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RESEARCH ARTICLE

Unilateral and Immediate Stimulation of Acupuncture Points Xiaohai (SI8) and Jianwaishu (SI14) of the Small Intestine Meridian Increases Electromyographic Activity and Strength in the Ipsilateral and Contralateral Upper Trapezius Muscle

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Abstract
We previously showed that a yin meridian of the upper limb decreased electromyographic activity (root mean square) and muscle strength ipsilateral and contralateral to the side of stimulation. Here, we tested the upper trapezius (UT) muscle response after stimulation of a yang meridian of the upper limb, the small intestine (SI). Thirty-eight healthy volunteers were randomized into the following groups: UT muscle (SI14), distant of the UT muscle (SI8), without stimulation (CG), and sham (R3). An acupuncturist certificated

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muscle activation;
strength

by the Brazilian Society of Physical Therapists and Acupuncturists performed the needle insertion. Each volunteer received only one stimulation to the right upper limb. The evaluation occurred before, 5 minutes after, and 20 minutes after needle withdrawal. The root mean square activity increased on the right side in the UT muscle for the SI8 and SI14 groups ($F_{3,37} = 4.67$; $p < 0.025$) at the 20-minute evaluation. The most vigorous response occurred on the contralateral side because the effects were maintained for 5 minutes after withdrawal ($F_{3,37} = 4.52$; $p < 0.025$). Both groups showed an increase in the UT muscle strength at the 20-minute evaluation ($F_{3,37} = 3.41$; $p < 0.025$). The CG and R3 groups did not show any changes. Our data indicate that SI a yang meridian increases the UT muscle response.

Q3

1. Introduction

Acupuncture is part of traditional Chinese medicine. According to the philosophy of acupuncture, the organic responses can be changed through the activation/inhibition of acupuncture points, which in turn will modify the acupuncture meridians [1].

The acupuncture points have been thoroughly studied by electronic devices and histological methods that have revealed, for example, differences in electrical resistance of the skin [2] and many somatosensory system receptors in the area of acupuncture points [3]. Studies using functional magnetic resonance imaging have also shown that specific acupuncture points modify specific brain regions. Thus, part of the philosophical concept behind acupuncture, defending the need for stimulus direction for the acupuncture points has been confirmed by modern science [4].

The acupuncture points are connected to other points constituting a chain of points called acupuncture meridians. There are different types of acupuncture meridians. However, the main acupuncture meridians apparently are the most essential for the production of Qi [5]. The main meridians run bilaterally through the surface of the body, are connected to the internal organs, where they receive your name, and control different organic and energetic functions [6]. The balance of the main meridians promotes the balance of the Qi by the equilibrium of Yin and Yang [7]. For this purpose, the main meridians are divided into meridians with Yin functions and meridians with Yang functions [8].

If on the one hand, the acupuncture meridians are essential for understanding the balance of Yin and Yang and are part of the philosophy of acupuncture bring, on the other hand, they are objects of difficult exploration from the scientific point of view [9]. Different scientific methods are used for this purpose. To this end, studies have been conducted in experimental animals using the injection of tracers [10], in humans using the injection of radioactive isotopes [11], with electrical impedance [2], and studies with biomechanical models in humans [12].

One possible way to visualize the points and acupuncture meridians can be through functional response to the stimulation. One of the organic systems that quickly responds to stimulation by acupuncture is the musculoskeletal system. According to MTC, the meridians nourish the
Q4
muscles that are in your path, and can modify the muscle response. Using surface electromyography (EMG) is possible to understand in real time because the stimulation at one point or acupuncture meridian modifies the pattern of muscle activation [13].

Costa and Araujo in 2008, using surface EMG and load cells, showed decreased electrical activation of the tibialis anterior muscle by stimulation of the ST36 and SP9 acupuncture points. However, only the ST36 stimulation reduced the dorsiflexion strength. This work showed a particular response to a point of the stomach meridian, which has its track exactly on the tibialis anterior muscle [14].

