OPEN ACCESS

Middle East Research Journal of Medical Sciences
ISSN: 2789-7699 (Print) & ISSN: 2958-2024 (Online)
Frequency: Bi-Monthly
DOI: 10.36348/merjms.2023.v03i01.001

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Impact of Gender on Post-Exercise Orthostasis Related Changes in EEG Amplitudes

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Abstract: Changes occur in brain functions before, during and after physical exercise as well as during orthostasis in males and females. The study aimed at understanding the effect of gender on post-exercise orthostasis induced changes in EEG amplitudes. 30 apparently healthy individuals consisting of 15 males (18.5 years) and 15 females (18.5years) were recruited for the study. They were divided into baseline, exercise and post-exercise orthostasis groups. Subjects were exercised on a treadmill for 10 minutes at 8km/hr. After which they were asked to stand for 10 minutes on both legs. EEG recording was carried out using PowerLab 26T using frontal and occipital electrodes as indicated in the operational manual. When compared with baseline, post-exercise orthostasis caused reduction in theta waves amplitude in males and females respectively and a decrease in alpha waves amplitude in males only. Post-exercise orthostasis lowered theta waves amplitude in males when compared with females while other EEG waves were not affected. There was a positive correlation was observed between shock index and alpha wave amplitude (r= 0.437, P<0.05) in males during post-exercise orthostasis but none in female. The findings of the study indicated that orthostasis after exercise relatively reduced theta waves in males compared to females.

Keywords: EEG amplitude, orthostasis, post-exercise, PowerLab, EEG recordings.

Research Paper

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How to cite this paper:
M. Adeniyi & A. Awosika (2023). Impact of Gender on Post-Exercise Orthostasis Related Changes in EEG Amplitudes. *Middle East Res J. Med. Sci*, *3*(1): 1-8.

Article History:
| Submit: 12.04.2023 |
| Accepted: 25.05.2023 |
| Published: 29.05.2023 |

INTRODUCTION

For long, brain has been known to be influenced by metabolism-perturbing internal and external events. Physical exercise for instance has been implicated in the enhancements of motor function [1,2], alleviation of anxiety [3] and improvement in cognitive abilities [4,5]. During intensive physical activity, a reduction in metabolic ratio (a measure of oxygen uptake by the brain relative to glucose) from 6 to 3 and a shift in energy substrate from glucose to lactate have been reported [6,7]. A study by Lambourne and Tomporowski, (2010) [8] showed that physical exercise enhanced cognitive performance causing enhancement in memory capacity, storage and retrieval as well as speeded cognitive processes. Sensory sensitivity has been reported to increase during exhaustive physical exercise [9] just the same way reaction time was decreased by maximal and submaximal physical exercise. Exercise causes profound changes in the functionality of reticular activating fibers [10] involved in cortical activation [11] and necessary for the generation of electroencephalographical waves.

Electroencephalogram records electrical activities occurring within the superficial part of the brain as understandable language ‘brain waves’. The waves are reflection of activity pattern and metabolic state of cerebral neurons. For instance, alpha waves are produced during resting visual cortex, delta and beta waves represent lowered cortical metabolic activities and cortical activation respectively. Interestingly, cortical activation is the resultant effect of uninhibited ascending reticular fibers. Exercise induced cortical activation causes changes in brain waves such as increase in frequency and amplitude of beta waves. Lin *et al.*, (2021) [12] reported that high-resistance exercise via sustained cycle ergometer program caused marked influences on beta-band phase locking value and a rise in alpha-band phase locking value. During intensive exercise, alpha wave amplitude may increase owing to changes in blinking frequency. Intensive physical exercise regularly caused a low spectral power delta band compared to the control group [13].

Studies also avail on EEG changes post-exercise. A study published by The Physiology Society in 2013 [14] on gender EEG implication before and after acute exercise indicated a reduction in alpha waves in right frontocentral region and a diminished left alpha waves in the central region. It was also noted that females were less relaxed following exposure to exercise of moderate intensity than male [14].

