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ORIGINAL RESEARCH ARTICLE

Comparative Impacts of Prolonged Orthostasis and Single Intermittent Prolonged Orthostasis on the Electroencephalogram in Adult Male Individuals

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Abstract

Background Orthostatic syncope is a significant public health concern. The study investigated the comparative effects of prolonged orthostasis and single intermittent prolonged orthostasis on the electroencephalogram in adult males. The objectives were to investigate the comparative impacts of prolonged orthostasis and single intermittent prolonged orthostasis on the alpha wave frequency, beta wave frequency, and alpha/beta ratio.

Methods The study adopted a pre-experimental study design (pre-(baseline) and post-comparison). Forty adult male individuals were selected through the respondent-driven sampling technique. Measurements were conducted at a reclining sitting position (baseline). The participants then underwent 20 minutes of orthostasis, followed by a single intermittent, prolonged orthostatic challenge. Orthostasis was defined as the assumption of upright standing from a sitting position for 20 minutes, and single intermittent prolonged orthostasis consisted of a 1-minute break between two consecutive 20-minute orthostasis periods. Electroencephalographic (EEG) recordings were obtained using a PowerLab 26T, as previously reported. The machine has an in-built hardware filtering (low pass filter of 1-2000Hz) and software-based filtering (Labtutor). Statistical significance was accepted at $p < 0.05$.

Results When compared to baseline and intermittent orthostatic sessions, respectively, orthostasis has no significant decrease ($p > 0.05$) in alpha wave frequency. However, alpha/beta ratio and beta wave frequency were significantly lower and higher ($p < 0.05$) during orthostasis when compared to baseline and intermittent orthostatic sessions, respectively.

Conclusion The findings of the study suggest that prolonged orthostasis (20 minutes) relatively elicited greater cortical activation when compared to single intermittent prolonged orthostasis in adult male individuals. Cautions are advised while subjecting patients to orthostatic tolerance tests.

Keywords Electroencephalogram, Electroencephalography, Orthostasis, Orthostatic stress, Standing position

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1 Introduction

Orthostasis is a physical stressor.[1-5] It has a great impact on the circulatory system, causing diversion of blood to the lower extremities. It also results in reductions in venous return and depletion of central venous blood. All these potentially lead to suppression of cerebral perfusion [6-9] and orthostatic hypotension.

Neural control mechanisms elicited by orthostasis-induced reductions in venous return include deactivation of baroreceptors with attendant improvements in vascular tone, increased diastolic blood pressure, and improved heart rate.[10-12] These are necessary to control gravity-related diversion of blood to the extremities, reduce orthostatic hypotensive tendency, and limit the risk of syncope.[13-15] In addition, glucocorticoid and other stress hormones are released. The renin angiotensin aldosterone system is also activated, and the attendant effects include improvement in blood pressure and heart rate.

Numerous studies have elucidated the effects of orthostasis on human physiology. Compared with sitting, accumulating 2 hours and 30 minutes of light-intensity physical activity or standing during an 8-hour workday reduced ambulatory systolic blood pressure during and after work hours.[16] When prolonged sitting during deskwork was interrupted by intermittent standing, diastolic blood pressure, mean arterial blood pressure, and carotid-ankle pulse wave velocity were reduced.[17] Bates et al.[18] showed that daytime blood pressure was systematically elevated after standing and walking when compared to being seated.

Upright standing abolished elevated delta and theta activities induced by sleep loss.[19] In the standing position, it was found that sleep deprivation-induced increase in theta wave activity was attenuated by upright standing. [20] Post-exercise standing caused lower theta wave amplitude in males when compared to females.[21] Alpha wave frequency and alpha/beta ratio were low during the standing blood pressure position when compared to the sitting blood pressure position.[9] Sudden sit-to-stand switch caused low alpha wave frequency and reduced alpha/beta ratio.[22] In the right unipedal simulation, prolonged orthostasis was associated with increased alpha-band frequency and a high alpha-to-beta ratio.[3]

Orthostatic challenge is a principal health problem owing to its relation with cardiovascular diseases, mortality, and morbidity.[23] Uncompensated decrease in cerebral perfusion is a risk factor for orthostatic hypotension and orthostatic syncope.[6-9] Beyond being a health hazard, prolonged occupational standing is characterized by varying orthostatic durations. While some stand for long periods with only brief periods of sitting, others experience intermittent orthostatic hypotension. The aim of the study was to determine the comparative effect of prolonged orthostasis and single intermittent prolonged orthostasis on the electroencephalogram in male adult individuals.

Objectives

The objectives of the study were to determine (a) the comparative effect of prolonged orthostasis and single intermittent prolonged orthostasis on the alpha wave frequency, (b) the comparative effect of prolonged orthostasis and single intermittent prolonged orthostasis on the beta wave frequency, and (c) the comparative effect of prolonged orthostasis and single intermittent prolonged orthostasis on the alpha/beta ratio.

