T.C.

YEDITEPE UNIVERSITY

INSTITUTE OF HEALTH SCIENCES

DEPARTMENT OF PHYSIOTHERAPY AND REHABILITATION

THE EFFECT OF ATTENTION ON POSTURAL CONTROL

MASTER THESIS

CAN SEÇİNTİ, PT.

Istanbul-2025

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ADVISOR

Assist. Prof. Çiğdem YAZICI MUTLU

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	Title, Name-Surname (Institution)
Chair of the Jury:	Dr Öğr Üyesi Ebru Akbuğa Koç (Yeditepe Üniversitesi)
Supervisor:	Dr Öğr Üyesi Çiğdem Yazıcı Mutlu (Yeditepe Üniversitesi)
Member/Examiner:	Dr Öğr Üyesi Meltem Yazıcı Gülay (Çankırı Karatekin University)

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Prof. Dr. Burcu GEMİCİ BAŞOL

Director of Institute of Health Sciences

DECLARATION

I hereby declare that this thesis is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person nor material which has been accepted for the award of any other degree except where due acknowledgment has been made in the text.

23.06.2025

Can SEÇİNTİ

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LIST OF SYMBOLS AND ABBREVIATIONS:

A-P	Anterior-Posterior
ADHD	Attention-Deficit/Hyperactivity Disorder
ANOVA	Analysis of Variance
ANT	Attention Network Test
ASRS	ADHD Self-Report Scale
ASRS-5	ADHD Screening Scale
AUC	Area Under the Curve
BMI	Body Mass Index
BoS	Base of Support
CFQ	Cognitive Failures Questionnaire
CNS	Central Nervous Systems
CoG	Center of Gravity
CoM	Center of Mass
CoP	Center of Pressure
CPT	Continuous Performance Task
DEHB	Dikkat Eksikliği ve Hiperaktivite Bozukluğu
DM	Decision-Making
DSM	Diagnostic Statistical Manual
DSM-5	DSM of Mental Disorders, Fifth Edition
DSM-5-TR	DSM of Mental Disorders, Fifth Edition, Turkish Version
DSM-III	Diagnostic Statistical Manual, version 3
DSM-IV	Diagnostic Statistical Manual, version 4
EF	Executive Functioning
GWAS	Genome-Wide Association Study
IQR	Interquartile Range
M-L	Medio-Lateral
pADHDt	Potential ADHD traits
PC	Postural Control
PTSD	Post Traumatic Stress Disorder
SART	Sustained Attention to Response Task
SD	Standard Deviation

SED	Serious Emotional Disturbance
TEA-Ch	Test of Everyday Attention for Children
WHO	World Health Organization

ABSTRACT (ENGLISH):

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A neurodevelopmental disorder that impacts both attention and motor function, Attention-Deficit/Hyperactivity Disorder (ADHD) often continues into adulthood. Although balance problems in children with ADHD are well-documented, adult populations remain under-researched. Postural control requires cognitive engagement, especially under dual-task conditions. This study aimed to investigate the relationship between postural control and sustained attention in individuals with potential ADHD traits (pADHDt), identified via the Adult ADHD Self-Report Scale (ASRS). Participants aged 18–30 were categorized into two groups based on ASRS scores: Group 1 (ASRS >14; n=21) and Group 2 (ASRS <14; n=21). The Sustained Attention to Response Task (SART) was used to assess attention performance. Postural control variables— medial-lateral (M-L) and anterior-posterior (A-P) sway velocity, and center of pressure (CoP) area measured by using the ProKin 252 stabilometer across different stance conditions (two-foot, tandem, soft surface), with and without a verbal dual task (backward counting), under eyes open and closed conditions. Data were analyzed using one-way ANOVA with Bonferroni correction for post-hoc comparisons. SART results showed that Group 1 made more total errors and had longer reaction times than Group 2 (p<0.05). In terms of balance, Group 1 exhibited significantly larger CoP area during dual-task conditions in the two-foot and tandem stances with eyes open (p=0.048; p=0.047), and in tandem stance with eyes closed (p=0.040; p=0.020). No significant group differences were found in sway velocities. These results suggest that cognitive load negatively affects balance in individuals with pADHDt. Incorporating balance training into therapeutic programs may support attentional regulation in this population.

Keywords: ADHD, postural control, sway velocity, CoP ellipse area, dual-task.

