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ORIGINAL ARTICLE

Laser photobiomodulation is more effective than ultrasound therapy in patients with chronic nonspecific low back pain: a comparative study

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Abstract

The purpose of this study was to compare the effects of laser photobiomodulation therapy (lPBMt) and ultrasound therapy (UST) in patients with chronic non-specific low back pain (CNLBP). Forty-five patients with CNLBP aged 30–40 years were divided randomly into three groups of 15 subjects each. The lPBMt group received 8 weeks of lPBMt with an exercise program, while the UST group received 8 weeks of UST with the same exercise program; the control group received only the exercise program for 8 weeks. Pain, disability, functional performance, and lumbar range of motion were assessed at the beginning of the study and after 8 weeks. There were no significant differences in demographic and clinical characteristics among the three groups at baseline ($p > 0.05$). At the end of the study, there were significant improvements in pain, disability, and functional performance in the two experimental groups ($p < 0.05$), but changes in the control group were non-significant. However, lumbar range of motion was significantly improved only in the lPBMt group ($p < 0.05$). When the three groups were compared in terms of a change in clinical variables, there was a significant difference among the three groups in all measures in favor of lPBMt group. Based on our results, both lPBMt or UST combined with an 8-week exercise program seemed to be effective methods for decreasing pain, reducing disability, and increasing functional performance in patients with CNLBP, although lPBMt is more effective than UST.

Keywords Laser photobiomodulation therapy · Ultrasound therapy · Low back pain · Disability

Introduction

Low back pain (LBP) is a major cause of morbidity and a common health and socioeconomic problem worldwide. The lifetime prevalence of LBP has been reported to be 80–85% [1].

Specific back pain occurs in approximately 2% of all patients with back complaints. In the majority of patients with LBP, a diagnosis cannot be made on the basis of anatomical or physiological abnormalities [2]. Non-specific LBP (NLBP) is assumed to be inflammatory or mechanical in nature [3], while chronic NLBP (CNLBP) can be defined as an activity limiting episode of confined LBP with no referring pain into both or either lower limb, lasting for at least 3 months [4].

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In physiotherapy, there are different methods of CNLBP management; some of the more widely used include therapeutic exercise, mobilization, and manipulation [5, 6].

However, it seems that exercise therapy as a standalone modality is not sufficient to treat CNLBP. It is recommended to be included within a combined multidisciplinary program of other pharmacological and non-pharmacological modalities [7].

In addition to exercise therapy for LBP, there are electrotherapeutical modalities can be used, such as TENS, interferential current, and infrared light, which have been reported in several studies [8–10]. Recently, low-level laser therapy (LLLT) is now called laser photobiomodulation therapy (lPBMt) [11, 12]. A significant pain reduction with lPBMt has been found in both acute and chronic painful conditions. lPBMt is useful for the treatment of different musculoskeletal disorders via its analgesic, muscle relaxant, tissue healing, and biostimulation effects [5, 8, 9]. Furthermore, lPBMt has anti-inflammatory effects [13, 14], stimulates ligament repair [15], and reduces the interstitial swelling by stimulating lymphatic flow [16, 17].

Ultrasound therapy (UST) is also frequently used in the management of musculoskeletal disorders [18]. UST exerts both thermal and mechanical effects which increase blood flow and metabolic activity, thus enhancing the regeneration and elasticity of the target tissues [19].

A number of trials have compared UST and lPBMt either for treating LBP or other musculoskeletal disorders. In a study of LBP management modalities, the laser therapy used was the high intensity type, which showed more effectiveness than UST, [20] while Boyraz et al. [21] showed that there were no significant differences between the two modalities with good long-lasting effect. Regarding these modalities' effect on joint pain, both modalities showed anti-nociceptive effects [22]. Based on the previously mentioned studies, it seems that the limited literature available shows contradictory effects. Thus, the aim of this study was to determine the effectiveness of lPBMt versus UST in the treatment of CNLBP.

Methods and materials

Design/setting

This randomized controlled study was conducted in the physical therapy outpatient department, College of Applied Medical Sciences, Prince Sattam Bin Abdulaziz University during the period of February to April 2018. Subjects were recruited through orthopedists and self-referral.

