Research Article

Aging-mediated neuromuscular instability and delayed choice reaction time

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Abstract

Background: Normal aging phenomenon is associated with cognitive decline, without any associated pathologies, over the lifespan of an adult. The fluid abilities; attention, processing speed, and executive functions are notably affected, which can hamper the everyday life. Reaction time (RT) test assesses all these abilities. Physical activity has been postulated to have a beneficial effect in the prevention of cognitive decline with aging.

Objective: To study the effect of aging on the choice auditory and visual RT in healthy adults and in those performing aerobic exercise.

Materials and Methods: The present cross-sectional study was carried out in the Physiology Department, IGMC, Nagpur. Twenty healthy adults and 20 aerobic exercisers were recruited in 3 groups of different age groups; Group 1: 31–40 years, Group 2: 41–50 years, and Group 3: 51–60 years—each group comprising 20 individuals. RT both with low- and high-frequency sound and with red, green, and indigo color was assessed. Statistical analysis was done using One-way ANOVA. Post-hoc analysis was done by Tukey–Krammer test. Statistical value of $p < 0.05$ was considered as significant.

Results: Auditory RT was significantly delayed in healthy controls with progressing age. In aerobic exercisers also RT was delayed, but less significant than controls. Visual RT was significantly prolonged in healthy individuals with progressing age. Aerobic exercisers had similar findings for red and green color, but less significant than controls. In aerobic exercisers, the RT for indigo color was statistically insignificant among the groups.

Conclusion: Auditory and visual RT gets delayed even with normal aging and aerobic exercise appears to have a protective role in delaying the cognitive decline.

KEY WORDS: Aging, cognition, auditory, visual, reaction time, exercise

Introduction

Aging causes both myriad of biological and psychological changes. The different aspects of functions of brain are affected in linear age line of an individual from adulthood to geriatric age.[1] Cognitive deterioration is one of the apprehensive aspects of aging. Cognitive changes associated with aging does not occur homogenously among all older individuals and also does not affect all aspects of cognition evenly.[2] Decrease in mental abilities such as attention, processing speed, reasoning, memory, and executive functions begin to appear from early adult age. These mental functions called as “fluid” mental capabilities are vital in performing everyday activities.[3] Attention span, processing speed, and filtering out the inappropriate information are essential for effective performance of various complicated cognitive tasks.[4] Deficits in cognitive domains with aging follow disruption in blood flow to the brain, atrophic changes in the white matter, and reduction in the number of synapses.[3]

Deterioration in skeletal muscle functioning has been evidenced with progressive aging. Elder people have difficulty in producing task-relevant and specific intensities of muscle force for muscular activities.[5] The coordinated motor control requires physiological muscular functions, neuromuscular stability, and neuronal integrative responses.

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Maintaining an active lifestyle may prove to be helpful in preventing the age-related cognitive decay and dementia, as proposed by the lifestyle-cognition hypothesis.[3] Activities that improve cognitive abilities are the ones that are intellectually engaging, physical activities and socially engaging activities.[3]

Reaction time (RT) is the process by which human use their cognition to respond towards the sensory input; visual or auditory. It involves the attention and processing speed coordinated with the performance of a motor skill.[7] In a previous publication from our study, we had reported a significant difference between aerobic exercisers and healthy controls, with aerobic exercisers having shortened RT in comparison to healthy controls.[6]

In continuation to our previous publication, considering the age-related changes in cognitive abilities, we have compared the effect of aging on the choice auditory and visual RT both in healthy adults group and in those performing aerobic exercise.

Material and Methods

The present research work was conducted in the Physiology Department, IGMC, Nagpur, and was a cross-sectional study. The approval of institute research committee was obtained. Written informed consent was obtained from the subjects.

The study involved RT assessment in three age groups namely Group 1, 31–40 years; Group 2, 41–50 years; and Group 3, 51–60 years. Sixty healthy adults as controls and 60 aerobic exercisers were conscripted into the three groups, each group comprising 20 individuals.

