Effect of Physical Activity on P300 and Working Memory

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CERTIFICATE

This is to certify that this dissertation entitled "**Effect of Physical Activity on P300 and Working Memory**" is a bonafide work submitted as a part for the fulfillment for the degree of Master of Science (Audiology) of the student Registration Number: 17AUD001. This has been carried out under the guidance of the faculty of this institute and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

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CERTIFICATE

This is to certify that this dissertation entitled "**Effect of Physical Activity on P300 and Working Memory"** has been prepared under my supervision and guidance. It is also being certified that this dissertation has not been submitted earlier to any other University for the award of any other Diploma or Degree.

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DECLARATION

This is to certify that this dissertation entitled **“Effect of Physical Activity on P300 and Working Memory”** is the result of my own study under the guidance of Dr. Chandni Jain, Reader in Audiology, Department of Audiology, All India Institute of Speech and Hearing, Mysore and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

Mysore **Registration No: 17AUD001**

May, 2019

<u>Dedicated to</u>

My Parents

&

Guide

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ABSTRACT

Physical activity has shown to have a positive effect on the cardiovascular system, cognition, and auditory system. The aim of the present study was to assess the effect of physical activity on auditory P300 and working memory. To fulfill the aim of study 43 normal healthy individuals were recruited. Participants of the present study were divided into four groups based on their physical activity. They were divided into physically active, moderately active, moderately inactive and inactive groups based on The General Practice Physical Activity Questionnaire (GPPAQ) validated screening tool. The auditory P300 was recorded binaurally, and working memory was also assessed binaurally from all the participants. The P300 was recorded with infrequent stimulus as /da/ and frequent stimulus as /ba/. The P300 responses were analysed in terms of onset latency, offset latency, peak latency and amplitude. Working memory was assessed using digit span and digit sequencing tests. The results of the study showed a significant difference in amplitude of P300 among different physically active groups and no significant difference was noted for the latency measure of P300. The results also showed no significant differences in scores of working memory task across different physical active groups.

Keywords: *GPPAQ, P300, digit span test, digit sequencing test*

Chapter 1

Introduction

Regular physical activity has shown to have a positive impact on mental, emotional (Kirk-Sanchez & McGough, 2014), as well as on auditory system performance (Yagi, Coburn, & Estess, 1999). Physical exercise can be in many forms for example aerobics (Yagi et a1., 1999), different forms of dance training (Zhang et al., 2014), strength training (Ozkaya et al., 2005), swimming (Zhang et al. 2014), etc. The benefits of physical exercises are well documented in the literature (Ozkaya et al., 2005; Yagi et a1., 1999; Zhang et al., 2014). Several studies have shown that physical exercise attenuates the age-related declination in cognitive performances (Bashore, 1989; Dustman, Emmerson, Ruhlinig, Shearer, Steinhaus, Johnson, 1990; Dustman, Emmerson & Shearer, 1994; Hawkins, Kramer & Capaldi, 1992; Spirduso, 1980), increases the alpha activity in the brain (Boutcher & landers, 1988; Farmer et al; 1978; Hatfield et al., 1984; Kamp & Troost, 1978). The effect of physical activity on the functioning of the brain can be assessed by using event-related potentials reflecting cortical activities related to cognition (Pedroso et al., 2017).

Event-related potentials are non-invasive techniques to assess the functions of the central nervous system (CNS). P300 is an endogenous or event-related potential which is highly dependent on the attention of the subjects for the auditory stimuli. Davis (1964) described the P300 as the third positive wave since it has a latency of around 300 ms and P3 label is also used because it is the third positive wave in the late response time. The P300 potential is recorded using odd ball paradigm. In an odd-ball paradigm, a series of frequent (standard) stimulus is presented along with different types of non- frequent (target) stimulus (Squires et al., 1975). The subject task is to respond for target stimuli by the motor response. If the person is attentive and responds for the target stimuli, then P300 will be generated. The classical P300 component or P3b, which occurs at 300–600 ms post stimulus presentation, has a parietal distribution on the scalp. It has been linked to the cognitive processes of context updating, context closure, and event-categorization (Donchin & Coles, 1988; Kok, 1990; Verleger, 1988). P3a has a fronto-central distribution and has mainly been associated with the orienting response (Friedman, Cycowicz & Gaeta, 2001). Studies have been done in the past to assess the effect of different levels of physical activity on P300.

Kutlu, Buyukyz, Kaptan, Selcuki and Artug (2014) studied the effect of physical training on P300 in elderly veteran males. Three groups of participants were taken for the study including an athlete who had been regularly exercising, sedentary healthy elderly individuals, and healthy sedentary middle-aged individuals. Results showed that P300 latency was earliest in middle age individuals than the individuals who were regularly exercising followed by healthy sedentary elderly individuals. Similarly, the amplitude of P300 was highest in middle age individuals compared to the other two groups. They concluded that long term physical exercises affect the cognition positively. In another study, Kim, Kim, Kim, Kim, and Nam (2015) studied the effect of Thi-chi exercises on cognitive function in elderly individuals using P300. It was noted that the latency of P300 was shorter in individuals who practiced the Thi-chi exercises compared to the control group. They concluded that long term aerobic exercises like Thi-Chi could reduce cognitive declination in older adults.

Working memory is another measure to assess cognitive abilities. The term working memory refers to the temporary storage of information and manipulation. Baddeley and Hitch (1974) gave a dynamic model of working memory. The model has a phonological loop, central executive, visuo-spatial sketchpad, and the episodic buffer. These components interact with each other to provide a comprehensive work space for cognitive abilities. The two-component, phonological loop, and visuo-spatial loops are thought to be parallel and independent. Coordination between the two loops is done by the central executive. Working memory can be assessed using simple span tasks and complex span tasks. Simple span tasks include forward, backward, ascending and descending digits, whereas the complex span tasks include visual and spatial span, reading span, operational task, rhyme judgment, visual letter monitoring, etc .

Studies have shown that working memory abilities deteriorate with aging (Nyberg, et al, 2012). Borella, Carretti, and De Beni, (2008) studied the effect of aging on working memory and concluded that regardless of the nature of working memory (i.e., verbal or visuospatial), it deteriorates with advancing age. These findings were supported by Nyberg, Lovden, Riklund, Lindenberger and Backman, (2012) in a longitudinal study and it was reported that the working memory remains stable during early and middle adulthood and then there will be a declination in the working memory after the age of 60. Reduction in the working memory capacity is identified as a major factor in cognitive impairment in older adults (Park et al., 2002). However, it would be worthwhile to see whether different levels of physical activity will affect working memory.

1.1. Need for the Study

Studies in the past have shown that physical activity has a positive effect on cognitive abilities (Boutcher & Landers, 1988; Farmer et al., 1978; Hatfield et al., 1984; Kamp & Troost, 1978). However most of these studies have been done on one particular group of physical activity like aerobics (Yagi et al., 1999), Thi Chi Exercise (Kim et al., 2015). Thus, it would be worthwhile to assess the effect of different levels of physical activity in the general population on cognitive abilities. Further, previous studies have mainly used visual stimulus to assess P300. As mentioned earlier increased physical activity has shown to have increased alpha activity in the brain; it is hypothesized that physically active individuals will have better auditory abilities also. Moreover, in previous studies, the effect of physical activity has mainly been studied using P300, which is an objective measure. Thus, in the present study both electrophysiological (P300) and behavioral measures (working memory) would be used to assess the effect of physical activity.

