Effect of physical activity on auditory evoked P300 and MMN

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Introduction

Physical activity has been shown to have physical and emotional benefits. Studies have shown that individuals who do brisk walk or swim have better sleep (Reid et al., 2010) and it also helps to regulate blood glucose levels (Bouchard et al., 1994). Long-term participation in physical activity can improve cardiovascular functioning, increase muscle strength, and enhance balance and flexibility (*World Health Organization. Regional Office for Europe. (1996). The Heidelberg Guidelines for Promoting Physical Activity among Older Persons. Copenhagen : WHO Regional*, n.d.). In addition, a number of remarkable psychological benefits like improved mood state and relaxation is seen in individuals who are involved in physical activity (Bouchard et al., 1994; Nieman et al., 1993).

Studies related to cardiovascular exercise and cental nervous system (CNS) health on animal models have shown positive effects of aerobic fitness on a wide range of brain health markers. These effects are seen due to the increased levels of brain-derived neurotrophic factor, serotonin, capillary density (Cotman, 2002), and neurogenesis (van Praag et al., 1999). It is also reported that there is increased brain-derived neurotrophic factor (nutrition for the brain) in individuals who are physically active which leads to the promotion of neurogenesis, and improvements in learning (Cotman, 2002).

Thus, from the literature, it is evident that CNS activity is enhanced in individuals who are physically active and this can be studied through electroencephalography (EEG). Event-related potentials (ERPs) are used to measure the EEG activity evoked by the auditory or visual stimulus. ERPs involve various neural processes including sensory (exogenous) and cognitive (endogenous) events. The P300 and mismatch negativity (MMN) are “endogenous” components and is associated with cognition. The P300 is a positive peak that occurs at around 300 ms beyond the stimulus presentation that is characterized by amplitude and latency and MMN is the negative component of the waveform with a latency of around 100-250 ms obtained by subtracting the event-related response to the standard event from the response to the deviant event (Sams et al., 1985).

Dustman et al., (1990) investigated the effects of aerobic fitness activities on visual- and auditory evoked long-latency components. Results showed that the P300 component latencies was related to the fitness level indicating that P300 latencies occurred significantly earlier in young and old high-fitness individuals than old low-fitness group. In a similar study, Bashore et al., (1989) reported that fitness level was related to P300 latency for the older adults subjects wherein P300 latencies were significantly longer for individuals with lower physical activity.

Studies in the past have mainly used visually evoked potentials to assess the effect of physical activity on brian activity. The purpose of the present study was to examine the effect of physical activity on auditory evoked P300 and MMN.

Material and Methods

Participants

A total of 36 participants participated in the study. The age range of the participants was between 20-40 years. The participants were divided into four groups, ie, active (A), moderately active (MA), moderately inactive (MI) and inactive (I) using GPPAQ (The General Practice Physical Activity Questionnaire was commissioned by the Department of Health and 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 (*Department of Health. The General Practice Physical Activity Questionnaire: A Screening Tool to Assess Adult Physical Activity Levels, within Primary*

Care. 2009, n.d.). It calculates the physical activity index and divides the individuals into four groups as active, moderately active, moderately inactive and inactive.

All individuals had hearing sensitivity within normal limits. Only male participants were included in the study because hormonal changes seen in females during menstrual cycle can have an effect on the results. Written consent was taken from all the participants for willingly participating in the study. All the participants of the four groups were assessed for hearing status and middle ear status. Further, P300 and MMN was recorded for all the participants. Ethical clearance was obtained from the relevant ethics committee at the institute prior to commencement of experimentation.

Procedure for MMN and P300 recording

MMN was recorded for voicing contrast using /pa/ and /ba/ stimuli, with /pa/ as frequent stimulus and /ba/ as the infrequent stimulus using the Intelligent Hearing System (EP-25, SmartBox). Natural /ba/ stimulus was recorded using male speaker and the duration was kept as 130 ms and /pa/ was generated from the stimulus by cutting the voice onset time and the duration was maintained 130 ms. The minimum voice onset time (VOT) to discriminate both sounds was noted and that VOT was the difference between both the stimuli.

P300 potential was recorded using readily available stimuli in the clinics. Pilot study was done with various permutations and combinations of stimulus pairs. The stimulus pair /i/and /I/ elicited P300 with higher amplitude, shorter latency and good morphology and were slected for the P300 recording.