Apart from exercise, orthostasis is another phenomenon that can affect brain activities. It causes blood to be drawn to lower extremities at the expense of the brain thereby causing significant changes in cerebral discharge [15,16]. Brenner *et al.*, (1997) [17] reported in their study that orthostasis was characterized by preliminary slowing of background rhythms, which was then followed by delta waves. Alpha wave activity was high following 15 minutes of head-up orthostasis [18]. Despite the fact that brain activities change before, during and after exercise and during orthostasis, there is no sufficient information about the effect of post-exercise orthostasis on EEG especially in both males and females. Hence, the aim of the study was to examine how orthostasis affected EEG amplitudes after exercise in both male and female.

MATERIALS AND METHODS

Study Design

The study adopted experimental research design. The work was carried out 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.

Subjects/Participants

30 apparently healthy young adult individuals consisting of 15 males (18.5years) and 15 females (18.5years) were used for the study. Ethical clearance was obtained from the Ethical Committee, Edo State University Iyamho. Written consent was obtained from each subject and a well-structured questionnaire was administered to rule out those with medical history of musculoskeletal, respiratory, cardiovascular, kidney, hepatic and metabolic diseases or anatomical deformities. History of smoking, alcoholism and caffeine and any form of medication was also taken. Medical examination and physical activity status were also done.

Inclusion Criteria

40 young adult individuals were accommodated into the groups. Written consent was gotten from each subject and a well-structured questionnaire was administered to rule out those with medical history of respiratory diseases, cardiovascular, kidney, hepatic and metabolic diseases or anatomical deformities. History of smoking, alcoholism and caffeine and any form of medication was also taken. Medical examination and physical activity status evaluation were also done. Physical examinations were also done and those that were not medically fit were disqualified. For example those with musculoskeletal abnormalities, high blood pressure, among others were ruled out.

Experimental Protocol

The study was done in the Physiology Laboratory at a temperature of 25˚C between 8.00 a.m. and 10.00am. The treadmill was calibrated according to the Bruce Treadmill Protocol (Bruce *et al.*,). Each subject was maintained on a speed of 8km/hr at an inclination of 10˚ for 10 minutes.

The subjects were grouped as follows:

1. Baseline group; Subjects were asked to sit comfortably.
2. Exercise group; Subjects were maintained on a speed of 8km/hr at an inclination of 10˚ for 10 minutes
3. Post-exercise orthostasis; maintained on a speed of 8km/hr at an inclination of 10˚ for 10 minutes. They were then asked to stand for 10 minutes on both legs.

Measurement of Electroencephalographic waves

Electroencephalographic (EEG) waves were recorded using Powerlab 26T (Adinstruments PTY, Australia). As stipulated in the manual, both white and blue marked electrodes were connected to the left and right side 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. As part of the measures aimed at preventing artifacts, ambient noise interference was avoided. Baseline (EEG) readings were taken at sitting position. EEG recordings were also obtained during exercise and post-exercise orthostasis for both males and females.

Measurement of blood pressure

Blood pressure was measured from the arm, an inch above the elbow using Omron BP7000 Evolve Wireless Upper Arm Sphygmomanometer (Iris Global Care, China). Baseline readings were taken at sitting position as previously reported [20-22]. Blood pressure measurements were also obtained for each of the legs at the first perception of exertion.

Pulse pressure was determined by subtracting diastolic blood pressure from systolic blood pressure. Mean arterial blood pressure was obtained using; diastolic blood pressure +1/3 of pulse pressure.

Statistical Analysis

Statistical analysis was conducted using Statistical Package for Social Science Students (SPSS) 23. Statistical test was done using Analysis of Variance (ANOVA) and student t test. Statistically significant difference was accepted at $P<0.05$.

Results

Effect of gender on post-exercise orthostasis induced changes in eeg amplitude

Post-exercise orthostasis caused a significant reduction ($P<0.05$) in alpha wave amplitude in male when compared with the baseline (Figure 1a). Female baseline showed significantly lower ($P<0.05$) alpha waves amplitude when compared with that of male. During exercise, female alpha waves amplitude was significantly lower ($P<0.05$) when compared to that of male.

