

ORIGINAL ARTICLE

Neurocognitive exercise program improves selective attention in children aged between 7-13 years: a pilot study

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Purpose: The purpose of this study was to test the effect of the neurocognitive exercise program (NEP) on the selective attention of typically developing children.

Methods: Twenty-eight typically developing children between the ages of 7 and 13 years, referred by their parents to improve their attention level, were included in this study. Children received 10 sessions (60 min/day, 1 day/week) of the NEP. The selective attention of children was tested before and after the NEP with the d2 Test of Attention.

Results: Comparison of outcome measures revealed a significant decrease in the percentage of inattention and impulsivity scores and total errors after the NEP ($p<0.05$). The significant increase was observed in processing speed ($p<0.05$). According to normative data, the number of poor performers decreased from 17 to 9 in inattention, and from 23 to 13 in impulsivity.

Conclusion: The NEP seems to be a promising training modality for improving selective attention in typically developing children. Randomized controlled studies are needed to replicate the effects of the program.

Keywords: Attention, Exercise, Impulsivity, Neurocognitive exercise program.

Nörobilişsel egzersiz programı 7-13 yaş arası çocuklarda seçici dikkati geliştirir: pilot çalışma

Amaç: Bu çalışmanın amacı, nörobilişsel egzersiz programı (NEP)'nin tipik gelişim gösteren çocukların seçici dikkatleri üzerine olan etkisini incelemektir.

Yöntem: Çalışmaya, aileleri tarafından dikkat düzeylerinin geliştirilmesi istenen 7-13 yaş arası tipik gelişim gösteren 28 çocuk katıldı. Çocuklar 10 seans (60 dk/gün, 1 gün/hafta) NEP eğitimi aldı. Çocukların seçici dikkat düzeyleri, NEP öncesi ve sonrası d2 Dikkat Testi ile değerlendirildi.

Bulgular: NEP uygulaması sonrasında çocukların dikkatsizlik ve dürtüsellik yüzdesi skorları ve toplam hata skorlarında anlamlı düşüş olduğu saptandı ($p<0,05$). İşleme hızında anlamlı artış gözlemlendi ($p<0,05$). Normatif verilere göre performansı zayıf olan çocukların sayısı dikkatsizlik alanında 17'den 9'a, dürtüsellik alanında ise 23'ten 13'e düştü.

Sonuç: NEP tipik gelişim gösteren çocukların seçici dikkatini geliştirmek için umut verici bir egzersiz programı olarak görülmektedir. Programın etkinliğini gösteren ileri randomize kontrollü çalışmalara ihtiyaç bulunmaktadır.

Anahtar kelimeler: Dikkat, Egzersiz, Dürtüsellik, Nörobilişsel egzersiz programı.

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Attention is a nervous system function that is important for executive functions of children in daily life and academic environment. Setting goals, planning of actions, monitoring goal-directed progress, detection of errors all rely on adequate attention in a child.¹ Selective attention is defined as the focusing of mental resources on a selected task, and the inhibition of irrelevant information.² Attention Deficit and Hyperactivity Disorder (ADHD) is characterized by the consistent presence of one or more of the following symptoms: inattention, hyperactivity and/or impulsivity that interfere with functioning or development over a period.³ The prevalence of ADHD has been reported between 5.2% and 7.2%, according to recent meta-analysis, and it is increasing across the world.^{4,6} The incidence of ADHD was found 8% in Turkish children aged between six and fourteen.⁷

Physical inactivity is among the factors that negatively affect attention in children. It has been shown that the duration of sedentary time is increasing, even in childhood, because of physically inactive lifestyles.⁸ The increase in sedentary time has an adverse effect on the physical and psychosocial functions of school-age children.⁹ For instance, prolonged sedentary time during childhood causes health problems, such as insulin resistance or metabolic syndrome, cardio-metabolic disease in addition to its negative effects on cognitive function and academic performance. However, playing video games during sedentary time may have some beneficial effects on some aspects of cognitive, social, and emotional functions.^{10,11} Thus, it is important to evaluate the type of activity a child does during the period of physical inactivity, and determine whether or not this activity supports the child's cognitive and socio-emotional development.^{9,12,13}

