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ORIGINAL ARTICLE

Gender Differences in Quantitative Electroencephalogram During a Simple Hand Movement Task in Young Adults

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ABSTRACT

Background: No consensus has been reached regarding the existence of gender differences during motor tasks in electroencephalography. This could lead to misinterpretation of electroencephalography clinical diagnosis and affect the calibration of brain-computer interfaces. **Objective:** To assess whether there are statistically significant gender differences in electroencephalography recorded during hand movements. **Methods:** Electroencephalography data were recorded from 18 women and 18 men while performing hand movements and rest. Electroencephalography power was computed for alpha (8-13 Hz), beta (14-30 Hz), and a broader band including alpha and beta (8-30 Hz) using wavelet transform. Statistical analysis was done using a General Linear Model for repeated measurements ($\alpha = 0.05$). Additionally, topographic maps were computed for each gender. **Results:** Significant gender differences were found for the rest condition in all analyzed bands. For the hand movement tasks, gender differences were mainly found in the beta band and located in temporoparietal areas. Power decrease observed in topographic maps was located in the centro-parietal areas for females and the centro-frontal areas for males. Additionally, greater power decreases were observed for women in all analyzed frequency bands. **Conclusion**: Electroencephalography parameters used for the diagnosis of neuromotor diseases, as well as for brain-computer interface calibration, must take gender into account. (REV INVES CLIN. 2016;68:245-55)

Key words: Alpha rhythm. Beta rhythm. Electrophysiology. Sensorimotor cortex. Wavelet analysis.

INTRODUCTION

Several studies have intended to show the anatomical and physiological differences in the nervous system between men and women[1]. These differences may seem obvious, but they have not always been demonstrated, although the studies assessing them have been conducted under rigorous methodologies. In this regard, one of the issues that has been extensively studied is the difference in the performance of motor skills. There are some studies that suggest a male superiority in gross motor skills such as ball skills[2] and simple

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index finger tapping[3,4], while the performance of females was often found to be superior to males in fine motor skills such as hand writing tasks[5] and pegboard tasks[3]. However, other studies with similar tasks have found no significant gender differences[6-8]. Most of these studies have been conducted in school children using neuropsychological tests. The reason for these differences could be due to anatomical sex dimorphisms[9-12] or to dissimilarities in functional cerebral organization[13-15], which have been analyzed using imaging studies. Although there are several studies related to the matter, there is still no consensus on whether there is a real biological difference in the performance of motor skills between men and women.

Quantitative electroencephalography (EEG) is an important tool in the analysis and understanding of movement. Currently, EEG features in time and frequency domain related to movement have applications in the field of clinical diagnosis and in the design of devices known as brain-computer interfaces (BCI). In clinical diagnosis, markers for assessment of motor-related conditions have been described in EEG elicited during motor execution. Some of these conditions are amyotrophic lateral sclerosis[16], progressive myoclonic epilepsy[17], cerebral palsy[18], and spinal cord injury[19]. In the field of BCI, changes in EEG are primarily elicited by means of motor imagery, which has been demonstrated to activate similar cortical areas such as motor execution[20-22], and are used to control external devices. Although most BCI systems are tailored to the user's EEG features, some of them have been designed to be calibrated with EEG data from a group of subjects in order to reduce calibration time of the system, which are known as subject-independent BCIs[23].

Since both subject-independent BCIs and quantitative EEG markers for motor-related conditions rely on EEG data extracted from a population, gender differences could produce a source of high variability that could lead to misinterpretation and poor performance of the mentioned applications. To take this variability into account, an analysis of EEG features needs to be done during the performance of motor skills. Some research groups have reported gender differences in EEG power amplitude across frequency bands in resting conditions. These studies have found that females had higher power amplitudes in the alpha band during rest than males[24,25]. Other studies have shown gender differences in the EEG associated to the performance of cognitive tasks. Significant gender differences during a simple visual-evoked potential were found in the EEG delta, beta, and gamma frequency bands[26], with the females having higher power amplitudes; however, no gender differences were found in the alpha frequency band. During REM sleep, a higher alpha and delta amplitude for the female gender was also reported[27]. Studies related to mental rotation have also found significant gender differences in EEG power[28,29]. Few researchers have studied gender differences in EEG activity when performing voluntary movement execution; e.g. index finger movements from both hands after an acoustic stimulus showed a higher normalized activation for women in frontal electrodes, while for men a higher activation was shown in the temporoparietal regions[30].

Since several studies have found significant gender differences in EEG features during rest and cognitive tasks, it might also be possible to find gender differences during motor execution. The main goal of this paper is to determine whether significant gender differences are elicited in EEG spectral power features, while performing simple hand movements, and how these changes are influenced by frequency band, spatial, and time feature selection of the EEG. These differences could affect the outcomes of studies that aim to use time and frequency EEG data for the assessment of motor-related diseases or affect the performance of BCIs.

