Neuropsychological Trends

32
November 2022

Study on neuropsychological and neurophysiological functions: acute effect of aerobic exercise training in sleep disturbed collegiates

Zainab Khan[1] - Muhammad Azharuddin[1] - M. Ejaz Hussain[2] - Anam Aseem[1] - Ashi Saif[1]

[1]Centre for Physiotherapy and Rehabilitation Sciences, Jamia Millia Islamia (Central university), New Delhi, India

[2]Faculty of Allied Health Sciences, Shree Guru Gobind Singh Tricentenary University (SGT), Haryana, India

DOI: https://dx.doi.org/10.7358/neur-2022-032-khan

jannat.zainab@jmi.ac.in

ABSTRACT

This study aimed to investigate the acute effects of aerobic-exercise (AE) on neurophysiological-functions and neuropsychological-functions in sleep-disturbed collegiates. 32 eligible students were included in study. They completed 30 minutes of single bout of moderate AE (at 60–70% of maximal heart rate reserve). Pre and post training measures were tested for both, neurophysiological-functions by recording event-related-potential-P300 [P300-amplitude and P300-latency], and for neuropsychological-functions by administering neuropsychological-test-battery [Attention, Working-memory, Sensorimotor-speed and Executive-function (EF)]. In experimental group, statistically significant improvements were observed when analyzed for all 3 (group-by-time interaction, main-time, and main-group) effects in neurophysiological-functions. However, results were not significant for all neuropsychological-functions measures except for EF. Correlation-analysis demonstrated no association between neurophysiological-functions and neuropsychological-functions except for post-intervention (p300-latency and attention). It is therefore can be concluded that acute bout of AE may be a promising approach to improve cognitive-functions in sleep-disturbed collegiates, however long-lasting effects are still unclear.

Keywords: sleep disturbance; cognitive impairment; ERP; neuropsychological test; aerobic exercise

1. Introduction

In today's world, insomnia is fairly frequent. Numerous sleep issues affect students in particular, with a reported prevalence of 19.2 to 57.5 percent among university students (Manzar et al., 2015). Consequences of sleep issues may be severe and protracted. Decreases in cognitive performance are among the worst effects of sleep disruptions, which damage an individual's overall physiology (Sweileh et al., 2011). Gray and white matter atrophy in the brain is linked to issues with sleep. According to Harrison and colleagues, the lateral prefrontal cortex and the medial temporal lobe system, which includes the hippocampus, are significantly damaged (Harrison et al., 2000). The "sleep-based neuropsychological viewpoint", which contends that sleep disturbances interfere with the functioning of specific cortical areas and hence impair cognitive function, is relevant here (Babkof et al., 2005). Prefrontal vulnerability ideas, put forth by Horne, are the most widely held theory in this category (Horne et al., 1993). Given that the prefrontal cortex and the hippocampus are responsible for controlling cognition, this exhibits complex presentation of cognitive abnormalities. Sleep disorders are linked to declines in performance across a range of cognitive domains, including speed of information processing, speed of perception, executive function, concentration and attention, inhibitory function, and memory (Haimov et al., 2013). It has been observed that sleep disturbances change the shape of event-related potentials (ERPs). Those who experience sleep disturbances see a slight delay in the P300 wave's beginning and a decrease in its amplitude (Lee et al., 2004). Additionally, it has been observed that sleep disturbances impact how well people do on neuropsychological test batteries (NBT) (Aseem et al., 2018). The body of research implies that in order to improve the diminished cognitive functioning in sleep-disrupted adolescents and young adults, a study should investigate certain non-pharmacological and non-invasive therapies.

There is support in the literature for the beneficial effects of acute exercise on cognitive performance (Chang et al., 2012). Aerobic exercise (AE) is a type of physical activity (PA) that is structured to achieve specific fitness goals (Caspersen et al., 1985). AE have been associated both with the betterment of the psychological health (De-yan et al., 2007) and improvements in cognitive performance both in college students (Li et al., 2014) and young adults (Tomporowski, 2003). Ample of previous evidences shows, that a beneficial effect of chronic AE exists, but it still remains unclear the acute effect of AE particularly in sleep disturbed collegiates. In reality, there have only been a few studies that have looked at how acute AE affects college students who have sleep problems in terms of their cognitive performance. The primary aim of the present study was to determine whether acute aerobic exercise training can help university students with their neurocognitive and neuropsychological performance and reduce cognitive changes linked to sleep disturbance. The secondary aim was to check if there exists a correlation between neurophysiological and neuropsychological functions. We hypothesized that there will be a significant association between neurophysiological and neuropsychological correlates and both functions will improve following an acute bout of AE training in sleep disturbed collegiates.

2. METHODS

2.1 Sample size

The number of subjects (n=28) were determined with Software G. Power 3.1.9.4 (Franz F, Universitat Kiel, Kiel, Germany), using the changes in the neurophysiological functions (measured by ERP-P300 amplitude) after physical activity training, in which post hoc analyses revealed a significant main effect for the test (P3 amplitude) and indicated that group differences were observed at the Fz site, $F(3, 28) = 5.5$, $p < .01$, partial $\eta^2 = 0.37$, with Bonferroni corrected t tests revealing significantly greater P300-amplitude for moderate and high active individuals. (Hillman et al., 2004). Total of 28 subjects (14 in each group) were shown to be necessary based on the effect size of 0.37, alpha level of 0.05 and power (1-beta) of 0.80. Total sample size was 32 patients (16 per group) considering for 20% of dropouts.

