treatment period ($p < 0.05$, Wilcoxon).

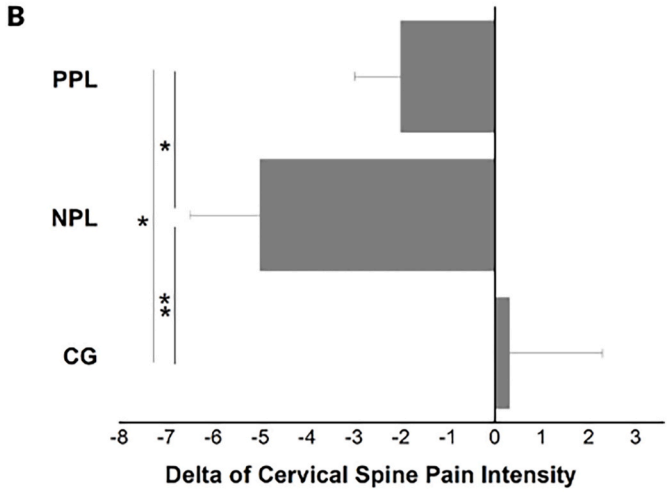
Regarding the clinical features, in the current study, the most workers remain sitting for long periods, indicating a factor which may lead to complaints of back pain. In this context, Mroczek et al. (2020) showed that severe back pain is associated with longer working hours, greater physical disability and, lower quality of life.

Regarding the treatments, in the current study, the chronic effects were reduced pain and increased physical functionality due to greater shoulder mobility and greater spinal flexibility for the NPL and PPL groups, indicating which the combined therapy with positive or negative pressure massage plus laser can be used for worker health.

However, NPL group showed better results compared to PPL group as evidenced by delta values for pain and mobility of the right shoulder. The greater mobility the right shoulder is, possibly, related to laterality, because the all workers were right-handed and, possibly, the right upper limb was the most involved in activities of work. Therefore, the negative pressure (vacuum therapy) combined with laser (red and infrared light) improved performance in the right arm, which lead to a protective effect of both the pain and the injuries. Similar results related to pain relief and increased functionality of the limb most often used to perform work tasks were found with application of infrared laser on classical ballerinas' feet (Paolillo et al., 2021). In this study, protective effect was found in the foot of the supporting leg, which has a high incidence of injury among the professional dancers, because the foot-floor contact during balance poses (Paolillo et al., 2021). These benefits of the photobiomodulation by laser are related to analgesic and anti-inflammatory effects (González-Muñoz et al., 2023).

Laser plus vacuum therapy device is a consequence of technological innovation. The prototype was developed considering the therapeutic