1.2. Aim of the Study

The aim of the present study was to assess the effect of different levels of physical activity on P300 and working memory.

1.3. Objectives of the Study

- To assess the effect of different levels of physical activity on latency and amplitude of P300.

- To assess the effect of different levels of physical activity on working memory tasks.

Chapter 2

Review of Literature

Chronic and acute exercises have a positive effect on cognitive function and improve the speed of information processing in older individuals (Mandolesi, Polverino, Montuori, Foti, Ferraioli, Sorrentinoet al., 2018). Studies have shown that physical exercise attenuates the age-related declination in cognitive function (Bashore & Goddard, 1993; Dustman, Emmerson & Shearer, 1994). Tomporowski and Ellis, (1986) also reported that physical exercise gives multiple benefits such as reduction in anxiety (Roth, 1989), feeling of increased energy, well-being, clarity of thought (Tuson & Sinyor, 1993) and increase in the speed of information processing (Hogervorst, Riedel, Jeukendrup & Jolles, 1996). To understand the effect of physical exercises on cognitive functions, physiological studies have been done. These studies have shown that physical training change the P300 components mainly because P300 is a valuable tool for measuring cognitive function which reflects the neural activity underlying the basic aspects of cognition (Donchin, 1981).

2.1. Effect of Physical Activity on the Auditory System

Studies have shown that different types of physical activity have an effect on hearing as well as in cognition, memory (Laurin, Verreault, Lindsay, Macpherson & Rockwood 2001; Middleton, Barnes, Luims & Yaffe 2010; Yaffe, Barnes, Nevitt, Lui & Covinsky, 2001), and brain health markers in the brain (Hawkins, Kramer, & Capaldi, 1992).

Cristell, Hutchinson, and Alessio (1998) studied the effect of exercise training on hearing abilities. They studied the effect of two months of training of aerobic exercises on hearing sensitivity. Participants were evaluated for temporary threshold shift (TTS) at 2000 Hz, 3000 Hz and 4000 Hz before and following 10 minutes of 104 dBSPL 1/3 octave band filtered noise center frequency at 2000 Hz exposure. The results revealed that pure tone hearing at 2000 Hz and 3000 Hz and TTS improved following two months of aerobic training. They hypothesized that the susceptibility to TTS improved with improvement in cardiovascular fitness after two months of exercising. In another study Anderson, White-Schwoch, Parbery-Clark, and Kraus (2013) studied the modulating effect of life experiences such as physical activity and musical training on the perception of speech in noise in older adults with normal hearing sensitivity. Participants were evaluated for their peripheral hearing, cognitive abilities, and central processing abilities. The results revealed that cognitive abilities and central processing help in speech perception in the presence of noise and life experiences such as physical activity, music training, and cognition strengthen the brainstem processing and indirectly influences the speech perception in noise.

Taneja (2015) studied the effect of Yoga on hearing. The effect of cervical or neck flexion-extension exercise, lateral flexion exercise, head rotation exercise, skandhachalan, bhramari pranayama (bee breath), kumbhak (A respiratory exercise), shankhanaad (A respiratory exercise), shunya mudra and gyan mudra on hearing sensitivity was studied. The author concluded that neck muscle exercises and respiratory exercises such as (Kumbhak) could increase the blood flow and oxygen supply to inner which inturn leads to improvement in the hearing performance and quality of life.

2.2. Effect of Physical Activity on EEG Activity

Studies have shown that physical exercises improve electroencephalographic activity (EEG). Lardon and Polich (1996) studied the changes in EEG after long term physical exercises on 36 Participants who were divided into two groups, experimental group, and control group. The experimental group had participants with a lifelong commitment to athletic endeavors through their participation in the Olympic-caliber events. The control group was defined by the absence of any previous participation in the high-level sports activity. The EEG was analyzed in terms of spectrum power and mean frequency. The result reveled that experimental groups had less delta and more alpha and beta compared to the control group. The result also showed that the more EEG power was produced when the eye was closed as compared to open in experimental groups compared to control groups. They concluded that physical exercises increase alpha power.

Magine et al. (2000) studied the effect of aerobic exercises on P300 and N400 on 20 French-speaking undergraduate students with normal hearing sensitivity in the age range of 18 years to 30 years. These individuals were further divided into two groups based on the fitness level. The high fit groups included ten cyclists and the low fit group had ten sedentary subjects. P300 as recorded in two sessions one before exercise and one after exercise using auditory odd ball paradigm. The results of P300 recordings showed that the high fit groups had shorter latencies and larger amplitude compared to the low fit groups. The results also revealed that in high fit groups the latencies were shorter and amplitude was higher after exercise recordings compared to before exercise recordings at all electrode sites. It was reported in the study that physical exercise affects the brain in several ways. Physical exercise increases the cerebral blood flow and also improve the cerebral neurotransmitter function and balance. According to these authors, physical exercise also enhances the neuroendocrine and autonomic tones.

In another study, Pontiflex, Hillman and Polich (2009) studied the effect of age, physical fitness and attention on P3a and P3b. A total of 48 participants were included in the study andwere divided into a younger group (18 to 22 years) and older group (61 to 73 years). The individuals were recruited in the study based on aerobic fitness. The visual odd ball task was designed to elicit the P3a component, and a three stimulus task was designed to record P3b. EEG activity was recorded from 64 different electrode sites. Results showed that the P3a latencies were shorter for younger adults compared to older individuals and individuals with higher fitness levels had shorter latencies and higher amplitudes. It was concluded in the study that the P3b was modulated by fitness, the mechanisms underlying fitness-related differences inattention may be due to differences in the locus-coeruleus-norepinephrine system.

Kamijoet al. (2011) studied the effect of an afterschool physical activity program on Contingent Negative Variation (CNV) potentials on 43 children in the age range of 7 to 9 years. They divided the children into two groups. The first group of children participated in the physical activity program and served as an experimental group and the second group of children did not participate in any physical activity and served as a control group. The EEG was recorded from the 64 electrodes sites, and the electrodes were placed based on the international 10-10 systems. The results revealed higher CNV amplitudes in experimental groups compared to the control group, and the frontal sites had the largest CNV amplitudes. This could be because the experimental group had effective cognitive control post physical activity program.

Chang, Huang, Chen and Hung (2013) studied the effect of physical activity on working memory using evoked potentials 46 healthy individuals in the age range of 65 to 72 years participants were divided into higher physical activity and lower physical activity groups. The group with higher physically active individuals participated in aerobics thrice a week whereas, lower physical activity groups individuals participated in a low-level exercise twice a week. Physical activity levels were measured by using the International Physical Activity Questionnaire (IPAQ). The working memory was evaluated using the Sternberg working memory test. The results revealed that higher physical activity group individuals had enhanced N1 and P3 amplitude and shorter P3 latencies which indicate that physical activity enhances the cognition through several neuro-cognitive mechanisms.

Thus from the above studies, it can be concluded that the different forms of physical exercise improve the speed of information processing in older individuals. Physical training shows a positive effect on the P300 components mainly because P300 is a useful tool for measuring the cognitive function which reflects the neural activity underlying basic aspects of cognition. Physical exercises increase the cerebral blood flow and also improve the cerebral neurotransmitter function and balance.