2.2 Participants

Total of 50 students (26 females and 24 males) with age ranging from 18 to 28 were checked for eligibility on PSQI (bad sleepers > PSQI) (Manzar et al., 2015) from Jamia Millia Islamia. Out of 50, 38 participants fulfill the criteria. Six participants refused to participate in the study. 32 participants (17 females and 15 males) were included in the study. The means (age, height, weight, BMI) are 20.93±1.52 years, 161.84±6.64 cm, 65.45±4.02 kg, 26.90±1.06kg/m^2, respectively (Table 1). All the included participants reported normal hearing, regular or modified to normal vision, and all understood the basic English language. Participants were excluded if they had a history of neurological, psychological and mental problem, physical impairment likely to impair regular exercise output, alcohol consumption, any substance misuse, centrally active drugs (that might affect ERP), or if they took sleeping pills and/or undergoing any form of physical training for the last 6 months, which could introduce the risk of biases in the result of the study. The study was approved by the Institutional Ethics Committee (IEC), Jamia Millia Islamia (Central university), New Delhi India, with reference no 19/2/213/JMI/IEC/2019. The study was conducted in Neurophysiology Lab, Centre for Physiotherapy and Rehabilitation Sciences, Jamia Millia Islamia. All the participants gave their written informed consent before the start of the study. Allocation of the participants was done by computer randomization method, and the participants were blinded and allocated to either of the two equal groups: AE group (AEG; n=16) or control group (CG; n=16) (Figure 1). Intervention was given to experimental group (AEG). After intervention, data from both the groups were analyzed.

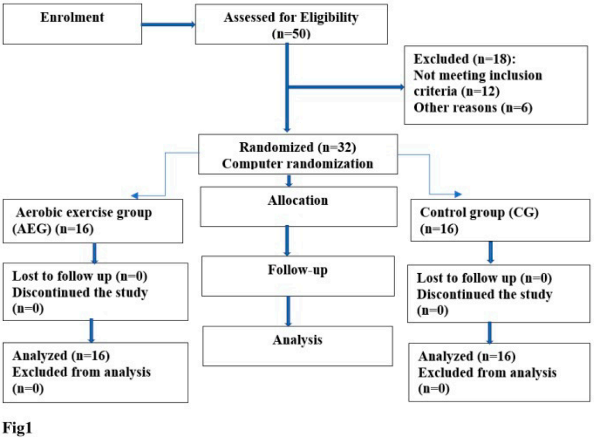

Figure 1. Flowchart of the study design

2.3 Outcome measures

2.3.1 Neuropsychological measures

This was carried out in calm and quiet environment. Under the supervision, the PennCNP, neuropsychological battery established by University of Pennsylvania was administered on desktop (Gur et al., 2010; 2012). There was a practice module before each test. Tests were done both before and after acute bout of AE for the following domains:

Attention

Continuous Performance Test (CPT) is a well-recognized paradigm for the measurement of attention and vigilance. It has been linked to fronto-parietal network activation. A typical CPT paradigm is applied by the Penn CPT. When the lines are set up as complete numbers (first half of task) or entire letters, the participant must press the spacebar. Vertical and horizontal lines in 7-segment displays emerge on the screen (at a rate of one second apiece) (second half of task). Each half lasts for 1.5 minutes, and the stimulus is only visible for 300 ms of each 1-s response window (leaving 700 ms of blank screen) (Gur et al., 2010; 2012).

Working memory

Penn letter n-back test (LNB2) measures the working memory and executive control. Participants followed three different rules while pressing the spacebar as a continuous stream of letters flashed on the screen (one at a time) (called the 0-back, 1-back, and 2-back). In the 0-back condition, the participant just needs to react to an active target. When the letter on the screen matches the preceding letter during the 1-back condition, the user must press the spacebar. When the letter on the screen is the same as the letter before the previous letter during the 2-back condition, they must press the spacebar (i.e., 2 letters back) (Gur et al., 2010; 2012).

Sensorimotor speed

The Finger Tapping Test measures the motor speed by assessing the number of times subjects depress a keyboard key using the index finger of their dominant and nondominant hands (Reitan & Davidson, 1985). Participants are instructed to use their index finger to push the space bar as frequently as they can. Their dominant and non-dominant hands are used alternately in six trials of 10 seconds each. A practise session for each hand is conducted before to the test. The total number of taps on the 6 trials is used to calculate speed (Gur et al., 2010; 2012).

Executive function

TMT-B is used to measure the executive function (Gaudino et al., 1995). On TMT-B, participants are asked to connect randomly spread numbers (from 1 to 13) and letters (from A to L) in alternating numeric and alphabetical order (1-A-2-B-3-C-…-13-L). In case of an error the examiner draws the attention of the participant to the error, so that the participant completes the task without errors (at the expense of additional time). TMT-B performance was calculated taking the time needed to perform TMT-B (Lezak, 1976). Normally, the TMT-B is valid and reliable measures for both adults and the elderly (Rabin et al., 2005).

2.3.2 Neurophysiological measures

ERP components during wakefulness are related to attention and information processing. P300 is the most well-known of these components and is regarded as the electrophysiological correlate of cognition (Hull et al., 2001). Both, ERP-P300 wave's latency and amplitude were measured.

P300 latency and P300 amplitude

The participant was made to sit comfortably. N-PrepTM skin preparing gel (Weaver and Company, USA) was used to gently clean the scalp before EEG paste (Ten20TM conductive) was applied to various areas of the scalp to prepare it for the implantation of electrodes. Electrodes made of Ag-AgCl discs were utilized for recording. The ground electrode was attached on the forehead (Fpz), active electrode on the vertex (Cz) and reference electrodes on mastoid (A1). This electrode implantation followed the procedures used in earlier research to measure the auditory event-related potential (Lee et al., 2004). The AERPs were captured while participants completed a task using the common auditory oddball paradigm. The respondents were told to count the number of (rare, target stimulus) presentations of a high-pitch tone (S1) rather than the number of (common, non-target stimuli) presentations of a low-pitch tone while they heard two different types of sounds through headphones (S2). The target: nontarget ratio for the S1 and S2 sounds was chosen at random in accordance with the previous studies (Aseem et al., 2018; Lee et al., 2003). The time between each stimulation was 1 s. Each tone lasted for 50 ms. Subjects were instructed to refrain from making excessive facial, eye, and neck movements while the AERPs were being recorded (Chatterjee et al., 2012). P300 recordings were made both before and after the study's length.