Exercise led to a significant rise ($P<0.05$) in beta waves amplitude when compared with baseline (Figure 1b). Male exercise group exhibited significantly higher ($P<0.05$) beta waves amplitude than female exercise group. When compared with the baseline (Figure 1c), there were significant reductions ($P<0.05$) in theta waves amplitude during exercise and post-exercise orthostasis in male and female respectively. Male baseline has significantly higher theta waves amplitude ($P<0.05$) when compared with that of female. Male post-exercise orthostasis showed significantly lower theta waves amplitude ($P<0.05$) when compared to that of female. In female (Figure 1d), exercise caused a significant reduction ($P<0.05$) in delta waves amplitude when compared with the baseline. Male baseline showed a significantly lower ($P<0.05$) delta wave amplitude when compared with that of female.

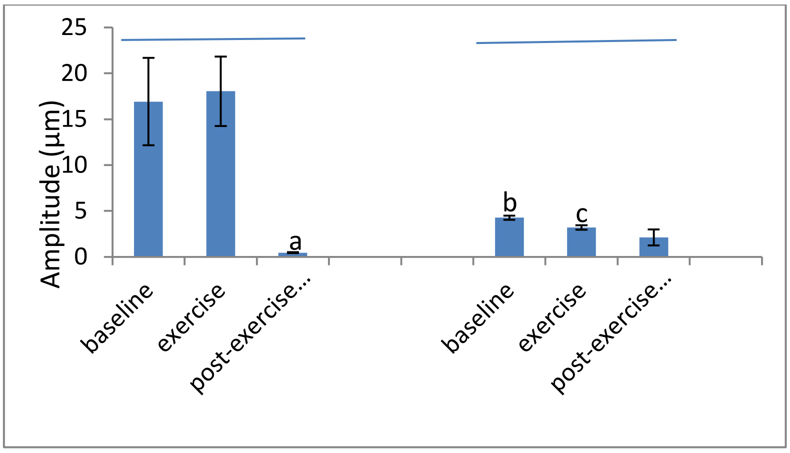

Figure 1a: Effect of gender on post-exercise induced changes in alpha waves amplitude. 'a' significant difference ($P<0.05$) from the baseline.'b' significant difference ($P<0.05$) between male baseline group and female baseline group. 'c' significant difference ($P<0.05$) between male exercise group and female exercise group.

Beta wave amplitude

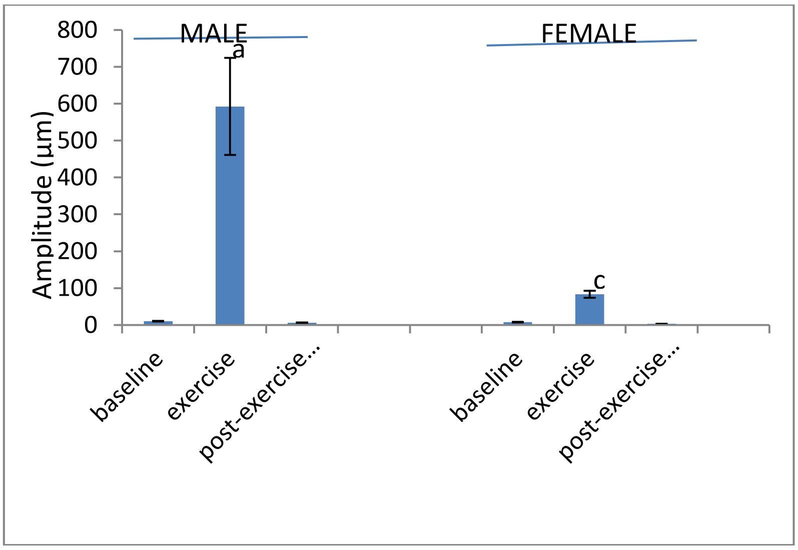

Figure 1b: Effect of gender on post-exercise induced changes in beta waves amplitude. 'a' significant difference ($P<0.05$) from the baseline. 'c' significant difference ($P<0.05$) between male exercise group and female exercise group.