Recently in our laboratory [13], we advanced the understanding of muscle control by acupuncture meridians. We showed that stimulation of the right branch of the heart meridian decreases the electrical activation and strength of the wrist flexor muscles in the contralateral arm to the stimulation. As in the work of Costa and Araujo [14], with the stomach meridian and the tibialis anterior muscle, the heart meridian has its anatomical tract related to the wrist flexor muscles. The heart meridian has yin function, and in this manner, the reduction in electrical activity and strength observed in this work are linked with the philosophical concepts of MTC. By showing the contralateral results to the stimulated side, possibly we present safe and functional evidence of the contralateral branch of the heart meridian.

Thus, the aim of this study was to investigate the activation patterns and strength responses of the deltoid muscle following stimulation of the yang meridian linked to the heart meridian, the small intestine, through the small intestine 14 (SI14), a local trapezius acupuncture point, and the small intestine 8 (SI8), a distant trapezius acupuncture point, ipsi- and contralateral to the side of stimulation using surface EMG and load cells.

2. Materials and methods

There were nine male and 29 female participants aged 18–30 years who were recruited by advertisements placed on bulletin boards in the Ribeirão Preto Campus of the University of São Paulo. For randomization of the participants in four groups, we used sealed envelopes with the indication for each treatment group. Each participant was able to choose freely a sealed envelope containing the assignment to an experimental group. The participants received written and verbal information detailing the procedures, and read and voluntarily signed consent forms that were written in agreement with Resolution 196-96 before the procedures. All participants were healthy. The exclusion criteria were upper limb pain, trauma history, neuromuscular impairments, uncontrolled epilepsy, epithelial allergy, pregnancy, or any panic reaction to needles.

The participants were divided in four groups. Of the experimental groups, three underwent acupuncture at specific points as follows: the local group (LG) received acupuncture at the SI14 point ($n = 10$); the distant group (DG) received acupuncture at the SI8 point ($n = 10$); and the control group (CG) received acupuncture at the K3 point ($n = 10$). The participants in the fourth group that is the naïve control group (NCG) ($n = 8$) did not receive any acupuncture (Fig. 1). The SI meridian points were chosen based on their anatomical locations and relationships with the deltoid muscle. The K3 acupuncture point was selected because it is located at the end of the lower limb and has no anatomical relationship with the deltoid muscle (Fig. 2).

The study was approved by the Ethics Committee on Human Research and Experimentation of the Medical School of Ribeirão Preto under protocol number 8864/2010 and registered in the National System of Information Ethics and Research Involving Human Subjects (CAAE-0301.0.004.000-10) as ethically and methodologically appropriate according to the percepts of resolution 196/96 of the National Health Council. The trial was carried out in the Laboratory of Neuropsychobiology and Motor Behavior at the University of São Paulo.

Acupuncture was performed by a physiotherapist specializing in acupuncture, certificated by the Federal Physical Therapy Council and Brazilian Society of Physiotherapists and Acupuncturists (SOBRAFISA). Sterile and disposable stainless steel needles with tubes (0.25 mm × 40 mm) were used. The snapping technique (without needle rotation) was used at an insertion depth of ∼1.5 cm. The needle remained in place for a total of 20 minutes and was rotated at 2 minutes, 5 minutes, 10 minutes, 15 minutes, and 19 minutes after insertion; the needle was immediately removed after 20 minutes. Each patient received only one treatment session.

We used a six-channel surface EMG machine (model 400c-200c; EMG System, São José dos Campos, São Paulo, Brazil) connecting to an Acer laptop computer. The electrodes were active, double, bipolar (with fixed inter-electrode distances), adhesive, and disposable. A force transducer (EMG System, São José dos Campos) was coupled to one of the channels of the EMG equipment and used as a dynamometer to convert the traction force applied to the load cell to kilogram-force (kgf). The force transducer had a rectangular shape and was fixed to the ground by one of its sides, while the opposite end was fixed to a nonelastic band held by the volunteer.

The participants sat and the skin was shaved and cleaned with 70% alcohol for the placed electrodes. The participants were asked to report any discomfort and ask questions during the procedure.

The maximal isometric contractions for 20 seconds of the trapezius muscle required from the participants were as follows: three maximal isometric contractions of the right; three maximal isometric contractions of the left; and three bilateral maximal isometric contractions. The acquisition of the EMG data during maximal isometric contractions occurred as follows: electromyographic signals and muscle strength data were collected before needle insertion (pre); after the needle removal before 20 minutes of stimulation (post); and 5 minutes after the removal of the needle (5 minutes); the muscle assessment protocol was repeated. The volunteers were instructed before the start of data collection to raise their shoulder, without performing the associated movements. There was no change in position throughout the procedure, and the room was locked to restrict the access of non-participants.