2.4 Intervention

For the purposes of this study, acute exercise was defined as a single session of exercise lasting up to 30 minutes. The AE protocols was based on previous work by (Chang et al., 2017). The AE session consisted of cycle ergometry for 30 minutes, with a warm-up of 5 minutes, 20 minutes of moderate exercise (i.e., 60–70% of maximal heart rate (HR) reserve), and a cool-down of 5 minutes (Chang et al., 2017). The index finger was placed with the probe of a pulse oximeter (Nihon Kohden's OLV-1100/1200 series, heart rate monitor) in order to measure the heart rate (HR) and oxygen saturation during the exercise regimen. Additional evaluation of exercise intensity was done using Borg's original (6-20) Rating of Perceived Exertion (RPE) scale (Borg, 1970). In an effort to match exercise intensity and reduce confounding factors across experimental interventions, the use of two distinct measures of exercise intensity was implemented (Harveson et al., 2016). The control group met twice with the researchers in the lab but did not get any training. Members of the study team talked with the subjects about broad matters pertaining to their interests for 15 minutes during these meetings. They were asked not to take part in any PA (Aseem et al., 2018).

2.5 Statistical Analysis

Data were analysed with SPSS version 28.0. Normality distribution of all outcome measures was verified using the Shapiro-Wilk-test, skewness and histogram. Outcome variables which showed non-normal distribution were analysed using a non-parametric-test or log-transformed. Using an independent sample t-test, baseline measurements and demographic characteristics were examined and found to be comparable between the two groups. All variables were assessed using a 2x2 mixed model ANOVA [group and time effect (pre and post)] for each participant in each group. All comparisons were considered significant at $p \leq 0.05$, and confidence interval was set at 95%. The correlation between neurophysiological and neuropsychological functions was computed using the Pearson's correlation analysis.

3. Results

All the demographic characteristics including age, weight, height, BMI, and Kuppuswamy socio-economic status were found to be comparable as assessed by independent t test (Table 1). While there was no significant difference between all the outcome variables values in the CG, there was a significant improvement in most of the outcome variables values in the AEG following single bout of AE.

Table 1. Comparison of demographic data between Aerobic-exercise-group and Control-group using independent sample-t-test

Outcome measures	CG(n=16), mean±SD	AEG(n=16), Mean±SD	F-values	P-values	t-test
Age (year)	20.93±1.52	20.93±1.52	0.000	1.000	0.000
Height(cm)	161.84±6.64	161.84±6.64	0.000	1.000	0.000
Weight(kg)	65.85±3.96	65.06±4.09	0.004	0.949	0.557
BMI(kg/m^2)	27.22±0.94	26.59±1.18	0.700	0.409	1.667
KSSS	24.06±1.23	25.31±1.19	0.244	0.625	-2.907
P300 Amp1(μV)	4.06±0.46	4.10±0.48	0.175	0.678	-0.223
P300 Lat1(ms)	308.55±13.56	304.64±13.41	0.016	0.901	0.820
CPT1	58.95±3.43	59.71±3.41	0.005	0.942	-0.625
LNB1	33.56± 6.08	32.12±5.93	0.062	0.804	0.680
TAP1	90.36±3.97	90.20±4.43	0.245	0.624	0.113
TMTB1	174.37±5.73	176.56±6.97	0.718	0.403	-0.969

Legend: CG: Control-group; AEG: Aerobic-exercise-group; BMI: Body mass index; KSSS: Kuppuswamy socio-economic score; P300 Amp1: P300 amplitude waves before training; P300 Lat1: P300 latency waves before training; CPT1: Continous performance test before training; LNB1: Letter-n-back test before training; TAP1: Finger tapping test before training; TMTB1: Trail making test part-B before training; cm: centimetre; kg: kilogram; kg/m2: kilogram/metre2; μV: micro-volt; ms: millisecond; SD: Standard deviation. Data are presented as mean and SD (M±SD), significant difference p<0.05

3.1 P300 Amplitude

Significant improvements were observed between the groups ($F[1, 30]=5.80$, $p=0.022$, $1=0.162$), as clinically there was increment in wave P300-amplitude in an AE group compare to CG following acute bout of AE training. Further significant improvement were observed in main effect of time ($F[1, 30]=18.210$, $p<0.001$, $1= 0.378$) and in interaction effect (time x group) ($F[1, 30]=87.180$, $p<0.001$, $1= 0.744$), showing the restoration of sleep disturbance-associated decreased P300 amplitude wave characteristics following acute bout of AE training (Figure 2a, Table 2).

3.2 P300 Latency

Significant improvements were observed between the groups ($F[1, 30]=4.707.80$, $p= 0.038$, $1= 0.136$), as clinically there was a reduction in latencies of P300 wave in an AEG compare to CG following acute bout of AE training. Further significant improvement were observed in main effect of time ($F[1, 30]=112.908$, $p< 0.001$, $1= 0.790$) and in interaction effect (time x group) ($F[1, 30]=131.682$, $p <0.001$, $1= 0.814$), indicating an improvement in cognitive function following acute bout of AE training in sleep disturbed collegiates (Figure 2b; Table 2).

3.3 Attention

No significant improvements were observed between the groups ($F[1, 30]=1.537$, $p= 0.225$, $1= 0.049$) and in the main effect of time ($F[1, 30]=1.707$, $p= 0.201$, $1= 0.054$), as there was no reduction in time taken to complete CPT test by the subjects in an AEG compare to CG following acute bout of AE training. However, significant improvement were observed in interaction effect (time x group) ($F[1, 30]=17.818$, $p< 0.001$,$1= 0.373$), indicating an improvement in executive function of cognition, following acute bout of AE training (Figure 2c; Table 2).

