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Negative Air Ions (NAIs) as Cognitive Rehabilitation Therapy for Cerebral Palsy Patients

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[1] Substantial contributions to the conception or design of the work for the acquisition, analysis or interpretation of data for the work, [1] Drafting the work or reviewing it critically for important intellectual content, [1] Final approval of the version to be published, [1] Agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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A B S T R A C T

Background: Cerebral Palsy or CP is a group of disorders which can influence various physiological functions, including blood parameters, cognitive abilities, hearing, muscle coordination, movement, oral health, vision, speech, and other metabolic processes.

Objective: To evaluate the effects of negative air ions (NAIs) on the cognitive functions of CP-inflicted patients.

Methodology: This first phase clinical trial involving 28 participants, took place from 1st of February to 30th March, 2021, following ethical approvals from both the institutional ethical board (ibc-2017) and the rehabilitation center (Al Umeed Rehabilitation Association) where the study was conducted. Parental consent was also obtained to include their children in the research. Using a concealed randomization method, the rehabilitation center administration assigned twenty-eight CP-inflicted participants to either control (eleven males and one female, median age 14±5 years) or intervention group (eight males and eight females, median age 14.5±7.1 years). The intervention group underwent thirty-one structured sessions, each lasting 40 minutes, with exposure to 10,000 NAIs/cm3 over six weeks. The assessment of cognitive functions employed five Lumosity games: highway hazards, lost in migration, tidal treasure, masterpiece, and space trace. The data followed a parametric distribution, paired t-test was utilized to assess the within-group comparisons for each cognitive function at both baseline and the sixth week, employing SPSS version 28.

Results: NAIs significantly improved information processing ($p<0.001$), selective attention ($p<0.01$), spatial reasoning ($p<0.01$), and spatial fluency ($p<0.01$) in the intervention group during the sixth week

Conclusion: The research findings indicate that NAIs have the potential to enhance cognitive functions in CP-inflicted patients. This improvement is believed to be linked to increased activity in specific brain regions, such as the cerebral cortex, prefrontal cortex, and parietal lobe, as well as the neurotransmitter serotonin.

Keywords: Brain, Cerebral Palsy, Cognition, Negative air ions, Neurotransmitter.

Introduction

Cognition refers to a range of complex processes involved in acquiring, storing, manipulating, and retrieving stored information in the brain.[1] Studies suggest that there exists an intricate and interrelated network within the brain responsible for governing learning, memory, and advanced cognitive functions.[2] Several variables that may influence cognitive functioning encompass age, attention deficits, cognitive biases, genetic factors, and memory constraints. Cognitive processes influence every age and aspect of life. Cognition can be distinguished into multiple distinct functions depending on the specific brain circuits and neuromodulators.

Cerebral Palsy or CP is a group of disorders caused by the formation of lesions in the brain during prenatal, perinatal, or postnatal development periods.[3] CP impacts approximately 17 million individuals globally, yet its epidemiology and etiology remain undetermined in Pakistan.[4,5] CP can influence various physiological functions, including blood parameters, cognitive abilities, hearing, muscle coordination, movement, oral health, vision, speech, and other metabolic processes.[1,6] In CP-inflicted patients, brain lesions may occur in several forms, altering early sensorimotor experiences by impairing general cognitive

development.[7] A CP-inflicted patient may exhibit cognitive dysfunction which affects their learning abilities, participation in activities of daily life, socio-professional integration, and quality of life. Memory, language, intelligence, attention, and visual perceptual skills possibly appear heterogeneously; therefore, it is impossible to mark the general cognitive skills of CP-inflicted patients.[7]

A negative ion generator operates on electricity and generates negative air ions (NAIs). An atmosphere abundant in NAIs is advantageous for enhancing alertness, exerting anti-depressant effects, boosting memory, increasing productivity, promoting psychological health, and fostering overall well-being through the induction of alkalinity in the body.[8-12] Despite numerous observations, there is a lack of evidence-based studies examining the utilization of NAIs for the rehabilitation of individuals inflicted with CP.

Methodology

For this first phase clinical trial, the sample size could be less than twenty.[13] This trial involving 28 participants, took place from 1st of February to 30th March, 2021, following ethical approvals from both the institutional ethical board (ibc-2017) and the rehabilitation center (Al Umeed Rehabilitation Association) where the study was conducted. Parental consent was also obtained to include their children in the research. The intervention's duration, method, inclusion, and exclusion criteria were informed to the rehabilitation center.

The administration of rehabilitation center used a concealed randomization method to allocate twenty-eight CP-inflicted participants to one of the groups: (1) control or (2) intervention. All the inducted participants in both groups continued their regular speech therapy, medications, and twice-a-week physiotherapy.

Twelve participants were allocated to the control group (eleven males and one female, median age 14±5 years) and sixteen to the intervention group (eight males and eight females, median age 14.5±7.1 years). The CP characteristics and presence of additional impairment were also recorded for all participants (table I).

