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Metilfenidat Tedavisinin Dikkat Eksikliği ve Hiperaktivite Bozukluğu Olan Çocuklarda Statik Denge ve Düşme Riski Üzerine Etkisi

Effect of Methylphenidate on Static Balance and Risk of Falling in Children with Attention Deficit Hyperactivity Disorder

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ÖZ

Giriş: Postüral stabilite, duyusal inputların entegre edilmesini ve uygun bir motor cevabın oluşturulmasını içeren bir süreçtir. Dikkat Eksikliği Hiperaktivite Bozukluğu (DEHB) motor performans ve postural stabilitede zorluğa neden olabilir. Metilfenidat (MPH) tedavisinin denge ve düşme riski üzerindeki etkisi henüz netlik kazanmamıştır. Bu çalışmanın amacı DEHB olan çocuklarda MPH tedavisinin denge, düşme riski ve duyu-motor entegrasyon üzerine etkilerini değerlendirmektir.

Yöntem: Bu kesitsel çalışmada ilk kez DEHB tanısı alan çocuklar DEHB grubuna (n=33), MPH ile en az 3 ay tedavi gören DEHB tanılı çocuklar tedavi grubuna (n=32), ve sağlıklı çocuklar kontrol grubuna (n=20) dahil edildi. Düşme riski, statik postüral denge ve duyu-motor entegrasyonu Biodeks Denge Sistemi (BDS) kullanılarak değerlendirildi.

Bulgular: DEHB grubunun salınım indeksi puanları tüm BDS pozisyonlarında kontrol grubuna göre istatistiksel olarak anlamlı derecede yüksekti ($p < 0.05$). DEHB grubunun salınım indeksi skorları, her iki göz açık/sert yüzey ve gözler kapalı/sert yüzey koşullarında tedavi grubuna göre istatistiksel olarak anlamlı derecede yüksekti ($p<0,05$). DEHB grubunun Biodeks analizlerinde düşme riski kontrol grubuyla karşılaştırıldığında anlamlı derecede yüksekti ($p < 0.05$). Tedavi grubu ile kontrol grubu arasında düşme riski skorları açısından istatistiksel olarak anlamlı bir fark yoktu ($p > 0.05$).

Sonuç: DEHB tanılı çocuklarda postüral denge ve düşme riski etkilenmiş olabilir. MPH tedavisi denge bozukluğunu ve düşme riskini pozitif yönde etkileyebilir.

Anahtar Kelimeler: dikkat eksikliği hiperaktivite bozukluğu, metilfenidat, postüral kontrol

ABSTRACT

Objective: Postural stability is a process that involves integrating sensory inputs and generating an appropriate motor response. Attention Deficit Hyperactivity Disorder (ADHD) can cause difficulty in motor performance and postural stability. The impact of methylphenidate (MPH) treatment on balance and risk of falling remains unclear. The purpose of this study was to evaluate the effects of MPH treatment on balance, risk of falling, and sensorimotor integration in children with ADHD.

Method: In this cross-sectional study children diagnosed with ADHD for the first were classified into the ADHD group (n=33), children with ADHD who were treated with MPH for at least 3 months were classified into the treatment group (n=32), and healthy children were classified into the control group (n=20). Risk of falling, static postural balance, and sensorimotor integration were evaluated using the Biodex Balance System.

Results: The sway index scores in the ADHD group were statistically significant higher than those in the control group in all experimental conditions ($p< 0.05$). The sway index scores in the ADHD group were statistically significant higher than the treatment group in both eyes open /firm surface and eyes closed /firm surface conditions ($p < 0.05$).The ADHD group had significantly higher risk of falling scores in the Biodex analyses compared to the control group ($p < 0.05$). There was no statistically significant difference in risk of falling scores between the treatment group and the control group ($p > 0.05$).

Conclusion: Postural balance and fall risk may have been affected in children with ADHD. MPH treatment can positively affect impaired balance and risk of falling.