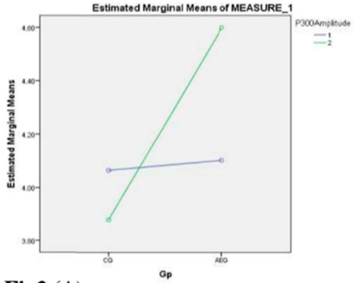

Fig2 (A)

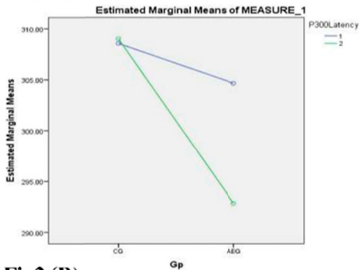

Fig2 (B)

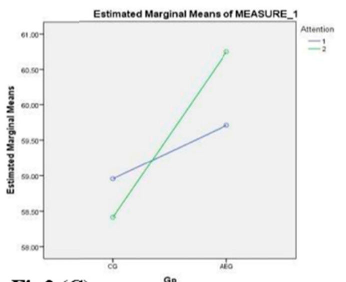

Fig2 (C)

Figure 2A-C. (A) Graph showing the effect of acute bout of Aerobic-exercise training on P300 Amplitude, with green line (Label 2) depicting results for Aerobic-exercise group (4.59±0.48) and blue line (Label 1) depicting results for Control group (3.87±0.39). (B): Graph showing the effect of acute bout of Aerobic-exercise training on P300 Latency, with green line (Label 2) depicting results for Aerobic-exercise group (292.82±12.85) and blue line (Label 1) depicting results for Control group (309.01±12.89). (C): Graph showing the effect of acute bout of Aerobic-exercise training on Attention, with green line (Label 2) depicting results for Aerobic-exercise group (60.74±3.39) and blue line (Label 1) depicting results for Control group (58.41±3.96). Data are presented as Mean and Standard deviation, Significant difference p<0.05

3.4 Working memory

No significant improvements were observed between the groups (F[1, 30]=0.392, p= 0.536, 1= 0.013) and in interaction effect (time x group) (F[1, 30]=0.556, p= 0.461, 1= 0.018), as there was no reduction in time taken to complete LNB test by the subjects in an AEG compare to CG following acute bout of AE training. However, significant improvement were observed in main effect of time (F[1, 30]=14.640, p= 0.001,1= 0.328), indicating an improvement in working memory component of cognition, following acute bout of AE training (Figure 2d; Table 2).

3.5 Sensorimotor speed

No significant improvements were observed between the groups (F[1, 30]= 0.698, p= 0.410, 1= 0.023), as clinically there was no reduction in time taken to complete TAP test by the subjects in an AEG compare to CG following acute bout of AE training .Though, significant improvement were observed in main effect of time (F[1, 30]= 28.594, p< 0.001, 1= 0.488) and in interaction effect (time x group) (F[1, 30]= 113.375, p< 0.001, 1= 0.791) indicating an improvement in cognition function, following acute bout of AE training (Figure 2e; Table 2).

3.6 Executive Function

Significant improvements were observed between the groups (F[1, 30]= 6.150, p= 0.019, 1= 0.170), as clinically there was a reduction in time taken to complete TMTB test by the subjects in an AEG compare to CG following acute bout of AE training. Further significant improvement were observed in main effect of time (F[1, 30]= 132.554, p< 0.001, 1= 0.815) and in interaction effect (time x group) (F[1, 30]= 165.111, p< 0.001, 1= 0.846), indicating an improvement in executive function of cognition, following acute bout of AE training (Figure 2f; Table 2).

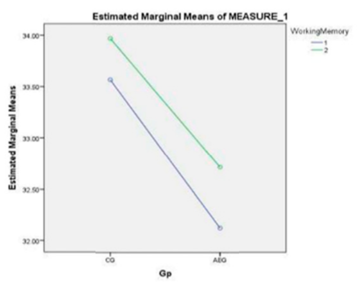

Fig2 (D)

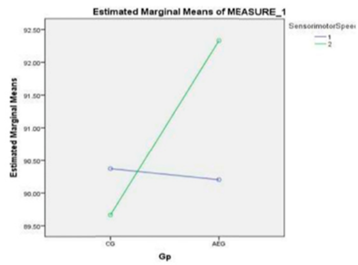

Fig2 (E)

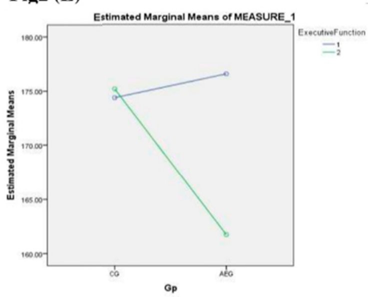

Fig2 (F)

Figure 2D-F.(D) Graph showing the effect of acute bout of Aerobic-exercise training on Working memory, with green line (Label 2) depicting results for Aerobic-exercise group (32.71±5.78) and blue line (Label 1) depicting results for Control group (33.96±6.56). (E): Graph showing the effect of acute bout of Aerobic-exercise training on Sensorimotor speed, with green line (Label 2) depicting results for Aerobic-exercise group (92.33±4.68) and blue line (Label 1) depicting results for Control group (89.66±3.84). (F) Graph showing the effect of acute bout of Aerobic-exercise training on Executive function, with green line (Label 2) depicting results for Aerobic-exercise group (161.75±7.62) and blue line (Label 1) depicting results for Control group (175.18±6.05). Data are presented as Mean and Standard deviation, Significant difference p<0.05

Table 2. Comparison of pre and post outcome variables between the groups along-with summary of 2x2 mixed model ANOVA

Outcome Variables	CG(n=16), Mean±SD	AEG(n=16), Mean±SD	Total	Source	f-value	p-value	η²
P300 Amp2 (µV)	3.8775± 0.39125	4.5988± 0.48267	4.2381± 0.56661	TGT×G	18.210 5.801 87.180	<0.001 0.022* <0.001	0.378 0.162 0.744
P300 Lat2 (ms)	309.0138± 12.89522	292.8269 ±12.85750	300.9203± 15.10196	TGT×G	112.908 4.707 131.682	<0.001 0.038* <0.001	0.790 0.136 0.814
CPT2	58.4125 ±3.96919	60.7438 ±3.39470	59.5781± 3.82123	TGT×G	1.707 1.537 17.818	0.201 0.225 <0.001	0.054 0.049 0.373
LNB2	33.9688 ±6.56554	32.7188 ±5.78783	33.3438 ±6.12130	TGT×G	14.640 0.392 0.556	0.001 0.536 0.461	0.328 0.013 0.018
TAP2	89.6625 ±3.84584	92.3313 ±4.68682	90.9969 ±4.42985	TGT×G	28.594 0.698 113.375	<0.001 0.410 <0.001	0.488 0.023 0.791
TMTB2	175.1875 ±6.05771	161.7500 ±7.62889	168.4688 ±9.61848	TGT×G	132.554 6.150 165.111	<0.001 0.019* <0.001	0.815 0.170 0.846

Legend: CG: Control-group; AEG: Aerobic-exercise-group; P300 Amp2: P300 amplitude waves post training; P300 Lat2: P300 latency waves post training; CPT2: Continous performance post training; LNB2: Letter-n-back test post training; TAP2: Finger tapping test post training; TMTB2: Trail making test part-B post training; cm: centimetre; kg: kilogram; kg/m2:kilogram/metre2; µV: micro-volt; ms: millisecond; M:Mean; SD: Standard deviation; T:Time; G:Group; TxG: Time x Group; η^2= Partial eta squared; *: significant difference between the groups. Data are presented as mean and SD (M±SD), significant difference p<0.05.

