



# Effects of Sport on Symptoms of Attention Deficit Hyperactivity Disorder and Performance Loss Caused by Distractors: Evaluation with MOXO d-CPT

*Sporun Dikkat Eksikliği Hiperaktivite Bozukluğu Belirtileri ve Çeldiricilerle Oluşan Performans Kaybı Üzerine Etkisi: MOXO d-CPT ile Değerlendirme*

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## ABSTRACT

**Objectives:** Attention deficit hyperactivity disorder (ADHD) is the most common childhood psychiatric disorder characterized by inattention, hyperactivity, and impulsivity. Treatment modalities should include medication, psychotherapy, and psychosocial treatments. Various studies concluded that sport has a positive effect on attention. The present study evaluates if football significantly improve the possible psychopathology of ADHD and reduce the negative impact of distractors.

**Materials and Methods:** One hundred forty-seven children from a sport school in a small city in Turkey were included in the current descriptive study. The MOXO distracted-CPT (d-CPT) (distracted-computerized continuous performance test) was applied to all children. Socio-demographic data form, behavior evaluation inventory for executive functions, and Conner's parent rating scale were applied to the parents.

**Results:** According to the MOXO d-CPT results, there was no significant difference between the group with possible psychopathology and the group with no possible psychopathology in terms of sport duration. But, there was a negative correlation between sport duration and attention Z score, timing Z score, and impulsivity Z score in the group that included children who showed poor performance or had possible psychopathology at the MOXO d-CPT. Further, the median value of sport duration was 6.03 months in the group with possible psychopathology severity 4, and the median value was 8.06 months in the group with possible psychopathology severity 1-2-3 at MOXO d-CPT. That is, the possible psychopathology severity decreased as sport duration increased. Also, there was a moderately negative correlation between sport duration and the score lost with visual distractor and/or auditory distractor in the MOXO d-CPT.

**Conclusion:** In conclusion, these findings revealed that exercise in football, a group game, improves or decreases the possible psychopathology severity and reduces the negative impact of visual and/or auditory distractors on MOXO d-CPT parameters.

**Keywords:** Attention deficit hyperactivity disorder, children, d-CPT, sport, Turkey

## ÖZ

**Amaç:** Dikkat eksikliği hiperaktivite bozukluğu (DEHB), çocukluk çağı psikiyatrik bozuklukları arasında en sık görülen; dikkatsizlik, hiperaktivite ve dürtüsellik belirtileriyle karakterize nörogelişimsel bir bozukluktur. Tedavi seçenekleri medikal tedavi, psikoterapi ve psikososyal tedavileri içermelidir. Birçok çalışma sporun dikkat üzerine olumlu bir etkisi olduğunu göstermiştir. Bu çalışma, futbolun olası DEHB psikopatolojisini iyileştirip iyileştirmeyeceğini ve çeldiricilerin olumsuz etkisini azaltıp azaltmayacağını değerlendirmeyi amaçlamaktadır.

**Gereç ve Yöntem:** Türkiye'nin küçük bir şehrindeki bir spor okulundan 147 çocuk bu tanımlayıcı çalışmaya dahil edilmiştir. MOXO d-CPT (bilgisayar tabanlı sürekli performans testi) tüm çocuklara uygulanmıştır. Sosyo-demografik veri formu, yönetici işlevlere yönelik davranış değerlendirme envanteri ve Conner's anne-baba derecelendirme ölçeği ebeveynler tarafından doldurulmuştur.

**Bulgular:** MOXO d-CPT sonuçlarına göre olası psikopatoloji olan ve olmayan gruplar arasında spor süresi açısından anlamlı bir farklılık bulunmamıştır. Fakat MOXO d-CPT'ye göre olası psikopatolojisi olan veya düşük performans gösteren çocuklarda, spor süresi ve dikkat Z skoru, zamanlama Z skoru ve dürtüsellik Z skoru arasında negatif bir korelasyon bulunmuştur. Ayrıca MOXO d-CPT testinde olası psikopatoloji şiddeti 4 olan grupta spor süresi ortanca değeri 6,03 ay; olası psikopatoloji şiddeti 1-2-3 olan grupta 8,06 ay olarak bulunmuştur. Yani spor süresi arttıkça olası psikopatoloji şiddeti azalmaktadır. Ayrıca MOXO d-CPT testinde görsel ve/veya işitsel çeldiriciler ile olan puan kaybı ile spor süresi arasında negatif orta düzeyli bir korelasyon bulunmuştur.

