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Difference in the Range of Floating In Individuals Diagnosed With Amyotrophic Lateral Sclerosis: A Preliminary Study with the RMS Float Function

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Abstract: *Fluctuations and their changes over time during walking could contribute to a better understanding of the physiology of gait, especially in age-related pathological changes in the locomotor control system and also a better understanding of mobility. In this study, we apply the detrended fluctuation analysis (DFA) method and the rms root mean square fluctuation function, in raw data obtained from people diagnosed with Amyotrophic Lateral Sclerosis (ALS) from the Physionet.org repository. Using the DFA method, we concluded that ALS patients have a significant difference in stride and posture compared to control patients. The results showed methodological contributions to the analysis of data extracted from sensors, which would be of interest to professionals involved in motor rehabilitation and pathological changes related to locomotor control.*
Keywords: *Temporal Series; Amyotrophic Lateral Sclerosis; Fluctuation Function.*

DIFERENÇA NA AMPLITUDE DA FLUTUAÇÃO DE INDIVÍDUOS DIAGNOSTICADOS COM ESCLEROSE LATERAL AMIOTRÓFICA: UM ESTUDO PRELIMINAR COM A FUNÇÃO DE FLUTUAÇÃO rms

Resumo: *As flutuações e suas mudanças ao longo do tempo durante a caminhada, poderiam contribuir com um melhor entendimento da fisiologia da marcha, sobretudo, nas alterações patológicas relacionadas à idade no sistema de controle locomotor e também uma melhor compreensão da mobilidade. Neste estudo, aplicamos o método detrended fluctuation analysis (DFA) e a função de flutuação raiz quadrática média rms, em dados brutos obtidos de pessoas diagnosticadas com Esclerose Lateral Amiotrófica (ELA) do repositório da Physionet.org. Usando o método DFA, concluímos que os pacientes com ELA têm uma diferença significativa na passada e postura em comparação com os pacientes controle. Os resultados mostraram contribuições metodológicas para a análise dos dados extraídos dos sensores, os quais seriam de interesse dos profissionais envolvidos na reabilitação motora e alterações patológicas relacionadas ao controle locomotor.*
Palavras-chave: *Series Temporais, Esclerose Lateral Amiotrófica, Função de Flutuação.*

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I. INTRODUCTION

Quantitative results of human locomotion (walking) initially focused on the properties of a stride or average, subtracting any conjecture about stride fluctuations and considering the fluctuations as noise. Over time, however, some studies have shown that the supposed noise would be transmitting important information and that investigation would be appropriate. The hypothesis raised is that step-by-step fluctuations and their changes over time during walking could contribute to a better understanding of gait physiology, especially in age-related pathological changes in the locomotor control system and also a better understanding of mobility [1, 2, 3, 4, 5, 6].

Contributions arise from the acquisition of signals in the form of time series extracted from force-sensitive resistors, with output approximately proportional to the force under the foot, pressure and force sensors, hip and knee angle sensors, surface electromyography electrodes, among others [7, 8, 9]. At the same time, methods are tested in order to quantify the complexity of gait dynamics.

Applications were made in order to understand the relationship between disease and old age, entropy as a measure to quantify regularity in time series, methods to estimate how the disorder evolves over time, multiscale entropy, the Lyapunov exponent to characterize the rate of separation of infinitesimally close trajectories and more recently the Detrended Fluctuation Analysis (DFA) method on a restricted scale to ($10 \leq n \leq 20$, n being the box size) was applied to evaluate elapsed time, stride interval, oscillation interval, interval of posture, support interval, among others [10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20]. More details in [21].

Today, we already know that the dynamics of human gait is altered as the person gets older and especially with the onset of neurodegenerative diseases. With neurological impairment, gait variability appears to be plagued, especially for people diagnosed with Parkinson's disease (PD), Huntington's disease (HD) and amyotrophic lateral sclerosis (ALS). A detailed description of these diseases can be found in [21].