Keywords: attention deficit hyperactivity disorder, methylphenidate, postural control

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INTRODUCTION

Attention deficit hyperactivity disorder (ADHD) is defined as impulsivity, hyperactivity, and inattention disorder (1). Children with ADHD exhibit abnormalities in the cerebellum and basal ganglia that are associated with sensorimotor control and abnormalities in the prefrontal cortex that are associated with executive functions (2).

Balance control is an important sensorimotor function that requires attention and the ability to integrate data from sensory systems. Attention can be defined as the data processing capacity of an individual. Last years, it has been reported that attention is key point for postural control and requires attention according to the age and balance capabilities of an individual (3). To keep the body in balance, data from the proprioceptive, visual, vestibular systems and the cognitive system should be integrated to generate the necessary motor responses (4).

In recent studies, it has been suggested that balance control is an important sensorimotor process and that it may be decreased in children with ADHD. Postural control requires the ability to integrate data from many different sensory systems (5, 6). Shorer et al. have assessed postural performance in children with ADHD during single- and double-task situations, and in both situations, the postural stability was found to be worse in the ADHD group (7). Shum et al. showed that simple static balance did not differ when all sensory components were assigned; however, balance deficits appeared in the mixed-type ADHD group when one of the sensory systems was removed (8). Konicarova et al. reported that balance deficits and symptoms of ADHD may be associated (9).

Methylphenidate (MPH), a drug that improves behavioral problems and increases attention, has long been used in children with ADHD (10). A few studies have reported that MPH also positively affects motor performance, gait, postural stability, and balance in ADHD (11–16). However, according to our review of the literature, no studies so far have researched the effect of MPH treatment and ADHD diagnosis directly on fall risk in children.

Based on the results summarized above, this study has two goals. First, to determine the impact of ADHD on balance, sensorimotor integration, and risk of falling, and second, to determine the effect of MPH treatment on balance, sensorimotor integration, and risk of falling in children diagnosed with ADHD.

MATERIALS AND METHODS

1.Patient enrolment methods & study parameters

1.1.Participants

The total study sample of the study included of 85 children aged 8 to 12 years who visited the Children and Adolescents Outpatient Department of the Faculty of Medicine of Kocaeli University between July 2016 and January 2017. All children who were diagnosed with ADHD for the first time, according to the diagnostic criteria of the DSM-V (American Psychiatric Association, 2013), were classified into the ADHD group (n=33), ADHD-diagnosed children using MPH for at least 3 months were classified into the treatment group (n=32), and healthy children were classified into the control group (n=20).

Thirty-three children newly diagnosed with ADHD, in the ADHD group, had no prior psychotropic drug treatment or psychiatric history. Thirty-two children previously diagnosed with ADHD, in the treatment group, had been using a regular daily dosage of MPH for at least three months. The 20 children in the control group, examined by the same child psychiatrist, were not diagnosed with ADHD. Control group also fulfilled the same exclusion criteria as the ADHD diagnosed groups. Figure 1 shows a flow diagram of the children election process.

Children who were diagnosed with neurological disorders such as cerebral palsy, epilepsy, ticks, chorea, and dystonia; psychiatric disorders such as obsessive-compulsive disorder, mental retardation, autism spectrum disorder; cardiac and pulmonary impairments; visual disorders ;coordination impairments musculoskeletal disorders that could be related to balance were not included in the present study. All children participating in this study were evaluated by the same experienced child psychiatrist.