MMN was recorded at Fz and Pz electrode sites and positive electrode was referenced to the tip of the nose. The ground electrode was placed on the lower forehead. A third channel was also used to record the eye blink response. The sweeps with large eye blink artifacts (1 μV) was eliminated from the averaging. Stimuli were presented in the odd ball paradigm with the probability of standard and deviant stimulus as 80% and 20% respectively at 70 dBSPL. The stimuli were presented binaurally in the rarefaction polarity with a repetition rate of 1.1/second. The response was averaged for 150 sweeps (150 infrequent stimuli + the corresponding number of frequent stimuli) from -50 to 500 ms (with reference to stimulus onset). The filter was set to band pass between of 0.1 to 30 Hz, while it was amplified from 50,000 times. P300 was also recorded from Fz and Pz site of both the ears. The protocol for the recording of P300 was same as that of MMN, with only difference here that the client needed to count the number of infrequent stimuli and indicate it by pressing a button. For all the clients MMN was performed before P300 to avoid subjects from concentrating on the stimulus.

Response Analysis

MMN was analyzed by overlapping the conventional Late latency response (LLR) of infrequent stimuli and the averaged waveform of the infrequent stimulus recorded through MMN paradigm. The infrequent response waveform was subtracted from frequent stimulus LLR and the onset, offset and peak latencies were marked and the amplitude at the peak latencies were noted. For P300 positive peak seen around 300 ms for infrequent stimulus was marked with onset latency, offset latency, peak latencies and amplitude. The amplitude of P300 and MMN was measured from the peak of P300 and MMN to the next trough. After response analysis, it was noted that MMN was clearly recorded for 28 participants and P300 was present in all 36 participants.

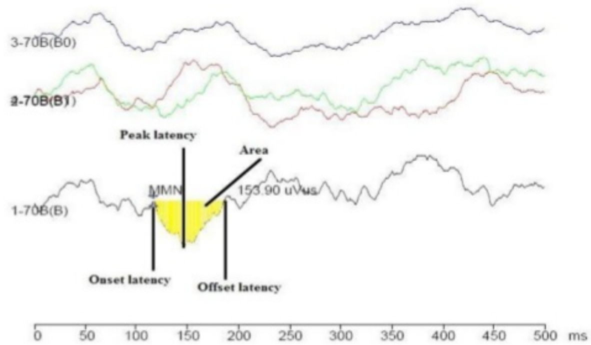

Figure 1: *Representation of MMN waveform with the response measures (onset latency, offset latency, peak latency, and area)*

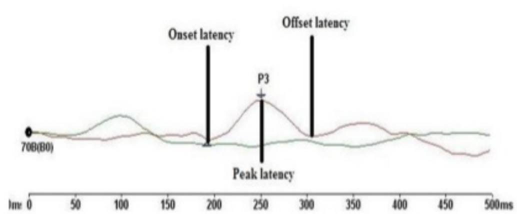

Figure 2: *Representation of P300 waveform with the response measures (onset latency, offset latency, peak latency, and area)*

Statistical Analyses

The data obtained from the study was subjected to statistical analyses using the Statistical Package for the Social Sciences (Version 20, SPSS Inc., Chicago, IL, USA).

Descriptive statistics was carried out to estimate the mean and standard deviation for all the parameters. Following this Shapiro-Wilk test of normality was done to check the assumptions of parametric statistics. It was noted that the data was not fulfilling the assumptions of normality and thus non parametric ststistics was done. Kruskal-Wallis test was carried out to analyze the effect of physical activity on the latency and amplitude of P300 and MMN.

Results

Table 1 shows the number of participants and the mean age of the participants in each group. Kruskal wallis test was done to check if age differed significantly among the four groups and it was noted that there was no significant main effect of age on four groups [$\chi^2(1) = 2.138, p > 0.05$].

Table 1.

The number of participants and the mean age of the participants in each group.

S. No.	Group	Number of participants	Mean Age (Years)
1	A	8	28
2	MA	7	25.4
3	MI	7	25.2
4	I	6	32.5

Note: A: Active, MA: Moderately Active, MI: Moderately Inactive and I: Inactive

Effect of physical activity on MMN

MMN was analyzed for onset latency, offset latency, peak latency, amplitude, area and this was compared across four groups of individuals with various levels of physical activity at two electrode placements (Fz and Pz).