2.3. Effect of Physical Activity on Cognition

Studies have shown that physical exercises improve the cardio-vascular fitness which prevents individuals from chronic disease and improves the brain function (Barnes, 2015). Physical exercise improves different body system which leads to increased performance of different tasks involving attention, cognition and memory (Coclcombe & Kramer, 2003; Etnier, Salazar, Landers, Petruzello & Nowell, 1997). In a meta-analytic study by Coclcombe and Kramer (2003), they reported that physical activity improves multiple cognitive functions such as speed, spatial, control and executive functions in older adults. These authors have also reported that in all the cognitive functions parameters, physical exercises positively affect executive function which requires effortful cognitive function. The subcomponent of an executive function includes updating, shifting and inhibition (Miyake et al., 2000) or could involve planning, scheduling, inhibition and working memory (Coclcombe & Kramer, 2003).

Pontiflex, Hillman, Fernhall, Thompson and Valentini (2008) studied the effect of acute aerobic and resistance exercises on working memory on 21 undergraduate students. Working memory was assessed using a modified Sternberg task that required the individuals to encode a memory set containing an array of three, five, or seven letters and decide whether a single probe letter was present in the encoded array. Working memory was assessed immediately after the physical exercise and after 30 minutes of aerobic exercises or resistance exercises. The result revealed that aerobic exercises lead to shorter reaction time immediate and post 30-minute exercises compared to baseline. The result also revealed increased working memory capacity after aerobic exercises. The current finding suggests that the aerobic exercises induce changes in the cognitive tasks which require an extensive amount of executive controls. Aerobic exercises lead to biochemical changes which increases the neuronal proliferation and serotonin. These neuronal proliferation and serotonin lead to neurogenesis in the hippocampus which playa major role in the completion of working memory task.

Kamijoet al. (2011) studied the effect of an afterschool physical activity program on working memory in 43 children in the age range of 7 to 9 years. The participants were divided into two groups. The first group of children participated in the physical activity program and served as an experimental group and the second group of children did not participatein any physical activity and served as a control group. Working memory was assessed using the modified Sternberg Task (Sternberg, 1966). The response was analyzed in terms of reaction time and accuracy of response. The working memory test was done pre and post physical activity in the experimental groups. The result showed a significant difference in the accuracy of responses post physical activity and shorter reaction time after physical activity in the experimental group. They concluded that physical activity training improves the functionality of fronto-parietal networks which improves working memory.

In another study, Langdon and Corbett (2012) studied the effect of physical and cognitive activity on working memory in Sprague-Dawley rats. Physical and cognitive activity included voluntary wheel running with Hebb-Williams and radial arm maze exercises. Tissue processing and Enzyme-Linked Immuno Sorbant Assay (ELISA) study were done to see the effect of physical and cognitive training. The result revealed that physical and cognitive training leads to superior performance in the learning and memory and it was independent of brain-derived neurotrophic factor (BDNF) and phosphorylated cyclic AMP response element binding protein elevations. They all performed superior in working memory task after physical and cognitive tasks. These findings explained increased BDNF levels in cortical, hippocampal structures in experimental groups compared to sedentary controls after eight weeks of training.

Chang, Huang, Chen and Hung (2013) studied the effect of physical activity on working memory in 46 healthy adults (65 to 72 years). Based on the physical activity level they were divided into higher physical activity and lower physical activity groups. The higher physical activity groups participated in aerobics thrice a week whereas, lower physical activity groups individuals participated in low-level exercises twice a week. Physical activity levels were measured using IPAQ. Working memory was measured with Sternberg Working Memory Task using NeuroScan Software. The result revealed that higher physical activity group had a shorter response time in working memory tasks compared to lower physical activity group which indicates that physical activity enhances the cognition through several neurocognitive mechanisms.

Padilla, Perez and Andres (2014) studied the effect of chronic exercises on working memory in 58 healthy young adults (18 to 30 years). These individuals were divided into active and passive groups based on their fitness level. Working memory was assessed using the Automatic Operational Span Task (AOSPAN) test which measures the phonological loop and central executive component of the working memory. Results showed a significant difference in scores of working memory test among active and passive groups. Physically active group showed high scores in working memory test than the passive groups. It was reported in the study that chronic exercise brings permanent changes in the physiological process such as formation and extension of new blood vessels which leads to improvement of brain perfusion. Physical activity also leads to neurogenesis and release of neurotrophic factors which increases the chance of neural growth and survival which in turns increases the learning and memory capabilities.

Thus, it can be concluded that physical exercises improve different body system which leads to increased performance of different tasks involving attention, cognition, and memory. Physical activity training improves the functionality of fronto-parietal networks which in turn enhances working memory.

Chapter 3

Methods

The aim of the present study was to assess P300 and working memory in participants with different levels of physical activity.

3.1. Participants

Forty three adults in the age range of 40 to 60 years (mean age: 49.72 years) participated in the study. They were divided into four groups, i.e., active (A), moderately active (MA), moderately inactive (MI) and inactive (I) based on the General Practice Physical Activity Questionnaire (GPPAQ) (Health, 2006). This questionnaire was developed by the London School of Hygiene and Tropical Medicine as a validated short measure of physical activity which is a validated tool to assess the physical activity of individuals.

3.1.1. Inclusion Criteria

- All the Participants with hearing sensitivity within normal limits (≤ 15 dB HL) for octave frequencies from 250 Hz to 8000 Hz [ANSI S3.1 (1991)].
- Normal middle ear functioning as indicated by immittance evaluation.
- A fair agreement between speech recognition threshold (SRT) and pure tone threshold (PTA) (+/- 12dB).
- Speech identification scores greater than 90 % scores

3.1.2. Exclusion Criteria

- Participants with any history of otologic and neurologic problems.
- Any illness on the day of testing.
- History of alcohol consumption and smoking habits
- Any history of diabetes, hypertension, and cardiovascular diseases.

3.2. Instrumentation

- A calibrated Grason-Stadler Incorporated 61 (Grason Stadler, Eden Prairile, USA) dual-channel audiometer with Telephonics TDH-39 headphones were used for estimating pure tone audiometry and speech audiometry.
- A calibrated Grason-Stadler Incorporated Tympstar (Grason Stadler, Eden Prairile, USA) immittance meter was used for tympanometry and reflexometry.
- Biologic Navigator Pro (Natus Medical Incorporated, Illinois,USA) version 7.0.0 with 580-SINSER-012 insert earphones were used for P300 recording.
- A personal computer Dell inspiron64 bit computer was used for performing working memory tests.

3.3. Test Environment

The study was carried out in an acoustically treated air-conditioned room (ANSI S3.1, 1999) with adequate illumination. Pure tone audiometry and speech audiometry were carried out in a two-room set up while tympanometry, P300, digit span test, and digit sequence test were administered in a single room suite.

3.4. Test Procedure

3.4.1. Assessment of Physical Activity based on GPPAQ.

The participants were selected based on convenient sampling. GPPAQ questionnaire was administered on them to group them into different groups based on their level of physical activity. GPPAQ questionnaire was developed by the World Health Organization for physical activity surveillance in countries. It probes information on physical activity participation in three domains (activity at work, travel to and from places and recreational activities) comprising of 16 questions (P1 – P16). The GPPAQ version 2 was used for the present study which is a validated screening tool that assesses adults (with the age range of 16 – 74 years) physical activity levels. Based on this questionnaire the participants were classified as Active, Moderately Active, Moderately Inactive, and Inactive.