ABSTRACT (TURKISH):

Seçinti, A. (2025). Dikkatin Postüral Kontrol Üzerindeki Etkisi. Yeditepe Üniversitesi Sağlık Bilimleri Enstitüsü, Fizyoterapi Anabilim Dalı Yüksek Lisans Tezi, İstanbul.

Dikkat Eksikliği ve Hiperaktivite Bozukluğu (DEHB), yetişkinlikte de devam edebilen ve dikkati ile motor kontrolü etkileyen bir nörogelişimsel bozukluktur. DEHB'li çocuklarda denge sorunları iyi belgelenmiş olmasına rağmen, yetişkinlerle ilgili araştırmalar sınırlıdır. Postüral kontrol özellikle ikili görev (dual-task) koşullarında dikkat katılımı gerektirir. Bu çalışma, Erişkin Dikkat Eksikliği ve Hiperaktivite Bozukluğu Kendi Bildirim Ölçeği (ASRS) ile belirlenen erişkin potansiyel DEHB özellilkli (pDEHBö) bireylerde, fiziksel ve bilişsel yükün denge üzerindeki etkisini incelemeyi amaçlamaktadır. Çalışmada 18–30 yaş aralığındaki katılımcılar ASRS puanlarına göre iki gruba ayrılmıştır: Grup 1 (ASRS >14; n=21) ve Grup 2 (ASRS <14; n=21). Bilişsel performansı değerlendirmek için Sürekli Dikkat Yanıt Görevi (SART) kullanılmıştır. Postüral kontrol değişkenleri, anteriyor-posteriyor (A-P) ve mediyal-lateral (M-L) salınım hızı ile basınç merkezi (CoP) alanı, ProKin 252 stabilometresi ile farklı duruş pozisyonlarında (iki ayak, tandem, yumuşak zemin), gözler açık ve kapalı şekilde, sözel çift görev (geriye doğru sayma) eşliğinde ve görev olmadan ölçülmüştür. Veriler, post-hoc karşılaştırmaları için Bonferroni düzeltmesi ile tek yönlü ANOVA kullanılarak analiz edildi. SART sonuçlarına göre Grup 1, daha fazla hata yapmış ve daha uzun tepki süresi göstermiştir ($p<0.05$). Postüral olarak, Grup 1'in, gözler açık durumdayken iki ayak ve tandem duruşlarda, çift görev esnasında CoP alanı anlamlı şekilde artmıştır ($p = 0.048$; $p = 0.047$); gözler kapalı tandem duruşta da benzer bir artış gözlenmiştir ($p=0.040$; $p=0.020$). A-P ve M-L salınım hızlarında anlamlı fark saptanmamıştır. Bu bulgular, pDEHBö bilişsel yükün dengeyi olumsuz etkilediğini göstermektedir. Bu nedenle, bu bireyler için müdahale programlarına denge eğitiminin dahil edilmesi faydalı olabilir.

Anahtar Kelimeler: DEHB, postüral kontrol, sallanma hızı, CoP elips alanı, çift(ikili) görev

1. INTRODUCTION AND PURPOSE

Attention Deficit Hyperactivity Disorder (ADHD) is classified as a neurodevelopmental condition in the Diagnostic and Statistical Manual (DSM-IV) (1). Children with ADHD commonly experience difficulties in both motor and inhibitory control, with motor deficiencies present in 30-50% of cases (2,3). While traditionally associated with childhood, it is now recognized to affect a significant portion of adults globally, with a prevalence of 3%-7% (4,5). In a meta-analysis by Faraone and colleagues, it was found that approximately 15% of individuals with a particular diagnosis retained the complete diagnosis by the age of 25, while an additional 50% were in partial remission (6). The symptoms of ADHD include impulsivity, hyperactivity, and inattention. (7). Of late years, there is growing awareness that ADHD symptoms like inattention can persist into adulthood (8). ADHD, with it is features of attention deficits, impulse control issues, and activity level problems, can have adverse effects on an individual's work capacity and performance (9,10). The Adult ADHD Screening Scale (ASRS) is a diagnostic instrument for ADHD that corresponds with the DSM-5 criteria, created by the World Health Organization (WHO). It suggests the possibility of ADHD (11).