Theta wave amplitude

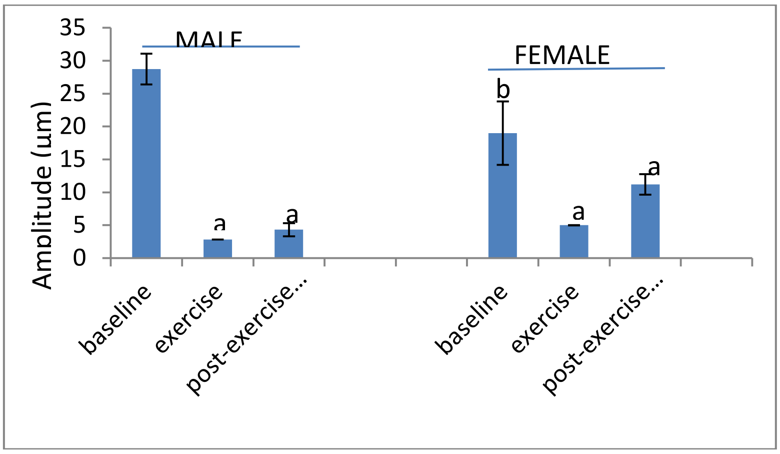

Figure 1c: Effect of gender on post-exercise induced changes in theta waves amplitude. 'a' significant difference (P<0.05) from the baseline. 'b' significant difference (P<0.05) between male baseline group and female baseline group. 'd' significant difference between male post-exercise orthostasis group and female post-exercise orthostasis group.

Delta wave amplitude

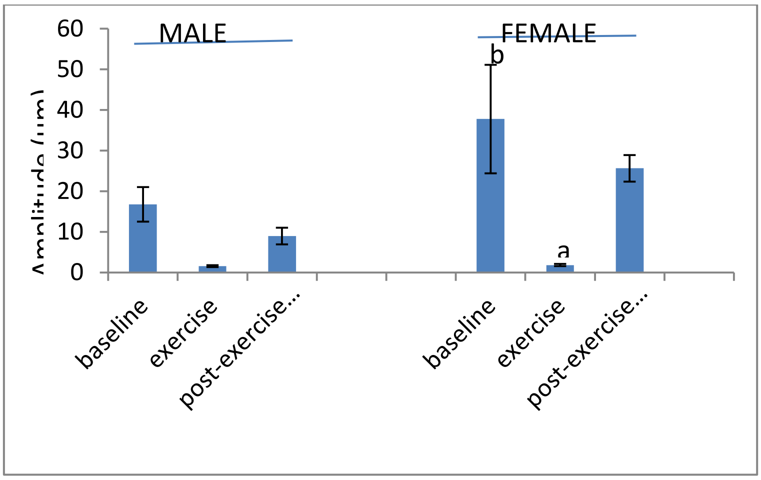

Figure 1d: Effect of gender on post-exercise induced changes in delta waves amplitude. 'a' significant difference (P<0.05) from the baseline. 'b' significant difference (P<0.05) between male baseline group and female baseline group. 'd' significant difference between male post-exercise orthostasis group and female post-exercise orthostasis group.

Effect of gender on post-exercise orthostasis induced changes in cardiovasular parameters

Post-exercise orthostasis caused significant decreases (P<0.05) in systolic blood pressure (SBP) in male and female and diastolic blood pressure (DBP) in female (Table 1). Post-exercise orthostasis caused significant increases in pulse rate in both male and female and rate pressure product and double product in male respectively. In male post-exercise orthostasis group, there was reduction in SBP and pulse pressure when compared to that of female. In male post-exercise orthostasis group, there was increase in DBP, pulse rate, rate pressure product and double product when compared to that of female. Male exercise group has significantly higher SBP, DBP, pulse rate, RPP and double product when compared with female exercise group. Female baseline group has significantly higher pulse rate, RPP and double product when compared with male exercise group.

Table 1: effect of gender on post-exercise orthostasis induced changes in cardiovascular parameters
'a' significant difference (P<0.05) from the baseline. 'b' significant difference (P<0.05) between male baseline group and female baseline group. 'c' significant difference between male exercise group and female exercise group. 'd' significant difference between male post-exercise orthostasis group and female post-exercise orthostasis group.