Controls

Inclusion Criteria

The healthy adults having normal vision and hearing were selected.

Exclusion Criteria

Individuals who were smokers, alcoholics, diabetic, with clinical evidence of any illness affecting cognition, and on any medication, therapy, or placebo treatment were excluded.

Aerobic Exercisers

Inclusion Criteria

The aerobic exercisers were regular joggers and brisk walkers, for the past 1 year. Aerobic exercisers included in the study regularly performed jogging for 3 miles and bicycling for 2 miles daily, along with slow breathing exercises.

Exclusion Criteria

Individuals who were smokers, alcoholics, diabetic, with clinical evidence of any illness affecting cognition and on any medication, therapy, or placebo treatment were excluded.

The auditory and visual RT was assessed using, "Response Analyzer" (YantraShilpa Systems, Pune). The instrument was accurate up to 0.001 s.

The response time was measured in milliseconds. Auditory RT was measured for low- and high-frequency sound stimuli. Visual RT was measured for red, green, and indigo light stimuli. Initially the subjects were familiarized with the instrument and the procedure was explained to the subjects. The subjects were instructed to respond by pressing a switch immediately after the perception of stimuli. Three readings for each of the parameters were recorded and the average of the three readings was calculated. The average value was taken as the RT for that individual.

Statistical Analysis

SPSS software (Ver.19, Chicago IL, USA) was used for statistical analysis. Kolmogorov–Smirnov test was done for normality testing of data. The data were expressed as mean along with standard deviation (SD). For intergroup comparison, one-way ANOVA was done, and post-hoc analysis was done using Tukey–Krammer test. Statistical significance was considered for a p value of <0.05.

Results

Table 1 depicts the results of auditory RT for low- and high-frequency sound. Table 2 shows visual RT for red, green, and indigo light.

Comparison of Auditory RT (Table 1)

Low-frequency Sound

Controls*:* Comparison of RT for low-frequency sound among the three age groups was significantly difference in healthy controls ($p < 0.001$). The post-hoc test for intergroup comparison showed extremely significant difference between Group 2 vs 3 ($p < 0.001$) and Group 1 vs 3 ($p < 0.001$), though no significant difference was seen between Group 1 vs 2.

Aerobic exercisers*:* The comparison among the three groups in aerobic exercisers showed extremely significant difference ($p < 0.001$). The post-hoc test revealed extremely significant difference between Group 2 vs 3 ($p < 0.001$) and very significant difference (significance less than Group 2 vs 3) between Group 1 vs 3 ($p < 0.01$). But, comparison between Group 1 vs 2 did not show significant difference.

High-frequency Sound

Healthy controls: RT for high-frequency sound, in healthy controls, was significantly different ($p < 0.001$) among the three groups. From the post-hoc test, extremely significant difference between Group 2 vs 3 ($p < 0.001$) and Group 1 vs 3 ($p < 0.001$) was observed. The RT did not vary significantly between Group 1 vs 2.

Table 1: Comparison of auditory reaction time (RT) between controls and aerobic exercisers

Parameters	Group	Group 1 (*N* = 20)	Group 2 (*N* = 20)	Group 3 (*N* = 20)	Anova *p* value	1 vs 2	1 vs 3	2 vs 3
Low-frequency sound	Control	138.5 ± 6.1	145.1 ± 8.2	167.4 ± 15.8	<0.001	ns	<0.001	<0.001
	Aerobic exercisers	136.2 ± 13.5	145.1 ± 12.1	158.7 ± 14.8	<0.001	ns	<0.001	<0.01
High-frequency sound	Control	139.3 ± 5.7	143.9 ± 7.7	166 ± 18.4	<0.001	ns	<0.001	<0.001
	Aerobic exercisers	138.5 ± 11.6	144.1 ± 11.4	159.0 ± 15.3	<0.001	ns	<0.001	<0.01

Data expressed as mean ± standard deviation. Group 1, 31–40 years; Group 2, 41–50 years; and Group 3, 51–60 years. RT values are expressed in milliseconds.

