Neuromusculoskeletal Medicine (OMT) Original Article

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Cranial osteopathic techniques and electroencephalogram (EEG) alpha power: a controlled crossover trial

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Abstract

Context: Osteopathic tradition in the cranial field (OCF) stated that the primary respiratory mechanism (PRM) relies on the anatomical links between the occiput and sacrum. Few studies investigated this relationship with inconsistent results. No studies investigated the occiput–sacrum connection from a neurophysiological perspective.

Objectives: This study aims to determine whether the sacral technique (ST), compared to the compression of the fourth ventricle (CV4) technique, can affect brain alpha-band power (AABP) as an indicator of a neurophysiological connection between the occiput and sacrum.

Methods: Healthy students, 22–30 years old for men and 20–30 years old for women, were enrolled in the study and randomized into eight interventions groups. Each group received a combination of active techniques (CV4 or ST) and the corresponding sham techniques (sham compression of the fourth ventricle [sCV4] or sham sacral technique [sST]), organized in two experimental sessions divided by a 4 h washout period. AABP was continuously recorded by electroencephalogram (EEG) of the occipital area in the first 10 min of resting state, during each intervention (active technique time) and after 10 min (post-active technique time), for a total of approximately 50 min per session. Analysis was carried out utilizing a repeated-measure ANOVA within the linear general model framework, consisting of a within-subject factor of time and a within-subject factor of treatment (CV4/ST).

Results: Forty healthy volunteers (mean age ± SD, 23.73±1.43 years; range, 21–26 years; 16 male and 24 female) were enrolled in the study and completed the study protocol. ANOVA revealed a time × treatment interaction effect statistically significant (F=791.4; p<0.001). A particularly high increase in mean AABP magnitude was recorded during the 10 min post-CV4, compared to both the CV4 and post-sCV4 application (p<0.001). During all the times analyzed for ST and sST application, no statistically significant differences were registered with respect to the resting state.

Conclusions: The ST does not produce immediate changes on occipital AABP brain activity. CV4, as previous evidence supported, generates immediate effects, suggesting that a different biological basis for OCF therapy's connection between the head and sacrum should be explored.

Keywords: alpha rhythm; electroencephalography (EEG); osteopathic manipulative treatment (OMT); osteopathy in the cranial field (OCF).

Osteopathy in the cranial field (OCF) is a system of diagnosis and treatment that consists of a gentle manipulation of the cranial and/or sacral regions and is aimed to restore the areas in dysfunction [1]. The biophysiological mechanism supporting OCF is still debated and remains largely anecdotal [2, 3].

The treatment model for OCF, traditionally based on the so-called primary respiratory mechanism (PRM), relies on the anatomical and physiological link between the cranium and sacrum, including bone joint movements,

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intrinsic brain and spine movements, and the fluctuations of the cerebrospinal fluid (CSF) [4, 5]. Osteopaths define the cranial rhythmic impulse (CRI) as perceptible fluctuations in different areas of the body that are supposed to be related to the previously mentioned tissue and fluids and that can be utilized as a diagnosis and treatment. However, the nature of such palpable phenomenon is still unknown [6], and simultaneous palpatory findings at the head and sacrum showed inconsistent results [7, 8].

Some evidences suggested an OCF effect on several clinical conditions and physiological functions in adults [9, 10] as well as in children [11, 12]. However, data synthesis is inconclusive and highlighted both a poor reliability of diagnostic procedures and a methodologically low evidence about the effectiveness of OCF [13]. Despite this, OCF is commonly provided to patients [14], animating the debate about its use.

Some evidence about the physiological effects of OCF come from the study of the compression of the fourth ventricle (CV4), a technique commonly utilized by OCF practitioners. CV4 seems to affect nervous system functions and results in lower sleep latency [15], changes in blood flow velocity, and cerebral tissue oxygenation [16] to electrical brain activity modulation [17]. However, the CV4 physiological mechanism is far from being uncovered [18]. A preliminary study of 10 subjects showed changes in alpha-band power (AABP) at the occipital area after CV4 treatment [17]. The authors supposed that the CV4 could indirectly influence brain activity through its effect on the dynamics of CSF and, in turn, on a better cortical perfusion [16, 17]. This hypothesis led us to wonder if an OCF technique applied to the sacrum region could indirectly affect brain activity via the PRM.