2 Methods

Study Design

The study was a pre-experimental research design (pre-(baseline) and post-comparison). The work was conducted in the Technologically Enhanced Laboratory unit of the Department of Physiology, College of Medical Sciences, Edo State University, Uzairue, situated in Etsako West Local Government Area of Edo State, Nigeria.

Participants

Forty young adult males aged 19.6 years were recruited for the study using respondent-driven sampling. Informed consent and approval were obtained from the Ethical Committee, Edo State University, Iyamho.

Inclusion Criteria and Exclusion Criteria

Inclusion criteria included being between the ages of 18 years and 21 years, male gender, systolic blood pressure (90 mmHg - 120 mmHg), diastolic blood pressure (60 mmHg - 80 mmHg), pulse rate (60 BPM - 100 BPM), and respiratory rate (12 cycles/min - 20 cycles/min).

Participants with a medical history of respiratory diseases, cardiovascular diseases, kidney diseases, hepatic diseases, metabolic diseases, and anatomical deformities were excluded. Those with a history of smoking, alcoholism, and caffeine or on any form of medication were ruled out, as was previously reported. [24-26]

Experimental Protocol

The study was conducted in the Physiology Laboratory at 25 °C between 8.00 am and 10.00 am. The participants were acquainted with the experimental procedure, including performance of orthostasis and how to report feelings of exertion and dizziness. They were asked to relax for 10 minutes in a sitting position. With electrodes attached and tethered through adhesive tape, baseline EEG was recorded in a sitting position.

Twenty-minute orthostasis EEG recording

With EEG electrodes attached to the scalp and tethered through adhesive tape, each subject assumed an erect position from a sitting posture and stood for 20 minutes, just as they were informed before the commencement of the study. EEG recording that spanned the period of orthostasis.

Single intermittent prolonged orthostasis

Single intermittent prolonged orthostasis consisted of a 1-minute break between two consecutive 20-minute orthostasis.

Immediately after the EEG orthostatic recording, participants underwent a 1-minute break during which they walked on a treadmill at 4km/hr. without the detachment of electrodes, but no EEG recording was done. The walking task was designed to simulate taking a light stroll after an initial prolonged standing.

Thereafter, they underwent another 20 minutes of standing, and an EEG recording was taken that spanned the period of orthostasis.

Measurement of Electroencephalographic Waves

EEG waves were recorded with the aid of Powerlab 26T (Adinstruments PTY, Australia). As indicated in the manual, both white and blue marked electrodes were connected to the left and right sides of the frontal part of the skull, while the black electrode was attached to the occiput. Electrodes were held in place by means of electrode pads and supported by adhesive tape to tether the electrodes to the skin and avoid disconnection during the sit-to-stand switch. Other measures aimed at preventing artifacts included avoiding ambient noise interference and maintaining proper cable connections. The sampling rate was 100,000 samples per second. The machine has in-built hardware filtering (low pass filter of 1-2000Hz) and software-based filtering (Labtutor). The input impedance was above 100 MΩ.

Statistical Analysis

Statistical analysis was conducted using Statistical Package for Social Science Students (SPSS) 23. Statistical test was done using a paired t-test and Analysis of Variance (ANOVA). Post-hoc test was done using Least Squares Difference (LSD). Significant difference was accepted at $p < 0.05$

3 Results

Effects of Prolonged Orthostasis and Intermittent Prolonged Orthostasis on Alpha Wave Frequency

According to Figure 1, 20-minute orthostasis did not significantly increase alpha wave frequency when compared with baseline. There was no significant difference between orthostasis and intermittent orthostasis.

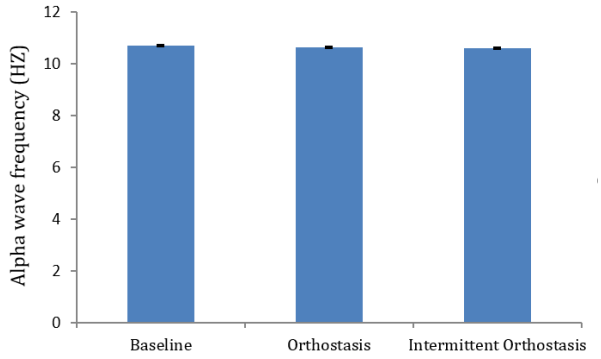

Figure 1 Comparative impacts of prolonged orthostasis and intermittent prolonged orthostasis on alpha wave frequency

Impacts of Prolonged Orthostasis and Intermittent Prolonged Orthostasis on the Amplitude of Alpha Wave

Figure 2 indicates that 20-minute orthostasis caused a significant decrease in alpha wave amplitude when compared to the baseline. During 20-minute orthostasis, alpha wave amplitude was significantly lower when compared to intermittent orthostasis.