Table 2: Comparison of visual reaction time (RT) between controls and aerobic exercisers

Parameters	Group	Group 1 (*N* = 20)	Group 2 (*N* = 20)	Group 3 (*N* = 20)	Anova *p* value	1 vs 2	1 vs 3	2 vs 3
Red	Control	167.2 ± 7.3	171.2 ± 3.3	184.9 ± 10.7	<0.001	ns	<0.001	<0.001
	Aerobic exercisers	153.3 ± 14.7	159.0 ± 13.7	173.4 ± 16	<0.001	ns	<0.001	<0.01
Green	Control	174.0 ± 6	176.4 ± 8.8	191.4 ± 10.5	<0.001	ns	<0.001	<0.001
	Aerobic exercisers	156.5 ± 15.7	165.4 ± 14.4	178.1 ± 14.7	<0.001	ns	<0.001	<0.05
Indigo	Control	174.5 ± 7.2	178.3 ± 8.4	191.4 ± 10.5	<0.001	ns	<0.001	<0.001
	Aerobic exercisers	157.8 ± 15.6	181.1 ± 57.9	179.2 ± 15.5	0.0817	-	-	-

Data expressed as mean ± standard deviation. Group 1, 31–40 years; Group 2, 41–50 years; and Group 3, 51–60 years. RT values are expressed in milliseconds.

Aerobic exercisers*:* Among aerobic exercisers, the RT for high-frequency sound among the three groups had extremely significant difference ($p < 0.001$). The post-hoc analysis revealed extremely significant difference between Group 2 vs 3 ($p < 0.001$) and very significant difference (significance less than Group 2 vs 3) between Group 1 vs 3 ($p < 0.01$). As in controls no significant difference was observed between Group 1 vs 2.

Comparison of Visual RT (Table 2)

Red Color

Healthy controls*:* Comparison of RT for red color among the three groups showed extremely significant difference in healthy controls ($p < 0.001$). The post-hoc test for intergroup comparison displayed an extremely significant difference between Group 2 vs 3 ($p < 0.001$) and Group 1 vs 3 ($p < 0.001$). And RT between Group 1 vs 2 had no significant difference.

Aerobic exercisers: An extremely significant difference in RT for red color among the three groups was revealed in aerobic exercisers ($p < 0.001$). The post-hoc test exhibited extremely significant difference between Group 2 vs 3 ($p < 0.001$) and very significant difference (significance less than Group 2 vs 3) between Group 1 vs 3 ($p < 0.01$), though no significant difference was seen between Group 1 vs 2.

Green Color

Healthy controls: RT for green color among the three age groups was significantly different in healthy controls ($p < 0.001$). The post-hoc test showed extremely significant difference between Group 2 vs 3 ($p < 0.001$) and Group 1 vs 3 ($p < 0.001$). Between Group 1 vs 2, the RT was not significantly different.

Aerobic exercisers: RT for green color among the groups showed extremely significant difference in aerobic exercisers ($p < 0.001$). The post-hoc test revealed extremely significant difference between Group 2 vs 3 ($p < 0.001$) and significant difference (significance less than Group 2 vs 3) between Group 1 vs 3 ($p < 0.05$), but there was no significant difference between Group 1 vs 2.

Indigo Color

Healthy controls: The comparison of RT for indigo color among the three age groups showed extremely significant difference in healthy controls ($p < 0.001$). The post-hoc test showed extremely significant difference between Group 2 vs 3 ($p < 0.001$) and Group 1 vs 3 ($p < 0.001$), and RT between Group 1 vs 2 did not vary significantly.

Aerobic exercisers: The comparison of RT for indigo color among the three age groups shows no significant difference in aerobic exercisers ($p = 0.0817$).

Discussion

RT for auditory stimuli (low- and high-frequency sound) in healthy controls was significantly different among the three age groups. It is observed that with increasing age, there is progressive increase in RT, that is, there is delayed RT both for low- and high-frequency sound. Similarly, response time (red, green, indigo) was also extremely different in three age groups. And visual RT was also found to be delayed with increasing age, although, there was no difference observed in auditory and visual response time between the two age groups of Group1 and Group 2. The delayed RT could be attributed to the aging process.