Latency of MMN. Figure 3 shows the mean and standard deviation (SD) for onset latency, offset latency, peak latency and area of MMN for the four groups of participants at two electrode sites. From the figure is can be noted that the group 1 has a mean shorter latency compared to the other three groups Further, the Kruskal Wallis test was done to see the significant difference in latencies across the groups. Results showed no significant main effect of physical activity on the latency parameters of MMN as noted for onset latency [$\chi^2(3) = 1.674$, $p > 0.05$], offset latency [$\chi^2(3) = 3.790$, $p > 0.05$] and peak latency [$\chi^2(3) = 2.595$, $p > 0.05$] at Fz position. Similarly, in Pz position also there was no significant difference in latency measures between the four groups as noted for onset latency [$\chi^2(3) = 0.917$, $p > 0.05$] and peak latency [$\chi^2(3) = 3.176$, $p > 0.05$]. However, offset latency showed a significant main effect of physical activity on MMN [$\chi^2(3) = 8.850$, $p < 0.05$].

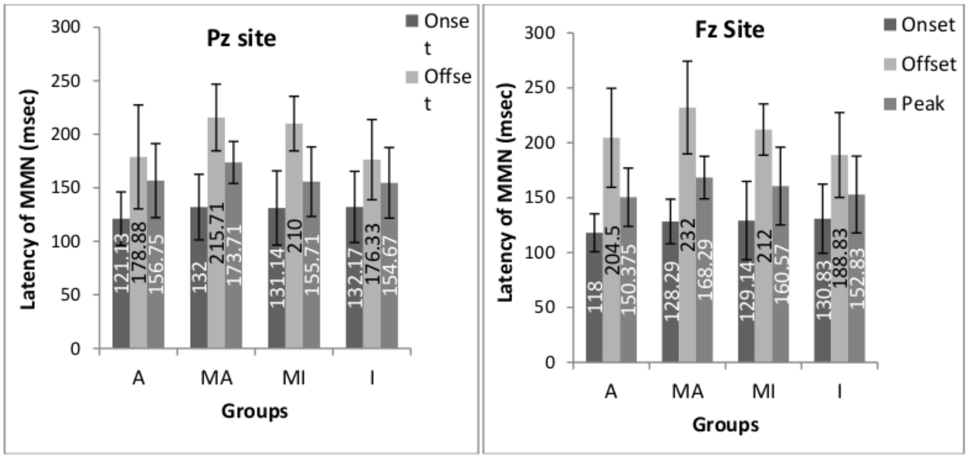

Figure 3: *Mean and SD of onset, offset and peak latencies of MMN for four groups at Fz and Pz electrode site*

*Amplitude of MMN***.** Figure 4 shows the mean and standard deviation for amplitude of MMN at Fz and Pz position across the four groups. It is evident from the figure that the mean amplitude of MMN for active group was higher compared to the other three groups for both Fz and Pz positions. The Kruskal Wallis test revealed that there was a significant main effect of physical activity on MMN amplitude for Fz electrode site [$\chi^2(3) = 22.692$, $p < 0.01$] and Pz electrode site [$\chi^2(3) = 14.895$, $p < 0.05$]. Further, Mann Whitney U test revealed that the amplitude of active group had a significantly higher amplitude compared to the moderately active, moderately inactive and inactive group. In Pz position amplitude of active and moderately active group differed significantly from moderately inactive and inactive group, indicating that active groups had a higher amplitude compared to the inactive groups.

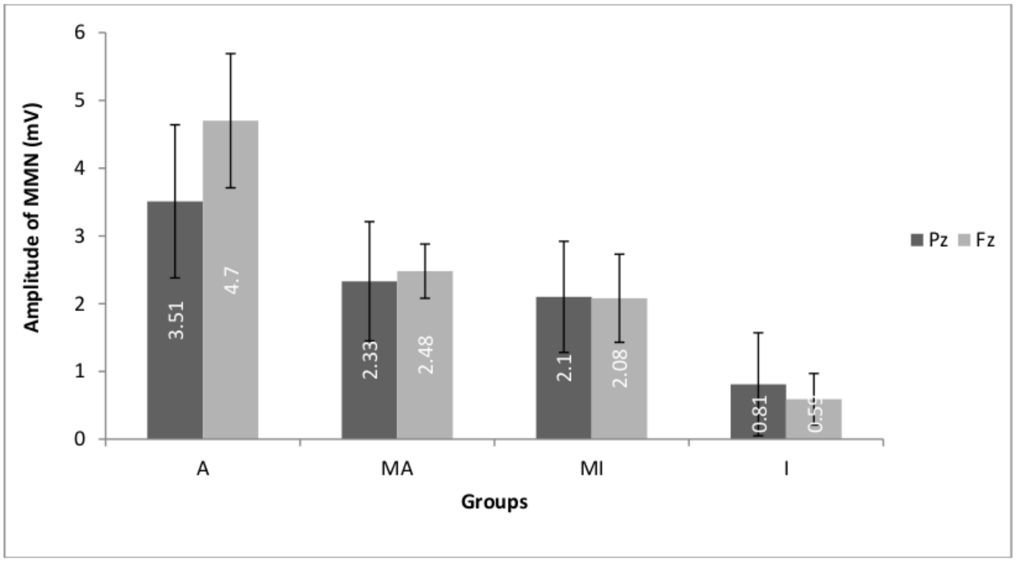

Figure 4: *Mean and SD of amplitude of MMN for four groups at Fz and Pz electrode site*