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**Sonuç:** Bulgular göstermiştir ki, bir grup oyunu olan futbol, olası psikopatolojiyi iyileştirmekte veya şiddetini azaltmaktadır ve görsel/işitsel çeldiricilerin MOXO d-CPT parametreleri üzerindeki olumsuz etkisini azaltmaktadır.

**Anahtar Kelimeler:** Dikkat eksikliği ve hiperaktivite bozukluğu, çocuk, d-CPT, spor, Türkiye

## Introduction

Attention deficit hyperactivity disorder (ADHD) is the most common childhood psychiatric disorder; It is a neurodevelopmental disorder characterized by inattention, hyperactivity, and impulsivity.<sup>1-3</sup> ADHD is a clinical diagnosis, and there is no specific test for diagnosis. Interviews with family and children, clinical observation, psychiatric examination, scales completed by parents and teachers are among the tools that assist the clinician in making a diagnosis.<sup>4</sup> Due to these difficulties in diagnosis and the subjective nature of measurement tools, neuropsychological tests are used to diagnose. Recently, computerized continuous performance tests (CPTs) have been frequently among neuropsychological tests.<sup>5</sup> The basic paradigm in CPTs involves selectively paying attention to or being alert to the non-continuous stimulus.<sup>6</sup> Distracted-CPT (d-CPT) also contains distracting stimuli to mimic everyday environments.<sup>7</sup>

Executive function impairments were detected in neuropsychological tests performed on children with ADHD.<sup>8</sup> A meta-analysis includes eighty-three studies; It has been reported that there is significant impairment in all functions of executive functions in ADHD, especially; in response inhibition (arrest of motor response), vigilance, working memory, and planning.<sup>9</sup> Executive dysfunction seen in ADHD has negative effects in various areas of daily life.<sup>3</sup> Solving the behavioral, cognitive, social, and familial problems that characterize ADHD is the first goal of treatment.<sup>4</sup> ADHD is often treated pharmacologically using methylphenidate. Because of its proven efficacy and high response rate often the first choice of current treatment modalities.<sup>10-12</sup> Treatment modalities should include medication, psychotherapy, and psychosocial treatments. Considering that 10.0 % to 30.0 % of children with ADHD give an insufficient clinical response to drug treatment, adjuvant therapies are required.<sup>13</sup>

For this reason, the management of cognitive impairment, which has adverse effects in many areas of ADHD, is not only limited to drug therapy, the benefits of physical exercise have also been accepted in the literature.<sup>14,15</sup> It has been reported that physical exercise has positive effects on physical,<sup>16</sup> behavioral,<sup>17</sup> cognitive,<sup>18,19</sup> psychosocial health,<sup>20</sup> sleep.<sup>21,22</sup> It has been reported that physical activity performed for ten weeks, 45 min 3 times a week for children with ADHD improves attention (continuous and split).<sup>23</sup> Similarly, another study found that six weeks of athletic activity improved the attention, cognitive symptoms, and social skills of children with ADHD.<sup>24</sup> Some studies found that dopamine is released in the prefrontal cortex and basal ganglia during sports activity<sup>25</sup> and that adrenaline, noradrenaline concentrations increase during physical activity.<sup>26</sup> The biological hypothesis of ADHD is based on catecholamine

dysfunction such as adrenaline, noradrenaline, or dopamine.<sup>27,28</sup> According to the results of all these studies, it can be concluded that sport has a positive effect on attention.

Based on the literature above-mentioned, physical exercise increases catecholamine release and positively affects attention. We evaluated the children enrolled in a football school with the MOXO d-CPT, assuming that football will significantly improve the possible psychopathology of ADHD and reduce the negative impact of distractors.

## Material and Method

### Participants and Procedures

One hundred forty-seven children enrolled in a sport school in Niğde were included in the current study. MOXO d-CPT was applied to all children. The school enrollment dates of eight of the children who underwent MOXO d-CPT, and five are missing scale data. During the MOXO d-CPT application, along with the Socio-demographic data form, behavior evaluation inventory for executive functions (BRIEF), Conner's parent rating scale (CPRS) were applied to the parents. The sport duration is calculated in months by subtracting the child's enrollment date to the sport school from the application date of MOXO d-CPT. According to the curriculum information obtained from the sport school, it was determined that the children did football exercises for 2 h once a week.