EMG electrodes were placed on the muscle bellies of the superior trapezius parallel to the muscle fibers, fixed in one middle point between the acromion and the seventh cervical vertebra. The hands of the volunteers were connected to the force transducer to enable the analyses of muscle activation and force during maximal isometric contraction of the trapezius as described in the Surface Electromyography for the Non-Invasive Assessment of Muscles (SENIAM) project [15]. The dispersive electrode was fixed in the wrist.

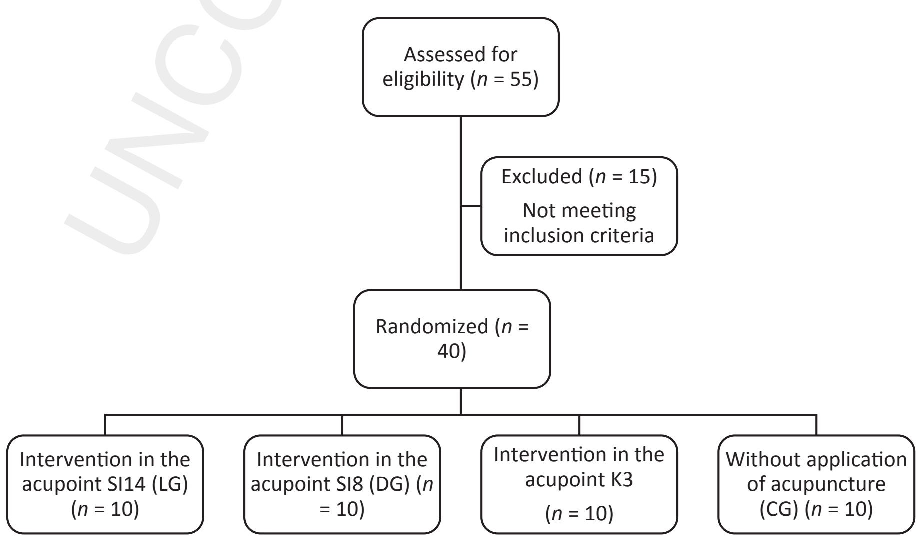

Figure 1 Random allocation of volunteers into the experimental groups.

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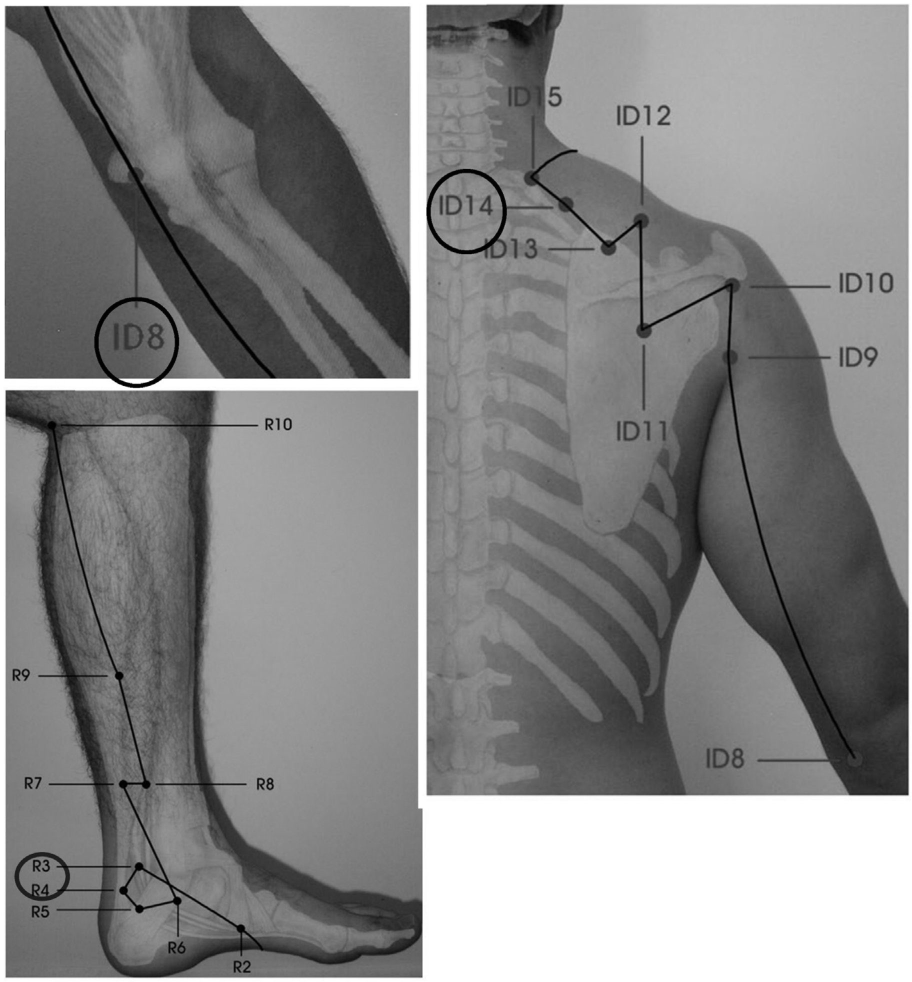