II. METHODOLOGY

2.1 Database

The time series were analyzed by the root mean square (rms) fluctuation function available in: https://archive.physionet.org/physiobank/database/gaitndd/ .We selected 8 people from the database, four diagnosed with ALS, and four from the control group. The raw data were obtained using force-sensitive resistors, with output approximately proportional to the force under foot. The measurements from the past to the past form the result of these signs. The series generated lasts for five minutes with varying number of points, see table 1. The data available in the database are delimited by tabulation with a description of age, sex, height, weight, walking speed and the measure of the severity or duration of the disease. The database also has data on people diagnosed with ALS, PD, HD and Control. Specifically for this study, we evaluated the time series of people with ALS with diagnosis time in months and a control group.

Table 1. Data of the people chosen for analysis

		Age	Height (meters)	Weight(kg)	Severity(months)	Number of points
ELA	Female	40	1.70	61.24	4.5	246
	Female	70	1.70	58.97	54	138
	Male	36	1.70	74.39	5.5	208
	Male	68	1.80	86.18	1	194
Control	Female	20	1.90	57	0	256
	Female	69	1.72	68	0	262
	Male	22	1.94	70	0	244
	Male	74	1.89	77	0	272

2.2 Methods

To analyze the time series of the stride and posture intervals, we briefly present the detrended fluctuation analysis (DFA) method [24], which involves the following steps:

1. Consider a correlated signal strength, $u(i)$, where i = 1, …, N_{max} and N_{max} the number of points in the time series being. integrating the signal $u(i)$, we get $y(k) = \sum_{i=1}^{k}[u(i) - < u >]$, where $< u >$ is the average of u;
2. The integrated signal $y(k)$ is divided into a box of equal length n (time scale);
3. For each size box n, we adjust $y(k)$, using a first-order polynomial function, which represents the trend in the box. The coordinate y of the adjustment line in each box is denoted $y_n(k)$;
4. The integrated signal $y(k)$ is subtracting the local trend $y_n(k)$ in each size box n;
5. For a given size box n, the float function$F_{DFA}(n)$ for this integrated and trendless signal is given by:

$$F_{DFA}(n) = \sqrt{\frac{1}{N_{max}}\sum_{k=1}^{N_{max}}[y(k) - y_n(k)]^2} \qquad (1)$$

6. The above calculation is repeated for a wide range of size scales n to provide the relationship between $F(n) \sim n^{\alpha_{DFA}}$ thus, α_{DFA} is the scaling exponent, a self-affinity factor that represents the long-range correlation (power law) properties of the signal. See table 2:

Table 2: types of signals

exponent	Type of signal
$\alpha_{DFA} < 0.5$	anti-persistent
$\alpha_{DFA} \cong 0.5$	uncorrelated, white noise
$\alpha_{DFA} > 0.5$	long-range correlated persistent
$\alpha_{DFA} \cong 1.0$	1/f noise
$\alpha_{DFA} > 1.0$	non-stationary
$\alpha_{DFA} \cong 1.5$	Brownian noise

In order to calculate the difference in the amplitude of the fluctuation in the stride and posture intervals, we used the root mean square fluctuation function (rms), proposed by Zebende [22]. The rms function was used to measure the difference in fluctuation between two electroencephalogram (EEG) channels. The tool is an enhancement given to the DFA method and has been shown to be very useful for electrophysiological signal applications. In practice we calculate the DFA of two time series and its logarithm individually, then subtract the result from the logarithms. From the function (equation 2) we can lower that the amplitude of the fluctuation relative to rms can be seen from three conditions. We describe the equation as being F_{DFA_E} the DFA of stride or left side stance and F_{DFA_D} the DFA of stride or right side stance

$$\Delta log F_{E:D} = F_{DFA\_E} - F_{DFA\_D} \qquad (2)$$

If $\Delta log F_{E:D} > 0$, then the amplitude of the rms fluctuation around the stride / left-to-right posture is higher;
If $\Delta log F_{E:D} = 0$, then the amplitude of the rms fluctuation around left-to-right stride/posture is zero;
If $\Delta log F_{E:D} < 0$, then the amplitude of the rms fluctuation around the left-to-right stride/posture is smaller;
Some works that cite the rms function [23, 25, 26, 27, 28, 29].

III. RESULTS AND DISCUSSION

Each time series of the dynamic gait experiment in the neurodegenerative disease database (https://archive.physionet.org/) is approximately 5 minutes, with the number of points varying with the characteristics of each person's stride and posture, see table 1. The investigated data were obtained from force-sensitive resistors, with the output approximately proportional to the force under foot.

