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Supine posture inhibits cortical activity: Evidence from Delta and Alpha EEG bands

Chiara Spironelli [a,b,*], Jessica Busenello [a], Alessandro Angrilli [a,b,c]

[a] Department of General Psychology, University of Padova, 35131 Padova, Italy
[b] CCN – Center for Cognitive Neuroscience, 35131 Padova, Italy
[c] CNR Institute of Neuroscience, 35121 Padova, Italy

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ABSTRACT

Past studies have shown consistent evidence that body position significantly affects brain activity, revealing that both head-down and horizontal bed-rest are associated with cortical inhibition and altered perceptual and cognitive processing. The present study investigates the effects of body position on spontaneous, open-eyes, resting-state EEG cortical activity in 32 young women randomly assigned to one of two conditions, seated position (SP) or horizontal bed rest (BR). A between-group repeated-measure experimental design was used, EEG recordings were made from 38 scalp locations, and low-frequency (delta and alpha) amplitudes of the two groups were compared in four different conditions: when both groups (a) were seated (T0), (b) assumed two different body positions (seated vs. supine conditions, immediate [T1] and 120 min later [T2]), and (c) were seated again (T3). Overall, the results showed no *a priori* between-group differences (T0) before experimental manipulation. As expected, delta amplitude, an index of cortical inhibition in awake resting participants, was significantly increased in group BR, revealing both rapid (T1) and mid-term (T2) inhibitory effects of supine or horizontal positions. Instead, the alpha band was highly sensitive to postural transitions, perhaps due to baroreceptor intervention and, unlike the delta band, underwent habituation and decreased after a 2-h bed rest. These results indicate clear-cut differences at rest between the seated and supine positions, thus supporting the view that the role of body position in the differences found between brain metabolic methods (fMRI and PET) in which participants lie horizontally, and EEG-MEG-TMS techniques with participants in a seated position, has been largely underestimated so far.

1. Introduction

The vertical stance is one of the most important achievements of the human species during its evolution. One probable direct consequence is that our everyday activities (e.g., working, driving, reading) are mainly carried out in upright or seated positions, whereas when we are resting or sleeping, we are generally supine. Also when working in the experimental domain, the supine position is usually mandatory when research aims at studying the physiological correlates of sleep (Skopin et al., 2015; Yilmaz et al., 2014). Among all EEG spectral components, delta and alpha rhythms are reliable indexes of cortical inhibition not only during sleep but also in awake adult individuals who are not engaged in specific cognitive tasks (Cantero et al., 2002; Czisch et al., 2002; De Jongh et al., 2003; Laufs et al., 2003). There is also relatively limited literature concerning weightlessness and space medicine (i.e., the study of the aftereffects of space environment on human health) on the effects of body posture on brain functioning. For example, in order to study interactions between the cardiovascular system and brain activity, Vaitl and colleagues (Vaitl et al., 1996; Vaitl and Gruppe, 1990, 1992) asked participants to adopt various orthostatic positions in order to simulate microgravity. In one experiment (Vaitl et al., 1996), participants lie in bed for 23 h in a 6° head-up or 6° head-down (the body position which most mimics space weightlessness). Electrophysiological activity, startle responses and reaction times were recorded every 2 h. EEG spectral analyses revealed that participants had increased delta and theta frequency bands in the head-down position, matching results from previous works (Vaitl and Gruppe, 1992, 1990). In addition, they showed increased reaction times (i.e., worse performance) with respect to the 6° head-up position (Vaitl et al., 1996). The increase in low-frequency EEG bands was associated with cardiovascular deconditioning, i.e., altered control of baroreceptor reflexes and blood pressure, which may represent one of the bottom-up physiological mechanisms linking postural/

* Corresponding author at: Dipartimento di Psicologia Generale, Via Venezia 8, 35131 Padova, Italy.
E-mail address: chiara.spironelli@unipd.it (C. Spironelli).

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cardiovascular changes to inhibition of cortical arousal (Dworkin et al., 1994; Lipnicki, 2009). Consistent with these results, a more recent study (Messerotti Benvenuti et al., 2011) revealed a lack of startle reflex habituation in male participants submitted to a 3-h head-down position compared with sitting controls, a result which indicated both reduced learning – reflex habituation being a form of learning – and short-term brain plasticity. Head-down bed rest also induced a significant inhibition of cortical emotional responses (i.e., P3 and Slow Positive Potentials) elicited by pleasant and unpleasant IAPS slides (Messerotti Benvenuti et al., 2013), matching past literature on the inhibitory effects of body posture on both perceptual and cognitive processing. Spironelli and Angrilli (2011) carried out a study on pain-related potentials in a sample of young healthy males lying head-down for 2 h and showed that, compared with a seated control group, the bed-rest group showed significantly reduced pain sensitivity, both considering the subjective perceptual domain and the amplitude of the P1, N1 and P2 pain-related components. Interestingly, also the horizontal body position – i.e., a less extreme and more ecological position – was able to influence pain-related somatosensory processing in healthy women, supporting the hypothesis that posture alters sensory and cortical thresholds (e.g., Fardo et al., 2013) and, more in general, EEG activity (Chang et al., 2011; Rice et al., 2013). Although all these studies agreed on the general effects of body position on brain functioning, showing selective inhibition of a few specific and complex perceptual/cognitive abilities, they also showed that EEG methods appear particularly suitable for studying cortical brain activity in very different conditions (e.g., early and late pain responses), including body position. This peculiar aspect cannot be extended to neuroimaging techniques such as (functional) Magnetic Resonance Imaging and PET, in which experimental settings require participants to lie supine during active cognitive processing and task execution (e.g., Yang et al., 2014). It should be noted that, although there are some MRI scanners designed for recording from seated/standing subjects, they are based on low magnetic fields which do not allow such good fMRI sequencing as that reached by standard fMRI scanners, in which, however, participants are necessarily forced, by the geometry of the instrument, to lie supine during task execution and data acquisition (e.g., Fransson et al., 2014; Yang et al., 2014).