Effect of physical activity on P 300.

Latency and Amplitude of P300 were also compared across four groups of participants with various levels of physical activity at two electrode placements (Fz and Pz).

Latency of P300. Figure 5 shows the mean and standard deviation for onset latency, offset latency, and peak latency of P300 across the four groups for two electrode site. It is evident from the figure that the latency measures across group did not vary much. The Kruskal Wallis test also showed that there was no significant main effect of physical activity on all the latency parameters of P300 as noted for onset latency [$\chi^2(3) = 2.041$, $p > 0.05$], offset latency [$\chi^2(3) = 2.144$, $p > 0.05$], peak latency [$\chi^2(3) = o.259$, $p > 0.05$] at Pz position. Similarly, there was no main effect noted in the Fz position for onset latency [$\chi^2(3) =0.447$, $p > 0.05$], offset latency [$\chi^2(3) = 2.275$, $p > 0.05$] and peak latency [$\chi^2(3) = 0.533$, $p > 0.05$].

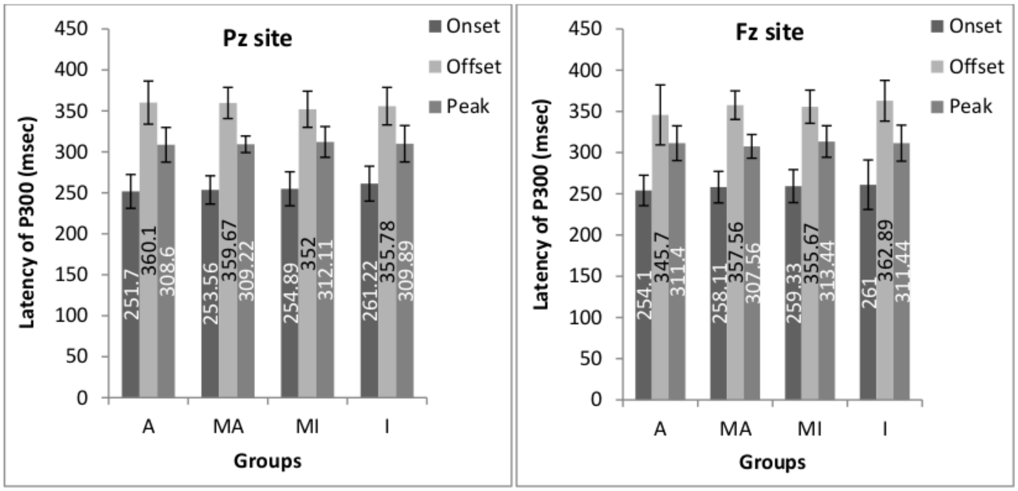

Figure 5: *The mean and SD of onset, offset and peak latencies of P300 for four groups at Pz and Fz electrode site*

Amplitude of P300. Figure 6 shows the mean amplitude and SD of P300 for the four groups at Pz and Fz. The Kruskal Wallis test revealed that there was a significant main effect of physical activity on the amplitude of the P300 for both Pz [$\chi^2(3) = 26.852$, $p < 0.01$] and Fz [$\chi^2(2) = 19.674$, $p < 0.01$] electrode site. Further, Mann Whitney U test revealed that the amplitude of active group significantly differed from that of moderately active, moderately inactive and inactive group. It was also seen that the amplitude of inactive group was significantly poorer than all the other groups.