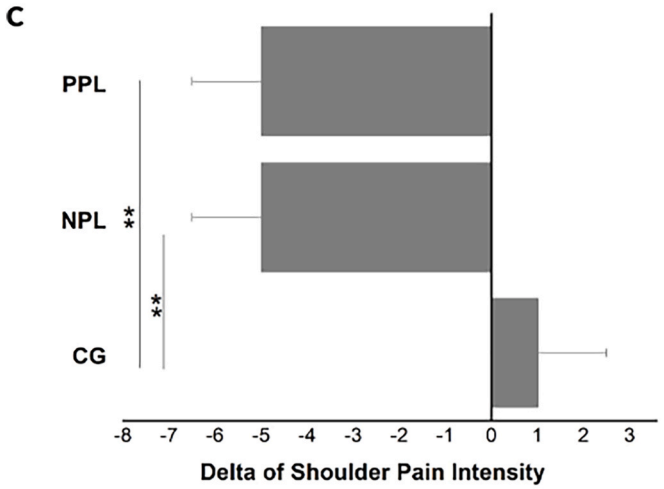
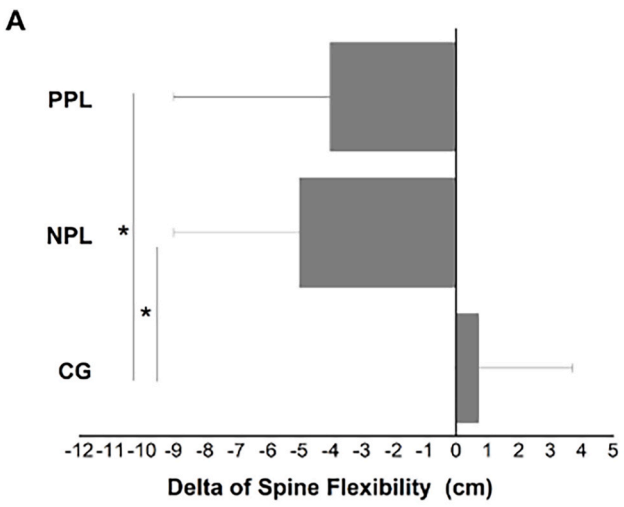
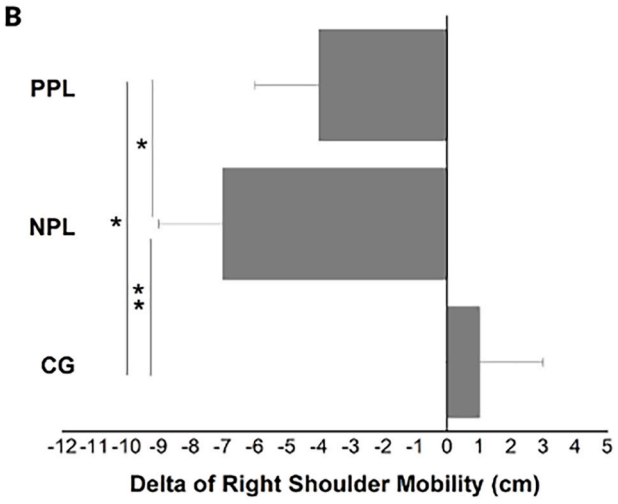


Fig. 3. Change in pain intensity between baseline and 7 sessions. The reduction of pain in the lumbar (A), cervical (B) and shoulder (C) was significantly higher for the PPL and NPL Groups compared to the CG. In addition, higher reduction of pain in lumbar and cervical was found in the NPL Group compared to PPL Group, showing significant inter-group differences. * Significant difference ($p < 0.05$, Mann-Whitney) ** Significant difference ($p < 0.01$).





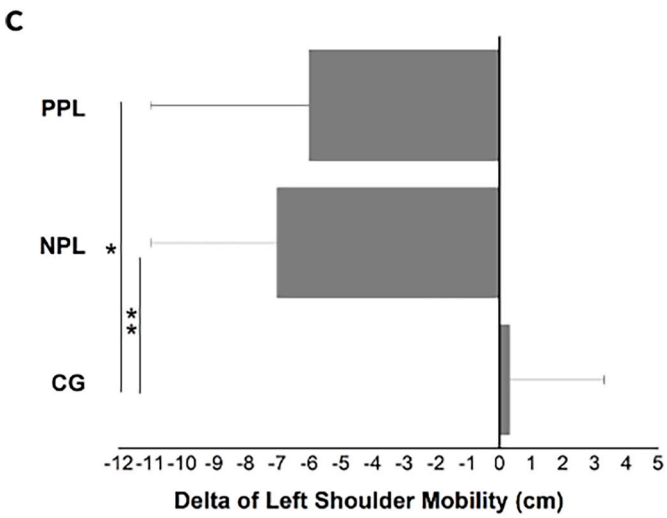


Fig. 4. Change in spine flexibility and shoulder mobility between baseline and 7 sessions. The spine flexibility (A) and the mobility of right (B) and left (C) shoulders were significantly higher for the PPL and NPL Groups compared to the CG. In addition, higher mobility of right shoulder was found in the NPL Group compared to PPL Group, showing significant inter-group differences. * Significant difference ($p < 0.05$, Mann-Whitney) ** Significant difference ($p < 0.01$).

