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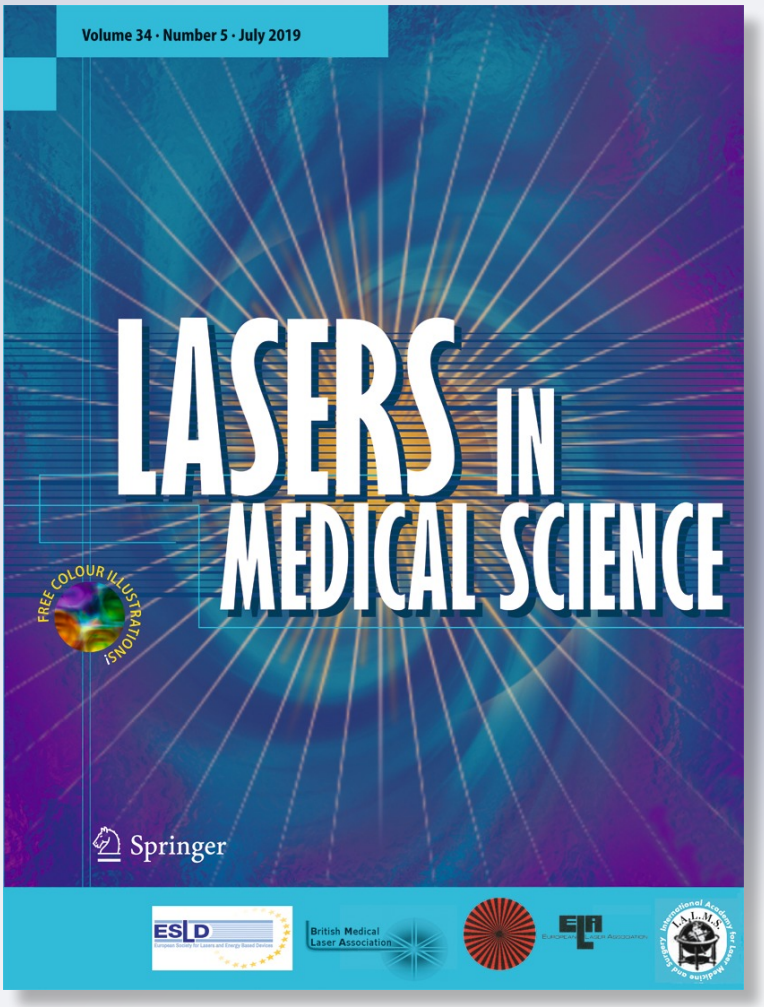

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ORIGINAL ARTICLE

Comparison of high-intensity laser therapy and combination of ultrasound treatment and transcutaneous nerve stimulation in patients with cervical spondylosis: a randomized controlled trial

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Abstract
The aim of the study was to compare the effect of high-intensity laser therapy (HILT) and a combination of ultrasound (US) treatment and transcutaneous nerve stimulation (TENS) on pain, range of motion (ROM), and functional activity in patients with cervical spondylosis (CS). A total of 84 patients with a mean age of 51.54 years (52 women and 32 men) affected by CS were enrolled in this study. Patients were randomly divided into two groups. In group A (42 subjects), patients received 12 sessions of HILT plus exercise, while in group B (42 subjects), they received a combination of US, TENS, and exercise. The outcomes measured were cervical segment ROM, pain level measured by visual analogue scale (VAS), and functional activity measured by neck disability index (NDI) at the end of the therapy. The level of statistical significance was set as $p < 0.05$. In the two groups, cervical ROM, VAS, and functional scores showed significant changes. Both HILT plus exercise and US/TENS plus exercise effectively increased cervical ROM and reduced pain (with a significant greater decrease in group A). Statistically significant differences in NDI scores were observed after treatment sessions with better results for participants enrolled in group A (HILT plus exercise) Both therapeutic modalities demonstrated analgesic efficacy and improved function in patients affected by cervical spondylosis 4 weeks after the therapy. HILT plus exercise was more effective than US/TENS plus exercise. HILT can be promoted and used in this pathology with positive outcomes. However, further studies are needed to optimize the dose and duration of HILT therapy.