For our analysis, we selected eight people, four females and four males. Strategically, we chose people with extreme ages for both groups (ALS and Control). The reasons for the choice of people are related to the influence of age on the locomotor control system, the seriousness of the disease was also taken into account. For the ALS group, we selected for females 40 and 70 years old and for males 36 and 68 years old. In the control group, we selected females 20 and 69 years old and males 22 and 74 years old.

We represent for identification and analysis of DFA and rms methods ($\Delta log F_{E:D}$) the color curves. In black we represent the DFA of the left side stride and in red the right side. In green we represent the DFA of the left side posture and in blue the right side. For the rms ($\Delta log F_{E:D}$), we represent in violet the difference in the amplitude of the fluctuation on the left side in relation to the right for the heavy one, and in orange the difference in the amplitude of the fluctuation for the left in relation to the right posture. See figures 1 and 2.

For each patient in their two tasks, left/right stride interval and left/right posture interval, we calculated the DFA for each set. The objective with DFA (equation 1) was to generate the values of fluctuations as a function of the scale (n) to support the root mean square fluctuation equation (rms). At this stage, we increased the observations of the scales, since the technique (DFA) had already been applied in a restricted scale ($10 \leq n \leq 20$) [6].

For the ALS and control groups, we calculated the DFA for (1.3 minutes) $4 \leq n \leq 60$ (4.09 minutes), with the exception of the 40-year-old female patient with ALS with 54 months of severity $4 \leq n \leq 33$. The difference in the n scale of the 40-year-old ALS patient is related to the number of points extracted from the sensor for the observation time of the experiment, in this case 194 points. The description of the number of points of the patients involved in the research are described in table 1.

Regarding the DFA of stride and posture, there were differences in fluctuation in relation to the scale, stride left / right side greater than posture left / right sides for all two groups with exercise of the patient (b) diagnosed with ALS who presented the same behavior for stride and posture. In terms of past, the fluctuation of the investigated people showed fluctuation to the left side greater than the right side. They were, patient (c) with ALS and (c) Control. In the past, the influence of fluctuation showed a significant difference for the patient (b), control group and in relation to the others