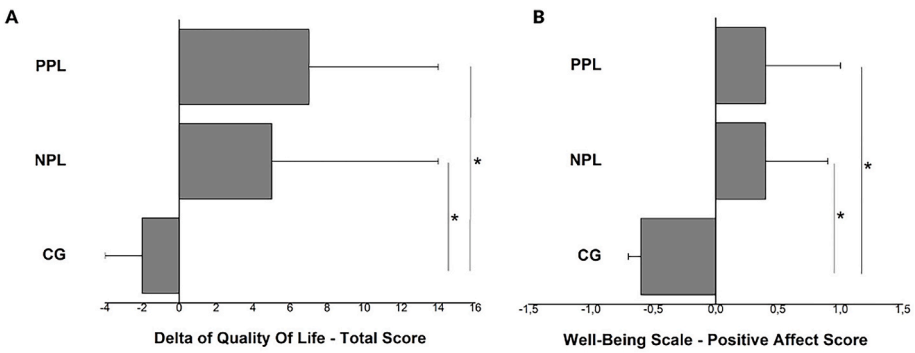


Fig. 5. Change in quality of life and well-being between baseline and 7 sessions. The quality of life (A) and positive affect (B) were significantly higher for the PPL and NPL Groups compared to the CG. * Significant difference ($p < 0.05$, Mann-Whitney).

potential of the technologies separately (Lopes et al., 2019). After prototype validation (Lopes et al., 2019; Tamae et al., 2020; Panhoca et al., 2020; Panhoca et al., 2021), it became a product. Then, this new technology should be widely investigated.

Laser plus massage gun is a new protocol clinical. Therefore, the current study is an important proof-of-principle for the development of new combined therapy devices as well as for clinical practice.

Each technology alone (massage gun or cupping or laser) presents benefits, but the technologies together may enhance the results. However, it is important to highlight that vacuum therapy with laser showed better results compared to the massage gun for pain relief and mobility.

Santos et al. (2022) applied positive pressure with a massage device and auriculotherapy on nursing team during the COVID-19 pandemic in a hospital. This study showed greater well-being due to relief of the muscle tension and pain, as well as improvement in the stress and anxiety, greater interaction between the workers, and consequently, better quality of care (Santos et al., 2022). Another study suggest that repeated application of massage gum may lead to reduced pain in patients with subacute and chronic low back pain (Prasetyo et al., 2024).

Massage gun (percussion massage) utilizes mechanical stimulus through vibration and, rapid and compressive tapping on the tissues (fascia, muscle belly or tendon), promoting increased blood flow, myofascial release, pain relief, muscle relaxation, break up trigger points and, improved range of motion (Ferreira et al., 2023).

Cupping therapy by manual bomb applied for 10 min during 5 sessions in patients with low back pain showed less pain and physical disability compared to the sham group (Salemi et al., 2021). Similar results were found with cupping therapy applied for 5 sessions in patients with neck pain, resulting in reduced pain, increased functionality and improved quality of life (Saha et al., 2017). Another study also show reduced pain and enhanced muscle extensibility when static cupping on the low back followed by dynamic myofascial cupping on the quadriceps and hamstring were performed in patients with low back pain (Harper, 2024).

Cupping promotes deep mobilization of the skin, adipose tissue and muscular fascia as well as induces vascular changes. It lead to myofascial release, increased blood flow, reduced inflammatory mediators, increased metabolic activity, analgesia by pain gate mechanism and, greater range of movement (Al-Bedah et al., 2018).

The use of laser to treat shoulder and neck pain has shown positive effects in both acute (Roche et al., 2016) and chronic (Kenareh et al., 2021; Ezzati et al., 2022) phase. Similar results have been found using laser to treat low back pain (Panah et al., 2021; Nardin et al., 2022).