This investigation was approved by the Ethics Committee of Niğde Ömer Halisdemir University (decision no: 2019/33, date: 04.10.219). The children and their families received information about the purposes and methods of the study. Written and verbal consent were obtained from all children and parents.

### Survey Instrument

MOXO d-CPT ADHD test; It is an objective measurement tool designed to detect ADHD-related symptoms, applied online via a computer, with 90.0% sensitivity and 85.0% specificity. It measures the four components of ADHD, attention, timing, hyperactivity, and impulsivity, separately. As in other continuous performance tests, the participant's task in this test is to maintain his attention on stimuli that are in a continuous flow and react (response) by pressing the space key on the keyboard only once, as soon as he sees the predetermined target image. The most important feature that distinguishes MOXO from other continuous performance tests is that it contains measurable distractors. In MOXO, the participant's attention, timing, impulsivity, and hyperactivity are evaluated under distractors by simulating real-life stimuli. It is possible to assess the variability of all these parameters with distractors one by

one. There are eight parts in MOXO. There are no distractors in the first and last parts. There are single and double visual distractors in two parts, and there are single and double auditory distractors in the other two. In the last two parts, there is a single and double visual and auditory distractor. After the test is completed, the system automatically presents the personal performance chart and attention profile. The performance chart allows to measure the person's performance over time during the test and evaluate the distractors' effects. Test profile gives a Z score for each parameter according to the age and gender of the person. The performance is classified according to the Z score, such as;

Z score is  $\geq 0$ : good performance

$-0.825 \leq Z \text{ score} < 0$ : average and above

$-1.65 \leq Z \text{ score} < -0.825$ : poor performance

Z score is  $< -1.65$ : out-of-normal distribution

If the Z score is out-of-normal distribution, the program presents a severity rating of 1-2-3-4 (1= low violence, 4= extreme violence) according to the Z score.<sup>29,30</sup>

The group of out of the normal distribution was defined as "possible psychopathology" in the current study. Score loss with distractors was obtained from the database of the d-CPT implementing company.

BRIEF; is a scale that evaluates the behaviors of children and adolescents (5-18 years old) in different environments within the framework of executive functions.<sup>31</sup> Turkish reliability and validity studies have been done.<sup>32</sup> There is a parent form and a teacher form. There are 86 expressions reflecting the way of behaving in both forms. Items in the BRIEF are organized under eight sub-scales. Two indicator scores are calculated as the behavioral regulation index (BRI) and the metacognition index (MI). The global manager score (GMS) is calculated from the two indicator scores (DBRI and MI). BRI consists of three sub-scales: Emotional control, set changing, and suppression, while MI consists of five sub-scales: planning/organizing, working memory, initiation, regularity, and monitoring. The items in the scale are evaluated on a 3-point scale as; never (1), sometimes (2), and often (3). A high score in BRIEF indicates impairment in executive functions.

CPRS; The original form was developed in 1978 to evaluate children's knowledge about hyperactivity, learning, and behavioral problems through their parents' information.<sup>33</sup> The scale includes five subscales: behavioral problem, aggression / hyperactivity, learning problem, anxiety and psychosomatic problems, and 48 items. Items in the scale are evaluated on a 4-point Likert-type scale, and the options of "never", "rarely", "often" and "always" in the scale are; It is scored as "0", "1", "2" and "3". The higher the total score obtained from the scale and the higher the subscales' scores indicate a high level of behavioral problems.

### Statistical Analysis

Statistical analyses were performed using the SPSS statistical package version 17 (Chicago, IL: SPSS Inc.). The Shapiro-

Wilk test was used to evaluate the compliance with a normal distribution. The Mann-Whitney U test was used for non-normally distributed variables. The Spearman Correlation test was used to assess the correlations. Values were expressed as numbers, frequencies, percentages, mean and standard deviation, or median and minimum-maximum values, and p values  $< 0.05$  were considered statistically significant (two-tailed).