Posture identifies to the static position of the body, while movements refer to the transition between static positions (12). Postural control (PC) is a complex process that relies on the coordinated functioning of various physiological and neurological systems. These include the nervous system, musculoskeletal system, and sensory system (13). The postural control system relies on sensory input from visual, somatosensory, and vestibular systems to execute motor actions (14). Simultaneously, tonic muscle activation to stabilize the body upright and keep the center of gravity over the base of support, which is crucial for preventing imbalance or falls (15–17). Postural control can be categorized as static or dynamic balance. Static balance involves keeping the center of gravity over the base of support while sitting or standing posture (18). Dynamic balance pertains to maintaining this balance during movement (16). Both static and dynamic balance can involve reactive responses, anticipatory preparations, or a mix of both (19–21). Reactive balance control consists of responding to unexpected events that may cause instability, such as slips or pushes. Anticipatory balance control entails adjusting for planned instability or predictable situations, like stepping onto the ice. Ideal balance function necessitates proficiency in both reactive and anticipatory control (17).

It was first proposed that postural responses are generated with adjustments in the "central set” by changes in cognitive and a new neuromotor state depending on the sensorimotor conditions at baseline (22). Later studies supported that cortical activity may play a role in optimizing postural responses through changes in the central set (23). It is known that any decrease in attention in the provision of conscious postural control increases the likelihood of impairment of stability and coordination of movement. This situation has been expressed in the literature with the theory of reinvestment. In the study supporting this theory, Seidler et al. stated that redirection of attention may affect task prioritization (24). While performing the first task using distractor dual tasks, the participant's attention is directed to an external point (such as arithmetic counting down or random letter generation). According to the constrained action hypothesis, this change in attention from postural control to the other task can result in more effective performance by enabling the motor systems to work automatically (25). Dual tasks can represent daily life and sports situations. The literature shows different results in postural stability variables during dual tasks.

Motor control problems are prevalent in children with ADHD, impacting up to 50% of them despite not being part of the diagnostic criteria. Research has consistently shown that children with ADHD struggle to maintain balance (26). Studies, including one by Zang and Qian, have demonstrated significant impairment in their ability to balance, even in various testing scenarios like standing on a foam platform with open or closed eyes (27,28). Children with ADHD experience balance deficits in simple standing postures and exhibit more pronounced deficits in challenging standing conditions (27–29). For instance, when sensory signals are disrupted, such as by closing their eyes or manipulating the platform and visual surroundings, children with ADHD perform poorly in maintaining their balance in comparison to healthy peers (30). These deficits may be linked to difficulties integrating and processing multiple sensory inputs, including visual and vestibular information (31). The literature reveals distinctions in postural control among children and adolescents, with notable gender differences between males and females. In addition, numerous studies affirm the influence of dual-task performance on postural control measurements in this demographic (32–35). However, when it comes to adults with ADHD, there is a scarcity of research addressing disparities in postural control compared to non-ADHD adults. Existing studies include an examination of cerebellar volume in adults with ADHD and a pilot study revealing postural instability in this population. Given the limited information on this subject, our study is designed to address this research gap (36,37).

Demonstrating the effect of attention on postural control in people with potential ADHD trails is essential in establishing balance protocols that can be applied for therapeutic purposes. Because of all this information, the study’s aim is to explore the connection between postural control and sustained attention in individuals with the potential ADHD trails (pADHDt). This study has two hypotheses:

H0: There is no relationship between postural control and sustained attention in individuals with the pADHDt .

H1: There is a relationship between postural control and sustained attention in individuals with the pADHDt.