Keywords Cervical spondylosis · High-intensity laser therapy · Ultrasound treatment · Transcutaneous nerve stimulation · Pain · Disability

Introduction

According to the World Health Organization (WHO), cervical spondylosis (CS) can nowadays be considered epidemic: neck pain is the second most common disorder in the musculoskeletal system after low back pain. The cervical spine is particularly sensitive to pain and the natural history of neck pain is generally persisting in two third of patients, thus causing severe discomfort, decreased quality of life, and inability to work [1]. The estimated prevalence of chronic neck pain is 10–24% [2, 3].

Poor posture, disc degeneration (mostly within C7, C6, or C5), and circulatory insufficiency of the vertebral arteries can be responsible for spinal nerve root compression and neuropathic pain [4].

A variety of treatments have been proposed for pain relief of CS such as non-steroidal anti-inflammatory drugs (NSAIDs) [5], analgesics [6, 7], physiotherapy [8, 9], and alternative medicine, such as neck exercise [8, 10], acupuncture [11], and herbal medication [12]. Different physiotherapic treatment modalities (ultrasound, laser therapy, massotherapy, cervical manipulations, transcutaneous nerve stimulation, tecar therapy, etc.) have been proposed but their precise effectiveness is still debated.

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Transcutaneous nerve stimulation (TENS) is a physical therapy based on the delivery of electric current across the intact surface of the skin to activate sensory nerve fibers, thus determining pain relief. It has been approved by the FDA (Food and Drug Administration) as a method for pain alleviation in 1972 and it is widely used in the treatment of acute or chronic pain.

Ultrasound (US), which is used by physiotherapists since the 1940s, exerts mechanical and thermal effects by increasing blood flow and metabolic activity. Ultrasound is applied using a specific probe (hand-held transducer) placed in direct contact with the skin via a coupling gel and constantly moved in a circular motion. US is generated by a piezoelectric effect determined by the vibration of crystals inside the probe, that is responsible for the vibration of soft tissues. US effects are not only mediated by heating but also by non-thermal mechanisms including ultrasonic cavitation and mechanical stress.

Laser therapy is a noninvasive treatment modality administered for a wide range of musculoskeletal disorders. High-intensity laser therapy uses a specific waveform with regular amplitude peaks and it is able to rapidly induce phototermic and photochemical effects in the deep tissue, thus stimulating collagen production, increasing blood flow and cellular metabolism, and removing painful stimuli.

The aim of the present randomized controlled trial was to evalutate the analgesic efficacy and the improvement of function of the cervical spine in two groups of patients with CS without peripheral neurological complications. In the first group, a protocol of high-intensity laser therapy (HILT) plus exercises was adopted; in the second group, a program of ultrasound (US) plus transcutaneous nerve stimulation (TENS) and exercises was proposed.

Materials and methods

A randomized single-blinded design was employed. Patient selection was based on history and physical examination. The demographic features of the patients as well as patients age, comorbid conditions, and medications were questioned. Patients with a history of positive neurological examination (presence of positive reflex, motor or sensory abnormalities related to spinal root compression or nerve entrapment), inflammation, infection, or degeneration related to rheumatic diseases, cerebrovascular abnormalities, spine fracture or trauma, cancer, systemic or metabolic disorders, a history of cervical spinal surgery, abnormal laboratory findings, psychiatric illnesses, or known photosensitivity were excluded. After baseline examination (clinical and radiographic evaluation) performed by a blinded orthopedic specialist, all patients were given a full explanation of the treatment protocol and asked to provide written informed consent. Patients agreed to interrupt analgesics, NSAIDs, or muscle relaxants 1 week before the beginning of the therapeutic program and throughout the whole course of the study and not to receive alternative drugs or physical therapies for their neck pain. Patients were randomized into two groups by assigning each a specific identification source code. All patients were informed to undergo 12 therapeutic sessions twice a week for 6 weeks.

This study included 84 patients (52 women and 32 men) affected by CS with a mean age of 51.54 years. Randomization into two groups was performed using a GraphPad program (GraphPad software, Inc., San Diego, CA, USA): group A (42 subjects) was treated with 12 sessions of HILT plus exercise; group B (42 subjects) received a combination of US, TENS, and exercise. All treatments were performed by the same 40-year-old therapist with a proven experience in the treatment of cervical spondylosis and with more than 10 years of professional activity (more than 2500 therapic sessions).