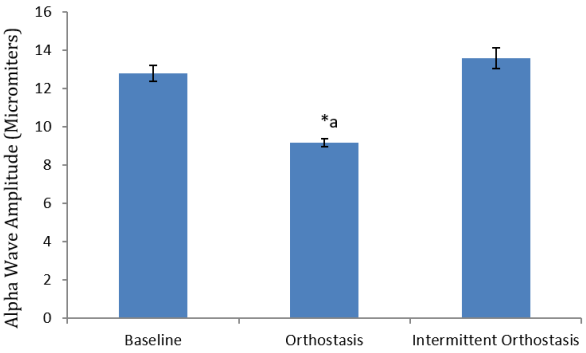

Figure 2 Comparative impacts of prolonged orthostasis and intermittent prolonged orthostasis on alpha wave amplitude. '*' represents a significant difference ($p < 0.05$) between baseline and orthostasis. 'a' represents a significant difference ($p < 0.05$) between orthostasis and intermittent orthostasis.

Relative effect of prolonged orthostasis and intermittent prolonged orthostasis on beta wave frequency

Figure 3 shows that 20-minute orthostasis caused a significant increase in beta wave frequency when compared to baseline. There was no significant difference between orthostasis and intermittent orthostasis.

Comparing the effect of prolonged orthostasis and intermittent prolonged orthostasis on beta wave amplitude

Twenty-minute orthostasis has no significant effect on beta wave amplitude when compared to baseline. There was no significant difference between orthostasis and intermittent orthostasis (Figure 4).

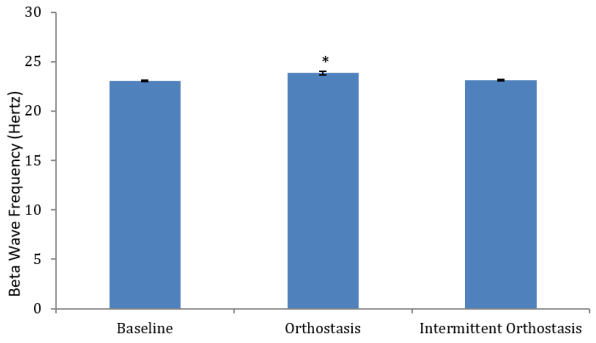

Figure 3 Comparative impacts of prolonged orthostasis and intermittent prolonged orthostasis on beta wave frequency. '*' represents a significant ($p < 0.05$) difference between baseline and orthostasis. 'a' represents a significant difference ($p < 0.05$) between orthostasis and intermittent orthostasis.

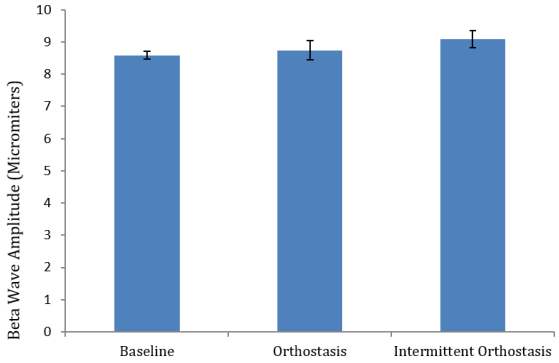

Figure 4 Comparative impacts of prolonged orthostasis and intermittent prolonged orthostasis on beta wave amplitude.

Comparative influence of prolonged orthostasis and intermittent prolonged orthostasis on the alpha/beta ratio

Figure 5 shows that 20-minute orthostasis led to a significant reduction in the alpha/beta ratio when compared to the baseline. Twenty-minute orthostasis resulted in a significantly lower alpha/beta ratio than intermittent orthostasis.

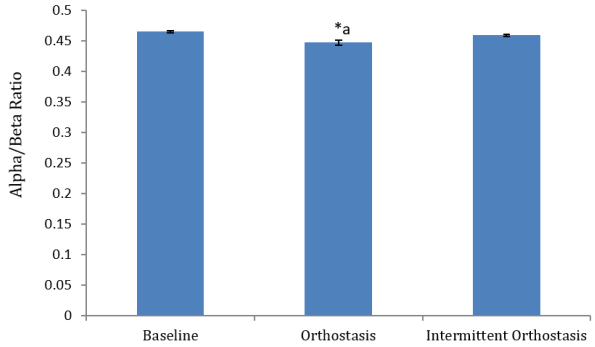

Figure 5 Comparative impacts of prolonged orthostasis and intermittent prolonged orthostasis on alpha/beta wave ratio. '*' represents a significant ($p < 0.05$) difference between baseline and orthostasis. 'a' represents a significant difference ($p < 0.05$) between orthostasis and intermittent orthostasis.