An electroencephalogram (EEG), a non-invasive affordable method commonly utilized to record and analyze the brain's electrical activity [19], could be a useful tool for this purpose. EEG analysis, based on frequency domains typically attributed to a specific brain state, is characterized by high temporal resolution allowing the identification of cortical excitability within fractions of a second after stimulus exposure. Like the precedent study on CV4 [17], we analyzed alpha rhythm, which is typically associated with relaxation and is a well-established proxy of cortical excitability [20].

To our knowledge, no studies have explored the potential effect of a sacral technique (ST) on brain activity as an indicator of a neurophysiological connection between the occiput and sacrum. The aim of this study was thus to explore the EEG alpha-band activity during the application of a ST compared to the CV4 application.

Methods

Participants and ethical aspects

Volunteers were recruited via an advertisement among the students of the Istituto Superiore di Osteopatia (ISO) in Milan (Italy) in September 2018. Men 22–30 years old and women 20–30 years old were selected in order to minimize the differences related to the development and maturation of the central nervous system (CNS) [21]. A total of 46 healthy volunteers were screened, 40 of whom met the inclusion criteria.

Exclusion criteria were the use of psychoactive/psychotropic substances, cerebrovascular diseases, frequent headaches, the use of nicotine during the 24 h before the EEG recording, the use of alcohol and coffee during the 12 h before the EEG recording, and less than 6 h of sleep in the experimental session to avoid alterations in EEG recording [22–26].

The research coordinator (M.C.) explained the procedures to the volunteer students, assuring them that there was no academic penalty for not participating or withdrawing from the study. The research coordinator carried out the anamnesis and enrolled the participants through their signed informed consent. All data, including demographic characteristics and inclusion criteria, were anonymized and collected in a secured electronic file. The volunteers did not receive any compensation for participation.

The study protocol was reviewed and approved by an expert board of the ISO, according to the standards of the Declaration of Helsinki and the recommendations of the Italian Committee on Bioethics. This trial was not submitted to ethic committees because osteopathic medicine is still not officially recognized by law as a healthcare practice in Italy, so it is not included in the Italian national healthcare system. The study protocol has been registered on clinicaltrial.gov (NCT04492917). This research did not receive any specific grant.

Study design and randomization

The experimental study was conducted according to a randomized crossover design, in which all the subjects received a combination of active techniques (CV4 or ST) and the corresponding sham techniques (sham compression of the fourth ventricle [sCV4] or sham sacral technique [sST]), organized in two experimental sessions as specifically described in Figure 1. The EEG was continuously recorded during each intervention and the following 10 min, for a total of 50–60 min per session.

A researcher (V.P.), who was not involved in the primary study, randomized the participants into eight groups by utilizing a free software (www.random.org) and then communicated the allocation via mail to the osteopaths who carried out the interventions. The study experiments took place at the Centro di Medicina Osteopatica, in a silent room, with an artificial soft light to minimize sensory interferences [27]. During all of the procedures, the subjects kept their eyes closed. EEG recordings were made under the following conditions: with a constant sound noise, the same illumination, and the same EEG neurophysiologist (A.A.). The participants, the EEG neurophysiologist, and the data analyst (M.G.) were blinded to the allocation groups, yet the osteopaths were not.