2. GENERAL INFORMATION

2.1. Attention-Deficit/Hyperactivity Disorder (ADHD)

The disorder that is today known as ADHD has been acknowledged since the early 1900s, but the label is relatively new. ADHD is a persistent neurodevelopmental disorder, as defined by the DSM-5, that includes a continuous and widespread presence of inattention and/or hyperactivity/impulsivity that affects adaptive functioning or development. (38). ADHD is one of the most common neurodevelopmental and behavioral problems affecting children, youth, and adults (39). In addition, ADHD is one of the most researched mental disorders, but many studies have shown that its origins remain unknown (40). However, research has pointed to several potential causes such as genetics, environment, and some psychological and maternal variables (41). There has been strong evidence that heredity plays a role in development of ADHD, and studies on families have uncovered eight genes with strong correlations to the disorder's etiology (42–44). According to a meta-analysis of 37 twin researches conducted in the Europe, United States, Australia and Scandinavia, 76% of cases of ADHD are inherited, suggesting that genes and the interplay between genes and the environment have a major impact on the development of this disorder (45,46). It was the "candidate gene" strategy that was initially used to identify the ADHD-related genes. These genes produce proteins that are believed to contribute to the pathophysiology of ADHD. The heritability of ADHD was only partially explained by the 10 genes that were shown to have strong evidence in these investigations (47). A large genome-wide association study (GWAS) meta-analysis on ADHD, involving 38,691 cases and 186,843 controls, identified 27 significant genetic loci and 76 potential risk genes, particularly active during early developmental phases of the brain. ADHD genetic risk was linked to midbrain dopaminergic neurons and shared 84–98% of its genetic variants with other psychiatric disorders. Genetic risk for ADHD was also associated with impaired executive functions and verbal reasoning, highlighting its broad cognitive and psychiatric implications(48).

Other factors: There are a lot of environmental factors that might make someone more likely to develop ADHD or symptoms of ADHD. After looking over it, Faraone et al. (49), showed that the strongest evidence is for:

1. *Maternal health and exposures*: include tobacco use, acetaminophen, valproate, high blood pressure, elevated phthalate levels, obesity, thyroid dysfunction, previous pregnancy loss, maternal sadness, and complications during pregnancy and delivery.

2. *Early environmental conditions*: involve adverse childhood experiences such as poverty, sexual abuse, physical neglect, loss of a family member, lack of community support, infections like enterovirus, and exposure to lead, tobacco smoke, food dyes, organic phosphate pesticides, nitrogen dioxide, dust, and perfluoroalkyl chemicals (49).

Research in neuropsychology and neuroimaging has linked various brain areas and networks to the causes and mechanisms of ADHD. According to research, people with ADHD often experience cognitive impairments in multiple areas, but it is unclear whether these deficits cause ADHD or result from other risk factors. ADHD is related with difficulties in visual-spatial processing, verbal working memory, inhibition, awareness, planning, and time processing. Additionally, individuals with ADHD may struggle with reward processing, leading them to overvalue immediate rewards over delayed ones (7).

2.2. ADHD Diagnosis Criteria

Clinicians, researchers, and public health authorities in the US all use the DSM of Mental Diseases as their standard terminology for discussing mental diseases. According to the most recent DSM of Mental Disorders, Fifth Edition (DSM-5) classification, ADHD is a neurodevelopmental condition(50). The typical onset of ADHD occurs between childhood and adolescence(51) Its diagnostic categorization depends on the detection of behavioral symptoms (52,53)(54). Individuals with ADHD exhibit three types of behaviors, according to the DSM of Mental Disorders: Inattention, hyperactivity, and impulsivity are the three primary symptoms that are linked with ADHD. When contrasted with normally growing people, these behaviors are more common, severe, and long-lasting in ADHD patients (55). Inattention is the primary symptom, with children often struggling to focus in class and displaying behaviors like not listening or failing to complete tasks (56). Impulsivity leads them to act without thinking, take risks, and potentially damage property, while also struggling to wait their turn in group activities and tending to take shortcuts (57). Hyperactivity, the third major symptom, is characterized by constant movement, restlessness, and an inability to sit still, often described as being "on the go" or "driven by a motor" (58).

ADHD remains one of the most prevalent chronic mental disorders affecting children in recent years. Considering the challenges in diagnosing ADHD in preschool-aged children, it is estimated that 2% of this population meets the criteria for diagnosis of the disorder. (72). Furthermore, approximately 4% to 12% of school-aged children have been impacted by this impairment. (59). This has also persisted into adolescence and adulthood in approximately 66% to 85% of children (54). The medical perspective views ADHD as a clinical condition and suggests a therapeutic approach for children diagnosed with ADHD. The psychological perspective characterizes ADHD as a cognitive weakness, hence advocating for cognitive therapy for affected children; both interpretations see ADHD as an impairment inherent to the kid. A treatment or reduction of symptoms is necessary. The present medical approaches to diagnosing ADHD fail to adequately link learning and behavioral issues to sociological variables, which is the foundation of the sociological view of ADHD (60).