Participants

Forty-five patients (32 males and 13 females) with CNLBP were recruited for this study. Subjects were included in the study if they were ambulatory patients with a history of CNLBP with symptoms persisting for 3 months and aged between 30 and 40 years old. Participants were excluded if the LBP was due to nerve root compression, disc prolapse, spinal stenosis, tumor, spinal infection, ankylosing spondylitis, spondylolisthesis, kyphosis or structural scoliosis, or a widespread neurological disorder. Also, participants were excluded if they presented as pre-surgical candidates, were involved in litigation or compensation, displayed a compromised cardiopulmonary system, had a body mass index (BMI) of more than 30, or had a severe life-threatening illness.

Randomization

From 51 patients with CNLBP, 45 subjects participated in this study. Four subjects did not meet the inclusion criteria of the study, and two subjects declined to participate in the study without any registered reason. Informed consent was obtained from all individual participants included in the study; participants also completed a LBP evaluation form during assessment. They were randomized to lPBMt group ($n = 15$), UST group ($n = 15$), and control group ($n = 15$) using a number generating table (the examiner numbered the patients randomly with two digits number from 01 to 45, then selecting a row on the number generating table and read numbers by groups of digits, then counting any sets in the range of patient numbers with ignoring the repeated numbers. The first 15 patients were lPBMt, second 15 were UST, and the third 15 were the control group. Examiners were blinded concerning the group to which each patient was appointed. This blinded random allocation was performed at the initial assessment. The flow diagram showing the study protocol is presented in Fig. 1.

Assessment and outcome measures

Pain severity was assessed using a visual analogue scale (VAS). Patients were asked to place a mark along a 100-mm line that best describes the severity of pain they were currently experiencing. The pain was assessed at rest and during activity.

The Modified Oswestry Low Back Pain Disability Questionnaire (m-OSW) consists of 10 items; each item is scored from 0 to 5. Items include pain intensity, personal care, lifting, walking, sitting, standing, sleeping, employment/homemaking, traveling, and social life [23, 24]. The total score ranges from 0 to 50. The disability level is increased by an increased total score.

The Pain Disability Index (PDI) consists of seven items, including family/home responsibilities, social activity, recreation, self-care, occupation, sexual behavior, and life-support activity [24, 25]. Each item is scored from 0 to 10, with 0 indicating no disability and 10 indicating worst disability. The total score ranges from 0 to 70, with 0 indicating no disability and 70 indicating severe disability.

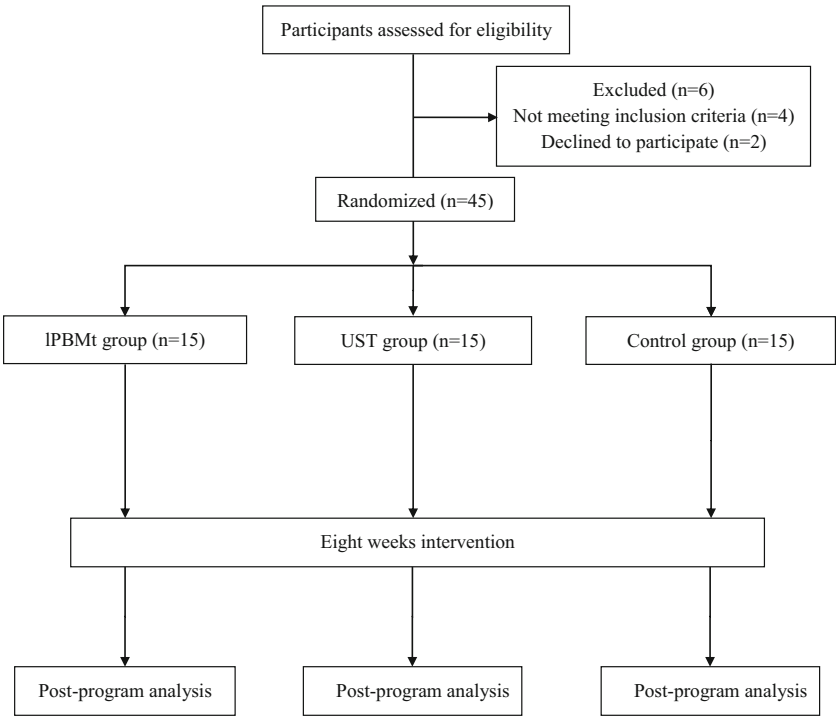

Fig. 1 Flow diagram showing the patients participating in the study

The 6-Minute Walk Test (6MWT) was performed by measuring the distance in meters to assess the functional performance of the participants.