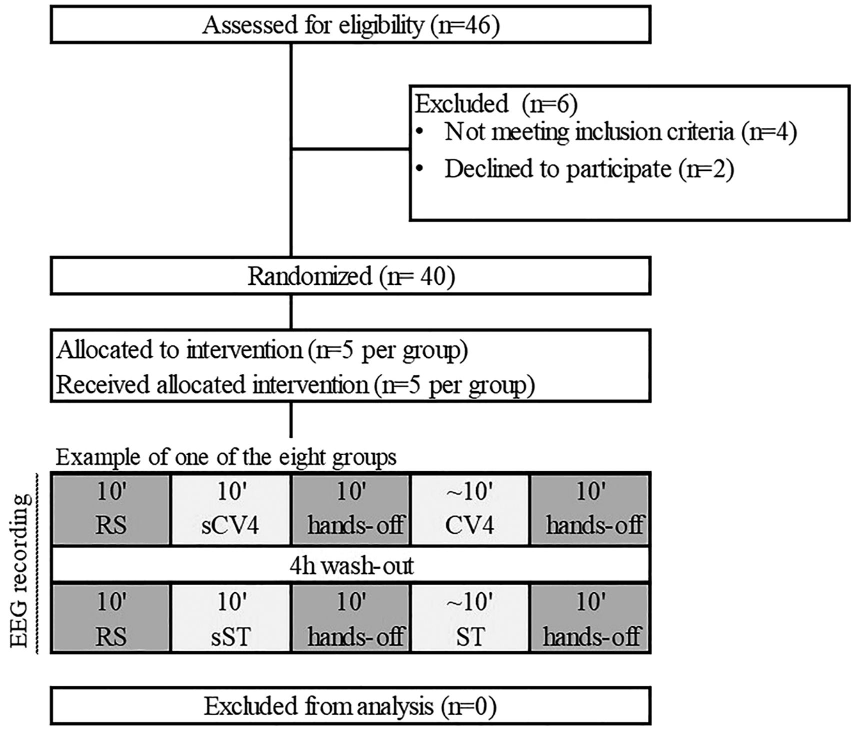

Figure 1: Study design and interventions. This randomized crossover study was organized into two experimental sessions separated by a 4 h washout period. During each session, the subjects first were lying down in a supine position at rest for 10 min, then they received two randomized techniques (CV4 plus sCV4; ST plus sST) for a total of eight possible combinations. The sham techniques lasted 10 min, while the active techniques lasted until the moment when the *still point* was no longer perceptible (6–8 min). The EEG was continuously recorded during each intervention (hands-on period) and the following 10 min (post-technique period, or hands-off period), for a total of approximately 50 min per session. In the first minute of registration, the data collector controlled for possible signal artifacts and set the instrument. CV4, compression of the fourth ventricle; EEG, electrocardiogram; sCV4, sham compression of the fourth ventricle; sST, sham sacral technique; ST, sacral technique; RS, resting state.

Table 1: Study interventions.

Technique	Description
Compression of the fourth ventricle (CV4)	The osteopath was sitting at the head of the examination table, while the subject was lying down in the supine position. The osteopath approximated his hands to the lateral angles of the subject's occipital squama, taking the subject's cranium in sustained extension. The technique ended when the osteopath was beginning to perceive the *still point*, the condition when the membranous or ligamentous tension is in balance.
Sacral technique (ST)	The subject was lying in the supine position, while the osteopath positioned his dominant hand under the subject's sacrum. Then, the osteopath established a point of balance according to the subject's CRI, facilitating his sacral extension until reaching the *still point*.
Sham techniques (sCV4 and sST)	Sham interventions were carried out with the hands in the same position of the corresponding active techniques by applying a nontherapeutic touch.

CRI, cranial rhythmic impulse; sCV4, sham compression of the fourth ventricle; sST, sham sacral technique.

Interventions

Two experienced osteopaths (M.M., E.A.), each with more than 5 years of clinical experience, participated in the study. To align their interventions, they undertook a training session one week before the study. Each subject group distribution, which received a specific combination of interventions, was balanced for the two osteopaths. Descriptions of the techniques utilized in this study are provided in Table 1.

Evaluation procedure and data analysis

Quantitative EEG recordings were made according to the 10–20 international system of EEG electrode placement with the 20-channel

Table 2: Means of the average alpha-band spectral power (AABP) at the different times.