The possibility that the incidence of ADHD changes among nations is one of the most contentious issues related to ADHD epidemiology. One piece of evidence that ADHD is more of a social phenomenon than a "real" medical condition is the fact that its clinical adversaries in Europe and North America use diagnostic rates that are significantly different from one another (59).

The increased universality of ADHD in boys relative to girls is a distinguishing aspect of this disorder in adolescents. Prevalence disparities between girls and boys have been found in a number of research investigations published in the past 20 years, with results varying from 1:1.8 to 1:16 (61–64). According to the study conducted in 2013, ADHD prevalence rate in Turkey is 13.8% with boys to girls ratio was found to be 3:2(65).

It is not well known why there are gender variations in the different phases of development of ADHD patients. Research suggests that gender has a role in the persistence of diseases throughout adulthood, where women's rates remain at approximately 60% and men's rates remain around 35% (66). Some research has shown that ADHD presents differently in the sexes; specifically, that girls are more prone to exhibit inattentive symptoms while boys are more likely to exhibit a combination of symptoms, including increased hyperactivity and impulsivity (64,67).

2.3. ADHD in Adults:

Many studies have shown that ADHD symptoms get better with age. This could mean that the symptoms have gone away completely, but it could also mean that they were mismeasured in adults or that they have learned how to deal with their condition. Although ADHD has long been associated with childhood, statistics show that its prevalence among adults worldwide ranges from 3% to 7% (4). Research via age-adjusted symptom restrictions and other evaluation metrics reveals that 40% to 50% of persons diagnosed with ADHD during infancy persist in exhibiting symptoms throughout adulthood (68). Despite updates to diagnostic criteria that lower the number of symptoms required for an adult diagnosis, is not clear on how ADHD presents in men and younger individuals (4,7). Uncertainty persists about the unique manifestations of ADHD in males and younger persons, even though diagnostic criteria have been revised to facilitate the diagnosis of ADHD in adults (by decreasing the necessary symptom burden). Additionally, childhood symptoms do not always fully reflect adult experiences, particularly in areas such as emotional control and concentration (7).

One notable symptom of attentional control issues in adults is hyperfocusing, or the inability to shift focus between tasks. Hyperfocus is a well-documented symptom of ADHD (Brown, 2005) (69) with research showing that individuals with ADHD experience longer and more intense periods of hyperfocus than those without the disorder (70). Although individuals with ADHD tend to experience longer and more intense episodes of hyperfocus compared to those without the disorder, they are less likely to exhibit this behavior in structured environments like schools or community settings. This suggests that while hyperfocus is a prominent feature of ADHD, its expression may depend heavily on context, possibly being suppressed or masked by external structures, expectations, or environmental demands. (69,71). Although people with ADHD tend to experience longer and more intense episodes of hyperfocus, they are less likely to show this ability in structured environments like schools or community settings. This suggests that while hyperfocus is a real and prominent experience for individuals with ADHD, it may not always appear in settings where it could be beneficial or easily observed, possibly due to external structure, expectations, or environmental demands.

Emotional dysregulation, now considered a related characteristic rather than a formal diagnostic criterion of ADHD according to the DSM-III (83), is frequently observed in adults with the disorder (41,72,73). However, whether emotional dysregulation is a core component of ADHD remains a subject of debate (74). Studies indicate that Emotional dysregulation occurs twice as often in young adults alongside ADHD, and when combined with the core characteristics of the disorder, is linked to a poorer quality of life (75).

2.4. Diagnosis Criteria of Adult ADHD

As people with ADHD age, it is difficult to effectively measure levels of impairment using the same criteria of symptoms from childhood for the expression of symptoms in adulthood. The impairment associated with ADHD symptoms in adults may differ from that observed in children (76). There is ongoing debate as to whether adults are underdiagnosed when using the minimum six criteria established for children (77). DSM-5 has improved the understanding and diagnosis of adult ADHD by refining its diagnostic criteria.

DSM-5 the first significant revision of criteria for diagnosis and categorization from the DSM-IV (1994) was released in May 2013 (1). DSM-IV of Mental Disorders (1) was the first version to acknowledge that ADHD symptoms may carry on throughout adulthood, providing light on the disorder's enduring nature in certain situations (77,78). If a person meets all five criteria outlined by DSM-IV, they will be labeled with ADHD (79). As a first requirement, six of the nine signs of hyperactivity/impulsivity and/or inattention must be present. Second, they can't just have one instance of the symptoms; they need to be present in both your home and your place of employment or school. Third, cognitive signs must have started while the kid was younger than seven years old. The fourth requirement is proof of a "clinically significant" impairment in one's ability to function socially, academically, or professionally. Lastly, unlike periodic diseases like depression or bipolar disorder, the signs and symptoms of this condition must be present all the time and not limited to unpredictable times of occurrence and becoming extinct (77,80,81).