Lumbar range of motion (ROM) was assessed in both flexion and extension using a modified Schober test.

Exercise program

The exercise program was initially carried out by physiotherapy session then continued at home for the three groups. The exercise program was easily performed at home without the need to use outside facilities or equipment. Exercise program included active strengthening, stretching, mobilization, coordination, and maintaining stabilization of the back, abdominal, pelvic, and lower extremity muscles, according to the clinical assessment [26]. Each patient performed strengthening exercise 3 days per week for each muscle group with intensity of 60–80% 1 repetition maximum. The duration was 8–10 strengthening exercises with a total of 2 to 4 sets and 8–12 repetitions per set and a rest interval of 2 to 3 min in between. A stretching exercise was a 10 min including the back and lower limb muscle groups (upper and lower back, pelvis, hips, and legs) with four repetitions (10–30 s for a static stretch). Stretching exercise were performed on days that strengthening exercise was performed. Participants were instructed to do exercise properly by the physiotherapist and one of their family members certified that the patients conducted the home exercise regularly.

lPBMt protocol

lPBMt was performed two times per week for 8 weeks using a Gallium-Aluminum-Arsenide (GaAlAs) device (FISIOLASER SCAN HP4, CHINESPORT, Udine, Italy) with the following features: wavelength of 808 nm, power density of 113.6 mW/cm^2, continuous wave, and spot size of 0.22 cm^2. The laser therapy session included 8-point application with energy density of 17.05 J/cm^2 for 20 min to cover the lumbar paravertebral region (L2-S3) [27]. The parameters of the device, irradiation, and treatment are demonstrated respectively in Tables 1, 2, and 3 following the approach of Jenkins and Carroll [28].

UST protocol

UST was performed two times per week for 8 weeks using a device (Chattanooga, 2738 w/ Ultrasound, New York, USA) with these characteristics; continuous wave, frequency of 1 MHz, and intensity of 1 W/cm^2 on the lumbar vertebral

Table 1 Device information

Manufacturer	CHINESPORT
Model Identifier	FISIOLASER SCAN HP4
Year Produced	2014
Number of Emitters	1
Emitter Type	Gallium-Aluminum-Arsenide (GaAlAs)
Beam Delivery System	Emitter mounted in external probe with light guide

Table 2 Irradiation parameters

Parameters (unit)	Value	Information source
Center wavelength (nm)	808 nm	Manufacturer's specification
Spectral bandwidth (nm)	3.24 nm	Manufacturer's specification
Operating mode	Continuous wave	Manufacturer's specification
Radiant power (mW)	25 mW	Independent test
Polarization	Linear	Manufacturer's specification
Aperture diameter (cm)	5 mm	Manufacturer's specification
Irradiance at aperture (mW/cm^2)	113.6 mW/cm^2	Independent test
Beam divergence	13.5 mrad	Manufacturer's specification
Beam shape	Circular	Manufacturer's specification
Beam profile	Gaussian	Manufacturer's specification

region for 10 min using a probe with an effective radiating area of 5 cm^2 [23].

Sample size

Sample size for this study was calculated using VAS measurements. A similar previous study has provided that the lPBMt combining with exercise program exhibited a significant mean difference in VAS measure (4.3 ± 2.0 mm) (2.0) [29]. According to these differences and to achieve a power of 0.8 ($\alpha = 0.05$), our study required 12 patients in each group. A dropout rate of 20% was assumed for this study; therefore, 15 patients were enrolled in each group to ensure that 12 patients would complete the study.

Statistical analysis

Descriptive statistics are presented in the form of means and standard deviations. The Kolmogorov-Smirnov test was used to assess the normality of the data. Inferential statistics evaluated changes of all measurements using analysis of variance (ANOVA) between lPBMt, UST, and control group. Paired *t* test was performed to measure changes within group. SPSS version 22.0 (SPSS, Chicago, IL) was used for statistical analysis with a significance level of 0.05 for all statistical measurements.