3.7 Correlations between neuropsychological and neurophysiological functions parameters

Few researchers have also concentrated on figuring out the relationship between ERPs and NBT because both (neuropsychological and neurophysiological) measurements evaluate cognition (Boller et al., 2002). Though few research have been published on the issue, there is a dearth of evidence defining the relationship between P300-wave features and NBT performance. As a result, in the current study, we exclusively examined the characteristics of the ERP-P300 in sleep-deprived college students in the aerobic exercise group, as opposed to the outcomes of typical NBT. Additionally, one of the two measures (neuropsychological and neurophysiological) can be used in a clinical or research setting if there is a relationship between them.

To address this, we correlated the post intervention neurophysiological correlates values (post p300 amplitude - P300Amp2 and post p300 latency-P300Lat-2) with the post intervention neuropsychological correlates values (post intervention attention-CPT2, post intervention working memory-LNB2, post intervention sensorimotor speed-TAP2, post intervention executive function-TMTB2) in an AE training group using Pearson's correlation. The relationship between P300 Amp2 and CPT2 [r= 0.059, p= 0.749; Table 3], between P300 Amp2 and LNB2[r= -0.189, p= 0.301; Table 3], between the P300 Amp2 and TAP2 [r= 0.156, p= 0.395; Table 3] and between P300 Amp2 and TMT2 [r=-0.299, p= 0.097; Table 3] was computed but it did not show any association. Therefore, the results point that neurophysiological functions cannot be replaced by neuropsychological functions tests or vice versa; rather, higher brain functions should be evaluated by both methods.

Similarly, a correlation analysis was also done for P300 Lat 2 and LNB2 [r= 0.073, p= 0.691; *Tab.3*], for P300 Lat 2 and TAP2 [r= -0.281, p= 0.119; Table 3] for P300 Lat 2 and TMT2 [r= 0.291, p= 0.106; Table 3] but no association was found in any of this analysis. However significant moderate negative linear correlation was found between P300 Lat 2 and CPT2 [r= -0.366*, p= 0.039; Figure 3; Table 3], demonstrating that participants who performed poor on P300 Lat 2, performed better on CPT2 task of neuropsychological functions.

Table 3. Correlations between neurophysiological correlates post intervention values (P300 amplitude and P300 latency) and neuropsychological correlates post intervention values (Continuous performance test, Letter-n-back test, Finger tapping test, Trail making test Part B) of an Aerobic-exercise-group. The r and p values are presented in the table

Neuropsychological variables	Neurophysiological variables			
	P300-Amp2		P300-Lat2	
	r	*p*	*r*	*p*
CPT2	0.059	0.749	-0.366*	0.039
LNB2	-0.189	0.301	0.073	0.691
TAP2	0.156	0.395	-0.281	0.119
TMTB2	-0.299	0.097	0.291	0.106

Legend: P300 Amp2: P300 amplitude waves post training; P300 Lat2: P300 latency waves post training; CPT2: Continuous performance post training; LNB2: Letter-n-back test post training; TAP2: Finger tapping test post training; TMTB2: Trail making test part-B post training

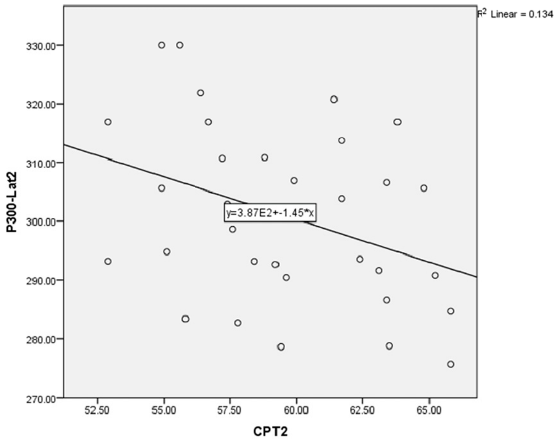

Figure 3. Pearson correlation coefficients showing association between post intervention value of P300 Latency (P300 Latency 2 - P300 Lat2) and post intervention value of Attention (Continuous Performance Test - CPT2) (r = -0.366, p = 0.039). (Data are presented as r and p values)*

4. Discussion

University students' sleep patterns have been shown to affect their cognition in a number of different ways. Sleep deprivation lengthens the P300 latency and shortens the P300 amplitude, as demonstrated by Lee and colleagues (Lee et al., 2003). Moreover, the group with sleep issues performed worse on a variety of cognitive tests (Haimov et al., 2013). The present study was undertaken to find out the effect of acute bout of aerobic exercise training on neuropsychological and neurophysiological correlates of cognition in sleep-disturbed university students. Our results indicate that neurophysiological and neuropsychological functions improved as a result of acute bout of aerobic exercise training for the aerobic exercise training group. However, few components of neuropsychological functions did not show any improvement in both the groups in our study.