The intervention was provided in 31 structured sessions, 5 days a week for 6 weeks.

Participants were exposed to the 'JHQ-801 ionizer' for a duration of 40 minutes within a confined classroom environment. The concentration of NAIs in the classroom was monitored using the 'KT-401 mini air ion tester counter'. NAIs monitoring occurred twice: once 10 minutes after activating the ionizer, and again when deactivating the ionizer at the end of the intervention session. A concentration of 10000 NAIs/cm^3 was maintained during each session.

Participants with no vision or hearing issues, Participants who can understand the given instructions to play games, Participants who can skillfully hold a computer mouse, Participants with no photosensitive epilepsy were included whereas participants who were not allowed by the parent institute were excluded from the study

Lumosity software games are online specially designed by cognitive scientists, and are proven to improve cognitive functions[14]. Lumosity software was purchased online, and professionals at rehabilitation center selected 5 Lumosity games suitable for study participants. The chosen games, namely highway hazards, lost in migration, tidal treasure, masterpiece, and space trace were employed to assess information processing, selective attention, working memory, spatial reasoning, and spatial fluency, respectively. Each participant underwent training based on recommendations from professionals at AURA. Two training sessions were provided at baseline and in the sixth week.

Since the data followed a parametric distribution, paired t-test was utilized to assess the within-group comparisons for each cognitive function at both baseline and the sixth week, employing SPSS version 28.

Results

Table I outlines the characteristics of the induced CP-inflicted participants. Within the intervention group, predominant features included GMFCS level IV (43.7%), spastic muscle tone (62.5%), wheelchair dependency (81.2%), moderate severity (50%), diplegia (56.2%), and moderate cognitive impairment (50%), in contrast to participants in the control group. Non-verbal participants (50%) were also prevalent more in the intervention group.

For paired t-tests, the participants who scored similarly in the pre- and post-evaluation were excluded (table II).

Spatial reasoning showed significant improvement in the control group (p<0.05), as illustrated in Figure 1. Conversely, information processing (p<0.001), selective attention (p<0.01), spatial reasoning (p<0.01), and spatial fluency (p<0.01), showed significant improvement in the intervention group during the sixth week, as illustrated in Figure 2.

Discussion

The lost in migration game assesses selective attention, and the intervention group participants scored significantly higher in this game. The affirmative impact of NAIs on attention has been

Table I: Physical characteristics of participants.		
Characteristics	Control Group N(%)	Intervention Group N(%)
GMFCS		
I	3(25)	2(12.5)
II	1(8.33)	2(12.5)
III	2(16.6)	4(25)
IV	6(50)	7(43.7)
V	0	1(6.25)
Muscle tone		
Spastic	7(58.3)	10(62.5)
Hypotonic	5(41.6)	6(37.5)
Mode of transition		
Wheelchair	5(41.6)	13(81.2)
Independent	5(41.6)	1(6.25)
Walker	2(16.6)	2(12.5)
Severity		
Mild	8(66.6)	4(25)
Moderate	2(16.6)	8(50)
Severe	2(16.6)	4(25)
Cognitive impairment		
Mild	9(75)	5(31.2)
Moderate	1(8.33)	8(50)
Severe	1(8.33)	1(6.25)
Profound	0	1(6.25)
Dull	1(8.33)	1(6.25)
Topography		
Diplegia	4(33.3)	9(56.2)
Athetoid	3(25)	3(18.7)
Hemiplegia	1(8.33)	2(12.5)
Dystonia	4(33.3)	0
Monoplegia	0	1(6.25)
Triplegia	0	1(6.25)
Additional impairments		
Epilepsy	2(16.6)	1(6.25)
Poor attention	4(33.3)	6(37.2)
Non-verbal	3(25)	8(50)

reported.[9] The prefrontal cortex governs the majority of advanced cognitive functions such as decision-making, reasoning, attention, cognition, memory, planning. However, the precise mechanism by which these cognitive functions are executed through the prefrontal cortex remains to be fully understood.[15] Thus, it is anticipated that negative ions may have stimulated the pre-frontal cortex, improved participants' selective attention skills while playing the game.

In the highway hazard game, the participants of the intervention group showed considerable effects on the information-processing skills of the brain. The cerebral cortex region of the brain controls information processing functions. Information processing is the ability of brain cells to quickly decode incoming information and execute a response to that information.[16]

Serotonin is crucial for influencing various bodily functions, including those related to the endocrine system, neurovascular processes, metabolism, and complex cognitive behaviors.[17]