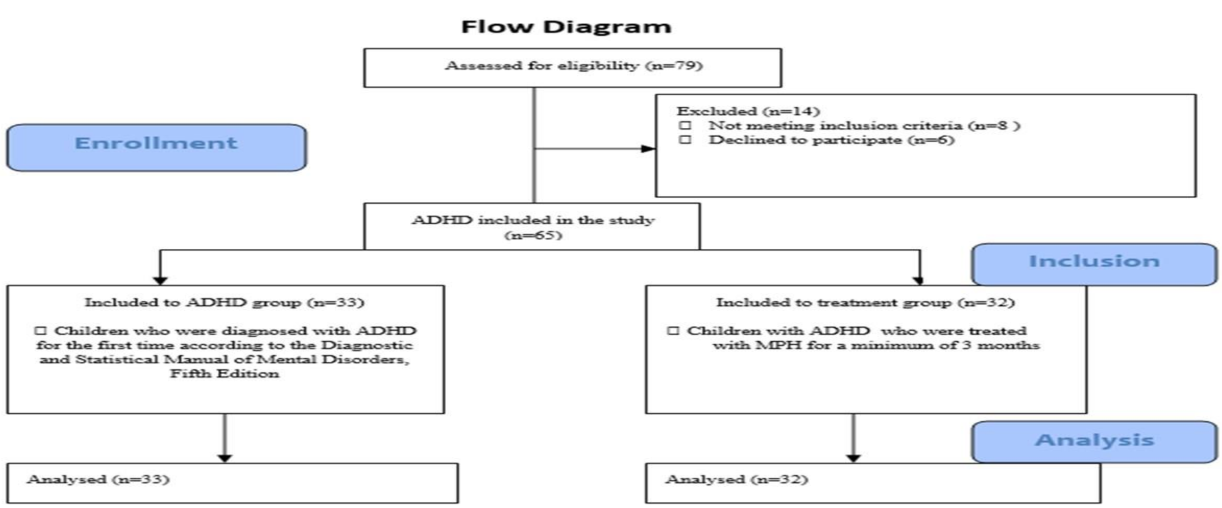

Figure1. Flow diagram of the children selection process.

1.2.Clinical assessment

1.2.1.Sociodemographic data

The sociodemographic information form (age, gender, height, weight, body mass index (BMI), family income, parents' educational status, parents' illness, type of birth, time of birth, sibling mental illness, parents' consanguineous marriage and regular physical activity) was prepared by the child psychiatrist in addition to clinical evaluation.

1.2.2.Schedule for Affective Disorders and Schizophrenia for School-Age Children – Present and Lifetime Version (K-SADS-PL)

It is a general assessment scale structured diagnostic interview developed to detect psychopathologies in the past and present situations in children and adolescents. The K-SADS-PL diagnostic interview consists of items that evaluate affective disorder, behavioral disorder, psychotic illness, anxiety disorder, substance use, and sub-findings of these diagnoses. In 2004, the reliability and validity of the Turkish version of this test was conducted by Gökler et al. (17).

1.2.3.Postural Stability Assessment

Biodex Balance System

Participants' risk of falling, postural balance and sensorimotor integration were assessed using the Biodex Balance System (Biodex medical systems Shirley, NY, USA). Biodex balance system (BBS) is reliable and validated method for objective evaluation postural stability (18, 19). Prior to the BBS measurements, each participant was provided with preliminary information regarding the procedure to be performed. During the measurements the laboratory was isolated from situations that might have affected the process, such as visual or audible stimuli. All measurements were taken by the same physiotherapist blinded to the subjects. All subjects were asked to take off their shoes and stand in a comfortable position in the center of the BBS platform. The subjects were not allowed to hold on to the handrails next to the device

1.Static Postural Stability Test

Postural stability tests, including overall stability index (OSI), anterior–posterior stability index (APSI), and medial-lateral stability index (MLSI), were used to estimate postural stability. On rigid BBS platform, the measurements were taken with the subjects' eyes open for 20 seconds. Three trials were conducted for each subject. Higher postural stability scores indicated poor postural control (20, 21).