3.4.2. Routine Audiological Evaluation.

Otoscopy was done to rule out any external ear deformity, presence of impacted wax, and any ear infection. The preliminary evaluation included case history, pure tone audiometry, immittance audiometry, and speech audiometry. A detailed case history was taken from all the participant to rule out any otological, neurological and medical conditions. Pure tone audiometry was done using modified Hughson-Westlake procedure (Carhart & Jerger, 1959) to evaluate pure tone thresholds at octave frequencies from 250 Hz to 8000 Hz for air conduction and 250 Hz to 4000 Hz for bone conduction. Speech recognition threshold was estimated using the standardized paired-word list in the participants' native language. Speech identification scores were obtained at 40 dB above

SRT using the standardized phonemically balanced (PB) word lists in the participants' native language. To rule out any middle ear pathology, tympanogram was done using a 226 Hz probe-tone by varying the air pressure in the ear canal from +200 to -400 daPa. Ipsilateral and contralateral acoustic reflex thresholds were obtained at octave frequencies from 500 Hz to 4000 Hz using the same probe-tone frequency as mentioned above.

3.4.3. Procedure of P300.

The actual experimental paradigm involved the recording of P300 only on those participants who fulfilled all the selection criteria. The participants were seated in a reclining chair and were instructed to avoid any extraneous movements of head, neck, and limbs during the test. The required electrode placement sites were scrubbed with an abrasive gel (Nuprep) to reduce the skin impedance. Using an adequate amount of conduction gel, the silver chloride disc-type electrodes were secured at appropriate sites using surgical plaster. The absolute electrode impedance and inter-electrode impedance were maintained below 5kΩ and 2kΩ respectively. The odd ball paradigm was used to record the P300. The /da/ stimulus was used as frequent, and the /ba/ stimulus was used as an infrequent stimulus. Figure 3.1 and Figure 3.2 shows the time domain waveform as well as the spectrum of /da/ and /ba/ stimulus used.

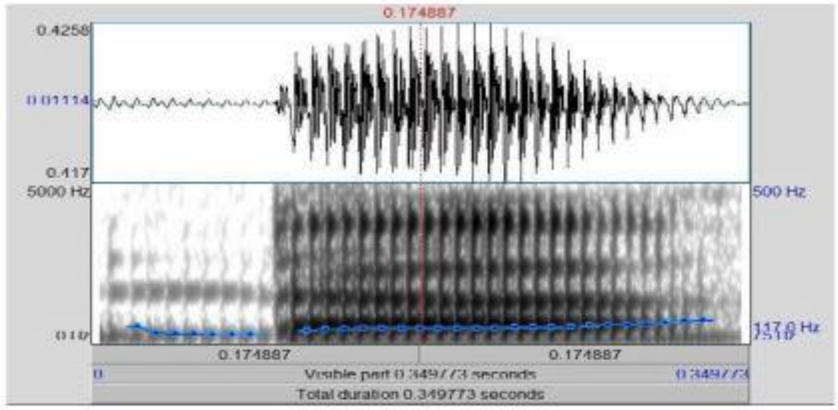

*Fig 3.1.*The time domain waveform (upper panel) and spectral representation (lower panel) of /da/ stimulus

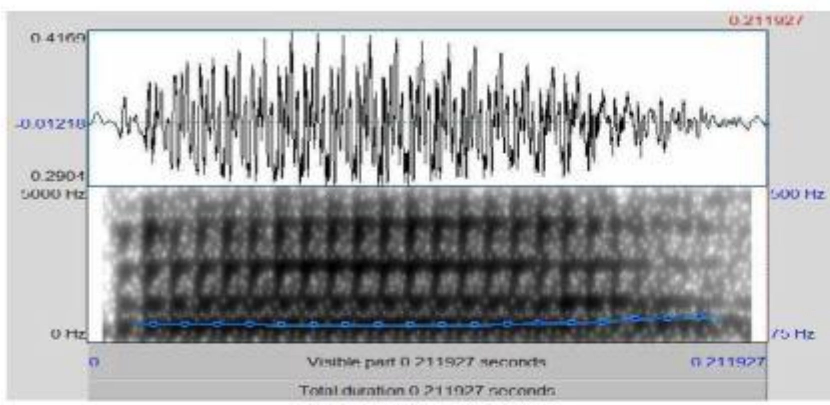

Fig 3.2. The time domain waveform (upper panel) and spectral representation (lower panel) of /ba/ stimulus

The infrequent stimulus was presented randomly, and it was 20 % of the frequent stimulus. The individuals were asked to listen to both the stimulus carefully and count the number of infrequent stimuli. The stimulus and acquisition parameters used to record P300 are given in Table 3.1.

Table 3.1.

Stimulus and acquisition parameters used to record P 300

STIMULUS PARAMETERS	
Transducer	Insert ER- 3A
Stimulus paradigm	Oddball paradigm
Stimulus type	Speech sounds Frequent: /da/and Infrequent: /ba/
Intensity	70dB nHL
Duration of the stimulus	200ms
Repetition rate	1.1/s
Stimulus probability (target)	20%
Polarity	Rarefaction
Presentation ear	Binaural
ACQUISITION PARAMETERS	
No. of sweeps	300
Amplification	50,000 (lesser for larger response)
Analysis time	900ms
Filter setting	1-30Hz
Notch filter	No
Electrode type	Disc
Electrode montage	Reference: Fpz Active: A1 Ground: Nasion

Response Analysis. The P300 was identified in each participant. The response was analyzed to note down the onset latency, peak latency, and offset latency and the peak amplitude. P300 was analyzed by giving the waveforms to two Audiologists with experts in P300. They were asked to mark any positivity seen around 300 ms for infrequent stimulus. P300 onset latency, offset latency, peak latency, and amplitude wasmarked.

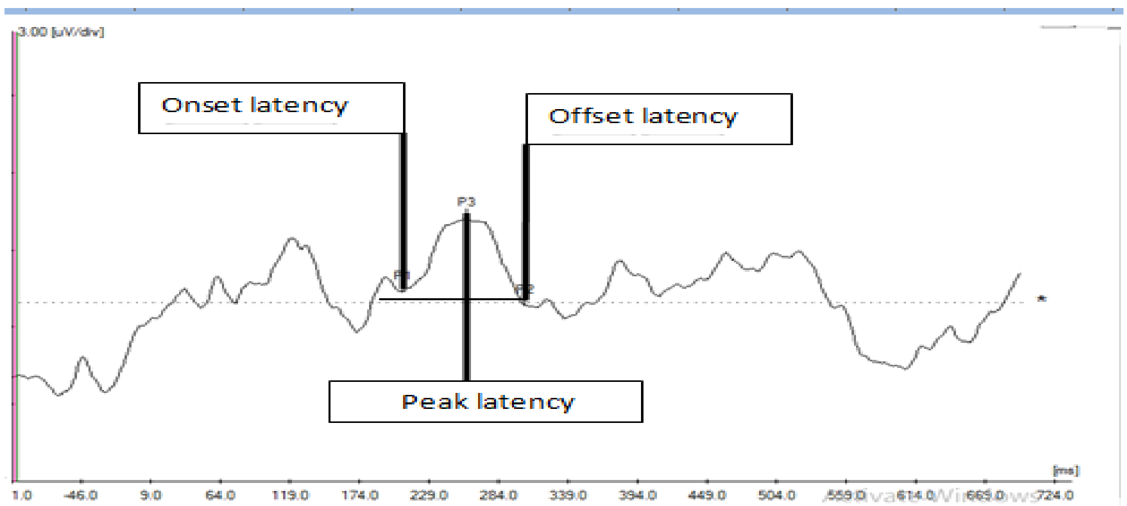

Figure 3.3 Representation of P300 waveform with response measure (onset latency, offset latency, peak latency, and amplitude)