Aging can have diverse effects on cognitive function. Among the cognitive abilities that vary with aging process, processing speed and central executive function are essential to everyday functioning.[8] Delayed RT in senescent adults suggests decreased attention, processing speed, and executive functions.[8]

Cognitive deterioration is a common occurrence with senility and is resultant of changes in brain during senescence. About 5% decrease in the brain mass and capacity has been reported to occur every decade after 40 years of age.[9] This volume loss is not uniform, in fact, the medial temporal lobe and prefrontal cortex are inexplicably affected. Neuronal atrophy, decreased synaptic density, and neuronal loss appear to be the contributing factors.[9] This suggests that cognitive decline is a part of normal aging phenomenon and is an inevitable phenomenon.

Senescence has also been related to decrease in speed and accuracy of muscular movements and motor control. Literature suggests that the declining motor functions are attributed to increased variability in firing rate of motor unit, reduced sensitivity, atrophied fast-twitch motor units, altered size of motor unit, and decreased alpha motor neuronal pool in spinal cord.[5,10] Also, muscle cross-sectional area and muscle mass appears to decrease resulting in reduced muscular strength.[5,10] Thus, the physiological and behavioral deterioration with aging is associated with delayed RT in healthy controls.

With the potentiality of cognitive decline to affect the everyday life of senescent adults, the emphasis has shifted toward achieving "Successful or Healthy Cognitive Aging."[3] As proposed by the "lifestyle-cognition hypothesis," an active lifestyle may prevent senile cognitive deterioration.[3] It is evidenced that successful brain aging could be contributed by involving in intellectually engaging activities, physical activities, and social engagement.[3,11] Regular physical activity is known to decrease the incidence and prevalence of diseases such as tumor, diabetes mellitus, cardiac diseases, and cognitive decline.[12] This is in coherence with the findings of our previous study, with aerobic exercisers having shorter RT.[6]

In furtherance of that, in this part, from our study, we have assessed the RT in aerobic exercisers over continuum of age groups. We observed that with increased age, there is increase in auditory and visual RT, but the increase was not as significant as in healthy controls. Also, the visual RT for the indigo color, showed no significant difference among the age groups. Hence, from these findings we can postulate that exercise is beneficial in the prevention of cognitive decline.

Physical exercise, particularly aerobic exercise, has been documented as a low-cost regime to prevent and protect against cognitive decay involving memory, executive function, visuospatial skills, and processing speed during the routine senescence. In fact, aerobic exercise even over a short term can promote cognitive health by ways of enabling neuroplasticity.[13] Routine practice of slow breathing exercises is known to have a beneficial effect on cognition and general well-being of individuals.[14] Regular aerobic exercise exerts the beneficial effects via action at the mitochondrial level. It has been postulated that mitochondrial decay that occurs with aging is counteracted by physical activity.[15,16] It has been observed from animal studies that physical activity has also been associated with structural changes in brain such as angiogenesis, neurogenesis, synaptogenesis, and neural cell proliferation. Also, improved cardiorespiratory fitness seen with regular aerobic exercise is associated with more efficient cognitive functions.[12] Also, the motor response improves regular practice of aerobic exercise due to enhanced antioxidants in the muscle tissue.[12,15] Hence, this study re-emphasizes the role of physical activity in prevention of cognitive decline and evolvement toward successful cognitive aging. The tasks that necessitate fluid mental capabilities appear to be amenable to training.

Limitation: The small sample size is a limitation to our study. Also, the deteriorating effects of aging on neuromuscular stability and the beneficial effects of exercise could have been substantiated by electromyographic recording.

Conclusion

We conclude that auditory and visual RT gets delayed with normal aging. Aerobic exercises such as jogging, cycling, or breathing appear to play a protective role in delaying the process of this cognitive decline.

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