	Resting state Mean (SD)	Active technique Mean (SD)	Post-active technique Mean (SD)	Sham technique Mean (SD)	Post-sham technique Mean (SD)
CV4 (μV^2)	28.352 (0.358)	29.280 (0.328)	37.530 (0.396)	30.307 (0.818)	29.955 (1.211)
ST (μV^2)	28.348 (0.300)	28.482 (0.376)	28.561 (0.407)	28.486 (0.316)	28.468 (0.398)

CV4, compression of the fourth ventricle technique; SD, standard deviation; ST, sacral technique.

Table 3: Comparison between the selected times and treatments (n=40).

	CV4			ST			CV4 vs. ST	
	Mean difference	t	*P*	Mean difference	t	*P*	t	*P*
Active technique vs. resting state	0.927	7.189	<0.001*	0.134	1.063	0.288	−49.137	<0.001*
Sham technique vs. resting state	1.955	15.153	<0.001*	0.139	1.099	0.272	−9.955	<0.001*
Active technique vs. sham technique	−1.027	−7.964	<0.001*	−0.005	−0.035	0.972	−5.606	<0.001*
Post-active technique vs. active technique	8.250	63.959	<0.001*	0.080	0.617	0.538	8.170	<0.001*
Post-sham technique vs. sham technique	−0.352	−2.731	0.007*	−0.018	−0.141	0.888	−0.334	0.068
Post-active technique vs. post-sham technique	7.575	5.873	<0.001*	0.093	0.722	0.471	41.015	<0.001*

CV4, compression of the fourth ventricle technique; ST, sacral technique. Pairwise T-test comparisons. *Significance level corrected for multiple comparisons with Bonferroni correction set at p<0.003 (0.05/18).

EEG System PLUS EVOLUTION (Micromed, Italy). The EEG signal was derived from the occipital O1 and O2 electrodes, the electrode impedance was kept below 10 kΩ, signals were band-filtered (0.01–100 Hz) and notch-filtered (50 Hz), and EEG was continuously recorded during each technique application and each resting state, with a 250 Hz sampling rate. The same adjustable nylon cap (CAP EEG SP, Micromed, Italy) was utilized for all subjects and remained on each subject's head during each phase of recording. The EEG neurophysiologist kept the subject's state of drowsiness under control during the EEG recording by utilizing an auditory stimulus. Ten epochs, with a duration of 60 s, were collected from the resting state, the sham, and the post-intervention (hands-off) times. Ten epochs, with a shorter duration, were collected from the active intervention times. To ensure the quality of the samples, the neurophysiologist visually controlled for free-artifact epochs and the presence of an alpha posterior dominant rhythm (PDR). All of the analyzed participants had an alpha PDR.

Statistical analysis

The analysis was carried out by utilizing a repeated-measure ANOVA within the linear general model framework. The model consists of a within-subject factor of time (resting state, sham technique, post-sham technique, active technique, post-active technique times) and a within-subject factor of treatment (CV4/ST). The interactions (*time x treatment*) of these two factors and their effects on the AABP were measured in a 10-min period and analyzed each 1-min epoch. The AABP difference was tested for each treatment between all times. Moreover, the pairwise differences between the two treatments were also compared (T-test).

The significance level (α) of the *time x treatment* effect (F-test) was set at 0.05. For the pairwise comparisons, the Bonferroni correction was applied, which led to a corrected α=0.003 (0.05/18). All analyses were conducted in R, version 3.5.3 (R Core Team, 2019).

Results

Forty healthy volunteers (mean age ± SD: 23.73 ± 1.43 years; range, 21–26 years; 16 males and 24 females) were enrolled to the study and completed the study protocol (Figure 1).