MATERIAL AND METHODS

Participants

We recruited 40 healthy young adults; four subjects were excluded prior to data analysis due to excessive blinking artifacts. Therefore, this study was performed with data from 18 females and 18 males. Age range for the total sample was 21-30 years with mean of 26.31 years and standard deviation (SD) of 2.99 years. The mean age for the female group was 26.33 years with a SD of 3.27 years, while for males the mean age was 26.28 years and SD of 2.78 years. A non-paired *t*-test revealed no statistical differences between the mean age of both groups ($t[34] = 0.055$; $p = 0.9516$). All participants were students with right hand dominance for writing, with normal or corrected-to-normal vision, and without a history of psychological diseases or brain injuries. An expert in clinical electrophysiology discarded any abnormality in the EEG using a qualitative approach. An expert in neuropsychology evaluated the ability of participants to follow instructions and concentrate on repetitive tasks without being distracted by other stimuli. This was done using the subscales of digit detection and visual detection of the neuropsychological test NEUROPSI Attention and Memory[31]; this test was developed and standardized for Spanish-speaking populations. All the participants achieved a normal performance in the NEUROPSI test. The participants signed an informed consent approved by the Ethics and Research Committee of the National Institute of Rehabilitation in Mexico.

Experimental task

Subjects were seated in a comfortable armchair. Visual cues were presented in the screen of a personal computer. The instructions were explained before starting the EEG acquisition. The experimental paradigm is extensively described in a previous work[23]. Participants performed real movements and motor imagery of both hands (continuous opening and closing of the left or right hand). In the present work, only the trials comprising rest with eyes opened and real movement were analyzed.

Each trial lasted eight seconds (three seconds for rest and five for hand movement) and was repeated 20 times; the right and left cues appeared randomly 10 times each to avoid the participants' habituation. The average frequency for grasp movement of all participants was approximately 0.6 Hz. From the EEG signals, we extracted 10 time segments of right hand movement, 10 of left hand movement, and 20 of the resting task.

EEG signal acquisition

The EEG data were recorded with a Nicolet® amplifier model NicONE (California, USA) with 32 channels and 16-bits resolution at a sample rate of 256 Hz. Twenty-two gold electrodes were located over the scalp according to the international 10-20 system of electrode placement. Ground and reference electrodes were located in the central forehead line. Electrodes were also placed in the orbicularis oculi muscle on both eyes to record their movements. The skin surface was lightly abraded to reduce the impedance between the skin and the electrode. Electrode impedances were kept below 5 kΩ. Electromyography (EMG) electrodes were placed in both arms above the deep flexor and superficial muscles of the fingers to verify that the subjects correctly performed hand movements on the specified time intervals. We analyzed 11 electrodes (F3, F4, C3, C4, P3, P4, T3, T4, Fz, Cz, Pz) located over the sensorimotor cortex since this area is involved in the central nervous system's processing of movement execution. The brain processes related to movement have been correlated in quantitative EEG with cortical oscillations known as mu rhythm, within a frequency range of 8-13 Hz (the same frequency range as the alpha rhythm), and beta rhythm, within a frequency range of 14-30 Hz. More specifically, voluntary movement is identified in the EEG as a suppression of power called event-related desynchronization (ERD) or an increase of power called event-related synchronization (ERS)[32].

All the recordings were conducted under consistent conditions: constant sound noise, same illumination, and same experimenter. Control records with intervals of open eyes and closed eyes were recorded before the movement tasks to evaluate basal brain activity of the participants.

Signal pre-processing

The technique known as common average reference (CAR) was used to generate a more ideal electrode reference for the EEG recordings. In CAR, the average value of the entire electrode montage is subtracted from that of the channel of interest. Because it emphasizes components that are present in a large proportion of the electrode population, CAR reduces such components, including movements and blink artifacts. Uncorrelated random noise with a zero mean is minimized through the averaging process[33]. After that, the re-referenced EEG signals were band-pass filtered from 8 to 30 Hz and a band-stop filter of 59-61 Hz was used to reduce line artifacts.

Time-frequency analysis

The method used to compute the EEG power for each trial and channel is based on a time-frequency wavelet decomposition of the signal. The main advantage of this approach is that it provides a better compromise between time and frequency resolution than methods using Fourier transform[34].

The EEG signal was convoluted by complex Morlet wavelets[35], having a Gaussian shape in both the time domain and the frequency domain around its central frequency f_0, as explained by Tallon-Baudry, et al.[36]. In our analysis, the wavelet family used is defined by a ratio (parameter that determines the width of the wavelets in number of cycles) of six, with f_0 ranging from 8 to 30 Hz with a resolution of 0.5 Hz. The analysis was performed in the time interval of 1-7 seconds (s) of each trial.