Figure 2 Acupuncture points examined in this study and their respective anatomical locations. The images were taken, with permission, from the ACUPUNCTURE software (SAE-MP the Instituto Paulista de Estudos Sistêmicos).

To ensure the quality of the signal, we determined the root mean square (RMS). The RMS values were obtained from three contractions accomplished by the participants. If the rest RMS was higher than the selected value, the participant was excluded from the study.

Because the data were normally distributed, one-way analysis of variance was performed, and significant between-group differences were further evaluated with Holm–Sidak *post hoc* tests. A *p* value of 0.025 was considered significant.

3. Results

The ipsilateral RMS values of the NCG did not show any significant differences for any time of evaluation ($F_{3,37} = 0.44$; $p = 0.64$). In the same direction, the K3 ipsilateral stimulation (CG) did not show any differences in the RMS values ($F_{3,37} = 0.12$; $p = 0.88$). The analysis of the SI14 (local) stimulation showed an increase in the post-evaluation RMS values in the NCG and the pre-acupuncture RMS values in the same group. For the SI8 (distant) stimulation, there was an increase in the pre-acupuncture RMS values in the same group, and for the post-evaluation RMS values in the NCG, CG and SI14 group ($F_{3,37} = 4.67$; $p < 0.025$) (Fig. 3).

The contralateral RMS values of the NCG did not show any significant differences for any time of evaluation ($F_{3,37} = 0.85$; $p = 0.43$). In the same direction, the K3 ipsilateral stimulation (CG) did not show any differences in the RMS values ($F_{3,37} = 2.33$; $p = 0.11$). Both analyses of the SI14 and SI8 showed an increase in the post-acupuncture RMS values ($F_{3,37} = 4.52$; $p < 0.025$) and in the 5 minutes after the withdrawal of the needle in relation to the pre-acupuncture RMS values ($F_{2,29} = 6.79$; $p < 0.025$) in the same group and in relation to the post-acupuncture and 5 minutes RMS values in the NCG and CG ($F_{3,37} = 5.53$; $p < 0.025$) (Fig. 4).

The kgf values of the NCG did not show any significant differences for any time of evaluation ($F_{2,23} = 0.46$; $p = 0.63$). In the same manner, the K3 ipsilateral stimulation (CG) did not show any significant differences in the kgf values ($F_{2,29} = 2.08$; $p = 0.14$). The stimulation of the SI14 and SI8 acupuncture points showed an increase in the post-acupuncture kgf values for the NCG and the pre-acupuncture kgf values in the CG ($F_{3,37} = 3.41$; $p < 0.025$) (Fig. 5).