3.4.4. Procedure of Working Memory. Working memory was assessed using digit span and digit sequencing tests. This was done through 'Smriti Shravan' software (Kumar & Sandeep, 2013). Stimuli consisted of digits from one to nine in the English language which were presented binaurally at 70 dBSPL. The numbers were presented in random order with increasing level of difficulty from digit one to digit nine with 250 ms of inter-stimulus interval and the minimum number of digits presented being two. The stimulus was presented through the personal laptop with calibrated head phone

In digit span tasks, forward and backward digit span was assessed. In forward digit span test, the participants were presented with clusters of numbers, and they were asked to repeat the numbers in the same order. For example, if the digit presented was 1548, they had to repeat it in the same order as 1548, and in the backward span test, they were asked to repeat the digits in the reverse order. For example, if the digits presented were 1548 then they had to repeat it in reverse order as 8451.

In digit sequencing tests, ascending and descending digit test were done. In ascending digit span, the participant was asked to repeat the number in ascending order. For example, for the digits 1548, participants had to arrange it in increasing order and repeat it as 1458. In descending digit span, the participants were asked to repeat the digits in descending order. For example for the digits 1548, they had to repeat it by arranging it in decreasing order as 8541. Auditory working memory capacity was calculated as the total number of digits the participants can recall in digit span and sequencing tasks.

3.5 Statistical Analyses

The obtained data was analyzed using Statistical Software for the Social Sciences (SPSS V.20). The descriptive statistics were done to obtain the mean and standard deviation of the different variables. Shapiro-Wilk test was administered to check the normal distribution of the data. Analysis of variance (ANOVA) was done to compare the latency and amplitude of P300 and working memory among the groups. Further, Bonferroni's multiple comparison post hoc analysis test was done for pair-wise comparison.

Chapter 4

Results

The aim of the present study was to assess the effect of different levels of physical activity on auditory P300 and working memory. To fulfill the aim, participants were divided into four groups based on the different levels of physical activity. The auditory P300 was recorded binaurally, and working memory was also assessed binaurally from all the participants. The details of the participant in each group are given in Table 4.1. The Shapiro-Wilk test of normality was done to check the normal distribution of data for P300 and working memory. The result of the Shapiro-Wilk test showed that data was normally distributed ($p>0.05$) and hence parametric test was used to analyze the data.

Table 4.1

Details of the total number of participants in each group

Group	No. of Participants
Active	10
Moderately active	10
Moderately inactive	10
Inactive	13

4.1. Effect of Physical Activity on Auditory P300

Auditory P300 was recorded from all the participants of four groups using speech stimuli /ba/ and /da/ at a repetition rate of 1.1 Hz. The P300 waveforms were analyzed by two experienced Audiologist for onset latency, offset latency, peak latency, and amplitude. It was noted that the P300 was present for all the participants in a physically active group, moderately active group and moderately inactive groups and it was present for only 6 out of 13 participants in physically inactive groups. Figure 4.1 shows the P300 waveforms of one participant from each group. Table 4.2 shows the mean and standard deviation (SD) of onset latency, peak latency, offset latency and amplitude of P300 of the four groups.

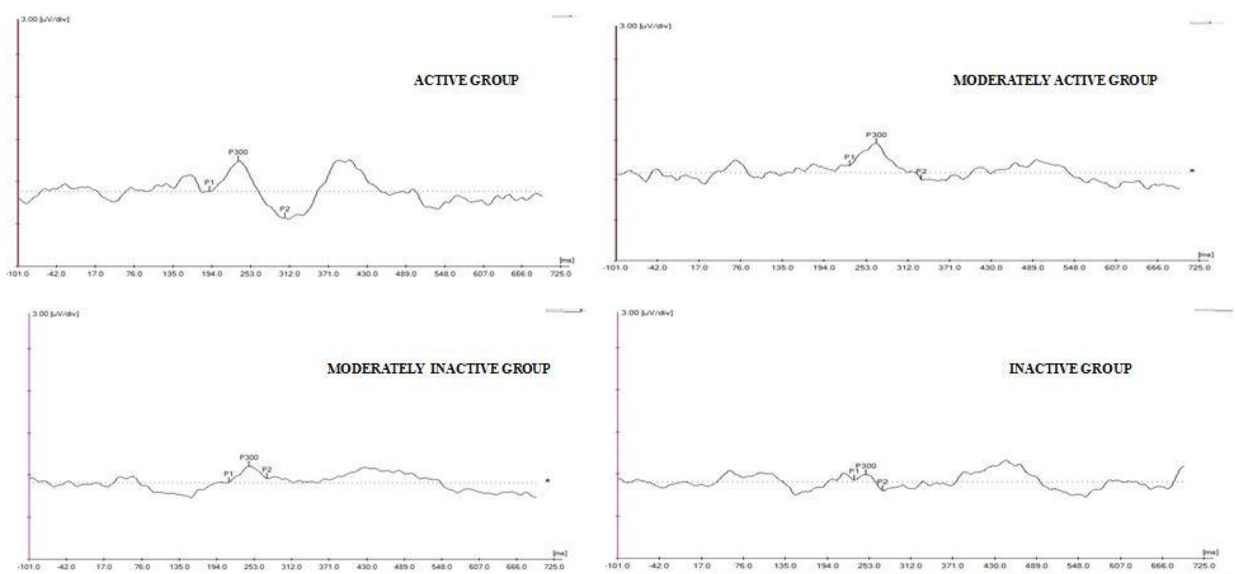

Figure 4.1 Representative example of P300 waveform of one participant from each group

Table 4.2

Mean and SD of different parameters of P300 of the four groups

	A		MA		MI		I	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Onset Latency (ms)	245.70	53.24	259.12	64.60	217.18	8.49	232.90	50.73
Peak Latency (ms)	295.95	55.28	292.70	64.16	261.36	38.65	271.96	47.28
Offset Latency (ms)	351.41	90.97	333.64	49.11	290.45	16.11	320.18	47.82
Amplitude (μV)	3.06	0.65	1.79	0.43	1.12	0.17	0.44	0.23

Note: 'A': Active Group; 'MA': Moderately Active Group; 'MI': Moderately Inactive Group; 'I': Inactive Group.