For each task and EEG channel, we computed the average power in two time windows: for the rest condition (REST) power was averaged from 1 to 3 sec and, for the left hand movement (LEFTMOV) and right hand movement (RIGHTMOV) power was averaged from a time window ranging from 3.5 to 7.0 sec. The first 500 ms following the movement cue onset of each time-frequency representation were not used for data analysis, since it was observed that EEG changes elicited during motor execution are detected in the signal with 300-500 ms of delay. The frequency bands used to extract the above-mentioned windows are alpha (8-13 Hz), beta (14-30 Hz), and their combination (8-30 Hz), named in this study, alpha-beta. This last band was selected because, in many BCI experiments, a broad frequency band is selected in order to select features for the processing stage[37,38]. A database was built with the averaged power values from the 10 trials, for 11 EEG channels and the three performed tasks. Data from only 10 randomly selected REST windows was used for data analysis.

In order to visualize cortex activations during hand movement, relative changes of power with respect to a baseline interval (from 1.5 to 2.5 sec) were calculated. Grand-averaged topographic maps for each gender were obtained for alpha, beta, and alpha-beta frequency bands.

All EEG signals were read, preprocessed, and processed using the Matlab® R2014b software and the free license toolbox Fieldtrip[39].

Statistical analysis

Since we have repeated measurements of the same variable, and these were computed under different conditions on the same subjects, we used a general linear model (GLM) with repeated measures to analyze the averaged power data. For every frequency band, we used a mixed design with 10 × 3 × 11 (trials by tasks by channels) within-subjects factors (repeated-measures) and gender as between-subjects factor. The dependent variable is the EEG power (μV^2) in each condition. GLM were performed to analyze main effects, three-way interactions, and simple main effects to communicate these interactions. The EEG power in every trial was analyzed to determine if gender differences could be found along time, despite inter-trial variability. The significance values were calculated for 95% confidence ($\alpha = 0.05$). Simple main effects were computed using a Bonferroni correction. Statistical analysis was performed using the SPSS v.17 software.

RESULTS

Statistical analysis revealed significant main effects of 10 different trials, 11 electrodes located above the sensorimotor cortex and three tasks (right hand movement, left hand movement, and rest) in the three analyzed frequency bands. The effect of gender was statistically significant only in beta and alpha-beta bands. There was no statistically significant three-way interaction between the effect of trials, task, and gender, except in the alpha band (Table 1).

Since we did not have significant three-way interactions, we analyzed simple main effects to determine if there were gender differences at each level of task, trials, and channels. We plotted the estimated marginal means for simple main effects between: trials × task × gender, trials × gender × task, channel × tasks × gender, channel × gender × task. Statistically significant values were obtained from the pairwise comparisons tables and marked by an asterisk in the plots shown in figures 1 to 4.

Gender differences across trials

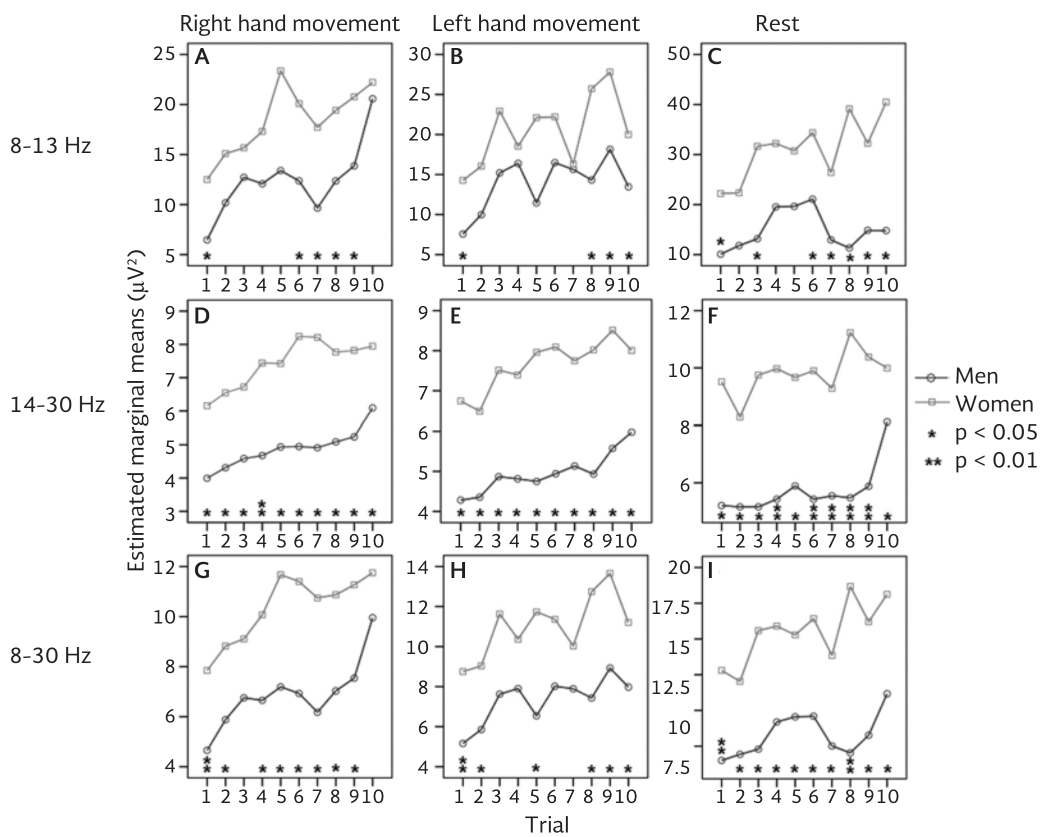
Figure 1 shows the estimated marginal means of EEG power for both genders in the RIGHTMOV, LEFTMOV, and REST tasks. Statistical differences were computed for each of the performed trials. In trial 1 and trials 6-10, significant gender differences ($p < 0.05$) were found in the alpha band for RIGHTMOV, LEFTMOV, and REST tasks (Fig. 1 A, 1 B, 1 C). Significant gender differences ($p < 0.05$) were found in beta in all trials