The AABP mean value and standard deviation for each time and treatment are reported in Table 2. The *time* × *treatment* interaction effect is statistically significant (F=791.4; p<0.001). Table 3 shows all the pairwise differences in the selected times. Regarding the CV4, both the active and sham techniques resulted in a significantly increased AABP mean compared to the resting state. The mean difference of CV4 compared to the resting state was 0.927 (p<0.001), whereas the mean difference of sCV4 compared to the resting state was 1.955 (p<0.001). The statistically significant and particularly high increase in mean AABP magnitude was recorded during the post-CV4, compared to both the CV4 (mean difference: 8.250, p<0.001) and post-sCV4 application (mean difference: 7.575, p<0.001). A representative AABP dynamic during intervention and the effects of the active techniques (CV4 and ST) on AABP compared to the related sham, recorded in the 10 min after the interventions (hands-off period), are shown in Figure 2 (panels A and B, respectively).

During the ST and sham ST applications, no statistically significant differences were registered with respect to the resting state. Moreover, no statistically significant changes occurred after the ST and sham ST suspension.

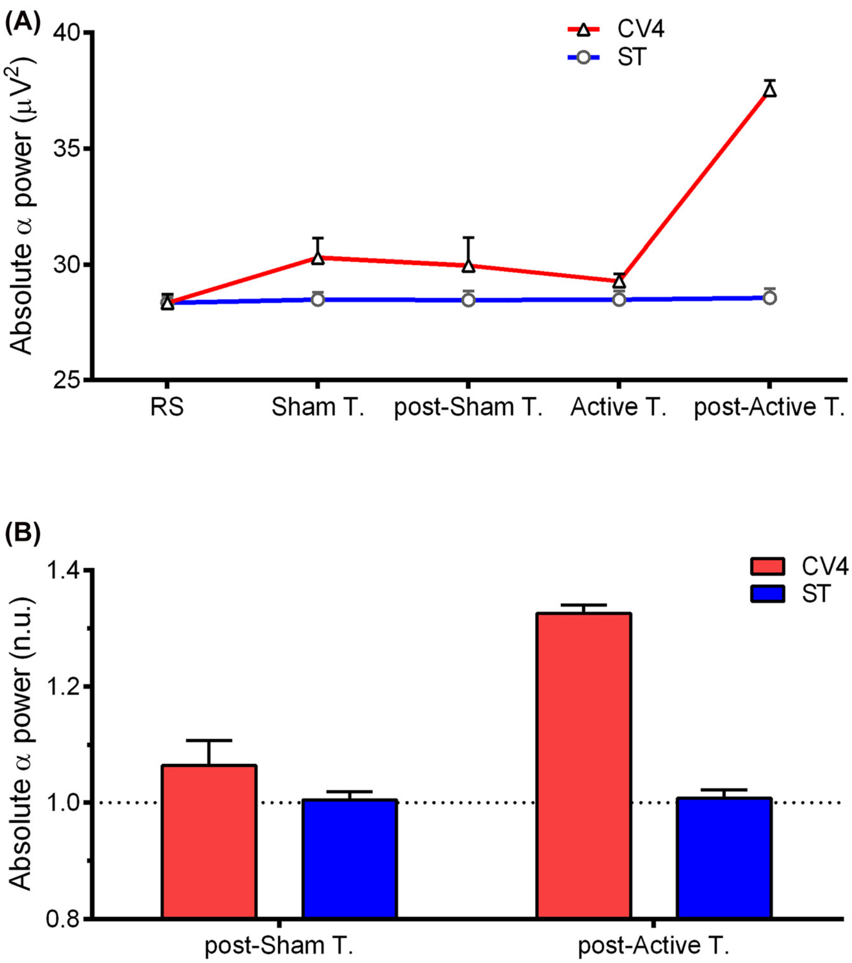

Figure 2: EEG response and dynamics during the active and sham techniques. (A) Representative dynamics of the average absolute alpha power during one of the eight combinations of the active techniques (CV4 or ST) and the corresponding sham techniques. Values are presented as mean ± standard deviation. (B) Effects of the active techniques (CV4 and ST) on the absolute alpha power compared to the related sham, recorded in the 10 min after the interventions (hands-off period). The average absolute alpha power was normalized to the average values of the resting state and expressed as normalized units (n.u.) ± standard deviation. CV4, compression of the fourth ventricle; EEG, electrocardiogram; ST, sacral technique.