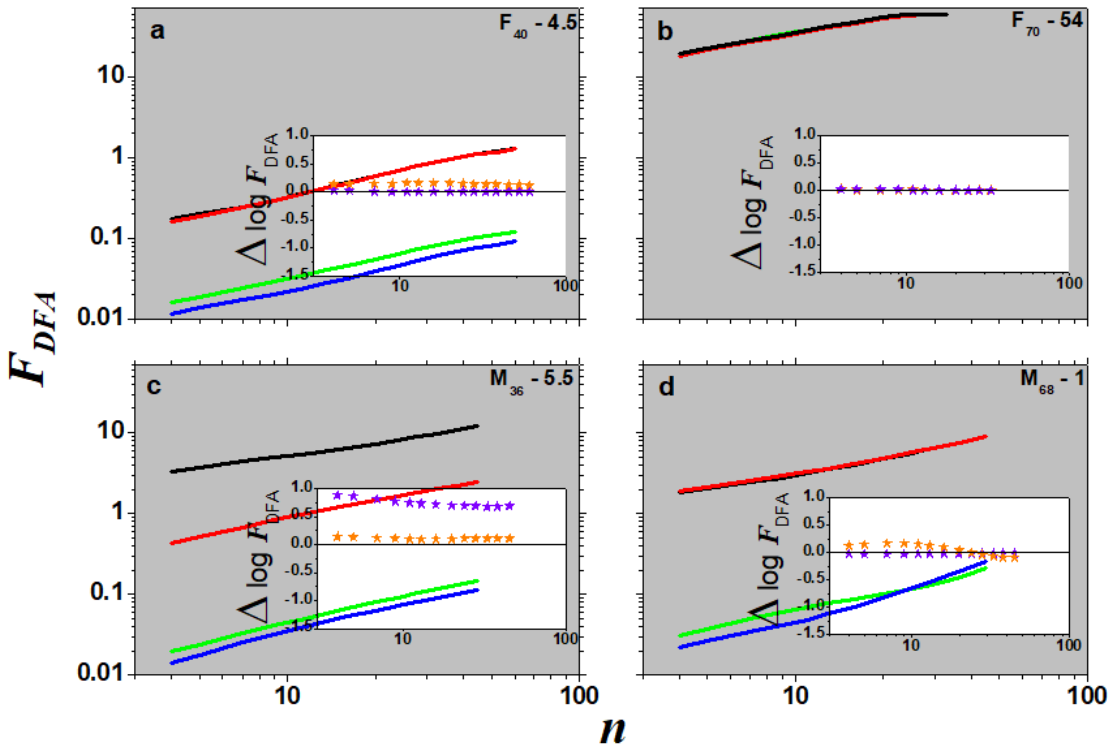

Figure 1: Group diagnosed with amyotrophic lateral sclerosis. (a) female patient with 40 years and 4.5 months of severity. (b) female patient aged 70 years and 54 months of severity. (c) male patient aged 36 years and 5.5 months of severity. (d) male patient with 68 years and 1 month of severity.

We also evaluated the influence of the disease effect on stride and posture symmetry in relation to the difference in the fluctuation amplitude. For the group with ALS, in (a), the influence of the stride on the left side prevailed in relation to the right side in all scales, whereas the difference in relation to stride was practically zero. In (b), for all scales the difference was zero. Here we have a differentiated result, considering the age (70 years) of the patient and the time (54 months) of disease severity. What can be seen in this case is that there is already a certain functional commitment. In (c), positive difference for stride and posture with higher values for stride, ie, left side influence is greater than right side. In (d), the difference in stride for all scales was around zero, but for posture with increasing scale the difference tends to be smaller in n > 30 (3.40 minutes), with a negative trend.

In the control group, in (a), the difference in the amplitude of the fluctuation in relation to stride and posture was around zero. In (b) for the stride, the difference for $n \leq 10$(2.30 minutes) is equal to zero, accompanied by a negative difference as the scale increases. Still in (b), the difference in posture was negative, which shows a greater influence on the left side in relation to the right. In (c), positive difference for all scales in stride and a difference around zero for posture. As for (d), with the increase of the scale n > 30, we verified a change in stride behavior, influence of the right side followed by a prevalence of the left side. The posture remained negative for all scales, that is, a prevalence of the right side over the left.