Photobiomodulation results in photophysical, photochemical and photobiological effects, such as an increase in electron transport in the respiratory chain of the mitochondria, which increases the synthesis of ATP, which generates changes in gene expressions, stimulates antioxidant and anti-inflammatory action mechanisms, promoting rapid tissue repair. Moreover, pain treatment using red and infrared light occurs through central and peripheral mechanisms. These mechanisms include modulation of chemical mediators (for example, cytokines, prostaglandins and, beta-endorphin) and changing in both the excitability threshold of nociceptors and the neural conduction speed, leading to analgesia (Hagiwara et al., 2007; Castano et al., 2007; Cheng et al., 2021).

Results of a meta-analysis showed that the photobiomodulation is effective for pain relief of various etiologies (Fulop, 2010). Another meta-analysis studies also revealed reduced myofascial pain and increased range of motion for the neck (Tehrani et al., 2022) and moderate quality of evidence for low back pain in the short term, but when used alone or in combination with other modalities was achieve a useful reduction in pain (Glazov, 2016). However, these studies emphasize multidisciplinary intervention strategies, considering that the laser is a valuable addition resource to pain treatment.

In this context, Lopes et al. (2019) showed the synergistic chronic effects of vacuum therapy associated with laser on low back pain, bursitis and hip dysfunction. In these cases reports, 10 treatment sessions resulted in reduced pain and increased range of motion (Lopes et al., 2019). Other cases reports also showed the synergistic chronic effects of vacuum therapy and laser in orofacial rehabilitation. There were reduced pain and improved quality of life in patients with temporomandibular joint dysfunction (Panhoca et al., 2020) as well as sensorimotor recovery and return of facial symmetry after facial paralysis (Panhoca et al., 2021).

Synergistic chronic effects of vacuum therapy and laser also were investigated in patients with Parkinson's disease. In this study, 6 sessions of the combined therapy showed greater pain relief and quality of life compared with the group who received the therapy alone, that is, only vacuum therapy or only laser therapy (Tamae et al., 2020).

A literature review (Saha et al., 2017; Tamae et al., 2020; Paolillo et al., 2021; Salemi et al., 2021; Panah et al., 2021; Nardin et al., 2022; Harper, 2024; Prasetyo et al., 2024) shows results similar to those found in the current study for reduced pain and/or increased function. However, different devices and methods are used by researchers, including parameters, mode of application and number of sessions.

A small sample size, lack of blinding, short treatment period, workers with different professions, and absence of biomechanical assessment are considered limitations in the current study. Future research should include major methodological criteria to determine optimal approaches to pain management.

5. Conclusion

This is the first study that showed the effectiveness of the combined therapy for pain relief and increased physical functionality in workers. The positive or negative pressure massage combined with laser showed reduced pain, enhanced shoulder mobility and greater spinal flexibility, improving quality of life. However, the most impactful finding was the

superiority of negative pressure massage (vacuum therapy) combined with laser, which led to reduced lumbar and cervical pain and increased shoulder mobility in workers. Indeed, there are specific implications for clinical practice.

CRediT authorship contribution statement

Danielle Izabel Assis Chaves: Resources, Methodology, Investigation, Data curation, Conceptualization. **Marco Antonio Carneiro de Jesus:** Resources, Methodology, Investigation, Data curation, Conceptualization. **Gabriella Dalarmi de Menezes:** Resources, Methodology, Investigation, Data curation, Conceptualization. **Lúcio Marques Vieira Souza:** Writing – review & editing, Writing – original draft, Formal analysis. **Gustavo Henrique Gonçalves:** Writing – review & editing, Writing – original draft, Formal analysis, Conceptualization. **Fernanda Rossi Paolillo:** Writing – review & editing, Writing – original draft, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no conflict of interest.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jbmt.2024.11.032.

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