2.Modified Clinical Test of Sensory Integration and Balance (m-CTSIB)

This testing protocol was used to assess sensory integration capabilities and balance. Four experimental conditions were assessed for the m-CTSIB test protocol: eyes open/firm surface (EOFS), eyes closed/firm surface (ECFS), eyes open/ soft surface (EOSS), and eyes closed/ soft surface (ECSS). In the last two positions, the BBS soft pads were placed on the platform in the same location as the hard floor where the previous hard floor tests were performed. Before having test protocol each condition was performed three times. Each participant was instructed to control the postural balance position for 30 seconds with a rest period of 10 seconds during the m-CTSIB test. The sway index scores were enrolled under four m-CTSIB test conditions. Higher sway indices in the m-CTSIB test indicated increased postural sway and poor postural control (21–23).

2.2.Statistical Analysis

Statistical assessment was performed using IBM SPSS 20.0 (SPSS Inc., Chicago, IL, USA). Normal distribution was assessed using the Kolmogorov–Smirnov Test. Variables were presented presented as mean ± standard deviation, median (25–75 percentile), and frequency (percentages). Mann–Whitney U test, Kruskal-Wallis one-way ANOVA, and Tukey and Dunn's post hoc test were performed for normally distributed numerical variables with normal distribution, Fisher's exact test, and Monte Carlo test, and Chi-square analysis were performed for normally distributed categorical variables. A $p<0.05$ was considered statistically significant. The sample size was estimated to be at least 17 subjects in each group using G power 3.1.9.2 software based on $\alpha=0.05$, effect size=1.0, and power=0.80 for in terms of overall balance scores between groups (24).

RESULTS

A total of 85 children cases were included in the study (31 females and 54 males).The mean age of the study group was 120.08±16.13 months. The demographic and clinical characteristics of participants are presented in Table 1.

The sway index scores in the newly diagnosed ADHD group were statistically significantly higher than the control group in all testing conditions ($p < 0.05$). The sway index scores in the newly diagnosed ADHD group were statistically significantly higher than the treatment group in EOFS and ECFS conditions ($p < 0.05$).There was not statistically significant difference in sway index scores in EOSS and ECSS conditions between newly diagnosed and treatment groups ($p > 0.05$). There was not statistically significant difference in sway index scores in four conditions between the treatment and control groups ($p > 0.05$) (Table 2) (Figure 2). There was no significant difference between the groups in terms of general postural stability indices OSI, APSI, and MLSI ($p > 0.05$) (Table 2).

The newly diagnosed ADHD group had significantly higher fall risk scores in Biodex analyses than the control group ($p < 0.05$) (Table 2). There was no statistically significant difference in fall risk scores between newly diagnosed and treatment groups ($p > 0.05$).There was not statistically significant difference in fall risk scores between treatment and control groups ($p> 0.05$) (Table2) (Figure 2).

DISCUSSION

The objective of this study was to assess the impact of ADHD as well as MPH treatment on balance, sensorimotor integration, and fall risk in children diagnosed with ADHD. According to our research, this is the first study to investigate the impact of MPH treatment and ADHD diagnosis directly on fall risk. Both postural control values as well as m-CTSIB scores were recorded for all three groups. While there was no difference in postural control measurements between the groups, there was a significant difference in m-CTSIB scores. The sway index scores in the newly diagnosed ADHD group were significantly higher than the control group in all testing conditions. The sway index scores in the newly diagnosed ADHD group were significantly higher than the treatment group in EOFS and ECFS conditions. Furthermore, highest postural sway index scores obtained in the newly diagnosed ADHD group among the groups in m-CTSIB test.