4.1 Neurophysiological functions

Our study depicts increased in P300 amplitude following acute bout of AE training. Our results are in line with the previous studies which shows improvement in P300 amplitude following acute bout of aerobic exercise training. (Magnie et al.,2000; Tsai et al., 2016). Magnie and colleagues concluded that acute exercise promotes cognitive processing via a general arousal effect from the observed increases in P300 amplitude (Magnie et al., 2000). Similar to this, Polich and colleagues contend that the effects of P300- workout are systemic and linked to rises in overall body arousal (Polich et al., 1995). Additionally, in line with earlier studies, our study shows a decrease in P300 latency after an acute bout of AE training, indicating an improvement in the cognitive function domain of response speed (Magnie et al., 2000; McDowell et al., 2003; Polich et al., 1997; Hillman et al., 2003). Event-related potentials (ERPs), which are observed in human scalp recordings, are indications of the neurophysiological activity elicited by internal or external events. These potentials might offer crucial details about the cognitive processes that take place from stimulus initiation to motor response. Most notably, the P300 wave is frequently employed to examine the connection between physical activity, cardiovascular fitness, and cognitive performance (Magnie et al., 2000; Themanson and Hillman et al., 2006).

This could be explained in a number of different ways. First, increased serum BDNF concentrations in the AEG could be explained by the fact that BDNF is a biochemical modulator of brain functioning (McAllister et al. 1999). Second, the catecholamine arousal system's cholinergic-catecholaminergic interactions have constituted the foundation of a broad theory of P300 physiology (Grossberg 1984). Third, there is proof that AE increases arousal in order to have its exercise-induced activation (EIA) effects on the auditory P300. It is clear that physical arousal brought on by exercise can change P300 amplitude and latency, providing a unified mechanism for EIA (Chmura et al., 1994).

4.2 Neuropsychological functions

Other finding from our results indicate that executive functions improved as a result of acute bout of AE training, as participants in the AEG performed faster on the part-B of TMT (TMTB) following acute bout of AE training. Our result is in consistent with other study where significant improvement with acute bout of AE training have been seen in relation to executive functions (Harveson et al., 2016). This finding suggests that acute exercise boosts certain cognitive functions, such as problem solving, goal-oriented action, response speed and accuracy, and stages of information processing. This hypothesis also outlines an allocation of attentional resources that serves to block irrelevant information and concentrate on information pertinent to the job (Tomporowski, 2003). Task switching and working memory are more heavily emphasised in Part B of the TMT than interference/inhibition or visuo-perceptual skills (Sanchez-Cubillo et al., 2009). In contrast, another study demonstrates no appreciable gain in the TMTB task (Piepmeier, et al., 2015).

Results from our other findings, however, show that an acute session of AE training in the AEG did not significantly increase sensorimotor speed (as evaluated by TAP). Similar findings that show no significant interaction effect on the TAP task following an acute bout of AE training in individuals with chronic obstructive lung disease have been reported in earlier research (Emery et al., 2001). Further our results also demonstrated no significant effect in attention (measured by CPT) and working memory (measured by LNB) following acute bout of AE training, which is contradicted by other study as this study demonstrated improved attention following single bout of aerobic exercise (Tine et al., 2012; Budde et al., 2008). Contrary to our other prediction, one study that looked at how acute aerobic exercise affected the working memory domain found that the LNB task significantly improved after exercise (Soga et al., 2015). These discrepancies may be explained by the use of a different sample size, different research populations, and a different exercise protocol in the current investigation compared to the earlier studies.

5. Conclusions

Nevertheless, future studies should be performed to reproduce and extend these findings, results from this study exemplify that a single bout of acute aerobic exercise of moderate intensity could enhance neurophysiological (i.e. P300 amplitude-μV and P300 latency-ms) and neuropsychological (i.e. executive functions measured by TMTB task) performance in young collegiates. These results confirm past findings that acute bout of aerobic exercise improves some aspects of cognition, most prominently for memory, reasoning and planning (Nanda et al., 2013), thereby improving both student academic performance and mental health at the same time (Li et al., 2017). To further understand how acute AE affect academic achievement or the mechanism underlying the same, researchers would be advised to directly apply these findings to academic performance.

However, present study had some limitations. Considering the relatively small number of patients, the question arises for the conclusion about effectiveness of acute AE training. Additionally, we did not continue to monitor the long-term advantages of acute AE training. Lastly, we have only seen the main effect of time, group and group with interaction effect and did not analyze the contrast or simple effect, as we were only evaluating the acute effect of AE on neurophysiological and neuropsychological measures. These are the crucial problems that should be taken into account in upcoming research. Another unavoidable drawback of our investigation was the possibility that central nervous system arousal could result from awareness of the purpose to exercise. Despite these shortcomings, our study has a lot of potential benefits because it has used a unique way to assess cognitive neurophysiological and neuropsychological capabilities and included testing methods using gold-standard equipment in accordance with regulations. The fact that every training session was scrupulously observed may be the reason there were no dropouts.

Acknowledgement

The authors express their gratitude to the participants for their participation and cooperation in the study.

Conflict of interest

Authors disclose no conflict of interest.

References

Aseem, A., Kauser, H., & Hussain, M. E. (2018). Non-action video game training ameliorates cognitive decline associated with sleep disturbance. *Sleep and Vigilance*, *2*(2), 157-165. https://doi.org/10.1007/S41782-018-0050-0

Babkoff, H., Zukerman, G. I. L., Fostick, L., & Ben-Artzi, E. (2005). Effect of the diurnal rhythm and 24 h of sleep deprivation on dichotic temporal order judgment. *Journal of Sleep Research,* *14*(1), 7-15. https://doi.org/10.1111/j.1365-2869.2004.00423.x

Boller, F., El Massioui F., Devouche E., Traykov L., Pomati, S., Starkstein, S. E. (2002). Processing emotional information in Alzheimer's disease: effects on memory performance and neurophysiological correlates. D*ementia and Geriatric Cognitive Disorders*, *14*(2), 104-112. https://doi.org/10.1159/000064932

Borg, G. (1970). Perceived exertion as an indicator of somatic stress. Scandinavian journal of rehabilitation medicine. https://doi.org/10.5523831

Budde, H., Voelcker-Rehage, C., Pietraßyk-Kendziorra, S., Ribeiro, P., & Tidow, G. (2008). Acute coordinative exercise improves attentional performance in adolescents. *Neuroscience Letters*, *441*(2), 219-223. https://doi.org/ 10.1016/j.neulet.2008.06.024.