Results

As demonstrated in Table 4, the mean age was 37.03 ± 6.74 years with a mean duration of symptoms of 4.12 ± 1.9 years in lPBMt group, the mean age was 36.32 ± 7.82 years with a mean duration of symptoms was 3.82 ± 2.3 years in UST group, and the mean age was 36.85 ± 7.14 years with mean duration of symptoms which was 3.87 ± 1.88 years. There were no significant differences among the three groups in terms of baseline characteristics ($p > 0.05$), including pain, disability, functional performance, and ROM.

At the end of the 8-week intervention, the pre- and post-treatment comparison showed significant improvement in all measures, including pain, disability, functional performance, and lumbar ROM in the lPBMt group ($p < 0.05$). The UST group exhibited significant improvement in pain and disability measures ($p < 0.05$) but a non-significant improvement in functional performance and lumbar ROM ($p > 0.05$) at the end of the study. On the other hand, the control group did

Table 3 Treatment parameters

Parameter (unit)	Value	Additional information
Beam spot size at target (cm^2)	0.22 cm^2	For each point
Irradiance at target (mW/cm^2)	113.6 mW/cm^2	For each point
Exposure duration (s)	150 s	For each point
Radiant exposure (J/cm^2)	17.05 J/ cm^2	For each point (30 J/1.76 cm^2)
Radiant energy (J)	3.75 J	For each point (30 J for all points)
Number of points irradiated	8	Application on the lumbar paravertebral area (L2-S3)
Area irradiated (cm^2)	0.22 × 8 = 1.76 cm^2	Total region covered per session is 1.76 cm^2
Application technique	Direct contact	Scanning light
Number and frequency of treatment sessions	16 sessions	two times per week for 8 weeks
Total radiant energy (J)	480 J	3.75 J × 8 points × 16 sessions

Table 4 Demographic and clinical characteristics of the participants

Variables	lPBMt group ($n = 15$)	UST group ($n = 15$)	Control group ($n = 15$)	p value
Genders (M/F)	11/4	10/5	11/4	0.99
Age (years)	37.03 ± 6.74	36.32 ± 7.82	36.85 ± 7.14	0.76
BMI (kg/m^2)	27.35 ± 4.24	26.92 ± 5.21	26.95 ± 4.75	0.87
Duration of symptoms (years)	4.12 ± 1.9	3.82 ± 2.3	3.87 ± 1.88	0.63
Occupations (%)				
Employee	7 (46.7)	7 (46.7)	8 (53.35)	0.99
Housewife	5 (33.3)	4 (26.65)	4(26.65)	0.98
Worker	3 (20)	4 (26.65)	3 (20)	0.99
m-OSW (%)	44.5 ± 15.6	42.7 ± 18.12	42.2 ± 16.3	0.77
VAS at rest	7.6 ± 2.1	7.8 ± 2.31	7.5 ± 2.4	0.80
VAS during activity	5.5 ± 3.2	5.7 ± 3.5	5.6 ± 3.6	0.80
PDI	36.7 ± 13.2	36.5 ± 15.4	37.1 ± 14.6	0.94
6 MWT	503.21 ± 87.7	517.3 ± 91.6	499 ± 81.4	0.67
Extension ROM (mm)	17.1 ± 6.7	17.5 ± 7.2	16.8 ± 6.4	0.85
Flexion ROM (mm)	41.8 ± 12.5	42.6 ± 15.7	41.2 ± 12.8	0.78

*Significant at p value < 0.05

Values are means ± standard deviations; BMI: body mass index. a; p value of Mann-Whitney U test; m-OSW: Modified Oswestry Low Back Pain Disability Questionnaire; VAS: Visual Analogue Scale; PDI: Pain Disability Index; 6 MWT: 6-Minute Walk Test; ROM: range of motion; mm: millimeters

not show any significant differences in the all measures ($p > 0.05$) as presented in Table 5.

The post-treatment comparison between the two study groups (lPBMt and UST) showed significant differences in all measures in favor of the lPBMt group ($p < 0.05$) as demonstrated in Table 6.