Table 1. Demographic and Clinical Characteristics of Children

	New Diagnosis Group Mean ± SD N=33	**Treatment Group** Mean ± SD N=32	**Control Group** Mean ± SD N=20	P value
Gender (male/female)	25/8	19/13	10/10	0.13
Age (months)	117.30±15.52	122.46±15.23	120.85 ± 18.47	0.427
Weight (kg)	40.06 ± 8.33	37.15 ± 6.79	36.7 ± 6.86	0.18
Height (cm)	139.75 ± 7.20	138.31 ± 5.77	139.85 ± 10.02	0.67
BMI (kg/cm^2)	20.7±2.83	19.36 ± 2.62	18.68 ± 1.99	0.06
	Number (%)	Number (%)	Number (%)	
Family income Low Medium High	3 (9.1%) 26 (78.8%) 4 (12.1%)	5 (15.6%) 25 (78.1%) 2 (6.3%)	4(20%) 15(75%) 1(5%)	0.73
Mother education level Primary school Secondary school High school University	16 (48.5%) 3 (9.1%) 10 (30.3%) 4 (12.1%)	16 (50%) 8 (25%) 5 (15.6%) 3 (9.4%)	10 (50%) 1(5%) 6 (30%) 3 (15%)	0.37
Father education level Primary school Secondary school High school University	13 (39.4%) 6 (18.2%) 11 (33.3%) 3 (9.1%)	10 (31.3%) 8 (25%) 9 (28.1) 5 (15.6%)	2 (10%) 6 (30%) 9 (45%) 3 (15%)	0.41
Family Nuclear Extended Shredded	26 (78.8) 4 (12.1) 3 (9.1)	26 (81.3%) 3 (9.4%) 3 (9.4%)	17(85%) 3(15%) 0(0%)	0.72
Mother illness Physical illness Mental illnes	1 (3%) 1 (3%)	3 (9.4%) 2 (6.3%)	0(0%) 1(5%)	0.35 0.83
Father illness Physical illness Mental illnes	1 (3%) 3 (9.1%)	4 (12.5%) 2 (6.3%)	1 (5%) 1 (5%)	0.37 0.88
Type of birth Hard delivery Vaginal delivery Cesarian Section	1 (3%) 15 (45.5%) 17 (51.5%)	1 (3.1%) 11 (34.4%) 20 (62.5%)	1 (5%) 8 (40%) 11(55%)	0.93
Time of birth Term Preterm Postterm	30 (90.9%) 1 (3%) 2 (6.1%)	25 (78.1%) 7 (21.9%) 0 (0%)	16 (80%) 3 (15%) 1 (5%)	0.14
Regular physical activity Yes No	6 (18.2%) 27 (81.8%)	5 (15.6%) 27 (84.4%)	7 (35%) 13 (65%)	0.24
Sibling mental illness	5 (15.2%)	4 (12.5%)	2 (10%)	0.92
Consanguineous marriage	3 (9.1%)	1 (3.1%)	1 (5%)	0.74

SD: standard deviation ($p < 0.05$ statistically significant)

Table 2. Comparison of Fall Risk, m-CTSIB Scores and Postural Control Between Groups

Variable	**New Diagnosis Group (N=33) median(p25-75)**	**Treatment Group (N=32) median(p25-75)**	**Control Group (N=20) median(p25-75)**	**p**
Postural control				
Postural stability Overall Stability Index (OSI)	0.9 (0.7-1.35)	0.9 (0.6-1.2)	0.75 (0.7-0.9)	0.19
Anteroposterior Stability Index (APSI)	0.6 (0.5-1.0)	0.7 (0.5-0.87)	0.55 (0.4-0.6)	0.07
Mediolateral Stability Index(MLSI)	0.5 (0.3-0.8)	0.4 (0.3-0.6)	0.3 (0.3-0.5)	0.17
Modified Clinical Test of Sensory Integration and Balance(m-CTSIB) EOFS **sway**	1.48 (0.88-2.02)	1.00 (0.80-1.26)	0.99 (0.78-1.07)	0.005*
ECFS sway	1.85(1.56-2.54)	1.42 (1.19-2.05)	1.59 (1.06-2.02)	0.003*
EOSS sway	1.44(1.03-1.93)	1.20 (0.82-1.56)	1.01 (0.72-1.43)	0.042*
ECSS sway	2.06 (1.60-2.71)	1.78 (1.16-2.31)	1.61 (1.24-1.78)	0.012*
Fall risk score	0.8 (0.5-1.35)	0.7 (0.5-1.07)	0.5 (0.4-0.77)	0.04*

m-CTSIB: Modified clinical test for sensory interaction and balance. EOFS – eyes-open, firm surface; ECFS - eyes-closed, firm surface ; EOSS- eyes-open, soft surface; ECSS - eyes-closed, soft surface ($p < 0.05$ statistically significant)