Treatment protocols

HILT

HILT group received HILT with a neodymium-yttrium aluminum garnet laser with a pulsating waveform produced by an HIRO®3 device (ASA, Arcugnano, Vicenza, Italy) setted at the following options: Nd:YAG laser with pulsed emission (1064 nm), very high power peaks (3 kW), short pulse duration (120–150 μs), low frequency (10–40 Hz), high levels of fluency (510–1780 mJ/cm energy density), 5-mm-bright-spot diameter. Scanning was performed in both transverse and longitudinal directions to the posterior neck on the paraspinal area, interscapular area, trapezius, and sternocleidomastoid muscles bilaterally. An initial phase involved fast manual scanning and a total of 1000 J/cm^2. In the second phase, HILT was applied to eight trigger points including four phases for each point until a pain reduction of 70–80% was achieved: a total of 200 J was administered in this phase. The final phase was similar to the initial phase but involved slow manual scanning. The total time taken to apply all three stages of HILT was approximately 30 min and the total dose of energy administered was approximately 2050 J [13–16].

Exercise

A specific program of 30-min exercise sessions was provided by the same therapist and all the patients were instructed to perform the active ROM, stretching and strengthening exercise program. All exercises were individualized according to each patient's abilities. Gentle stretching of trapezius, scaleni, rhomboid, levator scapulae, pectoral, and suboccipital muscles was performed to improve flexibility and pain-free ROM [17, 18]. Strengthening exercises included active flexion of the upper cervical and extension of the lower cervical

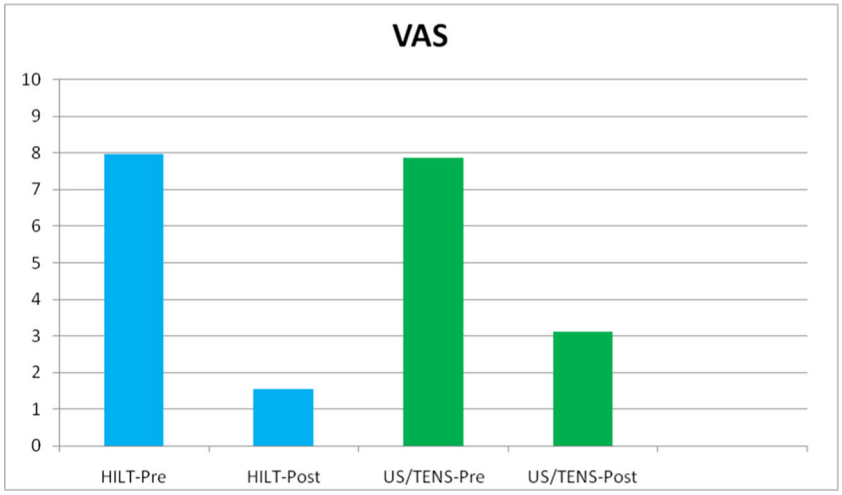

Fig. 1 VAST

area and were taught by the physiotherapist to be performed as self-training with a Thera-Band at home (Figs. 1 and 2) [19, 20].

Ultrasound

A Chattanooga intelect mobile US device was used in the therapeutic sessions. US was applied at 1.5 watt/cm for 10 min to the posterior neck and periscapular area. The US device granted the application of 1–3 MHz. Conductivity gel was used to enhance absorption and to achieve deep muscle thermal effects.

TENS

Patients were administered a hot pack applied to the posterior neck and periscapular area for 20 min along with TENS application in conventional mode for 20 min at 70-Hz frequency and 100-μs wavelength.

Patients did not complain about thermal effects during the physiotherapy sessions since US/TENS protocol increased tissue temperature of an average of 2 °C; similarly, the thermal effects of HILT physiotherapic sessions were not significant (although there is a lack of research into the thermal effects from commonly used high laser therapy devices).

Outcome measures

The outcomes measures were cervical segment ROM, pain level measured by visual analogue scale (VAS), and functional activity measured by Neck Disability Index (NDI). All of them were administered before the beginning and 4 weeks after the end of the treatment.

