



The importance of nGVS current density for postural control enhancement



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Noisy galvanic vestibular stimulation
Postural stability
Current density
Vestibular system

Introduction

Noisy galvanic vestibular stimulation (nGVS) is a non-invasive approach used to stimulate the vestibular end organs through the application of an imperceptible noise by means of multiple electrical currents. Adding noise to the vestibular system has been shown to elicit the mechanism of stochastic resonance (SR), which enhances information processing and detection of subthreshold signal. Recent studies demonstrated that nGVS has therapeutic potential and that it induces a sustained enhancement of postural stability in young adults, healthy elderly and in patient with bilateral vestibulopathy [1–4].

Despite the postural control enhancing effect of nGVS reported by several studies [1–4], the optimal stimulation procedures and parameters have yet to be defined and as such differ widely across studies.

Current density has been shown to be an important stimulation parameter to consider when investigating the effect of transcranial electrical stimulation (tES) [5–8], but there is no evidence of its importance, or lack thereof, for postural stability when applying nGVS. Current density is defined by current intensity divided by electrode size (surface area). Unfortunately, previous studies did not report electrode size and current density. Here we aimed at investigating the importance of current density on postural control by examining the effects of two different electrode sizes.

Methods

36 adults were recruited and they randomly received either nGVS applied with 3 cm² electrodes [n = 12; mean age: 22.92 ± 1.62], or with 35 cm² electrodes [n = 12; mean age: 22.75 ± 1.54], or sham stimulation [n = 12; mean age: 23.75 ± 3.25]. Participants underwent a complete peripheral vestibular assessment as described previously by Maheu et al. [9].

The static postural control assessment consisted of standing a foam surface (AIB Balance Foam, AIB, USA) placed on a platform (Accusway, AMTI, USA) with eyes closed. Center of Pressure (CoP) sway was measured three times at two measurement time points i) prior to stimulation (baseline), and ii) following the end of stimulation (T0). The first two CoP measurements were practice trials to acclimatize the patient to this unusual postural condition, and only the third measurement was analyzed. The CoP parameters recorded were sway velocity and path length, and they were analyzed using Balance Clinic software (AMTI, USA).

nGVS was applied using DC-Stimulator Plus (NeuroConn GmbH Germany). The stimulation intensity was set to 1 mA, a setting previously demonstrated to improve postural control in adults [1]. The noise ranged between 0 and 640 Hz and stimulation was applied for 30 minutes while the subject was sitting. An electrode was placed on each mastoid process to stimulate the vestibular end organs. Two different electrodes sizes were used to apply nGVS: one group was stimulated with 35 cm² electrodes and the other group with 3 cm² electrodes. The current density was 0.03 mA/cm² with 35 cm² electrodes and 0.33 mA/cm² with 3 cm² electrodes. The control group underwent the same experimental procedure but received a sham stimulation consisting of the current ramped up to 1 mA for 30 seconds and then ramped down. The sway velocity and path length values were normalized by the value at baseline, and the stimulation effect was calculated as the difference between baseline value and T0 value.

Results

Changes in sway velocity and path length following the application of nGVS are displayed in Fig. 1. The repeated measures ANOVA 3 groups (35 cm², 3 cm², sham) X 2 times (Baseline, T0) for sway velocity revealed a significant interaction (Group x Time) [F(2,33) = 7.588; p = 0.002] and a significant main effect of group [F(2,33) = 7.588; p = 0.002]. Post hoc analysis using Bonferroni correction revealed a significant difference between 3 cm² and sham (p = 0.01) and between 3 cm² and 35 cm² (p = 0.003). No significant difference was found between nGVS applied with 35 cm² and sham stimulation (p = 1.000). For path length, the repeated measures ANOVA 3 groups (35 cm², 3 cm², sham) X 2 times (Baseline, T0) also revealed a significant Group x Time interaction [F(2,33) = 6.848; p = 0.003] and a significant main effect of group [F(2,33) = 6.848; p = 0.003]. Post hoc analysis using Bonferroni correction showed that the 3 cm² group significantly differed from the 35 cm² group (p = 0.007) and sham group (p = 0.012). No significant difference was found between nGVS applied with 35 cm² and sham stimulation (p = 1.000).

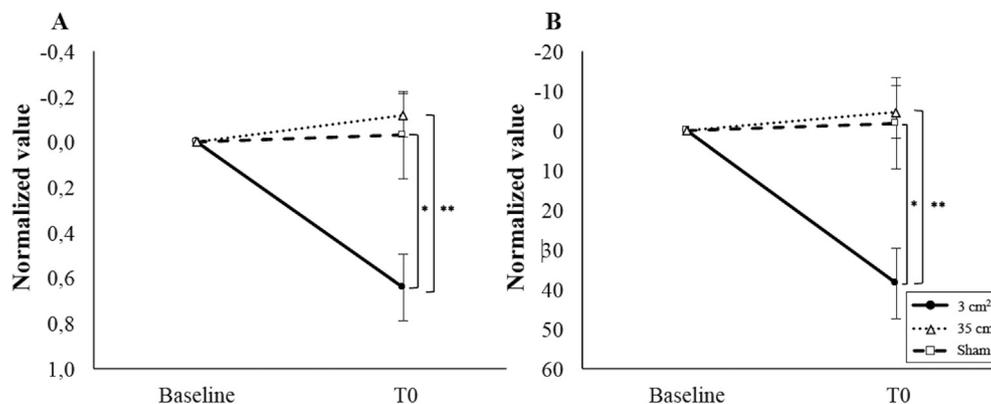


Fig. 1. Sway velocity (A) and path length (B) for groups receiving nGVS applied with 3 cm² and 35 cm² electrodes and in the sham group at each time point (Baseline; T0). Results suggest a significant improvement of sway velocity and path length at T0 induced by nGVS applied with 3 cm² compared to nGVS applied with 35 cm² and sham group. Error bars represent the standard error of the mean. * = $p < 0.05$; ** = $p < 0.01$.

Discussion

The results revealed that nGVS applied with electrodes of 3 cm² surface area induced a significant improvement of postural stability, but nGVS applied with electrodes of 35 cm² surface area did not. The significant difference found emphasizes the importance of current density on the effect of nGVS on postural control enhancement. To our knowledge the effect of current density when applying nGVS and its effect on vestibular end organs and postural stability were unknown until now. The present study demonstrated that when applying electrical stimulation, a higher current density induced a significant effect, whereas a lower density did not. This result is in line with a previous meta-analysis [6]. Results revealed that a higher current density can improve postural control and this is in line with results of tES studies [5–8].

The improvement of postural stability observed specifically with the smaller electrodes could also be related to nGVS focality. Stimulation with electrodes of 3 cm² may be more focalised on the vestibular end organs than electrodes of 35 cm² which by definition stimulate a larger area. To our knowledge there is no evidence of specific nGVS focality effects, but it is well established that other stimulation techniques, including transcranial direct current stimulation, have a reduced focality and the stimulation pattern is diffuse, which results in a wider stimulation area and causes unwanted effects [6,10]. Our results could suggest that increasing the focality of nGVS by decreasing electrodes size may induce a more efficient postural control enhancement effect. However, since current density varied between the two electrode sizes, a putative influence of stimulation focality remains undetermined. Future studies should consider applying a similar current density across the different electrode sizes used.

Conflicts of interest

The authors have no conflicts of interest to declare.

Acknowledgements

M.N., M.M., and F.C. designed and performed the experiment. M.N., M.M. and F.C. did data analysis. M.N., M.M., B.A.B., and F.C. wrote the article. All authors discussed the results and commented on the manuscript at all stages.

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