Cardiovascular Parameters	Groups	Baseline (Mean±SEM)	Exercise (Mean±SEM)	Post-Exercise Orthostasis (Mean±SEM)
SBP	Male	118.5 ± 0.158	121.0 ±0.316[a]	110.5 ±0.474[a]
	Female	118 ±0.316	125.0 ±0.316[ac]	106.5 ±2.056[ad]
DBP	Male	78.5 ± 0.158	81 ± 0.949[a]	71.5 ± 0.474[a]
	Female	79.0 ± 0.316	84.0 ±0.000[ac]	72.0 ± 0.633[ad]
Pulse Pressure	Male	40.0 ±0.000	40.0 ± 0.633	39.0 ± 0.000
	Female	39.0 ± 0.000	41.0 ± 0.316	34.5 ± 1.423[d]
Pulse Rate	Male	91.0 ±0.6325	131.1 ±2.055[a]	121.9 ±0.848[a]
	Female	93.0 ± 1.581	101.0 ± 0.316[ac]	133.5± 0.474[ad]
Shock Index	Male	0.768 ± 0.00636	1.08 ± 0.014[a]	1.1037 ± 0.012[a]
	Female	0.7883± 0.0045	0.808 ± 0.00407[c]	1.2557 ± 0.029 [ad]
Rate Pressure Product	Male	107.83 ±0.6056	158.66±2.902[a]	134.73 ±0.358[a]
	Female	109.7 ±1.572[b]	126.3 ± 0.076[ac]	142.14 ± 2.24[d]
Double Product	Male	8356.43 ±43.6928	12373.17 ±290.66[a]	10302.32 ±13.8069[a]
	Female	8554.0 ± 116.062[b]	9864.2 ± 20.239[ac]	11145.15 ± 108.16[d]

Effect of gender on post-exercise orthostasis induced changes in SP02

Male post-exercise orthostasis group has significantly higher SP02 when compared with that of female (Table 2).

Table 2: effect of gender on post-exercise orthostasis induced changes in SP02
'd' significant difference between male post-exercise orthostasis group and female post-exercise orthostasis group.

Groups	Baseline (Mean±SEM)	Exercise (Mean±SEM)	Post-Exercise Orthostasis (Mean±SEM)
Male	98±0.00	98.5 ±0.474	98 ±0.633
Female	98.5±0.158	99.5±0.158	93.5±1.739[d]

Correlation between eeg waves and SP02 in male during post-exercise orthostasis

There were strong significant correlations between shock index and alpha waves amplitude (P<0.05) in males (Table 3a).

Table 3: correlation between EEG waves and shock index in male during post-exercise orthostasis

Correlation (R)	Alpha Wave Amplitude	Beta Wave Amplitude	Theta Wave Amplitude	Delta Wave Amplitude
Shock Index	0.437*	-0.298	-0.214	-0.198

Correlation Between EEG Waves And Shock Index In Female During Post-Exercise Orthostasis

There were insignificant correlations between shock index and alpha, beta, theta and delta waves amplitude (P<0.05) in females (Table 3b).

Table 3: correlation between EEG waves and shock index in male during post-exercise orthostasis

Correlation (R)	Alpha Wave Amplitude	Beta Wave Amplitude	Theta Wave Amplitude	Delta Wave Amplitude
Shock Index	0.152	-0.158	-0.204	-0.234

DISCUSSION

Like other techniques explored in diagnosis and biomedicine [23-25], electroencephalography is useful in the diagnosis and prognosis of brain disorders. It also makes assessment of brain's functional status possible in various situations including exercise, post-exercise and orthostasis. The study examined the impact of gender on post-exercise orthostasis induced changes in EEG waves. Although on the basis of gender, post-exercise orthostasis exerted no significant effect on beta, delta and alpha waves amplitudes, the main finding of the study was that theta waves amplitude was lower in male during post-exercise orthostasis than female. Theta waves are low frequency waves (4-7Hz), penultimate to delta waves. They are generated principally by cortical neurons and hippocampus and are prominent during meditation, mental activities, memory consolidation, light sleep and rapid eye movement sleep. Significant difference has for long been reported between male and female brains anatomically. For instance, male brain was shown to be larger in size and overall weight than that of female [26]. Females were also reported to exhibit greater EEG amplitude in resting EEG in various frequency bands [27,28], it is however unclear whether age parity was put into consideration in these studies. In the present study, the EEG amplitudes of age-matched male and female individuals were compared.