Table 1. Main effects and interactions for the general linear model for the three analyzed frequency bands

Independent variable	Alpha (8-13 Hz)				Beta (14-30 Hz)				Alpha-beta (8-30 Hz)			
	DF	DFe	F	p	DF	DFe	F	p	DF	DFe	F	p
Trials (A)	1	34	15.43	< 0.001*	1	34	18.61	< 0.001*	1	34	22.75	< 0.001*
Task (B)	1	34	9.18	0.005*	1	34	27.42	< 0.001*	1	34	15.18	< 0.001*
Channel (C)	1	34	4.76	0.036*	1	34	3.35	0.076	1	34	0.88	0.354
Gender (D)	1	34	2.51	0.122	1	34	6.49	0.015*	1	34	4.84	0.035*
A × B × D	1	34	4.99	0.032*	1	34	0.32	0.573	1	34	1.97	0.169
C × B × D	1	34	1.64	0.209	1	34	0.22	0.640	1	34	2.35	0.135

*Significant. DF: degree of freedom; DFe: degree of freedom for error; F: F-value.

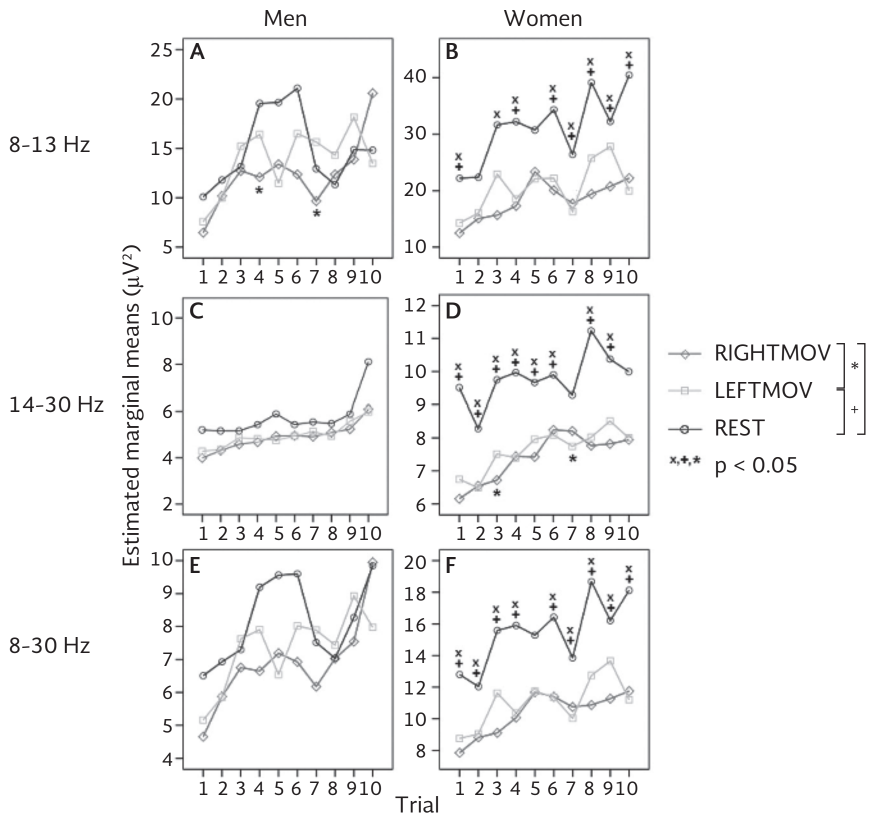
Figure 1. Estimated marginal means of EEG power in each trial for both genders. **A**, **B**, **C**: Gender differences in alpha band (8-13 Hz); **D**, **E**, **F**: in beta band (14-30 Hz); **G**, **H**, **I**; in alpha-beta band (8-30 Hz). One asterisk (*) indicates a significant difference with $p < 0.05$ and two asterisks (**) indicate significant difference with $p < 0.01$.