Discussion

The current study aimed to compare the effects of lPBMt versus continuous UST in patients with CNLBP. The study outcomes exhibited that the lPBMt and UST groups combined with exercise training could decrease pain, decrease disability, improve functional performance, and increase lumbar ROM. However, the between-groups comparison showed that lPBMt produced a greater more improvement than UST. In the current study, both groups received a therapeutic exercise program. It has been demonstrated that exercise therapy seems to be slightly effective at decreasing pain and improving function in adults with CNLBP and this was consistent with current results, while in acute LBP populations, exercise therapy is as effective as either no treatment or other conservative treatments [5]. Thus, it would seem that exercise alone is not recommendable, and the most effective

Table 5 Pre- and post-treatment mean differences of the clinical measures within each group

	lPBMt group ($n = 15$)			UST group ($n = 15$)			Control group ($n = 15$)		
	Pre-	Post-	p value	Pre-	Post-	p value	Pre-	Post-	p value
M-OSW (%)	44.5 ± 15.6	15.7 ± 5.32*	0.001	42.7 ± 18.12	27.6 ± 9.4*	0.001	42.2 ± 16.3	33.6 ± 12.4	0.11
VAS at rest	7.6 ± 2.1	3.5 ± 1.2*	0.001	7.8 ± 2.31	4.62 ± 1.5*	0.001	7.5 ± 2.4	6.4 ± 2.5	0.22
VAS during activity	5.5 ± 3.2	2.9 ± 0.45*	0.001	5.7 ± 3.5	3.7 ± 1.2*	0.045	5.6 ± 3.6	4.5 ± 3.1	0.37
PDI	36.7 ± 13.2	17.5 ± 8.27*	0.001	36.5 ± 15.4	26.4 ± 10.4*	0.044	37.1 ± 14.6	32.8 ± 13.8	0.41
6MWT	503.2 ± 87.7	631.8 ± 97.2*	0.001	517.3 ± 85.6	557.4 ± 94.8	0.234	499 ± 81.4	522.5 ± 88.6	0.45
Extension ROM (mm)	17.1 ± 6.7	27.8 ± 5.4*	0.001	17.5 ± 7.2	22.6 ± 7.3	0.064	16.8 ± 6.4	18.7 ± 7.1	0.44
Flexion ROM (mm)	41.8 ± 12.5	58.3 ± 11.4*	0.001	42.6 ± 15.7	49.1 ± 12.8	0.224	41.2 ± 12.8	44.3 ± 11.7	0.49

*Significant at $p < 0.05$

M-OSW: Modified Oswestry Low Back Pain Disability Questionnaire; VAS: Visual Analogue Scale; PDI: Pain Disability Index; 6 MWT: 6-Minute Walk Test; ROM: range of motion; mm: millimeters

Table 6 Post-treatment mean differences between the two study groups

Variables	lPBMt group ($n = 15$)	UST group ($n = 15$)	p value
m-OSW (%)	15.7 ± 5.32	27.6 ± 9.4	0.001
VAS at rest	3.5 ± 1.2	4.62 ± 1.5	0.03
VAS during activity	2.9 ± 0.45	3.7 ± 1.2	0.02
PDI	17.5 ± 8.27	26.4 ± 10.4	0.01
6MWT	631.8 ± 97.2	557.4 ± 94.8	0.04
Extension ROM (mm)	27.8 ± 5.4	22.6 ± 7.3	0.03
Flexion ROM (mm)	58.3 ± 11.4	49.1 ± 12.8	0.04

*Significant at p value < 0.05

Values are means ± standard deviations; m-OSW: Modified Oswestry Low Back Pain Disability Questionnaire; VAS: Visual Analogue Scale; PDI: Pain Disability Index; 6MWT: 6-Minute Walk Test; ROM: range of motion; mm: millimeters

plan seems to be a program of combined modalities including exercises [29].