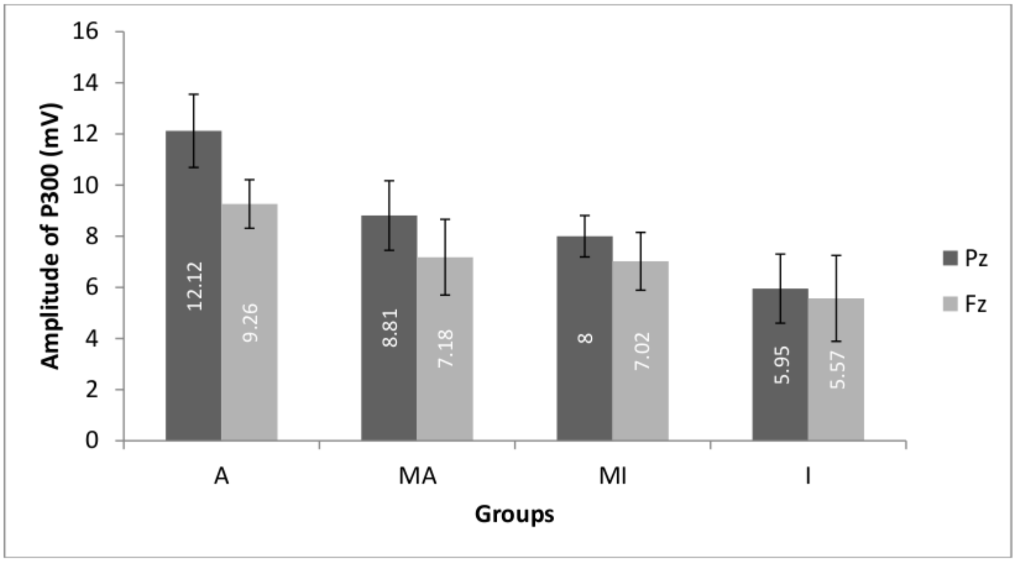

Figure 6: *Mean and SD of amplitude of P300 for four groups at Fz and Pz electrode site*

Discussion

The current study was designed to investigate the effect of physical activity on P300 and MMN. Results showed that the amplitude of P300 and MMN was significantly higher for participants who were physically active compared to that of individuals who were physically inactive. The result of the present study is in agreement with the studies reported in the literature. However the previous studies have mainly used visually evoked potentials to assess the effect of physical activity (Bashore et al., 1989; Dustman et al., 1990b, 1990b). This could be attributed to the benefits to the brain functions provided by physical activity. There are evidences that physical activity has an angiogenic effect on the cerebellum, which plays a role in executive function (Isaacs et al., 1992). Investigators have suggested that there are beneficial effects of physical activity on the cardiovascular system and which leads to benefit in CNS. Studies have reported that increased exercise is associated with improved neurotransmitter functioning (Fordyce & Wehner, 1993; Tümer et al., 1992), and it also leads to preservation of dopaminergic cells in old animals (MacRae et al., 1987). Exercise also leads to an increase in vascularization of activated brain areas (Isaacs et al., 1992) and an increase in cell hypertrophy and complexity (Gentile et al., 1987; Pysh & Weiss, 1979).

In the present study, latency of P300 and MMN was not related to the amount of physical activity, however, the latency of the potentials was relatively shorter for active and moderately active individuals. This indicates that there is a relationship between executive control process and physical activity. The transmission of information in the brain is speeded, as shown by faster nerve conduction times and by earlier ERP latencies in physically active individuals (Spencer et al., 1993) . However, no significant effect of physical acitivity was seen on the latency measure of P300 and MMN. This could be because the latency is not one the major diagnostic criteria for late latency potentials and latency has a wider normative value.

Studies related to the effect of exercise on humans have shown that there are structural and chemical changes within the CNS leading to faster information processing and task execution, as reflected by earlier ERP component latencies (Bashore et al., 1989; Dustman et al., 1990a) and quicker response times (Clarkson-Smith & Hartley, 1990; Dustman et al., 1990a). It also leads to better performance on cognitive tasks for effortful processing [20] or on tasks that measure fluid rather than crystallized intelligence (Dustman et al., 1990a; Elsayed et al., 1980; Powell & Pohndorf, 1971). Thus, it is evident that there is a widespread implementation of exercise on CNS health and cognitive-neuropsychological functioning as evident through the amplitude measures of MMN and P300. However, the major limitation of the present study is small sample size, thus the results should be taken cautiously and future research can be taken up with more number of participants.

Conclusion

It can be concluded from the present study that there is a significant effect of physical activity on the amplitude of P300 and MMN which could be attributed to the benefits to brain functions provided by physical activity.

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Figure legends

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Figure 2: *Representation of P300 waveform with the response measures (onset latency, offset latency, peak latency, and area)*

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Figure 4: *Mean and SD of amplitude of MMN for four groups at Fz and Pz electrode site*

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Effect of physical activity on auditory evoked P300 and MMN

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