of the three tasks. It is important to observe that for the REST task, significant gender differences occurred with a 99% confidence level ($p < 0.01$) (Fig. 1 A, 1 B, 1 C). In the alpha-beta band, for most of the trials, significant gender differences ($p < 0.05$) were found in RIGHTMOV and REST, while for the LEFTMOV tasks less trials showed gender differences.

Figure 2 shows the estimated marginal means of power calculated for the 10 performed trials, separated by the RIGHTMOV, LEFTMOV, and REST tasks, observed for each gender. For men, significant differences ($p < 0.05$) between RIGHTMOV and LEFTMOV were only found in the trials 4 and 7 of the alpha frequency band (Fig. 2 A, 2 C, 2 D). For women, no

Figure 2. Estimated marginal means of EEG power in each trial for the three analyzed tasks. **A**, **B**: Statistically significant differences in alpha band (8-13 Hz); **C**, **D**: in beta band (14-30 Hz); **E**, **F**: in alpha-beta band (8-30 Hz). "x" indicates significant differences (p < 0.05) between RIGHTMOV and REST. "+" indicates significant differences (p < 0.05) between LEFTMOV and REST. "*" indicates significant differences between RIGHTMOV and LEFTMOV.



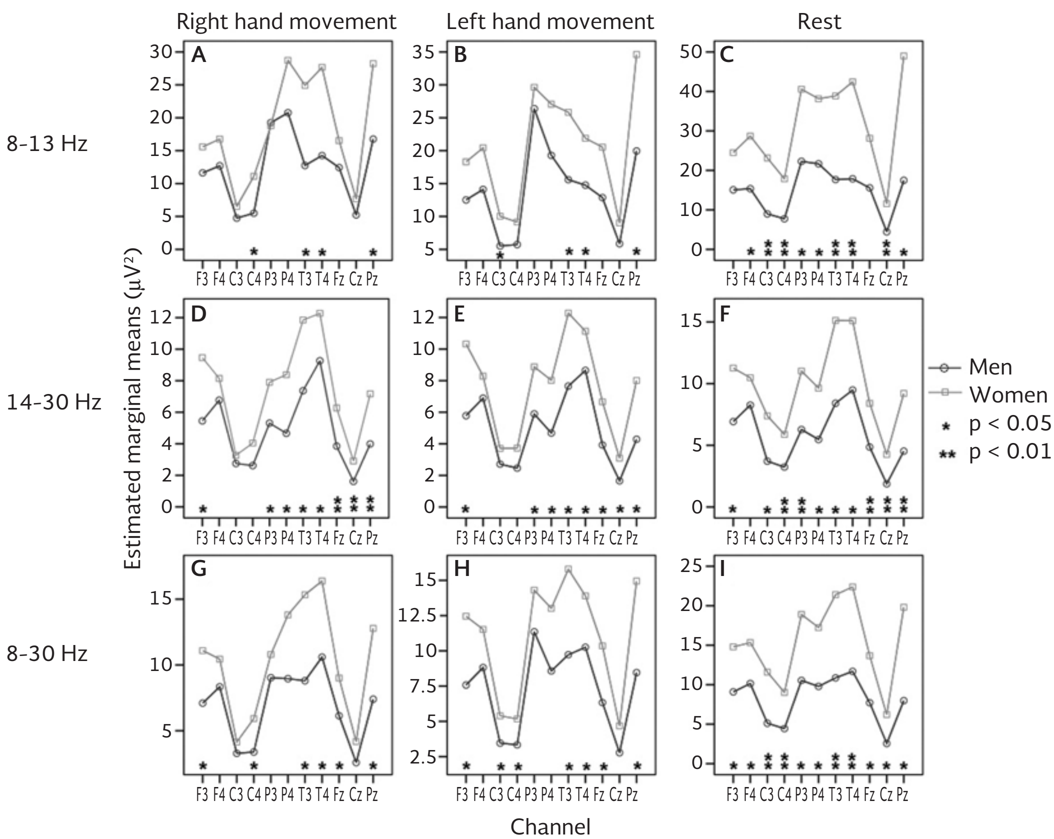
significant differences (p < 0.05) between RIGHTMOV and LEFTMOV were found in alpha or alpha-beta; however, these differences could be observed in the beta band in trials 3 and 7 (Fig. 2 D). For women, significant differences (p < 0.05) between RIGHTMOV and REST and between LEFTMOV and REST were found for all analyzed frequency bands and for most of the trials (Fig. 2 B, 2 D, 2 F).