### Results

The mean age of the children included in the study was found to be  $9.8 \pm 1.7$  years ( $n=142$ ). All participants were male. The median value of the time children was enrolled in sport school was 7.1 (0.9-44.6) months ( $n=139$ ). In the study, 70 of 147 (47.6%) children who underwent MOXO d-CPT had possible psychopathology in at least one of the parameters of attention-timing-impulsivity-mobility and, 82 of them (55.8%) either had possible psychopathology or showed poor performance in at least one of these four parameters. It was observed that the possible psychopathology severity was 3 or 4 in 55 (78.6%) of 70 children with possible psychopathology according to MOXO d-CPT. According to the MOXO d-CPT results, there was no significant difference between the group with possible psychopathology and the group with no possible psychopathology in sport duration ( $p=0.083$ ). According to the MOXO d-CPT results, the median value of sport duration was 6.0 (1.0-24.3) months in the group with possible psychopathology severity 4, and the median value was 8.1 (0.9-12.2) months in the group with possible psychopathology severity 1-2-3 ( $p=0.025$ ) (Table 1).

A two-stage analysis was performed in the correlation analysis between the sport duration and the Z score of the MOXO d-CPT parameters. In the first stage, 67 children outside the normal distribution in at least one parameter according to the MOXO d-CPT results were included in the analysis. According to the result of this analysis, a low level of negative correlation between the timing Z score and the sport duration ( $r=-0.275$ ); A low-level positive correlation ( $r=0.258$ ) was found between the impulsivity Z score and the sport duration ( $p<0.05$ ). In the second stage, 78 children who showed poor performance or had possible psychopathology in at least one parameter according to the MOXO d-CPT results were included in the analysis. According to the results of this analysis, a low level of negative correlation between the sport duration and attention Z score ( $r=-0.240$ ), a moderate negative correlation between the timing Z score ( $r=-0.301$ ); A low-level positive correlation ( $r=0.258$ ) was found between the impulsivity Z score and the sport duration ( $p<0.05$ ) (Table 2).

A two-stage analysis was used to analyze the correlation between the sport duration and the loss of score observed with distractors in the MOXO d-CPT parameters. In the first stage, 67 children outside the normal distribution in at least one parameter according to the MOXO d-CPT results were included in the analysis. Among these children, those who lost points for the respective distractors were included in the analysis. A moderately negative correlation was found between sport

duration and the score lost with one visual distractor ( $r=-0.590$ ), two auditory distractors ( $r=-0.534$ ), and one combination distractor ( $r=-0.343$ ) in the MOXO d-CPT attention parameter. A moderate negative correlation ( $r=-0.494$ ) was found between sport duration and the score lost with one auditory distractor in the hyperactivity parameter ( $p<0.05$ ). In the second stage, 78 children who showed poor performance or had possible psychopathology in at least one parameter according to MOXO d-CPT results were included in the analysis. Among these children, those who lost points for the respective distractors were included in the analysis. A moderate negative correlation was found between the sport duration and the loss of score in the attention parameter ( $r=-0.534$ ) and the loss of score in the hyperactivity parameter ( $r=-0.419$ ) between two auditory distractors in the MOXO d-CPT. A low-level negative correlation ( $r=-0.283$ ) was found between the two visual distractors and the

loss of score in the timing parameter. Also, a moderate positive correlation ( $r=0.380$ ) was found between an auditory distractor and loss of score in the impulsivity parameter ( $p<0.05$ ) (Table 3).

Among the scores of BRIEF subscale; between initiation, planning, monitoring subscale scores, behavioral regulation index, MI, GMS, and MOXO d-CPT attention sub-parameter Z score; between all subscale scores except “organization of materials” subscale, behavioral regulation index, MI, GMS and MOXO d-CPT timing parameter Z score; There was a low-level positive correlation between the baseline subscale score and the Z score of the MOXO d-CPT impulsivity parameter ( $p < 0.05$ ). No correlation was found between the sub-scale scores of BRIEF, behavioral regulation index, metacognitive index, and GMS, and the MOXO d-CPT hyperactivity sub-parameter Z score (Table 4).

**Table 1. The comparison of MOXO d-CPT test results with sport duration**

n=139		Sport duration (months)		p value*
		Median (min-max)		
MOXO d-CPT classification-1	Possible psychopathology§	7.06 (0.90-24.33)		0.083
	Poor performance/standart performance/good performance	8.05 (0.87-44.60)		
MOXO d-CPT classification-2	Possible psychopathology/poor performance <sup>§</sup>	7.06 (0.90-44.60)		0.394
	Standart performance/good performance	8.03 (0.87-24.33)		
n=67 Median (min-max)		Sport duration (months)		p value*
MOXO d-CPT severity classification-1	4	6.03 (1.00-24.33)		0.025
	1-2-3	8.06 (0.90-12.17)		
MOXO d-CPT severity classification-2	3-4	6.36 (1.00-24.33)		0.042
	1-2	8.06 (0.90-12.17)		

d-CPT: Distracted-computerized continuous performance test, \*Mann Whitney U test, §Children found to be out of normal distribution in at least one of the 4 sub-parameters of the MOXO d-CPT test, ¶Children found to be out of normal distribution/poor performance in at least one of the 4 sub-parameters of the MOXO d-CPT test