Furthermore, the study showed that the mean baseline theta waves amplitude was higher in the males than females. The cause and significant of this finding is sketchy since gender influence on mental activity is controversial [29,30]. Theta waves are seen during deep relaxation states [31], in the study, exercise was found to reduce theta waves amplitude in both males and females when compared to baseline. Although significant changes occur in brain waves during orthostasis [17], in the study, post-exercise orthostasis was shown to cause reduction in theta wave amplitude in both males and females when compared with the respective baseline.

Delta waves are EEG waves with the least frequency (0.5-4HZ). They are more noticed during deep sleep. They typically portray brain neurons in their less active states [32]. Hence during exercise, delta waves are expected to be less prominent because of increased activity of cortical neurons. In the study, exercise was found to cause reduction in delta waves amplitude in female relative to male. Furthermore, like previous report [27], in the study, baseline delta waves amplitude was found to be greater in females than males.

Alpha waves are due to inhibition of visual cortical neurons by spontaneous reticular thalamic discharge. They are prominent during relaxed mood with eyes closed as well as light sleep. Nishifuji, (2011) [33] in his study indicated that acute exercise with low intensity enhanced rapid recovery and alpha wave. Orthostasis has also been shown to influence alpha activity. For example, during 15 minutes orthostasis, Ivanovia and Lilia, [18] reported there was an increase in alpha waves. Blinking as a physiological process involves sequential closure of the eye lids and thus elicits prominent alpha waves. During exercise, eye movements and blinking are common. In the study, post-exercise orthostasis was shown to reduce alpha waves amplitude when compared with baseline. Furthermore, baseline alpha waves amplitude was found to be higher in male than female.

Cardiovascular responses to exercise have been widely documented in literatures [15,22]. Orthostasis, defined as standing upright, has also been identified as a stressor and modulator of cardiovascular activity [34]. The study showed that during post–exercise orthostasis, there was reduction in systolic blood pressure in males and females. It has been documented that during upright tilt, hemodynamic changes take place in blood circulation and distribution and at least 0.75L of blood, representing at least 10% of blood volume is pushed into the lower extremities during sudden standing from a reclining position [15,35]. Therefore, in order to avert gravitational stress-induced central blood volume deprivation, a number of physiological mechanisms have to be activated.

For instance, central nervous system ischemic response is a protective reflex that swerves into action in severe shortage of blood supply to the brain. This reflex works by inducing an increase in total peripheral resistance, thus increasing blood pressure. In the present study, it was also observed that during post-exercise orthostasis, males exhibited reduced systolic blood pressure and pulse pressure and increased diastolic blood pressure, pulse rate, rate pressure product and double product when compared to female.

Peripheral oxygen saturation and shock index indicate level of tissue perfusion. Peripheral oxygen saturation is a proportion of oxygenated blood and it is influenced by capillary density [21,36-40]. The study showed that post-exercise orthostasis elicited a decrease in peripheral oxygen saturation in males when compared to females. Shock index calculated by divided pulse rate by systolic blood pressure [22] increases in hypotension and during hypotension related event such as post-exercise orthostasis as indicated in the study. However, a positive correlation was observed between shock index and alpha waves amplitude in males during post-exercise orthostasis but none in females. Although baseline alpha waves amplitude was found to be higher in male than female, it is unclear whether this justifies the association.

CONCLUSION

The findings of the study indicated that post-exercise orthostasis exhibits gender-based effect on theta waves amplitudes.

ACKNOWLEDGEMENT

The authors are grateful to the non-academic staff of physiology department, Edo State University Uzairue.

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