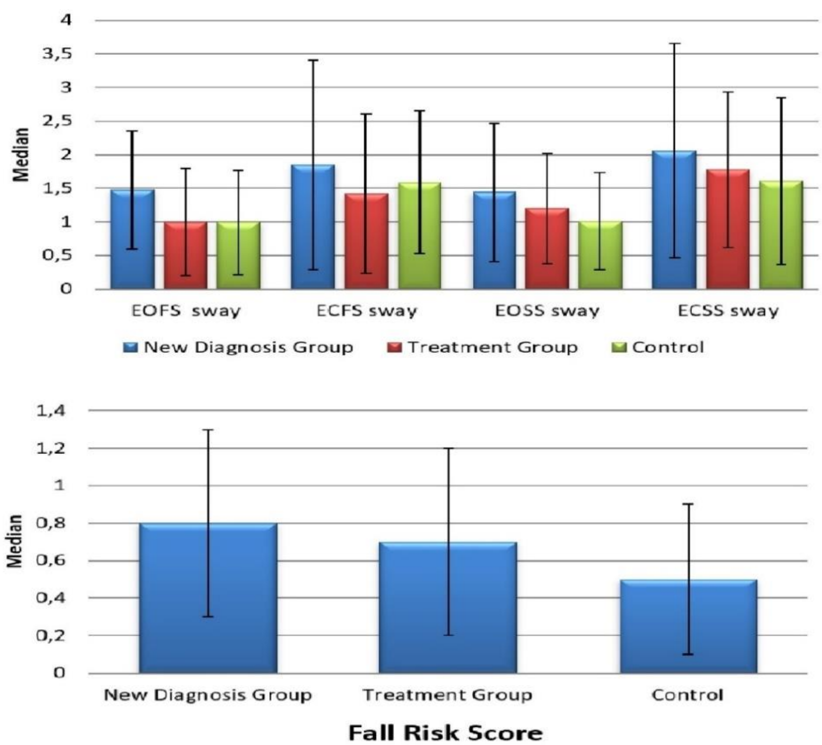

Figure 2. Comparison of modified clinical test of sensory integration and balance (m-CTSIB)and fall risk scores between 3 groups

Maintaining postural stability is a process that involves integrating sensory inputs and generating an adequate motor response (23). ADHD is a neurodevelopmental disorder that leads to difficulties in motor skills (7). The underlying reason for difficulties in motor skills has not been understood definitely. There may be abnormalities in the cerebellum and basal ganglia, which are responsible for sensorimotor control, and in the prefrontal cortex, which plays an important role in executive functions (2). Furthermore, many studies have shown that sensory information processing is impaired in ADHD (25-27). Balance and coordination problems may be related to sensory input, sensory integration, and inhibition of excessive movement in children with ADHD (25).

A few studies have reported that postural and motor performances do not change in ADHD (28, 29), whereas others have argued that postural performance is worse in ADHD (6-9). Our findings are similar to those reported by Shum et al., who found impaired balance functions in ADHD (8). Shum et al. found that standing balance was impaired in all cases of ADHD due to deterioration in sensory signals and that the visual system was more affected than the somatosensory and vestibular systems (8). Buderath et al. reported that children with ADHD have difficulty with postural stabilization when the role of the proprioceptive and/or visual systems in balance was disregarded and only the vestibular system was evaluated (30). On the other hand, Schlee et al. found no differences in center of pressure velocity between ADHD patients and healthy controls (28). These contradictory results could be related to the use of different balance measuring devices, small sample size, and difficulty in forming a homogeneous sample group. In our study, the postural sway index was found to be increased in children with ADHD. Our findings suggest that children with ADHD have deficits in all sensory systems, rather than a specific sensory afferent pathway, when it comes to maintaining postural sway and balance.