Current studies show the positive effects of physical activity and sports participation on the academic achievement, attention level, and executive functions in students.¹⁴⁻¹⁶ Researchers have focused on the role of exercise, such as aerobic or coordination, on improvement in attention ability, cognitive, and academic performance.¹⁷⁻²¹ In addition, in recent years, neuromuscular coordination exercises were commonly implemented in this field. Neuromuscular coordination exercises can be defined as smooth, precise simultaneous or

sequential movements in space and time, in accordance with visual-verbal stimuli and cognitive tasks. Generally, bilateral exercises requiring hand-eye coordination, such as throwing a ball, are used. In addition to coordination exercises, neurocognitive exercise program (NEP), which include visual and verbal stimuli and integrate some cognitive tasks, is an exercise program that can be used to improve attention and cognitive functions. However, the effects of the NEP on the attention of children have not been documented in the current literature.

Therefore, our aim in this study was to investigate the effects of a multimodal NEP using motor coordination exercises, and including visual, auditory, tactile stimuli and cognitive tasks on selective attention of children aged 7-13 years. In this respect, our hypothesis is that children's selective attention levels will increase after performing NEP.

METHODS

Ethical approval was obtained from Non-Invasive Research Ethics Committee of Izmir University of Economics (No: B.30.2.IEUSB.0.05.05-20-015) prior to the study, and all procedures were conducted according to the Declaration of Helsinki. Informed consents were obtained from all participants prior to the study.

Participants

Twenty-eight typically developing children between 7 and 13 years (mean: 9 y 5 mo \pm 1 y 7 mo, male: 16, female: 12) participated in the NEP between November 2012 and April 2014 with the permission of their parents. Children were excluded from the study if they were unable to participate in the exercise program because of motor impairment, mental retardation, systemic disease, visual impairment or illiteracy.

Procedure

Each child completed 10 sessions of a 60-minute exercise program. The test of d2 attention was applied before and after the exercise program. Sixteen participants with similar attention scores and age groups received group exercise sessions, while the others received individual exercise sessions. The frequency of the exercise program was adjusted

according to the children's school schedules. Each child received the NEP once a week. In addition, each child was followed with a home-based neurocognitive exercise.

Neurocognitive Exercise Program

Neurocognitive Exercise Program (NEP) is a multimodal exercise program that relies on perceptual-motor coupling. It consists of motor coordination responses to visual, auditory, tactile stimuli, and at more advance levels, it requires motor coordination and cognitive tasks together; for example, movement response is given according to the result of an arithmetic calculation. The NEP progresses as trainee's motor responses improve. Progression of tasks is from easy to difficult, and from simple to complex. The basic principle is maintaining individuals' vigilance by introducing novel, progressively more difficult and complex exercises that provide cortical level activation. Another important principle is to avoid automatic and reflexive movements to be developed by the trainee. Basic rules of the NEP were as follows:

(a) Each exercise session consisted of warm-up, cool-down and a training period with a short break in the middle. Explanation of each part was given in Table 1.

(b) A variety of materials (different sizes of balls, tulle, racket, pilates ball, eye band etc.) were used, depending on the age and interest. For example, tulle was preferred to a ball for preschool children, who had not yet developed the ability of catching a ball.

(c) Commands for exercises were given with visual stimuli (colored cards, numbered cards, gestures, etc.) or verbally, e.g. auditory stimuli (keywords, ring signal, etc.). For example, the command of showing red card commands throwing a ball with left hand, while showing blue card commands throwing a ball with the right hand.

(d) Exercises were made more difficult by using different material or multisensory stimuli at the same time, as children progressed towards advanced levels. Similarly, children could be asked to perform cognitive task, such as arithmetical calculations or memory task, for example, stepping with right foot in response to the blue card, while recalling 4-digit number.