Many previous researches in various scientific areas have approved that lPBMt has a beneficial effects in pain relief through different concepts. One concept, lPBMt is regarded to impede with the inflammation modules that lead to decrease the levels of mRNA, COX-2, and cytokines resulting in decreased pain [30–32]. Another concept provided that lPBMt enhances a decrease of endogenous opioid neuropeptides as explained in previous study evaluated the lPBMt with a wavelength of 780 nm and energy density of 2.5 J/cm, thereby leading to a reduce of endogenous endorphins and reducing pain [33]. The third concept, irradiation of lPBMt, leads to changes of the conductivity of the peripheral nerves. This concept was supported by Chow et al. who approved that lPBMt with wavelength of 830 nm results in production of varicosities at the axons [34]. The produced varicosities decrease the nerve conduction velocity through decreasing the axonal flow and potentials of mitochondrial membrane, thereabout leading to a decrease of ATP availability and failure of nociception neurotransmission (A δ and C fibers) [34].

lPBMt produced a significant within-group pain reduction. The mechanism behind the analgesic effect of lPBMt is that laser irradiation induces peripheral neural blockade, suppresses central synaptic activity, modulates neurotransmitters, reduces muscle spasm and interstitial edema, and exerts anti-inflammatory effects [35]. Furthermore, laser increases endogenous opioid neurotransmitter production [36], raises thermal pain threshold, and increases local blood circulation [37].

lPBMt produced a prolonged effect of pain reduction and function improvement in patients with non-radiating LBP lasting more than 30 days [38] or up to 3 months. This effect was noted whether lPBMt was applied as a standalone modality or combined with other approaches. However, more blinded trials are needed to validate this finding [39].

In the current study, the lPBMt wavelength used was 808 nm, which falls between 700 and 1000 nm; this is considered as the most often used wavelength to treat deep tissues because of superior penetration [40, 41].

Glazov et al. [39] reported that there appeared to be a dose threshold of 3 J/point for lPBMt to be beneficial. This is higher than the minimal dose suggested by reviews by Baxter et al. [42] (0.5 J/point for myofascial pain) and Chow et al. [43] (0.8 J/point for chronic neck pain), but closer to the dose recommended by WALT [44] (4 J/point for lumbar spine arthritis). This could be explained by the deeper location of structures in the low back area, requiring a higher laser irradiation dose for penetration. There was no upper dose at which laser appeared not to be effective or caused adverse effects.

On the other hand, the improvement noted in the UST group can be attributed to the UST transdermal tissue penetration, which improves the elasticity of collagen-containing tissues [45]. Furthermore, ultrasound promotes an increase in blood supply, hence increasing oxygen delivery, nutrients, and white blood cells at the site of application [46, 47].

The current study results showed a significant improvement in all clinical parameters except for the lumbar ROM, which can be explained due to the limited 3-min therapeutic window for stretching following UST application [48]. This way, participants who performed exercises after the treatment sessions as a home routine would have an extremely reduced benefit from the thermal effect. Taking into consideration that patients suffering from CNLBP usually present with muscle spasm [4], using continuous UST could have been effective in decreasing it [49]. The previously mentioned facts can explain the significant improvement in m-OSW score which was noted only in the lPBMt group. The application is often combined with other physiotherapy interventions, usually with exercise therapy [23]. The current study findings are consistent with those of Ansari et al. [50] who reported better functional outcomes in a continuous UST group in comparison with a placebo UST group. Nevertheless, the Ansari et al. study only applied either continuous or placebo UST. The effect of UST is commonly investigated in comparison with other therapeutic modalities [50, 51] or included in a rehabilitation program [52]; there is currently a lack of studies that investigate the effect of UST alone or compared to placebo UST in CNLBP.

No high-quality evidence was found to support the use of UST for improving pain or quality of life in patients with CNLBP. There is some evidence that therapeutic ultrasound has a small effect on improving low back function in the short term, but this benefit is unlikely to be clinically important [53].

The current study has two limitations. Firstly, our sample size was too small to detect differences between groups for some outcomes. Therefore, lPBMt versus UST should be investigated in trials with larger sample sizes. Secondly, short- and long-term follow-up of patients is needed to draw a definite conclusion in this respect. We have not yet performed an assessment of long-term follow-up on our patients.

According to the study results, lPBMt and UST seemed to be an effective method of decreasing pain, reducing disability, and increasing functional performance in CNLBP in combination with exercise training. We emphasize that lPBMt is more effective than UST in patients with CNLBP and the two modalities should be applied with appropriate exercises.

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Compliance with ethical standards

Conflicts of interest The authors declare that they have no conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

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