A cervical ROM goniometer was used to measure ROM of the cervical spine for its ease of use: the sagittal plane meter measures flexion and extension, while the lateral plane meter measures lateral flexion. All patients were verbally instructed to bend their head as far as possible until feeling tightness or pain. Each patient was instructed to keep his/her shoulders against the chair's backrest. Cervical ROM measurements were performed twice by two independent observers before

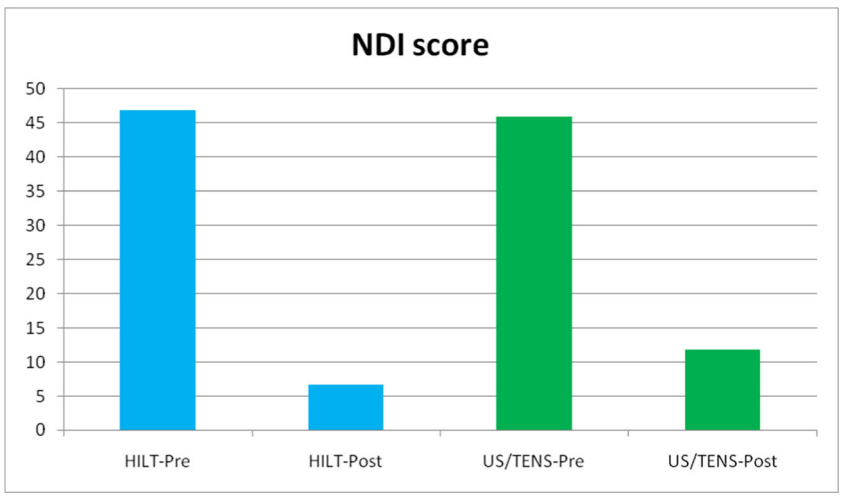

Fig. 2 NDI score

the beginning of the treatment and at 4 weeks follow-up examination.

Neck pain was assessed using the visual analogue scale (VAS), a 10-cm line where 0 is marked as no pain and 10 as the maximum pain. Patients were asked to indicate the severity of their neck pain on this line so that the distance between the 0 point and the marked point is measured and recorded.

The Neck Disability Index (NDI) developed by Vernon and Mior [21] is a self-administered condition-specific questionnaire adapted from the Oswestry Low Back Pain Questionnaire [22]. It consists of 10 items related to pain (pain intensity, headache) and different activities (work, driving, lifting, personal care, sleeping, concentration, reading, and recreation) with 6 possible answers for each item (from 0 for no pain/no functional limitation to 5 for worst pain/maximal limitation). Total score ranges from 0 (no disability) to 50 (totally disabled). It has been revalidated in several study populations and has shown stable psychometric properties [23].

Both VAS and NDI questionnaires are translated, validated, and currently available for Italian use.

Statistical analysis

All the results obtained were subjected to statistical analysis in which tests of the significance of differences were used. All analyses were performed using SPSS for Windows (version 16) and GraphPad InStat. Student's *t* test for dependent and independent samples was used to compare the obtained results of treatment by HILT plus exercise versus US/TENS plus exercise method (for the measurement before and after the therapy). A two-factor analysis of variance was applied for repeated measures. For nonparametric measures (VAS, NDI, ODI), the difference between the baseline and follow-up scores for each group was computed using the Friedman test. The level of statistical significance was set at $p < 0.05$.

Results

Eighty-four patients (52 women and 32 men) were enrolled in the present study. Mean age was 51.54 ± 17.32, with mean weight of 78.46 kg and mean height of 1.68 m. Patients were randomly divided into two equally distributed groups and were all available at follow-up (FU): no side effects were observed during physiotherapic sessions. There were no statistically significant differences in the demographic features or pre-treatment evaluation parameters in terms of age, severity of pain, and range of motion of the cervical spine between the two groups ($p > 0.05$) (Table 1). Statistically significant differences were found between the pre-treatment scores and the post-treatment scores in both groups.

Both group A (HILT plus exercise) and group B (US/TENS plus exercise) showed significant improvement in all parameters with a significant difference in ROM, VAS, and NDI scores at 4 weeks follow-up compared with baseline, in that ROM increased (Table 2) whereas VAS and NDI scores decreased after the physiotherapic treatment (Tables 3 and 4). Group A showed a significant improvement in neck function when compairing pre- and post-treatment NDI scores (pre 46.84 ± 3.18; post 6.68 ± 2.12), with better results than group B (pre 45.92 ± 4.64; post 11.82 ± 1.42). Similarly, VAS demonstrated a reduction in pain perception in both group A (pre 7.96 ± 0.68; post 1.56 ± 0.71) and group B (pre 7.86 ± 0.84; post 3.12 ± 0.75).