From Table 4.2 it can be noted that the mean value of latency measures did not differ among the four groups but mean amplitude value was higher in active groups compared to the inactive groups. Further, one way ANOVA was done to assess the significant difference in latency and amplitude measures among the four groups. The results showed no significant main effect of the groups on the onset latency [$F(3,33) = 1.313$, $p>0.05$], offset latency [$F(3,33) = 1.940$, $p>0.05$] and peak latency [$F(3,33) = 0.966$, $p>0.05$]. Since no main effect of groups on latencies was seen, post hoc analysis for pair wise comparison was not done. However, results showed a significant main effect of groups on the amplitude of P300 [$F(3,33) = 60.69$, $p=0.000$]. Table 4.3 shows the pair wise comparison using Bonferroni's corrections for multiple comparisons between the four groups for the amplitude of P300. From Table 4.3, it can be noted that the amplitude of the active group is significantly better than all the other three groups, the amplitude of moderately active group was also better than both the inactive groups. Further, it can also be noted that among the two inactive groups, the amplitude of the moderately inactive group was higher than the inactive group.

Table 4.3

Results of pair-wise comparison across groups for P300 amplitude

	A	MA	MI	I
A				
MA	S			
MI	S	S		
I	S	S	S	

Note: 'A': Active Group; 'MA': Moderately Active Group; 'MI': Moderately Inactive Group; 'I': Inactive Group;

Note: S-Significant at 0.05level (adjusted for Bonferroni's multiple comparisons)

4.2. Effect of Physical Activity on Working Memory

The effect of different levels of physical activity on forward, backward, ascending and descending digit span was seen.Table4.4 shows the mean and SD of various working memory measures across four groups. From Table 4.4, it can be noted that the mean working memory scores of all the measures did not vary among the groups. Further one way ANOVA was done to assess the significant difference in working memory measures among the four groups. The results showed no significant main effect of the groups on the scores of forward digit [$F(3,40) = 2.52$, $p > 0.05$], backward digit [$F(3,40) = 0.509$, $p > 0.05$] ascending digit [$F(3,40) = 0.801$, $p > 0.05$], and descending digit span [F (3, 40) =

0.301, p>0.05]. Since the present study showed no significant effect of groups on working memory, post hoc analysis was not done for pairwise comparison among the groups.

Table 4.4

Mean and SD of various working memory measures across four groups

	A		MA		MI		I	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Forward Digit	6.20	0.78	5.40	1.58	5.00	1.25	5.43	0.65
Backward Digit	3.50	1.27	3.80	1.03	3.70	1.06	4.00	0.68
Ascending Digit	5.10	0.99	4.50	0.97	4.50	1.43	4.71	0.91
Descending Digit	5.30	1.34	4.90	1.85	5.20	2.10	5.07	0.99

Note: 'A': Active Group; 'MA': Moderately Active Group; 'MI': Moderately Inactive Group; 'I': Inactive Group;

Chapter 5

Discussion

The aim of the present study was to see the effect of different levels of physical activity on P300 and working memory. To fulfill the aim of the study 43 participants were divided into four groups based on the different level of physical activity. The results of the present study are discussed below:

5.1. Effect of Physical Activity on P300

The result of the present study showed no significant difference between the different physically active groups in terms of onset latency, peak latency, and offset latency of P300. However, the amplitude of auditory P300 differed significantly among the groups. Physically active groups had higher P300 amplitude than the other groups of the present study. The results of the present study are in consensus with the studies in the literature (Chang, Huang, Chen & Hung, 2013; Kamijo et al. 2011; Lardon & Polich 1996; Magine et al. 2000; Pontiflex, Hillman, & Polich 2009; Kamijo et al. 2011. Kim et al. (2015) studied the effect of Thi-chi exercises on cognitive function in elderly individuals using P300, and they also reported better amplitude of P300 in the physically active group. Pontiflex et al. (2009) also reported that group with more physically active individuals had a higheramplitude of P3a and P3b than the non active groups.

Increase in the amplitude of P300 in the physically active group could be attributed to the benefits associated with increased physical activity. Various forms of physical activity increase cerebral blood flow and improve the cerebral neurotransmitter function and balance. Physical exercise also enhances the neuroendocrine and autonomic tones (Magine et al. 2000). A physical exercise also increases the alpha activity in the brain (Boutcher & landers, 1988; Farmer et al., 1978; Hatfield et al., 1984; Kamp & Troost, 1978).

However, in the present study, we did not see any difference in latencies of P300 across groups. These results are in contrary to the findings of the literature (Chang, Huang, Chen & Hung 2013; Kamijo et al., 2011; Lardon & Polich, 1996; Magine et al., 2000; Pontiflex, Hillman, & Polich, 2009). Kutlu et al. (2014) showed shorter latencies and higher amplitude in the physically active group than the non active elderly individuals. The difference in the results of the present study from the literature could be explained through three reasons. In the present study, the age range of the participants was from 40 to 60 years, and those studies wherein the difference in latency of P300 among different physically active groups was seen they had taken elderly individuals. The second possible explanation is that in most of the studies difference in latency is seen in P300 recorded in Cz site (Telles, Singh & Raghuraj, 2013) and in the present study P300 was recorded from Fpz site. In future, the comparison of the different physically active group can be done with different electrode site recording, and elderly participants can also be included. The third reason could be the small number of participants taken in each group.

5.2. Effect of Physical Activity on Working Memory

The results of the present study showed no significant difference between all the four groups of the study in forward digit span test, backward digit span test, ascending digit span test and descending digit span scores. These results are not in consensus with the studies reported in the literature (Chang et al., 2013; Kamijo et al.,2011; Langdon & Corbett 2012; Pontiflex et al., 2008).Several studies have shown that physical exercise attenuates the age-related declination in cognitive performances (Dustman et al.,1994; Dustman et al.,1990; Hawkins et al.,1992; Bashore,1989; Spirduso,1980). A physical exercise also increases the alpha activity in the brain (Boutcher & landers, 1988; Farmer et al., 1978; Hatfield et al., 1984; Kamp & Troost, 1978).Chang et al., (2013) reported that higher physical activity group had a shorter response time in working memory tasks compared to lower physical activity group which indicates that physical activity enhances the cognition through several neuro-cognitive mechanisms.

These differences in the results between the present study and studies reported in the literature could be attributed to a few factors. Studies reported in the literature to compare working memory among different physically active groups have used the complex working memory task and reaction time to assess working memory (Pontiflex et. al., 2008; Kamijo et. al., 2011; Langdon &Corbett, 2012; Chang et. al., 2013) where as in our study we have used simple tasks to assess the working memory. Further, the literacy level of the participants could also be a contributory factor in assessing working memory. Participants with higher literacy level would perform better in the working memory test, and participants with poor literacy level would perform poor in working memory task. In the present study literacy level would also be a confounding factor. Hence, in future, a more controlled study should be done wherein the literacy level should also be controlled to assess the effect of physical exercises on the working memory.

Chapter 6

Summary and Conclusion

Regular physical activity has shown to have a positive impact on mental, emotional (Kirk-Sanchez & McGough, 2014), as well as on auditory system performance (Yagi, Coburn, & Estess, 1999). The benefits of physical exercises are well documented in the literature (Ozkaya et al., 2005; Yagi et. a1., 1999; Zhang et al., 2014). The effect of physical activity on the functioning of the brain can be assessed by using event-related potentials reflecting cortical activities related to cognition (Pedroso et al., 2017). The aim of the present study was to investigate the effect of physical activity on P300 and working memory.