Very recently, both Messerotti Benevenuti et al. (2013) and Thibault et al. (2014) raised the question of how body posture affects cortical brain activity, and suggested that systematic brain imaging results obtained from supine subjects are not specific, generalizable and ecological. However, these authors implicitly assumed that it is not possible to generalize these findings to processes which mainly occur in seated/upright positions. Thibault et al. (2014) emphasized how EEG could be used to verify how posture affects cortical processes in both the resting state and during task execution. They examined participants' spontaneous EEG activity in four different positions (standing, seated, inclined supine at 45°, supine) and showed that high-frequency activity progressively increased from supine to 45° and still more to the upright position. In addition, in this study no posture effects have been found in low-frequency EEG bands (delta, theta and alpha power). The lack of effects in the low-frequency EEG bands was probably due to the particular experimental design adopted, in which participants randomly assumed four different positions and EEGs were recorded in four counterbalanced conditions, i.e., eyes open/closed, with/without a mental counting task, with a short 30-s interval for adaptation to the new body position (not analyzed) and 30-s recordings intervals for each condition. This design does not allow detection of the mid- and long-term effects which typically occur in postures lasting one or more hours.

The present study raises an important issue on the comparability of brain metabolic measures, typically carried out on supine participants, with those carried out with seated subjects (e.g., TMS and EEG) and on the unavoidable and not fully ecological conditions in which most metabolic studies are carried out. In addition, research in this field has important clinical implications, as it shows how supine condition, typical of hospitalized old patients, may lead to rapid cognitive decline which need to be contrasted with specific protocols or countermeasures.

Thus, we examined the effects of a 2-h horizontal body position on spontaneous EEG cortical activity in 32 young healthy women, subdivided into two groups, one supine and one seated (control) group. From past literature, it is not clear what the effects of short- vs. mid-term postural changes are on slow EEG bands, i.e., the delta and alpha spectral bands. If different effects of posture are seen for the two bands, they may depend on intermediate physiological mechanisms at work (e.g., baroreceptor, blood flow and perfusion to the brain, etc.) on specific networks. The adopted experimental design allowed us to examine both short- (minutes) and mid-term (hours) effects of postural changes. As mentioned above, past studies on open-eyes head-down bed rest have provided evidence of the effects of body position on low- but not high-frequency EEG rhythms (Vaitl et al., 1996), whereas recent research on horizontal bed rest has demonstrated the opposite effects on low- and high-frequency EEG bands (i.e., low-frequency decreased and high-frequency increased when upright compared to supine (Chang et al., 2011) or no effects on low-frequency EEG bands (Thibault et al., 2014)). However, the former study was carried out while participants kept their eyes closed and their cortical activity was measured at C3-C4 sites only, whereas the results found by Thibault et al. (2014) were achieved during both eyes open and eyes closed recordings by a high-density (128-channel) acquisition system. In addition, past studies of Vaitl et al. (1996) and Thibault et al. (2014) addressed different aspects of postural change (long term vs. short term effects). For this reason, in the present study low-frequency cortical activity (delta and alpha EEG bands[1]) was analyzed, and four EEG measurements were collected while participants were open-eyed and relaxed during the following intervals: (T0) both groups seated, (T1, a few minutes after T0) seated (SP) and supine (BR), (T2) after 120 min[2] of SP and BR positions and (T3), both groups seated again (Fig. 1). The first two measures allowed us to compare the EEG activity of various groups assigned to specific conditions. In particular, the between-group contrast on T0 excluded *a priori* EEG differences in the random assignment of participants to groups SP or BR, whereas EEG group comparison highlighted the rapid (T1) or mid-term (T2) effects of the seated vs. supine positions. In line with past literature (Vaitl and Gruppe, 1992; Vaitl et al., 1996; Chang et al., 2011, limited to C3-C4 sites only) based on head-down bed rest, we also expected that, in the horizontal position, we would find a significant increase in slow EEG band amplitude in T1 in group BR compared with group SP. We also expected a steady increase in delta and alpha amplitude in T2 in group BR compared with group SP (similar to those shown in T1), but not in T3. Therefore, the last EEG recording (T3) measured the slowing effects of a body posture maintained for 2 h on brain activity soon after return to a sitting position.

[1] We carried out analyses selectively on Delta and Alpha EEG bands as their functional meaning is unanimously recognized, in the awake state, as indices of cortical inhibition (see Discussion, for a more detailed description of both rhythms), whereas interpretation of Theta activity is still controversial (e.g., inhibition according to Vaitl and Gruppe (1996) or working memory functioning (Sauseng et al., 2004)) and we therefore did not plan, for Theta band, any *a priori* hypotheses.

[2] Several past head-down bed-rest studies have shown that an interval of at least 60 min reveals sustained alteration of cortical functioning: in the present study, we adopted a less extreme and more ecological position – i.e., horizontal body position – and selected a more appropriate time interval to highlight both rapid (T1) and mid-term (T2) effects of the seated vs. supine/horizontal position.