Student's *t* test revealed that the significant ROM improvement observed in group A was greater than that in group B 4 weeks after the treatment; similarly, the significant reduction in VAS score was greater in the HILT plus exercise group (post-operative scores 1.56 ± 0.71 and 3.12 ± 0.75 respectively). Both therapies resulted in significant improvement from pre- treatment values to post-treatment values.

Discussion

The most important finding of the present randomized controlled trial was the following: HILT combined with exercise is effective in increasing cervical ROM and in decreasing the VAS and NDI scores at 4 weeks follow-up after 12 therapic sessions (performed in 6 weeks) in patients with CS without peripheral neurological complications. Similarly, there was an increase of all parameters in the group of patients treated with US/TENS plus exercises. When the results of the HILT group were compared to those of the US/TENS group, statistically superior results in terms of functional improvement were observed in the HILT cohort.

CS is a common pathologic condition responsible for nonspecific neck pain: neck pain is one of the most frequent musculoskeletal cause of consultation in primary care worldwide. Cervical spondylosis is usually diagnosed on clinical grounds alone: pain can be generally referred to a wide area and is characteristically exacerbated by neck movements. Plain radiographs of the cervical spine may show a loss of normal cervical lordosis and many other features of degenerative disease. Degenerative changes start in the intervertebral discs with osteophyte formation and involvement of adjacent soft tissue structures. Imaging may be misleading because important pathologic abnormalities at CT and MRI may be present in asymptomatic subjects too. Most mechanical neck pain is responsive to conservative therapy, but the optimal treatment has yet to be established.

The common approach consists of gentle exercise program associated with a wide spectrum of anti-inflammatory medical devices such as laser, ultrasounds, and TENS.

Exercise program is considered a valuable approach in the conservative treatment of patients with CS as it effectively

Table 1 Patients' demographic data

	HILT plus exercise	US/TENS plus exercise	Total
Age	49.76 years	53.32 years	51.54 ± 17.32 years
Weight	76.24 kg	80.68 kg	78.46 ± 10.12 kg
Height	1.74 m	1.62 m	1.68 ± 0.12 m
Duration of illness	7.8 months	8.8 months	8.3 ± 2.2 months

decreases pain and increases function and muscle flexibility, especially when combined with physical therapy modalities. Specific exercises facilitate decreased pain and improvements in function and muscle strength. Exercise therapy has been proven to be economical and practical, improving the effect obtained by physical therapy as high-intensity laser therapy [19, 20, 24, 25].

Pulsed Nd:YAG laser therapy, a form of HILT, has been used widely for different musculoskeletal conditions: knee arthritis, shoulder pain, lateral epicondylitis, chronic ankle pain [14, 26–28]. Fiore et al. compared the short-term effectiveness of HILT with US therapy in the treatment of low back pain [29]. In previous studies, Alayat et al. [30]and Stiglic-Rogoznica et al. [31]investigated the analgesic effect of HILT in the treatment of knee osteoarthritis with different protocols. HILT is supposed to have anti-inflammatory, analgesic, anti-edema, and reparative effects. The analgesic effect is based on a direct action on nerve structures (altering Aδ- and C-fiber transmission) [32] and its ability to slow the transmission of the pain stimulus and to increase the production of morphine-mimetic substances in the body [33]. Moreover, HILT acts altering the release of histamine and bradykinin from injured tissues and of substance P from the peripheral nociceptors thus increasing the pain threshold. Finally, pain is inhibited centrally by an increase in the secretion of endogenous opioids like β-endorphin [34]and the reduction of inflammation by the stimulation of increased neutrophil and macrophage activity [35]. Laser therapy decreases interleukin 1 and C-reactive protein and enhances lymphocyte response and superoxide dismutase levels, thus determining its anti-inflammatory response and its ability to accelerate tissue healing [36].