The results reported show two distinct effects of the CV4 and ST techniques respectively. Such evidence is supported by the statistical significance of the CV4 vs. ST comparison (Table 3).

Discussion

This study investigated the EEG brain activity through occipital alpha power changes during the application of the ST compared to the cranial technique (CV4).

As expected, the CV4 technique significantly increased the alpha power rhythm in the occipital area, compared to the levels measured during the resting state. Such findings confirmed a preliminary evidence in which the alpha power level recorded in the post-CV4 increased [17]. Although both the sham and active CV4 showed a minimal but statistically significant increase in alpha power level during the interventions compared to the resting state, the significant effect of CV4 with respect to the sham was registered during the post-intervention recording, when the therapist's hands were removed from the subject's occiput after the perception of the so-called *still point*. During the application of the ST, no effect was observed for both the sham and active techniques during and after interventions, suggesting that the hypothesis of a neurophysiological link between the two techniques was inconsistent, at least over the occipital alpha rhythm.

The alpha rhythm (~8–13 Hz) is the most prominent brain rhythm associated with the awake resting state with the eye closed. A large but not exhaustive body of evidence links the alpha rhythm to several neurocognitive functions such as the visual attention and the visual perception through top-down control and memory [28]. However, its functional role is still controversial and the mechanisms underlying its generation are not fully understood [29]. Alpha oscillations in the visual cortex reflect a complex product of both thalamo-cortical and cortico-cortical interactions [30, 31]. The alpha rhythm is thus a complex brain signal whose functional relation with higher-order brain structures, including those underlying cognitive control, is still uncovered. In this scenario, we can only hypothesize provisional explanations about the functional effect of the CV4 on the occipital alpha rhythm, which cannot apply to the ST.

It is commonly thought that in a resting state with the eyes closed, EEG rhythms reflect a condition of relative behavioral relaxation and of inhibition of the brain mechanisms underlying the interaction with external stimuli and, more so, a state oriented to internal perception [32–34]. In particular, the alpha rhythm modulation is closely linked to changes in the direction of attention regardless of the presence of visual sensory inputs [35]. The CV4-related alpha power increase may thus suggest a condition of more internal attention and active inhibition of external sensory input. In support of this hypothesis is a recent study about the effect of OMT on the activation of specific brain interoception-related areas in patients with low back pain [36].

C-tactile (CT) fibers could mediate the interoceptive effect via touch, inducing a state of well-being [37]. The increase in alpha power level that we already observed during the hands-on period, under both the sham and CV4 treatments, could be intuitively associated with the touch effect. This hypothesis is supported by a study showing that cranial deep-touch modulates the parasympathetic nervous systems as well as the interoceptive system [38]. Instead, the specific increase observed during post-CV4 treatment (hands-off period) may result from a more complex mechanism indirectly activated by the CV4. This simplistic interpretation may also explain the null effect that we observed during the ST application, in which there was no skin-to-skin contact between the patient and operator. However, we cannot overlook that the few previous EEG studies on tactile stimulation suggested a general alpha suppression in different scalp areas, especially in the somatosensory cortex [39–41]. In particular, one study showed that touch, irrespective of CT-optimal speed, decreases alpha activity, mainly in the frontal and central scalp areas, whereas no differences were recorded in the occipital area when the patient's eyes were closed [41]. Although in contrast with our hypothesis, it should be noted that these results cannot discriminate the specific touch effect from the subject's alertness/attention state during EEG alpha activity.