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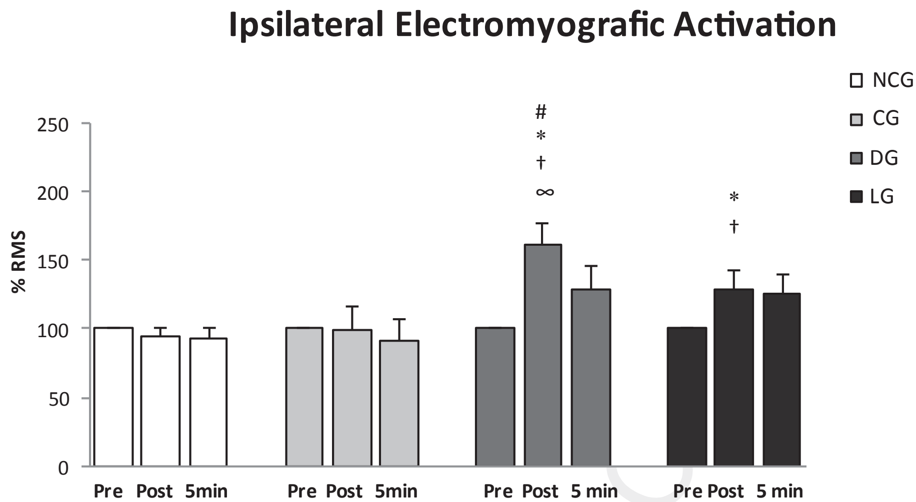

Figure 3 Ipsilateral electromyographic activation in response to stimulation. The data are presented as the mean and standard deviation. *Compared with the post in the CG and NCG; #compared with the pre and 5 min in the same group; †compared with the pre in the same group; ∞compared with the post in the LG. Analysis of variance followed by Holm–Sidack test, $p < 0.025$. Ten participants in all groups. Q11 Q12

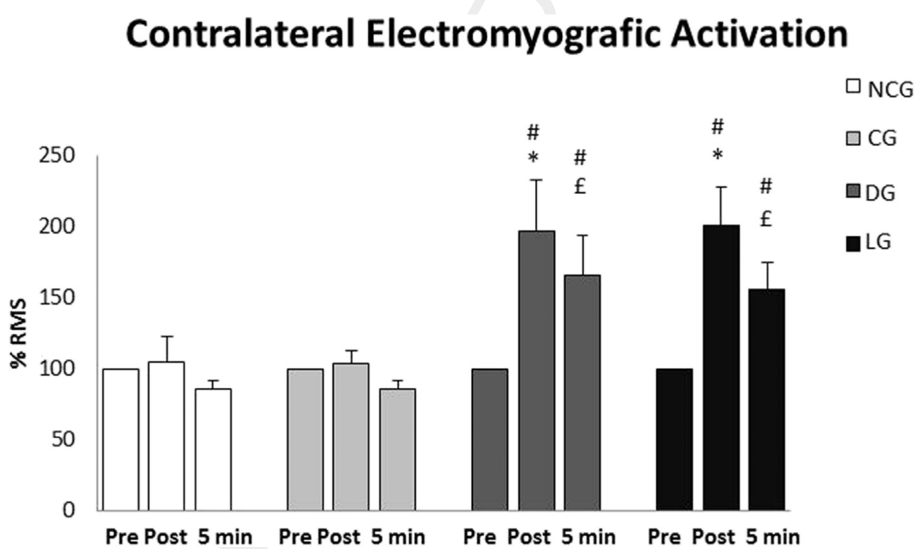

Figure 4 Contralateral electromyographic activation in response to stimulation. The data are presented as the mean and standard deviation. *Compared with the post in the CG and NCG; #compared with the pre in the same group; £compared with the 5 min in the NCG and CG. ANOVA followed by Holm–Sidack test, $p < 0.025$. Ten participants in all groups. Q10 Q13

4. Discussion

The present work revealed that the stimulation of local and distant acupuncture points from the trapezius muscle was able to increase ipsi- and contralateral muscle strength and to increase the RMS values. However, the contralateral effect was more expressive because the effects were present not only after the stimulation, but also at 5 minutes after the post-acupuncture evaluation.

Voluntary motor behavior depends on the balance of many structures that comprise the motor system [16]. Beyond the cortical areas, the nucleus of the descending control system, as the medial and lateral and nonspecific pathways, interferes with the spinal motor neurons to increase or decrease the motor response [17].

Studies with functional magnetic resonance imaging and acupuncture points have shown the possibility that these points increase or decrease activation of the brain areas rather than changing the motor behavior [4]. We have found studies of activation of the brainstem, basal ganglia, cerebellum [18–22], thalamus and insula [23], and motor area [24].