Caspersen, C. J., Powell, K. E., & Christenson, G. M. (1985). Physical activity, exercise, and physical fitness: definitions and distinctions for health-related research. *Public Health Reports*, *100*(2), 126. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1424733/

Chang, Y. K., Alderman, B. L., Chu, C. H., Wang, C. C., Song, T. F., & Chen, F. T. (2017). Acute exercise has a general facilitative effect on cognitive function: A combined ERP temporal dynamics and BDNF study. *Psychophysiology*, *54*(2), 289-300. https://doi.org/10.1111/psyp.12784

Chang, Y. K., Labban, J. D., Gapin, J. I., & Etnier, J. L. (2012). The effects of acute exercise on cognitive performance: a meta-analysis. *Brain Research*, *1453*, 87-101. https://doi.org/10.1016/j.brainres.2012.02.068

Chatterjee, A., Ray, K., Panjwani, U., Thakur, L., & Anand, J. P. (2012). Meditation as an intervention for cognitive disturbances following total sleep deprivation. *The Indian Journal of Medical Research*, *136*(6), 1031.

Chmura, J., Nazar, K., & Kaciuba-Uścilko, H. (1994). Choice reaction time during graded exercise in relation to blood lactate and plasma catecholamine thresholds. *International Journal of Sports Medicine*, *15*(04), 172-176. https://doi.org/10.1055/s-2007-1021042

De-yan, S. (2007). A Research on Aerobic Exercise as a Way of Affecting the College Students' Psychological Health Physical [J]. *Fujian Sports Science and Technology*, *5*. https://en.cnki.com.cn/Article_en/CJFDTOTAL-FUJI200705020.htm

Emery, C. F., Honn, V. J., Frid, D. J., Lebowitz, K. R., & Diaz, P. T. (2001). Acute effects of exercise on cognition in patients with chronic obstructive pulmonary disease. *American Journal of Respiratory and Critical Care Medicine*, *164*(9), 1624-1627. https://doi.org/10.1164/ajrccm.164.9.2104137

Gaudino, E. A., Geisler, M. W., & Squires, N. K. (1995). Construct validity in the Trail Making Test: what makes Part B harder?. *Journal of Clinical and Experimental Neuropsychology*, *17*(4), 529-535. https://doi.org/ 10.1080/01688639508405143

Grossberg, S. (1984). Some psychophysiological and pharmacological correlates of a developmental, cognitive and motivational theory. *Annals of the New York Academy of Sciences*. https://doi.org/10.1111/j.1749-6632.1984.tb23523.x

Gur, R. C., Richard, J., Calkins, M. E., Chiavacci, R., Hansen, J. A., Bilker, W. B., Loughead, J., Connolly, J. J., Qiu, H., Mentch, F. D., Abou-Sleiman, P. M., Hakonarson, H., & Gur, R. E. (2012). Age group and sex differences in performance on a computerized neurocognitive battery in children age 8– 21. *Neuropsychology*, *26*(2), 251. https://doi.org/10.1037/a0026712.

Gur, R. C., Richard, J., Hughett, P., Calkins, M. E., Macy, L., Bilker, W. B., Brensinger C., & Gur, R. E. (2010). A cognitive neuroscience-based computerized battery for efficient measurement of individual differences: standardization and initial construct validation. *Journal of Neuroscience Methods*, *187*(2), 254-262. https://doi.org/10.1016/j.jneumeth.2009.11.017

Haimov, I., & Shatil, E. (2013). Cognitive training improves sleep quality and cognitive function among older adults with insomnia. *PloS One*, *8*(4), e61390. https://doi.org/10.1371/journal.pone.0061390

Harrison, Y., Horne, J. A., & Rothwell, A. (2000). Prefrontal neuropsychological effects of sleep deprivation in young adults--a model for healthy aging?.

Sleep, *23*(8), 1067-1073. https://pubmed.ncbi.nlm.nih.gov/11145321

Harveson, A. T., Hannon, J. C., Brusseau, T. A., Podlog, L., Papadopoulos, C., Durrant, L. H., Hall, M. S., & Kang, K. D. (2016). Acute effects of 30 minutes resistance and aerobic exercise on cognition in a high school sample. *Research Quarterly for Exercise and Sport*, *87*(2), 214-220. https://doi.org/ 10.1080/02701367.2016.1146943

Hillman, C. H., Belopolsky, A. V., Snook, E. M., Kramer, A. F., & McAuley, E. (2004). Physical activity and executive control: implications for increased cognitive health during older adulthood. *Research Quarterly for Exercise and Sport,* *75*(2), 176-185. https://doi.org/10.1080/02701367.2004.10609149

Hillman, C. H., Snook, E. M., & Jerome, G. J. (2003). Acute cardiovascular exercise and executive control function. *International Journal of Psychophysiology*, *48*(3), 307-314. https://doi.org/10.1016/S0167-8760(03)00080-1

Horne, J. A. (1993). Human sleep, sleep loss and behaviour: implications for the prefrontal cortex and psychiatric disorder. *The British Journal of Psychiatry*, *162*(3), 413-419. https://doi.org/10.1192/bjp.162.3.413

Hull, J., & Harsh, J. (2001). P300 and sleep-related positive waveforms (P220, P450, and P900) have different determinants. *Journal of Sleep Research*, 10(1), 9-17. https://doi.org/10.1046/j.1365-2869.2001.00238.x

Kamijo, K., Hayashi, Y., Sakai, T., Yahiro, T., Tanaka, K., & Nishihira, Y. (2009). Acute effects of aerobic exercise on cognitive function in older adults. *Journals of Gerontology: Series B*, *64*(3), 356-363. https://doi.org/10.1093/geronb/gbp030

Lee, H. J., Kim, L., & Suh, K. Y. (2003). Cognitive deterioration and changes of P300 during total sleep deprivation. *Psychiatry and Clinical Neurosciences*, *57*(5), 490-496. https://doi.org/10.1046/j.1440-1819.2003.01153.x

Lee, H. J., Kim, L., Kim, Y. K., Suh, K. Y., Han, J., Park, M. K., Park, K. W., & Lee, D. H. (2004). Auditory event-related potentials and psychological changes during sleep deprivation. *Neuropsychobiology*, *50*(1), 1-5. https://doi.org/10.1159/000077933

Lezak M, (1976). Orientation and Attention. 3 ed. Neuropsychological Assessment. New York: Oxford University Press. pp 335–384.