Gender differences by EEG channel

For alpha, significant gender differences (p < 0.05) were found in RIGHTMOV in C4, T3, T4, and Pz (Fig. 3 A); for LEFTMOV these differences were found in C3, T3, T4, and Pz (Fig. 3 B); in REST these differences were found in most of the channels except for F3 and Fz (Fig. 3 C). For beta, significant gender differences (p < 0.05) while performing both RIGHTMOV and LEFTMOV were found for almost all channels except for F4, C3, and C4 (Fig. 3 D, 3 E), and for the REST, the only channel without significant gender difference was F4 (Fig. 3 F). For the alpha-beta band, significant gender differences (p < 0.05) were found in all channels of REST (Fig. 3 I), while for LEFTMOV no significant differences were found in F4, P3, P4, and Cz (Fig. 3 H), and for RIGHTMOV no significant gender differences were found in F4, C3, P3, and P4 (Fig. 3 G). In the three analyzed frequency bands, the recorded EEG channels with the lower mean power were C3, C4, and Cz, placed above the central area of the brain cortex. The recorded electrodes with the higher mean power were the ones placed above the parietal area in case of alpha, and in case of beta were the ones placed over the temporal area of the brain cortex.

Figure 4 shows the marginal means of EEG power for each one of the 11 acquired channels, calculated for the RIGHTMOV, LEFTMOV, and REST tasks. For men, no significant differences between different tasks were seen, except in beta for F3, F4 and C3 (Fig. 4 C). For women, significant differences (p < 0.05) between

Figure 3. Estimated marginal means of EEG power in each channel for both genders. **A**, **B**, **C**: Gender differences in alpha band (8-13 Hz); **D**, **E**, **F**: in beta band (14-30 Hz); **G**, **H**, **I**: in alpha-beta band (8-30 Hz). One asterisk (*) means a significant difference with $p < 0.05$ and two asterisks (**) means a significant difference with $p < 0.01$.



RIGHTMOV and LEFTMOV were observed in the alpha and alpha-beta bands in channels C3, P3 and Pz (Fig. 4 B, 4 F); for the beta frequency band significant differences ($p < 0.05$) between RIGHTMOV and LEFTMOV were only present in P3 (Fig. 4 D). Moreover, significant ($p < 0.05$) differences were observed, in the three analyzed frequency bands, between REST and the RIGHTMOV, LEFTMOV tasks in most of the channels (Fig. 4 B, 4 D, 4 F).