**Table 2. Correlation between sport duration and Z score of MOXO d-CPT sub-parameters**

		MOXO d-CPT ADHD test							
		Attention Z score		Timing Z score		Impulsivity Z score		Hyperactivity Z score	
		r	p value*	r	p value*	r	p value*	r	p value*
Sport duration (months)	Possible psychopathology (n=67) <sup>§</sup>	-0.221	0.073	-0.275	0.024	0.258	0.035	-0.023	0.854
	Possible psychopathology/Poor performance (n=78) <sup>¶</sup>	-0.240	0.034	-0.301	0.007	0.258	0.023	0.040	0.726

d-CPT: Distracted-computerized continuous performance test, \*Spearman Correlation test, §Children found to be out of normal distribution in at least one of the 4 sub-parameters of the Moxo d-CPT test, ¶Children found to be out of normal distribution/poor performance in at least one of the 4 sub-parameters of the Moxo d-CPT test

In the correlation analysis results between CPRS subscale scores and total scale score and Z scores of the four parameters of MOXO d-CPT; the score between the timing Z score and the Conner’s behavioral problem subscale ( $r=0.186$ ) and the total scale ( $r=0.191$ ) score There was a low level of positive correlation ( $p<0.05$ ). There was no correlation with attention, impulsivity, and hyperactivity Z scores. No significant correlation was

found between CPRS subscale scores and total score and sport duration.

### Discussion

In the current study, we evaluated the children enrolled in a football school with regular sport, using the MOXO d-CPT, and evaluated whether the sport duration had a positive effect

**Table 3. Correlation between sport duration and loss of score with MOXO d-CPT distractors**

The loss of score	Possible psychopathology*		Possible psychopathology/poor performance <sup>§</sup>	
	Sport duration (months)			
	r	p value <sup>¶</sup>	r	p value <sup>¶</sup>
Attention				
No distractors	-	NS	-	NS
One visual distractor	-0.590	0.034	-	NS
Two visual distractors	-	NS	-	NS
One auditory distractor	-	NS	-	NS
Two auditory distractors	-0.534	0.023	-0.534	0.023
One combined distractor	-0.343	0.044	-	NS
Two combined distractors	-	NS	-	NS
Timing				
No distractors	-	NS	-	NS
One visual distractor	-	NS	-	NS
Two visual distractors	-	NS	-0.283	0.044
One auditory distractor	-	NS	-	NS
Two auditory distractors	-	NS	-	NS
One combined distractor	-	NS	-	NS
Two combined distractors	-	NS	-	NS
Impulsivity				
No distractors	-	NS	-	NS
One visual distractor	-	NS	-	NS
Two visual distractors	-	NS	-	NS
One auditory distractor	-	NS	0.380	0.046
Two auditory distractors	-	NS	-	NS
One combined distractor	-	NS	-	NS
Two combined distractors	-	NS	-	NS
Hyperactivity				
No distractors	-	NS	-	NS
One visual distractor	-	NS	-	NS
Two visual distractors	-	NS	-	NS
One auditory distractor	-0.494	0.016	-0.419	0.030
Two auditory distractors	-	NS	-	NS
One combined distractor	-	NS	-	NS
Two combined distractors	-	NS	-	NS

NS: Non-significant, d-CPT: Distracted-computerized continuous performance test, \*Children found to be out of normal distribution in at least one of the 4 sub-parameters of the MOXO d-CPT test and who have a score loss related to the distractor in the MOXO d-CPT test, <sup>§</sup>Children found to be out of normal distribution/poor performance in at least one of the 4 sub-parameters of the MOXO d-CPT test and have score loss related to the distractor in the MOXO d-CPT test, <sup>¶</sup>Spearman Correlation test