Li, J. W., O'Connor, H., O'Dwyer, N., & Orr, R. (2017). The effect of acute and chronic exercise on cognitive function and academic performance in adolescents: A systematic review. *Journal of Science and Medicine in Sport*, *20*(9), 841-848. https://doi.org/10.1016/j.jsams.2016.11.025

Li, L., Men, W. W., Chang, Y. K., Fan, M. X., Ji, L., & Wei, G. X. (2014). Acute aerobic exercise increases cortical activity during working memory: a functional MRI study in female college students. *PloS One*, *9*(6), e99222. https://doi.org/10.1371/journal.pone.0099222

Magnie, M. N., Bermon, S., Martin, F., Madany-Lounis, M., Suisse, G., Muhammad, W., & Dolisi, C. (2000). P300, N400, aerobic fitness, and maximal aerobic exercise. *Psychophysiology*, *37*(3), 369-377. https://pubmed.ncbi.nlm.nih.gov/10860414

Manzar, M. D., Moiz, J. A., Zannat, W., Spence, D. W., Pandi-Perumal, S. R., BaHammam, A. S., & Hussain, M. E. (2015). Validity of the Pittsburgh sleep quality index in Indian university students. *Oman Medical Journal*, *30*(3), 193. https://pubmed.ncbi.nlm.nih.gov/26171126

Manzar, M. D., Zannat, W., Kaur, M., & Hussain, M. E. (2015). Sleep in university students across years of university education and gender influences. *International Journal of Adolescent Medicine and Health*, *27*(3), 341-348. https://pubmed.ncbi.nlm.nih.gov/25470605

McAllister, A. K., Katz, L. C., & Lo, D. C. (1999). Neurotrophins and synaptic plasticity. *Annual Review of Neuroscience*, *22*(1), 295-318. https://doi.org/10.1007/7854_2012_231

McDowell, K., Kerick, S. E., Santa Maria, D. L., & Hatfield, B. D. (2003). Aging, physical activity, and cognitive processing: an examination of P300. *Neurobiology of Aging*, *24*(4), 597-606. https://doi.org/10.1016/s0197-4580(02)00131-8

Nanda, B., Balde, J., & Manjunatha, S. (2013). The acute effects of a single bout of moderate-intensity aerobic exercise on cognitive functions in healthy adult males. Journal of clinical and diagnostic research: *JCDR*, *7*(9), 1883. https://doi.org/10.7860/JCDR/2013/5855.3341

Piepmeier, A. T., Shih, C. H., Whedon, M., Williams, L. M., Davis, M. E., Henning, D. A., Park, S. Y., Calkins, S. D., & Etnier, J. L. (2015). The effect of acute exercise on cognitive performance in children with and without ADHD. *Journal of Sport and Health Science*, *4*(1), 97-104. https://doi.org/10.1016/j.jshs.2014.11.004

Polich, J., & Kok, A. (1995). Cognitive and biological determinants of P300: an integrative review. *Biological Psychology*, *41*(2), 103-146. https://doi.org/10.1016/0301-0511(95)05130-9

Polich, J., & Lardon, M. T. (1997). P300 and long-term physical exercise. *Electroencephalography and Clinical Neurophysiology*, 103(4), 493-498. https://doi.org/: 10.1016/s0013-4694(97)96033-8

Rabin, L., Barr, W., and Burton, L. (2005). Assessment practices of clinical neuropsychologists in the United States and Canada: a survey of INS, NAN, and APA division 40 members. *Archives of Clinical Neuropsychology*. *20*, 33–65. https://doi.org/doi: 10.1016/j.acn.2004.02.005

Reitan, R. M., & Wolfson, D. (1985). The Halstead-Reitan neuropsychological test battery: Theory and clinical interpretation (Vol. 4). *Reitan Neuropsychology*. https://searchworks.stanford.edu/view/11561397

Sánchez-Cubillo, I. 1., Periáñez, J. A., Adrover-Roig, D., Rodríguez-Sánchez, J. M., Ríos-Lago, M., Tirapu, J. E. E. A., & Barceló, F. (2009). Construct validity of the Trail Making Test: role of task-switching, working memory, inhibition/interference control, and visuomotor abilities. *Journal of the International Neuropsychological Society*, *15*(3), 438-450. https://pubmed.ncbi.nlm.nih.gov/19402930

Soga, K., Shishido, T., & Nagatomi, R. (2015). Executive function during and after acute moderate aerobic exercise in adolescents. *Psychology of Sport and Exercise*, *16*, 7-17. https://doi.org/10.1016/j.psychsport.2014.08.010

Sweileh, W. M., Ali, I. A., Sawalha, A. F., Abu-Taha, A. S., Zyoud, S. E. H., & Al-Jabi, S. W. (2011). Sleep habits and sleep problems among Palestinian students. *Child and Adolescent Psychiatry and Mental Health*, *5*(1), 1-8. https://doi.org/10.1186/1753-2000-5-25

Themanson, J. R., Hillman, C. H., & Curtin, J. J. (2006). Age and physical activity influences on action monitoring during task switching. *Neurobiology of Aging*, *27*(9), 1335-1345. https://doi.org/10.1016/j.neurobiolaging.2005.07.002

Tine, M. T., & Butler, A. G. (2012). Acute aerobic exercise impacts selective attention: An exceptional boost in lower-income children. *Educational Psychology*, *32*(7), 821-834. https://doi.org/10.1080/01443410.2012.723612

Tomporowski, P. D. (2003). Effects of acute bouts of exercise on cognition. *Acta*

Psychologica, *112*(3), 297-324. https://doi.org/10.1016/S0001-6918(02)00134-8

Tsai, C. L., Pan, C. Y., Chen, F. C., Wang, C. H., & Chou, F. Y. (2016). Effects of acute aerobic exercise on a task switching protocol and brain-derived neurotrophic factor concentrations in young adults with different levels of cardiorespiratory fitness. *Experimental Physiology*, *101*(7), 836-850. https://doi.org/10.1113/EP085682