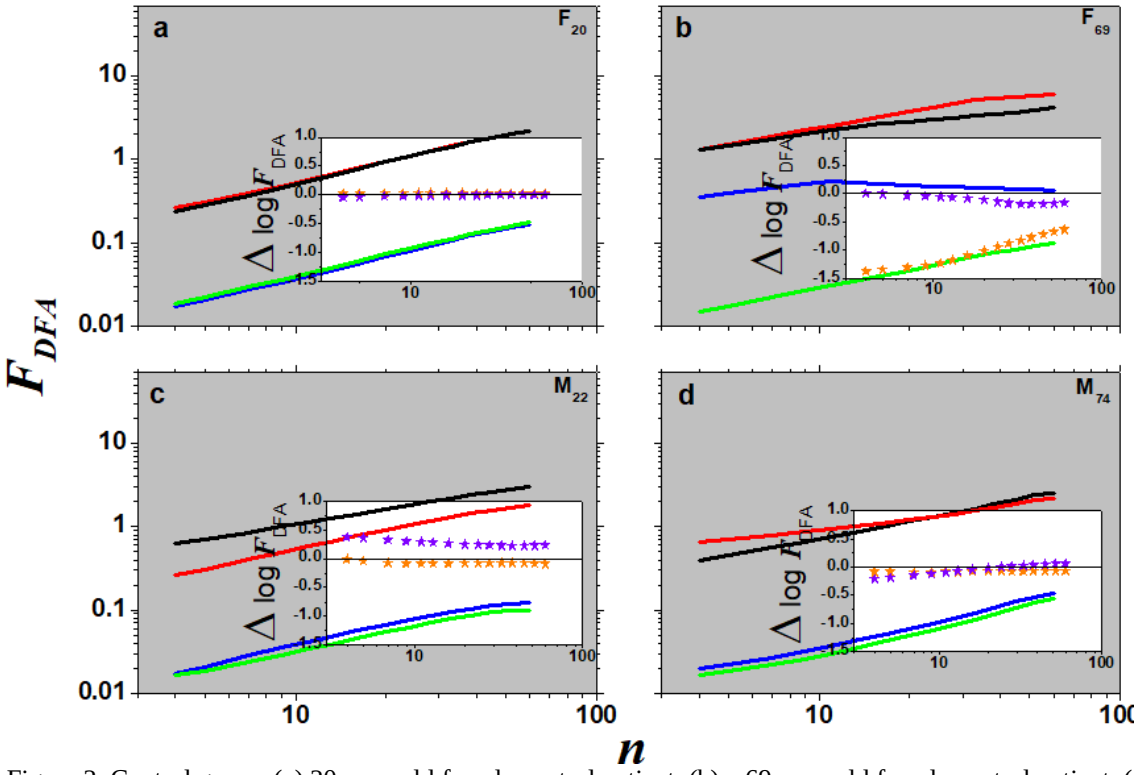

Figure 2. Control group. (a) 20-year-old female control patient. (b) a 69-year-old female control patient. (c) 22-year-old male control patient. (d) 74-year-old male patient.

IV. CONCLUSION

In this study, we propose a new reading for gait and mobility in patients with amyotrophic lateral sclerosis, in terms of stride and posture. We analyzed time series obtained from force-sensitive resistor sensors with output proportional to the force under foot. We started this study by calculating the signal fluctuation by the DFA method for $4 \leq n \leq 60$ scales. Our objective in this step was to calculate the rms function from the FDFA and the information about the amplitudes of the stride and posture intervals.

To understand the dynamics of symmetry in stride subphases and the effect on gait regularity influenced by ALS disease, we calculated the difference in fluctuation amplitude using the rms function. The results shown by the rms function, revealed variation in the difference with increasing scale, also evidenced the subtlety of the difference between stride and posture.

It is evident that the analysis took into account a small group of patients diagnosed with ALS. We understand that this is a new strategy and that it could be replicated to a larger sample of people diagnosed with the disease in order to better understand its pathophysiology and improve the ability to accurately quantify the gait dynamics.

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REFERENCES

[1]. Stergiou N, Decker LM. **Human movement variability, non-linear dynamics, and pathology: is there a connection?** Hum Mov Sci 30:869-888, 2011.
[2]. Holt KG, Saltzman E, Ho CL, Ulrich BD. **Scaling of dynamics in the earliest stages of walking**. Phys Ther 87:1458-1467, 2007.
[3]. Hausdorff JM, Zemany L, Peng CK, Goldberger AL. **Maturation of gait dynamics: stride-to-stride variability and its temporal organization in children**. J Appl Physiol 86:1040–1047, 1999.
[4]. Dingwell JB, Cusumano JP. **Non-linear time series analysis of normal and pathological human walking**. Chaos 10:848-863, 2000.
[5]. Harbourne RT, Stergiou N. **Movement variability and the use of non-linear tools: principles to guide physical therapy practice**. Phys Ther 89:267-282, 2009.
[6]. Hausdorff JM, Mitchell SL, Firtion R, Peng CK, Cudkowicz ME, Wei JY, Goldberger AL. **Altered fractal dynamics of gait: reduced stride-interval correlations with aging and Huntington's disease**. *J Applied Physiology*; **82**:262-269, 1997.
[7]. Van Orden GC, Kloos H, Wallot S. **Living in the pink: intentionality, wellbeing, and complexity**. In: Van Orden GC. Ed. Handbook of the philosophy of science volume 10: Philosophy of complex systems, vol 10. Amsterdam, 2009. P. 639 - 682.

[8]. Webster KE, Wittwer JE, Feller JA. **Validity of the GAITRite walkway system for the measurement of averaged and individual step parameters of gait**. Gait Posture 22:317-321, 2005.

[9]. Beauchet O, Herrmann FR, Grandjean R, Dubost V, Allali G. **Concurrent validity of SMTEC® footswitches system for the measurement of temporal gait parameters**. Gait Posture 27:156–159, 2008.

[10]. Catai AM Pastre CM, Godoy MF, Silva ED, Takahashi ACM, Vanderlei LCM. **Heart rate variability: are you using it properly?** Standardisation checklist of procedures. Braz J Phys Ther 24(2):91-102, 2020.