**Table 4. Correlation between brief subscale scores and Z score of MOXO d-CPT Sub-parameters**

n= 140		Attention Z score	Timing Z score	Impulsivity Z score	Hyperactivity Z score
Behavioral regulation index	R	0.181*	0.285*	-	-
	P value	0.032	0.001	NS	NS
Inhibit	r	-	0.232*	-	-
	p value	NS	0.006	NS	NS
Shift	r	-	0.270*	-	-
	p value	NS	0.001	NS	NS
Emotional control	r	-	0.238*	-	-
	p value	NS	0.005	NS	NS
Metacognition index	r	0.170*	0.249*	-	-
	p value	0.045	0.003	NS	NS
Initiate	r	0.169*	0.242*	0.192*	-
	p value	0.046	0.004	0.023	NS
Working memory	r	-	0.200*	-	-
	p value	NS	0.018	NS	NS
Plan/organize	r	0.169*	0.229*	-	-
	p value	0.046	0.006	NS	NS
Organization of materials	r	-	-	-	-
	p value	NS	NS	NS	NS
Monitor	r	0.199*	0.250*	-	-
	p value	0.018	0.003	NS	NS
Global executive composite	r	0.177*	0.272*	-	-
	p value	0.036	0.001	NS	NS

d-CPT: Distracted-computerized continuous performance test, NS: Non-significant, \*Spearman correlation test

on attention, and we aimed to examine the effect of sport duration on visual and auditory distractors in children with possible psychopathology at least one of the parameters of attention-mobility-timing-impulsivity. In the literature, studies have shown that physical exercise and sport induce dopamine releases.<sup>25</sup> Physical activity is a potent stimulator of the hypothalamic-pituitary-adrenal and noradrenergic systems.<sup>34</sup> Considering that the leading biological hypothesis of ADHD is based on catecholamine dysfunction;<sup>27,28</sup> The question arises to how this effect of sport will affect ADHD symptoms.

In the current study, there was a negative correlation between sport duration and attention Z score, timing Z score, and impulsivity Z score in the group that included children with possible psychopathology or poor performance at the MOXO d-CPT. Studies show that regular physical exercise or sport has positive effects on cognitive functions and behavior control.<sup>35-40</sup> A study conducted with children with poor impulse control and attention disorders has shown that physical exercise is associated with decreased negative behavior and improvements in cognitive functions.<sup>37</sup>

In the current study, when we classified the children who had possible psychopathology from one of the MOXO d-CPT's

parameters, according to the possible psychopathology severity; we found that the sport duration for those with low intensity (1 and 2) was longer than that of those with high intensity (3 and 4). This suggests that even if the sport duration does not eliminate the possible psychopathology, does it reduces the possible psychopathology severity? Studies indicate a positive relationship between the amount of physical exercise and academic performance in the literature.<sup>40-45</sup> Similarly, in another study, it was stated that children with the higher aerobic condition had better inhibition.<sup>46</sup> It has been reported in previous studies that a high aerobic fitness level is associated with attention-working memory-reaction time parameters and provides better performance in response accuracy.<sup>47</sup> These findings are very interesting for children with ADHD when viewed considering Barkley's theoretical model<sup>48</sup>, suggesting that inhibition is a fundamental deficiency of ADHD. Therefore, if physical exercise can improve inhibition and executive functions, it can provide an improvement in one's self-regulation. As a result, it has been shown that physical activity or fitness level has beneficial effects on cognitive performance.<sup>46</sup>

We examined how the negative effects of auditory and visual distractors, which we cannot always disable in daily life, change

with sport in children with possible psychopathology at least one of the parameters of the MOXO d-CPT. In particular, we found that the negative effect of visual and auditory distractors on attention decreased with the sport. As the duration of the sport increased, the loss of performance caused by distractors decreased. When the negative effect of distractors on attention was evaluated in detail, we assessed that in the section where one visual distractor is given, in the section where two auditory distractors are given, and in the combined section where one visual and one auditory distractor is given, the sport significantly decreases the performance loss caused by the distractor and has a healing effect. But all of these were related to the sport duration, so we thought that when children were allowed to exercise longer or more intensely, the negative impact on performance could be reduced with two visual distractors or in the combined part with two visual and two auditory distractors. A study in which three groups of children who did not exercise did little exercise and exercised more intensely; only improvement was observed in executive functions of children who exercised intensely.<sup>49</sup> This suggests that the positive effects can only occur with a greater amount of physical activity. When the literature is reviewed, it has been reported that there are gains in cognitive functions in studies using aerobically-based intense exercise interventions.<sup>49-51</sup>