(e) When children showed 70-80% of success in performing the exercise, the difficulty level was increased or a new exercise was

introduced, in order to keep children vigilant and awake.¹⁹

(f) The program included home exercise sessions on a daily basis, which consisted of oculomotor, visual-motor and auditory-motor coordination tasks. The home exercise program took five to ten minutes to complete.

(g) Before the NEP started, ocular dominance was tested using the Hole-in-the-Card-Test, which was based on Dolman method and convergence near-point test.^{22,23} A piece of cardboard with a central circular hole three cm in diameter was used. Children were asked to hold the cardboard with both hands and to focus on a target six meter away through the hole, with both eyes open. Then children were asked to occlude each eye separately. When the dominant eye was covered, the target could not be seen through the hole, but when the non-dominant eye was covered, it was still visible. This procedure was defined as a 'forced choice' test of dominance.

(h) All children were given a similar home exercise program. Home exercises consisted of five to ten minutes of oculomotor, visual-motor coordination, auditory-motor coordination exercises performed daily during the NEP. Home exercises were followed up by the trainer on a weekly basis, under the supervision of the family.

The d2 Test of Attention

The test of d2 attention is a standardized valid and reliable neuropsychological measurement of selective attention. Turkish validity and reliability have been performed by Yayci.^{24,25} In this study, four outcome measures (TN: total number of items processed; E1: the number of omission errors; E2: the number of commission errors; E%: sum of E1 and E2 errors divided by total number of items processed) of the d2 attention test were used (Table 2). The d2 Test of Attention Manual provides normative tables for children and adults from nine years of age, which includes TN and E% but not E1 and E2.²² According to normative tables, TN and E% percentiles can be interpreted (Table 2). For E1 and E2, the percentage of inattention (E1%: E1/TN) and impulsivity (E2%: E2/TN) were calculated. For interpretation of whether these percentages were normal or not, we referred to a large cross-sectional study on the development of selective attention in children from seven to thirteen years of age.² This study set a

borderline of 3% for inattention and 1% for impulsivity (Table 2). All children were evaluated by the same psychologist before and after the exercise program.

Statistical analysis

We used IBM SPSS Statistics version 21 for all analyses. As a first step, distributions of all variables were inspected to check for normality, thereby to apply an appropriate statistical analysis. In order to test the difference before and after NEP, comparisons were made on outcome measures. A paired-samples t-test was used for normally distributed outcome measures, and related-samples Wilcoxon Signed Rank Test for the not normally distributed. Also, by using percentile ranks and cut-off limits, performance on the d2 Test of Attention was compared with normative data. Frequency tables were prepared, and the chi-square test was used to compare the number of children in risk groups before and after the NEP. Effect sizes were calculated with r for Wilcoxon signed rank test and Cohen's d for the paired-samples t-test.

RESULTS

Change in processing speed, percentage of total errors, inattention and impulsivity after Neurocognitive Exercise Program

When distributions of outcome measures were inspected, processing speed (TN) had a normal distribution but percentage of total errors (E%), inattention (E1%), impulsivity (E2%) were not normally distributed.

Comparison of outcome measures before and after NEP revealed significant increase in TN (Cohen's $d = 0.68$, Figure 1(a)) and significant decrease in E% ($r = 0.62$, Figure 1(b)), E1% ($r = 0.58$, Figure 1(c)) and E2% ($r = 0.57$, Figure 1(d)).

Change in children's percentile rank of processing speed and percentage of total errors after Neurocognitive Exercise Program

Children's scores of TN and E% were compared with normative tables of the d2 Test of Attention, allowing identification of weak and good performance according to age and gender. Normative tables were available from 9 years of age and this resulted in 22 out of 28 children's comparisons.