To fulfill the aim of the present study, 43 participants in the age range of 40 to 60 years were taken and were divided into four groups based on their physical activity. They were divided into four groups, i.e., active (A), moderately active (MA), moderately inactive (MI) and inactive (I) based on The General Practice Physical Activity Questionnaire (GPPAQ). The auditory P300 was recorded using the stimulus odd ball paradigm with /da/ as frequent and /ba/ infrequent stimulus. The response of P300 was analyzed for onset latency, peak latency, offset latency and the peak amplitude. Working memory was assessed using digit span and digit sequencing tests digit span tasks, forward and backward digit span was assessed and in digit sequencing tests, ascending and descending digit test were done.

The result of the study showed a significant difference in amplitude of P300 among the different physically active groups whereas no significant differences in various latency measure of P300 was seen among the groups. Further, Bonferroni multiple comparison post hoc analysis showed that the P300 amplitude was highest in the active group, followed by moderately active, moderately inactive and the inactive group showed the poorest amplitude. Results also showed no significant difference in working memory scores acorss different physically active groups.

6.1. Implication of the Study

- The study contributed to identify the effect of physical activity on cognition.
- The study would help in counseling individuals regarding the prevention of effect of age on cognition by indulging in various physical activities.

References

Anderson, S., White-Schwoch, T., Parbery-Clark, A., & Kraus, N. (2013). A dynamic auditory-cognitive system supports speech in noise perception in older adults. *Hearing Research, 300,* 18-32.

Baddeley, A. (2000). The episodic buffer: a new component of working memory?*Trends in Cognitive Sciences*, *4*(11), 417-423

Baddeley, A., & Hitch, G. J. (1974). Working memory. *The Psychology of Learning and Motivation, 8,* 47–89.

Barnes, J. N. (2015). Exercise, cognitive function and aging. *Advances in Physiology Education, 39(2),* 55-62.

Bashore, T. R. (1989) Age, physical fitness, and mental processing speed. *Annual Review of Gerontology & Geriatrics.* 9, 120-44.

Bashore, T. R., & Goddard, P. H. (1993). Preservative and restorative effects of aerobic fitness on the age-related slowing of mental processing speed.

Borella, E., Carretti, B., & De Beni, R. (2008). Working memory and inhibition across the adult life-span. *Acta psychologica*, 128(1), 33-44

Boutcher, S. H., & Landers, D. M. (1988). The effects of vigorous exercise on anxiety, heart rate, and alpha activity of runners and nonrunners. *Psychophysiology*, *25*(6), 696-702.

Carhart, R., &Jerger, J. (1959). Prefered method for clinical determination of pure-tone thresholds. *Journal of Speech and Hearing Disorder, 16, 340-345*.

Chang, Y., Huang, C., Chen, K., & Hung, T. (2013). Physical activity and working memory in healthy older adults: An ERP study.*Psychophysiology, 50,* 1174-1182.

Colcombe, S., & Kramer, A. F. (2003). Fitness effect on cognitive function of older adults: meta-analysis study. *Psychological Science, 14,* 125-130.

Cristell, M., Hutchinson, K. M., & Alessio, H. M. (1998). Effects of exercise training on hearing ability. *Scandinavian Audiology*, *27*(4), 219-224.

Davis, H. (1964). Enhancement of evoked cortical potential in human related task requiring decision. *Science, 145,* 182-183.

Donchin, E. (1981). Surprise! Surprise? *Psychophysiology,18, 493-513.*

Donchin, E., & Coles, M. G. (1988). Is the P300 component a manifestation of context updating?. *Behavioral and Brain Sciences*, *11*(3), 357-374

Dustman, R. E, Emmerson, R. Y., Ruhling, R. O., Shearer, D. E., Steinhaus, L. A., Johnson, S. C., et al. (1990). Age and fitness effects on EEG, ERPs, visual sensitivity, and cognition. *Neurobiology of Aging.11 (3),* 193-200.

Dustman, R. E., Emmerson, R., & Shearer, D. (1994). Physical activity, age, and cognitive-neuropsychological function. *Journal of Aging and Physical Activity*, *2*(2), 143-181.

Etnier, J. L., Salazar, W., Landers, D. M., Petruzello, S. J., Han, M., & Nowell, P. (1997). The influence of physical fitness and exercise upon Cognitive Functioning: a meta-analysis. *Journal of Sports Exercise Psychology, 19,* 249-277.

Farmer, P. K., Olewine, P., Comer, D., Edwards, M., Coelman, T., Thomas, C., & Hames, C. (1978). Frontalis muscle tension and occipital alpha production in young males with coronary prone (Type A) and coronary resistant (Type B) behavior patterns: effects of exercise (abstract). *Medical Science and Sports, 10*, 51.

Friedman, D., Cycowicz, Y. M., & Gaeta, H. (2001). The novelty P3: an event-related brain potential (ERP) sign of the brain's evaluation of novelty. *Neuroscience & Biobehavioral Reviews*, *25*(4), 355-373.

Hatfield, B. D., Vaccoro, P., Brown, E., Moore, T., & Ostrove, S. (1984). Electrocortical (EEG) relaxation response in high and low cognitively anxious person as a result of cardiovascular exercise stress, *Motor Development-Sports Psychology and Motor Learning/Motor Control Scientific Program Abstracts* (pp. 65-66). Proccdings of the 1984 Olympic Scientific Congress, Eugene, OR.

Hawkins, H. L., Kramer, A. F., & Capaldi, D. (1992). Aging, exercise, and attention. *Psychology and Aging.*7 (4), 643-53.

Hogervorst, E., Riedel, W., Jeukendrup, A., &Jolles, J. (1996). Cognitive performance after strenuous physical exercise. *Perceptual and Motor Skills, 83*(2), 479-488.

Kamijo, K., Pontifex, M. B., O'Leary, K. C., Scudder, M. R., Wu, C., Casteli, D. M., & Hillman, C. H. (2011). The effect of an afterschool physical activity program on working memory in preadolescent children. *Developmental Science, 14(5),* 1046-1058.

Kamp, A., & Troost, J. (1978). EEG signs of cerebrovascular disorder, using physical exercise as a provocative method. *Electroencephalography and Clinical Neurophysiology, 45*(2), 295-298.

Kim, S., Kim, S., Kim, M., Kim, M., & Nam, S. (2015). The effect of Thi-chi exercises on cognitive function in older adults: an examination of P300. *Indian Journal of Science and Technology, 8(S7).* 452-461.

Kirk-Sanchez, N. J., & McGough, E. L. (2014).Physical exercise and cognitive performance in the elderly: current perspectives. *Clinical Interview of Aging*, 9, 51-62.

Kok, A. (1990). Internal and external control: A two-factor model of amplitude change of event-related potentials. *Biological Psychology, 74,* 203–236.

Kutlu, N., Buyukyazi, G., Kaptan, G., Selcuki, D., Artug, R. (2014). Examination of P300 in veteran males: aging physical activity and cognitive processing. *Medical Science and Discovery, 1(1),* 9-15.

Langdon, K. D., &Corbett, D. (2012). Improved working memory following novel combinations of physical and cognitive activity. *Neurorehabilitation and Neural Repair*, *26*(5), 523-532.

Lardon, M. T., &Polich, J. (1996). EEG changes from long-term physical exercise. *Biological Psychology, 44*(1), 19-30.

Laurin, D., Verreault, R., Lindsay, J., MacPherson, K., & Rockwood, K. (2001). Physical activity and risk of cognitive impairment and dementia in elderly persons. *Archives of Neurology*, *58*(3), 498-504.