The trapezius is a proximal muscle and is influenced by the descending medial pathways. These pathways descend to the ipsilateral ventral columns of the spinal cord [17]. Our ipsilateral data with muscle activation post-

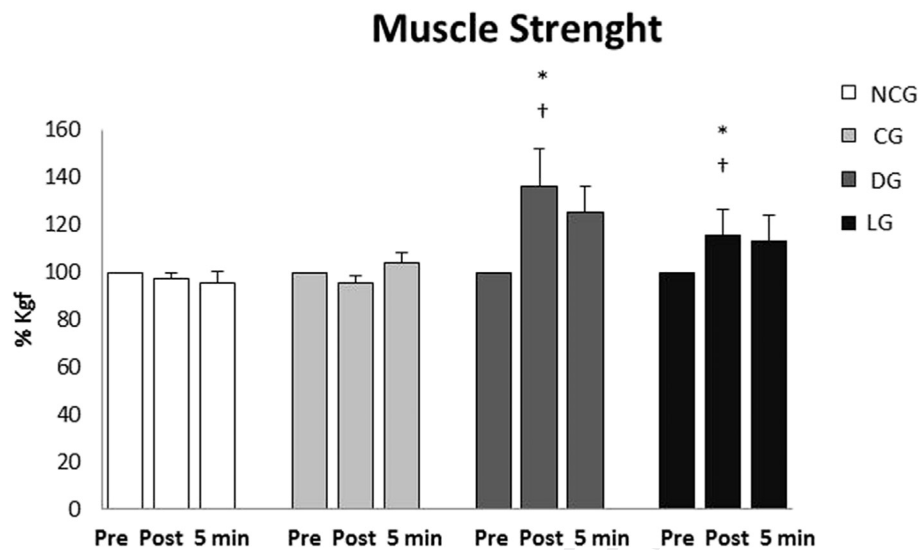

Figure 5 Muscle strength in response to stimulation. The data are presented as the mean standard deviation. *Compared with the pre in the same group; †compared with the post in the NCG and CG. Analysis of variance followed by Holm–Sidack test; $p < 0.025$. Ten participants in all groups.

acupuncture can be interpreted from this anatomical point of view.

After the "De qi" sensation in manual acupuncture, A fibers are activated [25]. Probably, activation of the ipsilateral side of the brainstem during acupuncture stimulation justified our ipsilateral results with the improvement in the muscle patterns of activation. In contrast, the contralateral results do not support the anatomical interpretation.

In the MTC, the treatment side is emphasized as a factor for success. Usually, for example, treating the right side produces results in the left side [26]. In many diseases, the evidence shows that contralateral treatment is a usual procedure in acupuncture, for example, in post-stroke rehabilitation [27]. Our data are consistent with this proposal. Only in the contralateral effects de SI8 and SI14 increases the electrical muscle activation and muscle strength for a longer time. By stimulating the right branch of the SI meridian, we could enhance the performance of the left branch of the SI meridian and thus increase the motor response of the trapezius muscle.

In a previous study, we showed that the ipsilateral and contralateral responses in the heart meridian are the RMS activation decrease including the decline in strength of the flexor muscles of the wrist. In the present work, the results were similar to the most robust response on the contralateral side. However, the results are going to the opposite side for the pattern of muscle activation.

This opposite pattern of muscle response is the same pattern of opposition of the Yin and Yang concepts. The Yin pattern is correlated with inhibition, while the Yang pattern is correlated with activation [7]. Our data are in agreement with this concept. While the heart meridian, a Yin meridian, decreases the pattern of muscle response, the SI, a Yang meridian, increases the pattern of muscle response.

Our data should be interpreted strictly in its dimensions and generalizations should be made with caution. Other acupuncture meridians exert their activity on different muscle groups and the pattern of activation or inhibition after acupuncture needs to be tested. Our study consisted of healthy individuals and it is necessary to test our methodology in different situations and changes in the musculoskeletal system. Our data highlight the contralateral stimulation of the trapezius muscle by the SI meridian, which is necessary to improve the function and strength in this muscle.

Disclosure statement

The authors confirm that there are no conflicts of interest and that the authors have no financial interests related to the material in this manuscript.

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