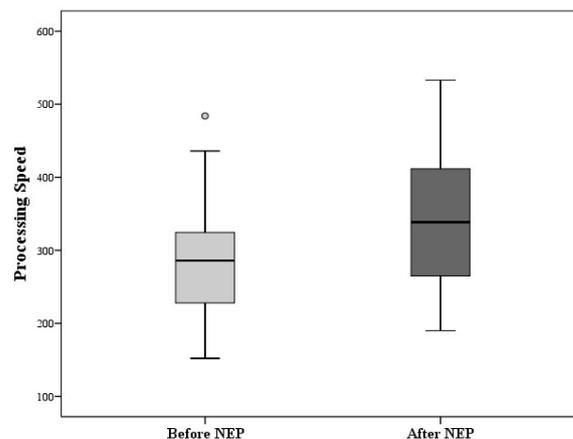


Figure 1(a). Comparison of processing speed (TN) before and after NEP. (Box-plots show Median=thick bar, interquartile range=box height, min/max=lower/upper whiskers, outlier=dots). NEP: Neurocognitive Exercise Program.

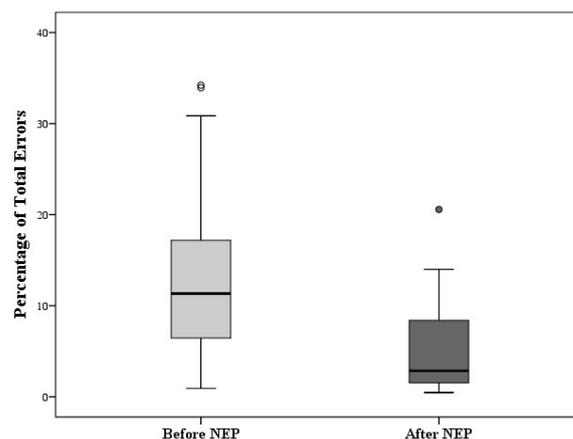


Figure 1(b). Comparison of percentage of total errors (E%) before and after NEP. NEP: Neurocognitive Exercise Program.

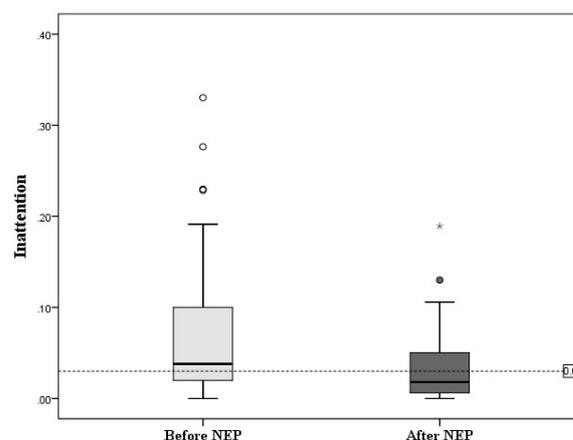


Figure 1(c). Comparison of inattention (E1%) before and after NEP. Reference line on X-axis presents the borderline between weak and normal performance. Above reference, line indicates weak performance. NEP: Neurocognitive Exercise Program.

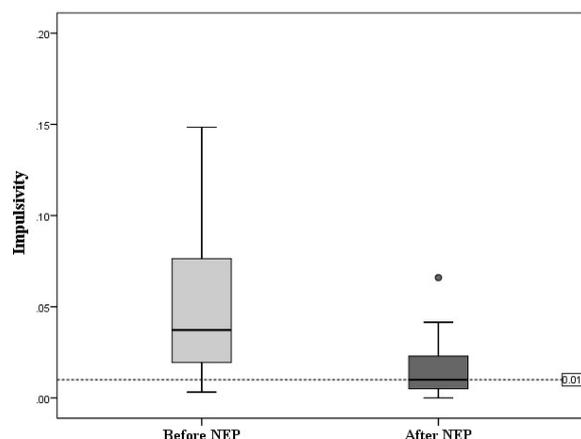


Figure 1(d). Comparison of impulsivity (E2%) before and after NEP. Reference line on X-axis (0.01) presents the borderline between weak and normal performance. Above reference, line indicates weak performance. NEP: Neurocognitive Exercise Program.