[11]. Mosca PRF. **Modelos sobre a variabilidade da frequência cardíaca**. Faculdade de Medicina, UFRGS, 2020.

[12]. Kurz M, Stergiou N. **The aging human neuromuscular system expresses less certainty for selecting joint kinematics during gai**t. Neurosci Lett 348:155-158, 2007.

[13]. Matjaz P. **The dynamics of human gait**. Eur J Phys 26:525, 2005.

[14]. Moraiti C, Stergiou N, Ristanis S, Georgoulis AD. **ACL deficiency affects stride-to-stride variability as measured using non-linear methodology**. Knee Surg Sports Traumatol Arthrosc 15:1406-1413. 2007.

[15]. Smith BA, Teulier C, Sansom J, Stergiou N, Ulrich BD. **Approximate entropy values demonstrate impaired neuromotor control of spontaneous leg activity in infants with myelomeningocele**. Pediatr Phys Ther 23(3):241, 2011.

[16]. Tochigi Y, Segal NA, Vaseenon T, Brown TD. **Entropy analysis of tri-axial leg acceleration signal waveforms for measurement of decrease of physiological variability in human gait**. J Orthop Res 30:879-904, 2012.

[17]. Robbins SM, Astephen Wilson JL, Rutherford DJ, Hubley-Kozey CL. **Reliability of principal components and discrete parameters of knee angle and moment gait waveforms in individuals with moderate knee osteoarthritis**. Gait Posture 38:421-427, 2013.

[18]. Goldberger AL, Amaral LA, Hausdorff JM, Ivanov PC, Peng CK, Stanley HE. **Fractal dynamics in physiology: alterations with disease and aging**. Proc Natl Acad Sci USA 99:2466-2472, 2002.

[19]. Hausdorff JM, Peng CK, Ladin Z, Wei JY, Goldberger AL. **Is walking a random walk? Evidence for long-range correlations in stride interval of human gait**. J Appl Physiol 78:349-358, 1995.

[20]. Hausdorff, Jeffrey M. et al. **Altered fractal dynamics of gait: reduced stride-interval correlations with aging and Huntington's disease**. Journal of applied physiology, v. 82, n. 1, p. 262-269, 1997.

[21]. Mosca, Paulo Roberto Ferrari. **Multifractalidade e Doenças de Parkinson e de Huntington**.

[22]. Zebende GF, Oliveira Filho FM, Leyva Cruz JA (2017). **Auto-correlation in the motor/imaginary human EEG signals: A vision about the F_{DFA} fluctuations**. PLoS ONE 12(9): e0183121.

[23]. Oliveira Filho, F. M., et al. "**Correlação cruzada na aprendizagem motora: um estudo com sinais de EEG (Eletroencefalografia) via estatística de sinais**." *Atena Editora: Engenharia 3* (2021): 198–205.

[24]. Peng CK, Buldyrev SV, Havlin S, Simons M, Stanley HE, Goldberger AL. **Organização em mosaico de nucleotídeos de DNA**. Phys Rev E. 1994; 49: 1685–1689.

[25]. Baravalle, Román, Osvaldo A. Rosso, and Fernando Montani. "**Causal shannon–fisher characterization of motor/imagery movements in eeg**." *Entropy* 20, no. 9 (2018): 660.

[26]. Baravalle, Roman, Natalí Guisande, Mauro Granado, Osvaldo A. Rosso, and Fernando Montani. "**Characterization of visuomotor/imaginary movements in EEG: An information theory and complex network approach**." *Frontiers in Physics* 7 (2019): 115.

[27]. Oliveira Filho, F. M., JA Leyva Cruz, and G. F. Zebende. "**Analysis of the EEG bio-signals during the reading task by DFA method**." *Physica A: Statistical Mechanics and its Applications* 525 (2019): 664-671.

[28]. Zebende, G. F., A. A. Brito, and A. P. Castro. "**DCCA cross-correlation analysis in time-series with removed parts**." *Physica A: Statistical Mechanics and its Applications* 545 (2020): 123472.

[29]. Hirekhan, Sunil R., Ramchandra Manthalkar, and Shruti Phutke. "**The Detrended Fluctuation Analysis of EEG Signals: A Meditation-Based Study**." In *Computing, Communication and Signal Processing*, pp. 771-780. Springer, Singapore, 2019.