In the current study, performance loss with two auditory distractors decreased in the group that included children with possible psychopathology or poor performance at the MOXO d-CPT attention parameter. This means that even if the child does not have possible psychopathology; if the child shows poor performance in terms of attention, the negative effect caused by the auditory distractor decreases with the sport. In the same group, in the section where there were two visual distractors in the MOXO d-CPT, it was observed that the negative effect on timing decreased with the sport duration. When we evaluated the negative effects of distractors on hyperactivity; we found that an auditory distractor had a healing effect in the group that included children with possible psychopathology or poor performance. When we looked at the effect of distractors on impulsivity, we found a positive correlation: those who exercised longer were more impulsive. This may be because children with high impulsivity can be sent to sport more consistently by their families. These data, which we obtained using an objective measurement using the MOXO d-CPT, disable subjective evaluations with the healing anticipation effect of sport. In this respect, we think that it will make a significant contribution to the literature. Also, since there is no study evaluating the negative effect of distractors in the literature, this study is important in providing novel information.

We found a positive correlation between the Z scores of the attention and timing parameters of the MOXO d-CPT and the BRIEF behavioral regulation index, MI, and GMS. Since ADHD, which is characterized by behavioral control, attention, and reasoning deficit, is known to have executive dysfunctions,<sup>52,53</sup> it is not surprising that the MOXO d-CPT parameters predict the possible psychopathology of ADHD, and the BRIEF scale scores are correlated with Z scores of MOXO d-CPT.

Finally, it is necessary to highlight a few issues whose answers are not yet known. Considering whether the type of exercise affects the results or not, interventions in physical education, after fitness, or aerobic exercise, all have positive effects, and the type of exercise is unimportant.<sup>38</sup> So, how is the result affected in group sports? The coordination required for group activity and a more strategic approach to group games (e.g., planning) raises whether it could positively affect executive functions. For this reason, the answer to the question “Does the exercise of children alone or in a group change the effect on cognitive functions, is one more effective than the other?” It can be evaluated in future studies. Besides, referring to a study that states that physical activity is at the highest level in children of secondary and primary school age,<sup>38</sup> it is beneficial to conduct more comprehensive future studies in a wide age range to understand how sports vary by age group. Another important issue with an unknown answer is “Whether the improvements in cognition caused by exercise continue or decrease after the end of physical activity”. So, studies in a prospective design are needed after the sport is quit.

### Study Limitations

One of the strengths of the current study is that it is the first study to evaluate how visual and auditory distractors, which have negative effects on possible ADHD symptoms, affect performance loss change with the sport. Latter; By objectively measuring possible psychopathology with MOXO d-CPT, we have eliminated the bias that will occur with subjective measurement. Because the anticipation or the Halo effect can affect the positive response between physical activity and cognition.<sup>39</sup> The first of the limitations of the current study is; It has a retrospective pattern. In this prospectively planned study, we had to retrospectively change the design of the study, as the football school was closed due to the coronavirus disease-2019 pandemic. Latter; The fact that the study was conducted with a relatively small sample limits the statistical power of the study. Third; The sport practiced in the football school is done once a week. More positive results can be obtained using more frequent and intensive exercise. Therefore, the results of this study should be regarded as a preliminary assessment and repeated. However, it can be useful to guide future research. Finally, this study analyzed how long the child has attended sport school. Another limitation of the study is that physical activities outside the sport school were not evaluated.

### Conclusion

In conclusion, these findings revealed that exercise in football, a group game, decreases possible psychopathology severity and negative impact of visual and/or auditory distractors on the performance. Our findings seem promised for additional research is showing the positive effect of sport, especially on attention problems in children with ADHD. Physical exercise can be used as an additional supportive treatment to increase the effectiveness of pharmacological treatment in children with ADHD or as an alternative non-pharmacological treatment in children who cannot be given pharmacological treatment.

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## Ethics

**Ethics Committee Approval:** This investigation was approved by the Ethics Committee of Niğde Ömer Halisdemir University (decision no: 2019/ 33, date: 04.10.2019).

**Informed Consent:** Written and verbal consent were obtained from all children and parents.

**Peer-review:** Internally peer-reviewed.

## Authorship Contributions

Concept: M.E., E.D., E.Değ., Design: M.E., N.Y., E.D., E.Değ., Data Collection or Processing: M.E., N.Y., E.D., E.Değ., Analysis or Interpretation: M.E., N.Y., Ü.G., Literature Search: M.E., N.Y., Ü.G., Writing: M.E., N.Y., Ü.G., E.D., E.Değ.

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