The frequency of children in percentiles ranks were compared before and after the NEP. Examining TN scores, we observed that one child fell below 10th percentile before and after NEP, on the other hand, the number of children in 10th-25th percentile, 25th-75th percentile and 75th-90th percentile decreased significantly after NEP. Above 90th percentile significant increase was observed in the frequency of children (Chi-square=10.48, $p<0.05$) (Table 3).

Examining E% scores, there was also a similar trend. The frequency of children below the 10th percentile, and in 10th-25th percentile and 25th-75th percentile decreased while the frequency of children in 75th-90th percentile and above 90th percentile increased (Chi-square=8.23, $p<0.05$) (Table 3).

Change in inattention and impulsivity before and after Neurocognitive Exercise Program

The frequency of children performing weak and good in E1% and E2% was compared before and after NEP. The number of poor performing children in E1% significantly decreased from 17 (61%) to 9 (32%), whilst good performing children significantly increased from 11 (39%) to 19 (68%) (chi-square=4.59) ($p<0.05$). For E2%, the frequency of children performing weakly significantly decreased from 23 children (82%) to 13 children (46%); whilst frequency of children performing good significantly increased from 5 (18%) to 15 (54%) (Chi-square=7.78) ($p<0.05$).

DISCUSSION

Our study showed the positive effect of neurocognitive exercise program on selective attention of primary school children. Previous studies on the effect of exercise (aerobic, coordination, cognitive) on attention have reported positive effects on attention and impulsivity.¹⁷⁻²¹ Acute and chronic coordination exercises, which also demand perceptual-motor coupling, have additionally been shown to be beneficial by other studies.^{18,19,21} For the first time, children have been shown to benefit from a neurocognitive exercise program, which consists of perceptual-motor coordination and cognitive tasks, and proceeds to advance levels based on motor learning principles.

Chang et al.²¹ showed that two sessions of a 90-minute combination of aerobic and coordination exercise for eight weeks increased attention level of pre-school children, as well as increasing in reaction time and processing speed. Similarly, Gallotta et al.¹⁷ showed an increase in processing speed in typically developing children after a combination of physical and cognitive exercise training, similar to our results. More importantly, we found that an increase in processing speed was coupled with a decrease in percentages of errors in omission and commission. This meant that children performed faster, and at the same time, became more accurate in the task. In a recent study, healthy adults received a similar training program to NEP once a week for 13 weeks, and results showed exercise-driven neural activation in different brain regions, revealed by functional magnetic resonance imaging.¹⁹

Processing speed, inattention, and impulsivity are known to be affected in children with ADHD. Processing speed has been found to related to comorbid learning difficulties in this population²⁶, whilst executive functions have been found to related to inattention and impulsivity.¹ Participants of our study were referred by parents concerned about their children's daily functioning and school success related to attention. During the training, one child was diagnosed with ADHD, but was not excluded since he had no problem following the exercise program. Study results were controlled with and without this participant, with no difference. Impulsivity, in other words, problem

Table 1. Parts of neurocognitive exercise session.

Part	Duration	Explanation
Warm-up	5 min	Consists of bilateral coordination, visual-motor coordination, head-neck and breathing exercises that prepares trainee for training session.
Training Part-1	25 min	Learning part: consists of learning a novel perceptual motor task and trying out different sensory modalities for the same motor task.
Break	5 min	Short break for trainees to have a rest
Training Part-2	20 min	Loading part: consists of progressively difficult perceptual motor tasks.
Cool-down	5 min	Consists of completion of perceptual motor tasks and relaxing exercises to complete session.

Table 2. Outcome Measures and Interpretation of d2 Test of Attention^a.