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,* 369-377.

Mandolesi, L., Polverino, A., Montuori, S., Foti, F., Ferraioli, G., Sorrentino, P., & Sorrentino, G. (2018). Effects of physical exercise on cognitive functioning and wellbeing: biological and psychological benefits. *Frontiers in psychology*, *9*.

Middleton, L. E., Barnes, D. E., Lui, L., &Yaffe, K. (2010). Physical activity over the life course and its association with cognitive performance and impairment in old age. *Journal of American Geriatric Society, 58(7),* 1322-1326.

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The unity and diversity of executive functions and their contributions to complex “frontal lobe” tasks:Alatent variable analysis. *Cognitive Psychology, 41,* 49–100.

Nyberg, L., Lovden, M., Riklund, K., Lindenberger, U., &Bäckman, L. (2012). Memory aging and brain maintenance. *Trends in Cognitive Sciences*, *16*(5), 292-305

Ozkaya, G. Y., Aydin, H., Toraman, N. F., Kizilay, F., Ozdemir, O., Cetinkaya, V. (2005). Effect of strength and endurance training on cognition in older people. *Journal of Sports Science and Medicine, 4,* 300-313.

Padilla, C., Pérez, L., & Andrés, P. (2014). Chronic exercise keeps working memory and inhibitory capacities fit. *Frontiers in Behavioral Neuroscience, 8*, 49.

Park, D. C., Lautenschlager, G., Hedden, T., Davidson, N. S., Smith, A. D., & Smith, P. K. (2002). Models of visuospatial and verbal memory across the adult life span. *Psychology and Aging, 17,* 299–320.

Pedroso, R. V., Fraga, F. G., Ayan, C., Cancela, C. J. M., Scarpari, L., & Santos, G, R. F. (2017). Effect of physical activity on the P300 component in elderly people: a systematic review. *Psychogeriatrics, 17(6),* 479-487

Polich, J., & Lardon, M. T. (1997). P300 and long-term physical exercise. *Electroencephalography and clinical neurophysiology, 103(4), 493-498.*

Pontifex, M. B., Hillman, C. H., &Polich, J. (2009). Age, physical fitness, and attention: P3a and P3b. *Psychophysiology*, *46*(2), 379-387.

Pontifex, M. B., Hillman, C. H., Fernhall, B. O., Thompson, K. M., &Valentini, T. A. (2009). The effect of acute aerobic and resistance exercise on working memory. *Medicine & Science in Sports & Exercise*, *41*(4), 927-934.

Pontifex, M. B., Hillman, C., Fernhall, B., Thompson, K. M., &Valentini, T. A., (2008). The effect of acute aerobic and resistance exercise on working memory.*Official Journal of the American College of Sports Medicine.* 927-934.

Roth, D. H. (1989). Acute emotional and psychophysiological effects ofaerobic exercise. *Psychophysiology, 26,* 593–602.

Spirduso,W. W. (1980). Physical fitness, aging, and psychomotor speed: a review. *Journal of Gerontology*.35(6), 850-65.

Squires, N. K., Squires, K. C., & Hillyard, S. A. (1975).Two varieties of long-latency positive waves evoked by unpredictable auditory stimuli in man. *Electroencephalography and Clinical Neurophysiology.* 38, 387–401.

Sternberg, S. (1966). High speed scanning in human memory. *Science, 153,* 652-654.

Taneja, M. K. (2015). Improving hearing performance through yoga. *J Yoga PhysTher*, *5*(194), 2.

Telles, S., Singh, N., &Puthige, R. (2013). Changes in P300 following alternate nostril yoga breathing and breath awareness. *BioPsychoSocial Medicine*, *7*(1), 11.

Tomporowski, P. D., & Ellis, N. R. (1986). Effects of exercise on cognitive processes: A review. *Psychological Bulletin*, *99*(3), 338.

Tuson, K. M., &Sinyor, D. (1993). On the affective benefits of acute exercise: Taking stock after twenty years of research. In P. Serganian (Ed.), Exercise psychology: The influence of physical exercise on psychological processes (pp.) 80–121. New York: Wiley.

Verleger, R. (1988) Event-related potentials and cognition: A critique of the context updating hypothesis and an alternative interpretation of P3. *Behavioral and Brain Sciences 11:343–56.*

Yaffe, K., Barnes, D., Nevitt, M., Lui, L. Y., &Covinsky, K. (2001). A prospective study of physical activity and cognitive decline in elderly women: women who walk. *Archives of Internal Medicine*, *161*(14), 1703-1708.

Yagi, Y., Coburn, K. L., Estes, K. M., & Arruda, J. E. (1999). Effects of aerobic exercise and gender on visual and auditory P300, reaction time, and accuracy. *European Journal of Applied Physiology and Occupational Physiology*, *80*(5), 402-408

Zhang, X., Ni, X., & Chen, P. (2014). Study about the effects of different fitness sports on cognitive function and emotion of the aged.*Cell Biochemistry Biophysics*, *70*, 1591-1596.

APPENDIX 1

Informed Consent Form

Title: Effect of Physical Activity on P300 and Working Memory

I have been informed about the aims, objectives and the procedure of the study. The possible risks- benefits of my participation as a human subject in the study are clearly understood by me. I have understood that the research aims at obtaining voluntary responses from me and the total duration of this would be around 1 hour. I am also aware that by subjecting to this investigation, I will have to give time and that these assessments may not result in any benefits to me. I understand that I have a right to refuse participation or withdraw my consent at any time. I am interested in participating in the study and at this moment give my written consent for the same.

I, ______________________________, the undersigned, give my consent to be participant of this research.

Signature of Individual   Signature of the Researcher

(Name and Address)

____

____

Appendix II

General Practice Physical Activity Questionnaire

Developed by the World Health Organization, 2006

Date………………………

Name……………………..

1. Please tell us the type and amount of physical activity involved in your work.

		Please mark one box only
a	I am not in employment (e.g., retired, retired for health reasons, unemployed,full-time carer etc.)	
b	I spend most of my time at work sitting (such as in an office)	
c	I spend most of my time at work standing or walking. However, my work does not require much intense physical effort (e.g., shop assistant, hair dresser, security guard, child minder, etc.)	
d	My work involves definite physical effort including handling of heavy objects and use of tools (e.g., plumber, electrician, carpenter, cleaner, hospital nurse, gardener, postal delivery workers, etc.)	
e	My work involves vigorous physical activity including handling of very heavy objects (e.g., scaffolder, construction worker, refuse collector, etc.)	

2. During the *last week*, how many hours did you spend on each of the following activities?

Please answer whether you are in employment or not

Please mark one box only on each row

		None	**Some but less than 1 hour**	**1 hour but less than 3 hours**	**3 hours or more**
a	Physical exercise such as swimming, jogging, aerobics, football, tennis, gym workout etc.				
b	Cycling, including cycling to work and during leisure time				
c	Walking, including walking to work, shopping, for pleasure,etc.				
d	Housework/Childcare				
e	Gardening/DIY				

3. How would you describe your usual walking pace? Please mark one box only.

Slow pace

(i.e. less than 3 mph) ☐

Steady average pace ☐

Brisk pace ☐

Fast pace

(i.e. over 4 mph) ☐