4 Discussion

Postural changes are known to affect brain activities.[27] Brain efficiency was shown by Jung et al.[27] to be lower during lying posture and greater during standing and sitting positions. Sudden switch from sitting to standing has been reported to cause a reduction in alpha wave frequency as well as a low alpha/beta ratio.[22,28] When compared to quiet standing, dual-tasking decreased alpha-band power, particularly in the central regions bilaterally, and increased theta/beta power ratio in the anterior regions bilaterally.[29] Prolonged unipedal orthostasis with the right leg caused an increase in alpha wave frequency and alpha/beta ratio.[3] Occupational exposure to prolonged standing is a health hazard. Occupationally related prolonged standing is characterized by varying orthostatic durations. The aim of the study was to determine the comparative effects of prolonged orthostasis and intermittent prolonged orthostasis on the electroencephalogram in adult male individuals.

One of the major findings of the study was that prolonged orthostasis caused a lower alpha/beta ratio when compared to single intermittent prolonged orthostasis and baseline, respectively. As an electroencephalographic index of fatigue, the alpha/beta ratio is a more reliable predictor of cortical activation[3,9,22] than either alpha or beta wave power. An increase in the alpha/beta ratio signifies fatigue, rest, drowsiness, engagement in repetitive monotonous tasks, and reduced attention. Reduction in the ratio implies either a relative reduction in alpha wave frequency or a relative increase in beta wave frequency. Nevertheless, the ratio is low during increased alertness and concentration. In previous studies, a sudden transition from sitting to standing has been shown to reduce the alpha/beta ratio.[22] During the standing blood pressure measurement position, the alpha/beta ratio was reported to be low.[9] Orthostasis causes baroreceptor deactivation and sympathetic dominance. Catecholamine-mediated sympathetic effects are cortically excitatory, thus creating arousal, alertness, and an increase in mood.

When compared to single intermittent prolonged orthostasis, prolonged orthostasis created a higher cortical activation and arousal. This might be mediated through orthostasis-induced sympathetic activation. In a previous investigation, prolonged unipedal orthostasis involving the right leg was shown to elicit a higher alpha/beta ratio, with a stronger positive correlation between the alpha/beta ratio and the rate of perceived exertion.[3] In essence, while standing for a long time elicits higher cortical activation, standing for a long time on the right leg causes fatigue.

In the present study, neither orthostasis nor single intermittent orthostasis caused a significant effect on alpha wave frequency. However, orthostasis caused decreased

alpha wave amplitude when compared to baseline and single intermittent orthostasis. The amplitude of the alpha wave is a reflection of the level of prominence of visual neuron inactivity. Beta wave frequency was found to be higher during prolonged orthostasis when compared to baseline and single intermittent orthostasis, respectively. This implies that single, intermittent, prolonged orthostasis induced a relative reduction in cortical activation. In a previous work, a low beta wave frequency was obtained after cessation of seated rotatory chair activity.[29] Moreover, neither orthostasis nor single intermittent orthostasis has an effect on beta wave amplitude.

Besides being a physical activity, standing is one of the natural postures exhibited by human beings. Although the present study investigated the comparative effects of prolonged orthostasis and intermittent prolonged orthostasis on the brain waves, limitations of the study included the small sample size and its narrow gender coverage. Studies investigating the impacts of prolonged standing in both males and females are essential for understanding the physiological responses to the stressor and to draw a level of caution that could prevent orthostatic hypotension, orthostatic tachycardia, as well as other orthostatic challenges in healthy individuals and those who are susceptible to orthostatic problems.[14,30-32]

5 Conclusion

The findings of the study showed that prolonged orthostasis for 20 minutes caused relatively greater cortical activation when compared to single intermittent prolonged orthostasis in adult male individuals. Given the established links between orthostatic intolerance and cardiovascular diseases, cautions are advised while subjecting patients and individuals who are vulnerable to orthostatic hypotension to orthostatic tolerance tests. Future studies are required to demonstrate the gender related influence of prolonged orthostasis and intermittent orthostasis on brain activities and cerebral blood flow.

Declarations

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Artificial Intelligence Disclosure
No Artificial Intelligence tools were used.

Authors' Contributions
Mayowa Jeremiah Adeniyi was responsible for the conceptualization, manuscript writing, and analysis of the study. Ayoola Awosika was responsible for critiquing and reviewing. Phoebe Nwamaka Kanikwu was responsible for critiquing.

Availability of Data and Materials
The data supporting the findings of this study are available within the article.

Conflict of Interest
The authors declare no conflict of interest.

Consent for Publication
Not applicable.

Ethical Considerations
The Code of Ethics ED035-2 was granted by the Institutional Research Board for the study.

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