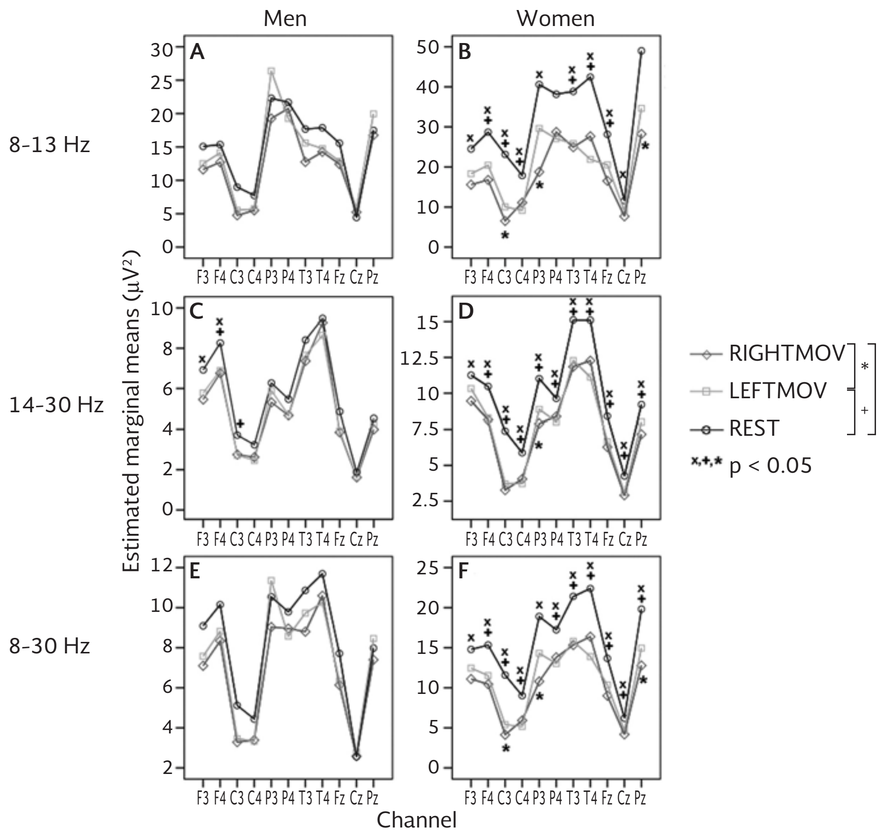
Brain topographic maps

Grand-averaged topographic maps of relative power of each gender are shown in figure 5. For both genders, a contralateral activation was elicited by RIGHTMOV (the dominant hand of the subjects) and an ipsilateral activation for LEFTMOV. For women, the more pronounced decreases in power were elicited in the alpha frequency band during RIGHTMOV and LEFTMOV. For men, the stronger decrease in power was elicited in alpha by RIGHTMOV, while for LEFTMOV the most significant decrease in power occurred in beta. Cortex activation in women was more pronounced and had a greater activation area than those from men for all of the analyzed frequency bands and for both RIGHTMOV and LEFTMOV tasks. For women, for both RIGHTMOV and LEFTMOV tasks, activations seem to concentrate in the centro-temporal regions (C3, T3, C4 and T4 electrodes), for all the analyzed frequency bands. For men, this dominance of centro-temporal activations is only seen in alpha, while predominant frontal (F3 and F4 electrodes) activations are elicited by LEFTMOV in beta and alpha-beta, and predominant centro-frontal and left centro-temporal activations (Fz, C3, T3) are elicited by RIGHTMOV in both beta and alpha-beta.

DISCUSSION

The results of this study showed significant gender differences in EEG spectral power calculated by means

Figure 4. Estimated marginal means of EEG power in each channel for the three analyzed tasks. **A**, **B**: Statistically significant differences in alpha band (8-13 Hz); **C**, **D**: in beta band (14-30 Hz); **E**, **F**: in alpha-beta band (8-30 Hz). "x" indicates significant differences ($p < 0.05$) between RIGHTMOV and REST. "+" indicates significant differences ($p < 0.05$) between LEFTMOV and REST. "*" indicates significant differences between RIGHTMOV and LEFTMOV.

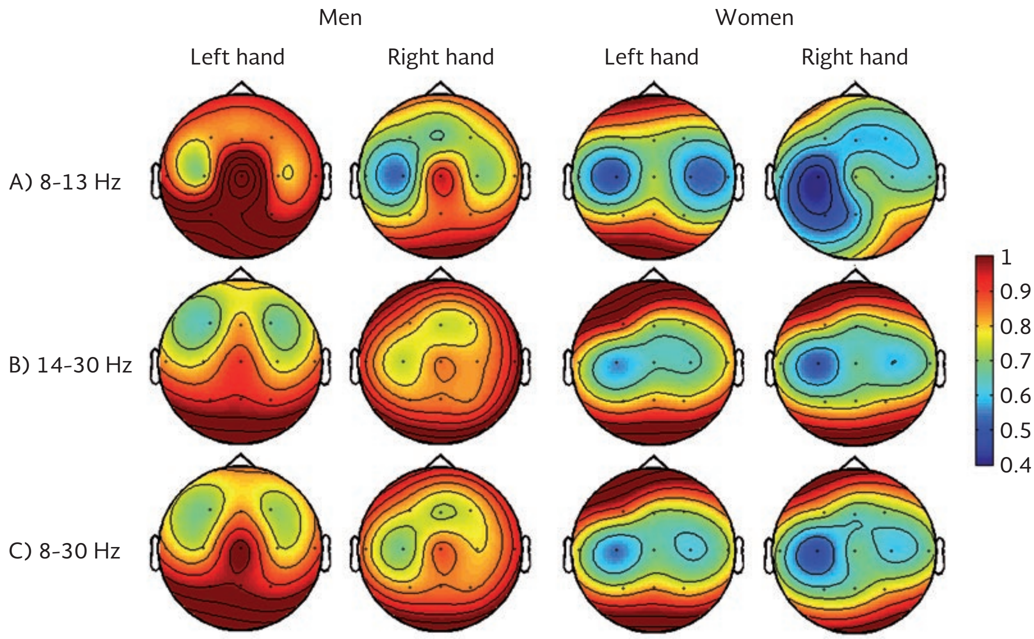


of time-frequency wavelets decomposition in young adults. These gender differences were found in EEG cortical activations during hand motor execution tasks and in a rest condition with open eyes.

Significant gender differences were found along time, despite inter-trial variability, for the RIGHTMOV, LEFTMOV, and REST tasks. These differences were found in the beta and alpha-beta frequency bands; however, for the alpha band, only the last trials showed significant gender differences. Power for the three analyzed tasks was higher in a 2:1 ratio for women in all the analyzed frequency bands. Gender differences for the beta band are similar to the ones reported by other studies that describe a higher power amplitude in the EEG for women in rest conditions[24,25] during the observation of a simple visual stimulus[26] and during mental rotation tasks[28,29]. These differences were observed along different cortical areas due to the distinct nature of each performed task. Hand movement tasks analyzed in this study seem to show a habituation process, observed as an increase in power as the performed trials progress, even though the order of the tasks was randomized, which is not observed in the REST task.