The results of our study apparently link the occipital EEG alpha increase to the 10 min after the therapist perceived the *still point* and removed his hands from the patient's occiput. Two studies correlated the CRI to the Traube-Hering-Mayer (THM) oscillations [42, 43]. The authors showed that the CV4 application results in an amplification of the 0.1 Hz low-frequency oscillations in blood flow. This effect is particularly evident 10 min after the *still point* was perceived [42]. The 0.1 Hz component of THM oscillations is believed to depend on the sympathetic subsystem of the baroreflex blood pressure regulation [44]. The local increased blood flow that occurred during the post-CV4 probably activated baroreceptors, resulting in decreased cardiac sympathetic activity and increased vagal output to the heart [16, 45]. The concomitant increased occipital alpha power that we observed is consistent with an overall physiological relaxed state [46], anecdotally described by osteopaths, in response to the CV4 [6]. Moreover, a study provided interesting evidence on the causal coupling among the neuronal activity, the microvascular hemodynamics and blood supply oscillations in the 0.1 Hz frequency range [47]. The results of this study suggested that the THM waves connected with blood pressure oscillations seem to be the primary cause of amplitude fluctuations in the central alpha and beta rhythms. This evidence could partially provide a mechanical explanation of the CV4 effect on the neuronal activity. However, it should be noted that the blood-oxygen-level dependent (BOLD) oscillations in the 0.1 Hz frequencies also have a neural origin [48], suggesting that such complex mechanisms may also be influenced by cerebral structures [47].

In our study design, the ST did not have an effect on occipital alpha brain activity either during or after treatment. None of the previously mentioned functional hypotheses may apply to sacral treatment. Previous studies showing OMT effects on brain activity [49–51] included cranial treatment in a general OMT approach addressing somatic dysfunctions. Their results supported the osteopathic concept that a whole-body intervention may exert more evident central effects and, in turn, assume a more clinical significance, differently from a single technique in healthy volunteers. However, this may explain, only in part, the null immediate effect of ST on occipital alpha brain activity. Moreover, if the ST may affect the cerebral hemodynamics or neuronal activity through the whole system of the PRM, we probably cannot monitor this effect through occipital alpha rhythm fluctuations. Likewise, the ST does not induce a more relaxed state.

The clinical significance of increased occipital alpha rhythm is limited if this signal is analyzed separately from other brain regions and other frequency signals. Several pathologies show altered alpha EEG patterns during spontaneous or event-related activity, mainly in neuropsychiatric disorders [52]. Moreover, changes in alpha rhythms correlate to high-level sports performance in healthy athletes [53]. Further studies are needed to investigate the possible alpha effects of the CV4 technique on this type of patient. For OCF practitioners, our results should have implications for clinical reasoning, with the awareness that OCF tradition considers the cranium and sacrum a unity of structure and function, yet a technique to the sacrum may not induce the same neurophysiological effects of the one to the cranium.

Limitations

Because we started from an unvalidated physiological hypothesis, the occipital alpha activity could not have represented the correct biological marker to study the connection between the occiput and sacrum during an osteopathic sacral approach. Due to the exploratory nature of this study, we captured only the occipital alpha EEG signal in the eye-closed condition. Simultaneous analysis of other cortical rhythms (e.g., the mu rhythm overlying the sensorimotor cortex) and other sensory nerve conduction (SNC) markers would have provided more information about the specific effect of the cranial therapy mediated by touch; this could be an area for future research. Finally, the participants in this study were osteopathy students, mainly in their first academic year. Although we are inclined to think that the participants did not recognize the treatment received, we cannot firmly rule out the influence that expectation or the attentive state may have exerted on their alpha power expression.

Conclusions

This study supported previous evidence that the osteopathic cranial technique CV4 produces immediate effects on occipital alpha brain activity. ST does not induce the same results, suggesting that OCF therapy should be investigated on a different biological basis.

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Competing interests: None reported.
Informed consent: All participants in this study provided written informed consent prior to participation.
Ethical approval: Istituto Superiore di Osteopatia approved the study protocol according to the standards of the Declaration of Helsinki and Good Clinical Practice Guidelines. The study protocol has been registered on clinicaltrial.gov (NCT04492917).

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