Table II: Descriptive statistics for Lumosity game scores of all groups			
Evaluation	N	Mean	Std. Deviation
Lost in migration			
Baseline			
Control	10	1135.0000	914.94543
Intervention	13	676.6272	416.39486
Sixth week			
Control	10	1590.0000	1409.51945
Intervention	13	1150.0000**	705.37119
Highway Hazard			
Baseline			
Control	12	31334.1667	4427.09931
Intervention	16	27328.7500	1374.29679
Sixth week			
Control	12	31186.6667	4236.76621
Intervention	16	31036.2500***	4013.94714
Tidal Treasure			
Baseline			
Control	12	7341.6667	3711.62153
Intervention	15	10520.0000	4824.05751
Sixth week			
Control	12	11616.6667	6258.89320
Intervention	15	12686.6667	5225.34072
Space Trace			
Baseline			
Control	10	6070.0000	1938.06102
Intervention	13	3476.9231	2644.87367
Sixth week			
Control	10	7760.0000	3637.90018
Intervention	13	6830.7692**	4720.03960
Masterpiece			
Baseline			
Control	12	5863.3333	3961.81895
Intervention	16	5307.5000	4813.92909
Sixth week			
Control	12	9068.3333*	3450.11672
Intervention	16	8719.3750**	3499.59771
Significant values denoted as *p<0.05, **p<0.01, and ***p<0.001.			

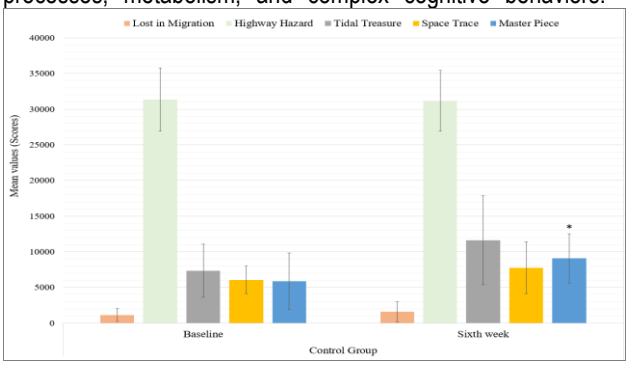

Figure 1: Evaluation of the control group at baseline and sixth week

Significant values are denoted as *p<0.05. Error bars are standard deviations.

et al., reported that information processing ability can be due to enhanced brain alertness or neuronal processing in an environment enriched in NAIs.[8] Thus, it is anticipated that the intervention may have stimulated serotonin and neuronal processing which improved information processing.

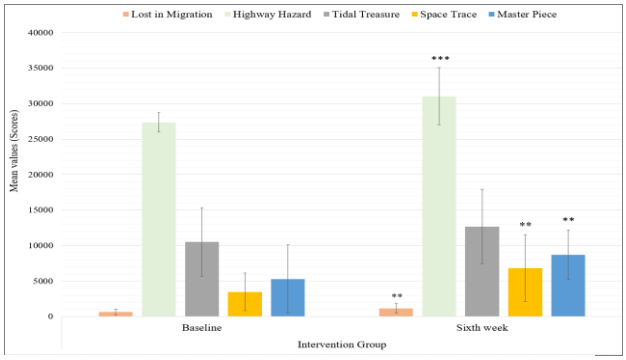

Figure 2: Evaluation of the intervention group at baseline and sixth week

Significant values are denoted as **p<0.01, and ***p<0.001. Error bars are standard deviations.

In the space trace game, intervention group participants showed improvement in spatial fluency. This game requires high mental alertness to create novel patterns under a time constraint of 45 seconds. A study by Kim et al., (2008) demonstrated the affirmative effects of NAIs condition on stress[12] which might be the reason for the improved performance of participants in the space trace game despite the stress of time constraints.

The intervention improved spatial reasoning as assessed by the masterpiece game. The parietal lobe regulates spatial reasoning which is a skill to manipulate nonlinguistic or symbolic information and is malleable throughout life.[18] The parietal lobe stimulation may be the reason for improved spatial reasoning skills in the intervention group participants.

The brain possesses a malleable nature, allowing it to modify its neural connections. Based on our results, it is evident that the provided intervention enhanced cognitive skills by stimulating certain brain regions. All cognitive functions were not improved by the provided intervention as general cognitive development depends on the brain lesions in participants.[7]

The limitation of the study is that it was a first-phase clinical trial. Hence, exposure to NAIs can be suggested as an inclusive therapy after going through the second and third-phase clinical trials. Another limitation was that only a small number of parents granted consent to be included in the study, which is reasonable as the parents of special children are extra sensitive and cautious compared to the parents of healthy children. The study was conducted at a single rehabilitation center to maintain the same environmental conditions for all the study participants, but we could have inducted more rehabilitation centers.

Despite these limitations, based on the findings, it can be envisaged that exposure to NAIs along with regular oral medications, casting, surgeries, and physical or occupational therapy programs can lead to the holistic progress of such patients.

Conclusion

Conclusively, findings demonstrated that the intervention was innocuous and improved cognitive functions in the intervened patients. Based on the findings, it is suggested that NAIs can be a progressive, non-pharmacological, economical, and effective cognitive rehabilitation therapy for CP-inflicted patients. However, further second and third-phase clinical trials are needed to obtain more accurate evidence.

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