Outcome Measures	Description	Criteria for Interpretation
Processing Speed (TN)	Total number of items processed	
Percentage of Total Errors (E%)	Sum of all types of errors $E\% = (E1 + E2)/TN \times 100$	Below 10th Percentile: Risk for pathology 10th-25th Percentile: Risk for weak selective attention 25th-75th Percentile: Normal 75th-90th Percentile: Good Above %90: High
Inattention (E1%)	Percentage of errors of omission $E1\% = E1/TN$	Below %3: Risk of inattention
Impulsivity(E2%)	Percentage of errors of commission $E2\% = E2/TN$	Below %1: Risk for impulsivity

a: Wassenberg R, et al².

Table 3. Number of children in percentile ranks of Processing Speed, and Percentage of Total Errors (E%) before and after Neurocognitive Exercise Program (NEP).

		< 10 th percentile	10 th -25 th percentile	25 th -75 th percentile	75 th -90 th percentile	> 90 th percentile
Processing Speed (TN)	Before NEP	1	4	9	5	3
	After NEP	1	1	5	2	13
Percentage of Total Errors (E%)	Before NEP	5	7	7	1	2
	After NEP	1	4	6	5	6

Table 4. Pre and post results of d2 Test of Attention^a.

	Before Neurocognitive Exercise Program	After Neurocognitive Exercise Program
Processing Speed (TN)	285.79	337.82
Percentage of Total Errors (E%)	13.03	5.17
Inattention (E1%)	7.98	3.62
Impulsivity (E2%)	5.06	1.55

of response inhibition, is one of the main symptoms in ADHD. Renske et al.² determined a 1% cut-off point for impulsivity problems in a study of 451 typically developing children. By using this cut-off, 82% of children in the current study were grouped as weak performers. After NEP, almost half of these children showed better response inhibition. The NEP training demands a relatively high level of response inhibition and consequently, resulted in a positive outcome. However, caution is needed in the interpretation of this result, since the cut-off point is somewhat arbitrary. Diagnosis of ADHD is based on adaptive functioning, it is not solely based on inattention and impulsivity scores.³

Even though exercise is known to be a promising tool for promoting cognitive functions in healthy children, and may be a treatment option for ADHD, there is a lack of clarity over the type, intensity, duration, and frequency of exercise. Studies vary in type (aerobic, coordination, cognitive and combined exercises), duration (15 min-75 min/ day), and frequency (3 to 5 days/week for 3 weeks to 10 months).^{16-18,21,27} Most children in this study received one session of exercise training program per week, but they also performed daily home exercises during the whole period. Although not our main aim, our calculations revealed no difference between individual or group application of NEP. However, children and trainer reported that the group application was more enjoyable. Our findings supported the value of ten sessions of NEP application, if possible in a group, instead of longer term, more frequent and more expensive programs. Of course, more sessions of NEP can be added. Different from other exercise types, the NEP consists of simultaneous dual, triple, or even quadruple perceptual-motor and cognitive tasks, which gradually improves working memory capacity. As expected, this was shown to stimulate different brain regions and the enhancement of neural plasticity.^{19,28} Another advantage of the NEP is the low intensity of physical movements, which prevents fatigue and fatigue-originated inattention.

Limitations

The limitation of this study is the lack of a control group. Another issue might be related to the test-retest effect of the d2 test of attention, which we believe was diminished during the period of the exercise program.

Conclusion

To conclude, all outcome measures showed improvement after the NEP, indicating its prospective value for furthering our aim in different pediatric populations, such as ADHD or learning difficulties. Randomized controlled studies should be designed to qualify evidence-based effects of NEP. Also, mediating factors such as fitness level, cognitive functions might be also controlled to understand who would benefit more from NEP.

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Conflict of Interest: *None*.

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Ethical Approval: The protocol of the present study was approved by the Non-Invasive Research Ethics Committee of Izmir University of Economics (issue: B.30.2.IEUSB.0.05.05-20-015 date: 08.05.2018).

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