Temporal and parietal regions seem to have different activation or organization across genders since, for T3, T4 and Pz, significant differences were always found in RIGHTMOV, LEFTMOV, and REST tasks in all the analyzed frequency bands. For the alpha band, parietal (P3 and P4) and frontal (F3 and F4) areas do not seem to show significant gender differences in RIGHTMOV and LEFTMOV. While for beta band, central channels (C3 and C4) do not show significant gender differences for these motor tasks. These results suggest that motor cortex activation is similar for both genders, while somatosensory cortex activation is different for both genders, since temporoparietal brain activity is related to the sensory processing of hand movement[30].

Figure 5. Grand-averaged topographic maps for three frequency bands across each gender. **A**: Alpha band (8-13 Hz), **B**: beta band (14-30 Hz), **C**: alpha-beta (8-30 Hz). Relative power was computed with respect to a baseline interval from 1.5 to 2.5 seconds.



For all analyzed frequency bands, cortex activations for men were very similar when performing both hand movements and rest since there were no significant differences between tasks when analyzing power across trials or channels. Moreover, women showed significant differences between REST and either RIGHTMOV or LEFTMOV in all trials, channels, and frequency bands. Besides, for women, only in the central and parietal channels of the left hemisphere a significant difference between RIGHTMOV and LEFTMOV was found. Many BCI applications require discriminating between cortex activations during LEFTMOV and RIGHTMOV in order to translate them into control signals for external devices. However, the observations made in this study seem to indicate that many of the subjects in the sample generate very similar activation patterns for these two tasks. This highlights the importance of user training or neuromodulation to increase the ability of the subjects to generate different EEG patterns that can be recognized in their EEG signal. Some of the subjects could have a similar level of dexterity in both hands, which could explain the similarity in cortex activations while performing hand movements.

Topographic maps show that both genders elicit contralateral activations during RIGHTMOV, which is in accordance with the literature. However, women compared to men showed more pronounced power decrease with a larger activation zone, which involves the sensory association area. During LEFTMOV, gender differences were observed: for women, a bilateral activation with a small dominance of the central cortex area of the ipsilateral hemisphere is elicited, while for men, the activation is also bilateral but more focalized in the frontal area of the hemispheres, which is related to movement preparation. As well as for RIGHTMOV, women had more pronounced power decrease during LEFTMOV. The larger power decrease of the female gender was also reported by Cheng, et al. during the observation of hand movements by a group of subjects[40]. It is important to notice that the women's power decrease is constant across alpha, beta, and alpha-beta bands. A possible explanation for the observed bilateral activation during LEFTMOV could be that the non-dominant hand movement is a more complex task than the dominant hand movement (RIGHTMOV); therefore, both hemispheres are activated in order to correctly perform the movement. This activation is in concordance with two functional magnetic resonance studies that showed that left hand movement activates the ipsilateral hemisphere to a greater degree than right hand movement[41,42]. Additionally, Tomasi and Volkow[43] have shown that women present a less functional lateralization, so they have a tendency to show bilateral hemispheric activation for verbal and non-verbal tasks, whereas men have a higher tendency to unilateral activation when performing such tasks.

The observed gender differences may be a product of physiological, anatomical, or psychological features among genders; for example, some neuroimaging-based morphological studies have suggested that women have a more complex and thicker brain cortex in the frontal and parietal lobes than men[44-46]. Other studies even suggest that women have an increased gray matter volume adjacent to the central sulcus, this being an area closely related to motor and somatosensory functions[47,48]. On the other hand, histological studies have shown an increased cortical neuron density in men with respect to women, with an increased number of neuronal processes (neuropil) in women[49]. All these anatomical and cellular differences can contribute to the gender differences in EEG power observed in the current study.

In this analysis, some of the features that could influence the results were controlled, including the subject's age, hand dominance for writing, and education level. Nevertheless, one limitation of this study is that a quantitative assessment of the handedness of subjects was not performed, so in order to further inspect this particular hypothesis the Edinburgh Inventory will be applied to the participants of future studies.

To the authors' knowledge, no study has analyzed gender differences, elicited in EEG power features during hand motor execution, in the recorded channels (spatial distribution), and the performed trials (time evolution). Therefore, this work contributes to improve the understanding of gender differences in the performance of gross motor skills in young adults. However, it is important to acknowledge that a larger sample of both subjects and trials per subject may be needed to achieve a larger perspective of the effect of time and the habituation effects that may be seen during motor execution tasks.

The observed results are a valuable contribution to the establishment of quantitative EEG markers for the diagnosis of neurological and motor disorders that take gender into account, and to BCI research.

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