Table 2 ROM of cervical spine measured pre- and post-treatment

ROM		HILT plus exercise	US/TENS plus exercise
Flexion	Pre	50.62 ± 3.06	51.23 ± 2.85
	Post	57.83 ± 3.12	54.12 ± 3.02
Extension	Pre	48.32 ± 1.95	49.23 ± 1.78
	Post	54.86 ± 2.88	52.16 ± 1.95
Right bending	Pre	33.17 ± 1.96	32.65 ± 1.46
	Post	40.32 ± 1.35	35.48 ± 1.53
Left bending	Pre	32.88 ± 2.65	32.40 ± 2.05
	Post	39.52 ± 3.50	35.23 ± 2.58

According to recent research, laser therapy stimulates mitochondria with an active role of Cytochrome c-oxidase (Cox), a multicomponent membrane protein, responsible for the acceleration of electron transfer reactions following the absorption of photons. This increases ATP (adenosin triphosphate) synthesis and increased proton gradient is responsible for the increasing activity of the Ca++/Na+ and Na+/H+ antiporters and of all the ATP-driven carriers for ions. The activation of second messengers (as cAMP and Ca++ pumps) is important in the activation of biological cascades responsible for cellular contraction, gene expressions, blood coagulation etc. According to the findings by Wang et al., HILT could also lead to cellular ATP increment [37–39].

Several studies have shown that HILT was more effective than low-level laser therapy thanks to its ability to reach and stimulate the larger and deeper fascial areas [40]. HILT leads to reduced and slower light absorption by chromophores and melanin [41] responsible for the phenomenon of tissue stimulation (photobiology effects) [42]. The phototermic and the photochemical effects of HILT may increase blood flow and stimulate collagen production within tendons; in addition, HILT may increase vascular permeability and has an anti-inflammatory effect, thus removing the pain stimulus [43].

Ultrasound is a therapeutic modality commonly used by physiotherapists: it works by driving alternating compression and rarefaction of sound waves with a frequency of more than 20,000 cycles per second. The hand-held transducer is applied with coupling gel and moved in a circular motion over the painful area to warm muscles, tendons, and other tissue to improve blood flow and accelerate healing. Thermal effects aid in pan relief, whereas non-thermal effects enhance cell-repair effects of the inflammatory response.

Transcutaneous electrical nerve stimulation (TENS) is the delivery of electric current across the intact surface of the skin to activate sensory nerve fibers, thus determining pain relief [44]. According to the conceptual model proposed by Melzack and Wall in 1965 [45],a large diameter (Aβ) sensory nerve stimulation is responsible for the closure of a "pain

Table 3 Visual analogue scale (VAS) measured pre- and post-treatment

VAS	HILT plus exercise	US/TENS plus exercise
Pre	7.96 ± 0.68	7.86 ± 0.84
Post	1.56 ± 0.71	3.12 ± 0.75

Table 4 Neck Disability Index (NDI) administered pre- and post-treatment

NDI	HILT plus exercise	US/TENS plus exercise
Pre	46.84 ± 3.18	45.92 ± 4.64
Post	6.68 ± 2.12	11.82 ± 1.42

gate" in the spinal cord that inhibits the transmission of pain signals carried by nociceptive afferent (C and Aδ fibers) to the brain. TENS is characterized by a number of electrical parameters including frequency, amplitude, pattern, duration, and the stimulation pulse shape [46]. Several studies showed high-frequency (50 Hz) TENS are safe and effective in multiple forms of chronic pain [47–52].

With the notable findings, the present study has some limitations. First of all, the number of patients is limited and the fact that the study has been carried out in only one center may have influenced the results. Moreover, the optimal setting (frequency, dose, and wavelength) of HILT devices and the duration of its application is not standardized by an univoque protocol. Third, a short follow-up duration may be a limitation. Large well-designed randomized studies with standardized protocols are still needed to clarify the efficacy and cost effectiveness and to warrant the present results.

Conclusions

HILT plus exercise program was more effective than US/TENS plus exercise in improving pain levels, function, and quality of life, and in decreasing pain in patients with cervical spondylosis without peripheral neurological complications.

Compliance with ethical standards

Ethical approval All procedures performed in this study were in accordance with the ethical standards of the institutional and national research committee and with the 1964 Helsinki declaration.

Informed consent All individual participants included in the study gave spontaneously their own informed consent.

Conflict of interest The authors declare they have no conflict of interest.

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