MPH, which is a drug that increases attention, regulates behavioral problems, and improves motor functions. MPH may improve postural stability and balance in a few ADHD studies (10,13). In this current study, the newly diagnosed ADHD group showed statistical significant increased sway index scores compared to treatment group in EOFS and ECFS conditions. However, the treatment and control groups showed no statistical significant difference in terms of postural sway index scores in all conditions. Therefore, it may be concluded that MPH may have a positive effect on balance and sensorimotor integration in ADHD according to this cross-sectional study. Similar to our study, Sarafpour et al. reported that medical treatment improves postural balance along with hyperactivity symptoms in children with ADHD (15). Feng et al. found an improvement in the results of a sensory organization test following MPH treatment in children with ADHD (16). Polishook et al. showed that MPH improves postural stability, particularly in tasked situations, which suggests that MPH may contribute to maintaining balance control in situations that require attention (31). To reach a clear conclusion on this subject, we believe that in future studies, during the evaluation of postural stability, it will be beneficial to also assess brain functions using advanced imaging methods, such as functional magnetic resonance imaging, and to collect objective data.

In this study, the fall risk was significantly higher in the newly diagnosed group compared to the control group. In addition, the fall risk scores of the newly diagnosed group were higher than those of the treatment group, although this difference was not significant. There was no difference between the treatment and control groups. According to our literature review, there have been no studies that directly evaluated the impact of MPH treatment and ADHD diagnosis on fall risk in children. However, several studies have examined the individual effects of MPH treatment and ADHD on balance, but none have specifically addressed the relationship between these factors and fall risk in pediatric populations (11, 32). Gait rhythm and stride time variability in older adults are associated with executive functions and attention (12). Itzhak et al. reported that a single dose of MPH improves executive functions in older adults and may be an option to reduce fall risk in this population (33).

The dopamine network, particularly in the frontal and prefrontal cortex, is crucial in motor and executive functions (12, 33). Möhring et al. reported that MPH increases the amount of dopamine in the frontal and prefrontal cortex and regulates gait when used in the treatment of ADHD (11). Similarly, Leitner et al. found a decrease in gait rhythm and automaticity in ADHD. They also reported that MPH increased the functions of the dopamine network (12). In the pathogenesis of Parkinson disease, dopamine deficiency is present and gait is affected. Ramos et al. reported that fall risk may be predicted in non-faller Parkinson disease patients. Additionally, these patients have a higher fall risk in unstable conditions than healthy people of the same age (34). Auriel et al. reported that MPH improves gait and decreases falls in Parkinson disease (35). In the literature, we could not find any study that evaluated the impact of MPH treatment on the risk of falling in ADHD; however, Pastor et al. reported that the rate of nonfatal injuries is high in patients with ADHD (36). Considering the positive effects of MPH on balance observed in previous studies (11-16), we believe that MPH can reduce fall risk and the rate of fall-related injuries in children with ADHD. Therefore, more research with larger patient groups and homogeneous subjects, where fall risk is evaluated using objective measurement tools, is warranted.

The limitations of our study are small sample size, groups comprising different children, and a cross-sectional study design. A longitudinal study in this area with a larger sample size is required. Another limitation of our study is that that the impact of MPH may differ depending on the ADHD subtype, but we did not consider this subclassification in our study.

In conclusion, on the basis of this study it can be concluded that ADHD can have a negative impact on postural stability. Somatosensory systems associated with maintaining postural balance may have been affected in the children with ADHD. Moreover, MPH treatment can positively affect the impaired balance and fall risk. However, further research in this area is required.

Ethics Committee Approval: This study was got approval by the Kocaeli University Faculty of Medicine clinical research ethics committee (aprovval number:2016/291).

Author Contributions: All authors contributed to the article.

Conflict of Interest: None

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Informed Consent: All participants were verbally informed and informed consent forms have been obtained from the parents of all participants.

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