The DSM-IV is widely used for ADHD in adulthood; however, there are several problems regarding these criteria that might cause under- or overdiagnosis. As stated by the DSM-IV, the amount of ADHD symptoms may decrease with age. This means that not all people who had ADHD as a child match the full diagnostic standards, but they may still have serious problems. McGough and Barkley (2004) suggested that DSM-IV does not adequately identify all adults severely impaired by ADHD symptoms, absence of age-adjusted symptoms, and diagnostic thresholds that compensate for developmental modifications in ADHD and have not been approved in adults. Adults with ADHD sometimes report symptoms that aren't already on the list. These include issues with organizing their time, procrastination, low-interest threshold, responding to anger and emotional instability, and difficulty sleeping(76,81). While six symptoms were previously considered necessary for an adult ADHD diagnosis, Kooij and colleagues (2005) determined that four symptoms were sufficient (82).

The revision from DSM-IV to DSM-5 introduced significant structural changes in the classification of mental disorders. Some disorder categories—such as those typically diagnosed in childhood, disorders due to general medical conditions, factitious disorders, and adjustment disorders—were removed as standalone classes but not eliminated. Instead, these disorders were reorganized under new or existing diagnostic groups to reflect current scientific understanding and improve clinical applicability. DSM-5 added six new diagnostic classes, including Neurodevelopmental Disorders, Obsessive Compulsive and Related Disorders, and Trauma and Stressor Related Disorders. This reclassification aimed to group disorders based on shared symptoms, etiological factors, or developmental trajectories. For instance, ADHD and autism spectrum disorder were moved under Neurodevelopmental Disorders to emphasize their early onset and neurological basis, while post traumatic stress dissorder (PTSD) was placed under Trauma and Stressor Related Disorders. These changes reflect a shift toward a lifespan and dimensional perspective in psychiatry. Although the reorganization does not directly affect estimates of serious emotional disturbance (SED), it is important when comparing diagnostic data across DSM versions (38).

In DSM-5, key revisions were made to the diagnostic criteria for ADHD to improve recognition across age groups. While the core symptom domains inattention and hyperactivity impulsivity—remained unchanged, the age-of-onset criterion was raised from before age 7 to before age 12, allowing broader identification, especially in school-aged children and adolescents. Additionally, the minimum symptom count for individuals aged 17 and older was reduced from six to five, enhancing diagnostic sensitivity in older populations. DSM-5 also updated the language of symptom descriptions, including more age-appropriate and functional examples, improving clarity and clinical utility. To support more individualized assessment, DSM-5 introduced specifiers for presentation types (combined, inattentive, or hyperactive-impulsive), severity levels, and partial remission. These changes reflect a lifespan approach to ADHD, acknowledging its persistence beyond childhood and improving diagnostic accuracy, especially in previously underdiagnosed groups (38).

2.5. The Adult ADHD Self-Report Scale (ASRS)

The Adult ADHD Self-Report Scale (ASRS) is one of the tools used for diagnosing ADHD in adults. Developed by the World Health Organization (WHO) in collaboration with New York University and Harvard University, the ASRS is intended to evaluate the existence and intensity of ADHD symptoms in persons aged 18 and older (83,84). There are two common versions: ASRS V1.1 and ASRS-5. ASRS-5, based on DSM-5 criteria, consists of six questions, with two items (questions 5 and 6) related to executive dysfunction. The original English version demonstrated 91.9% sensitivity and 74.0% specificity in a clinical sample (85). The Turkish version of ASRS-5 showed 85.2% sensitivity and 89.7% specificity (86).

ASRS-5, developed in alignment with DSM-5, is a reliable and efficient screening tool for identifying ADHD symptoms in adults. Its high accuracy makes it valuable for both clinical and general populations, contributing to bridging the gap in ADHD diagnosis and treatment (86).

In addition to ASRS-5, assessing executive functioning (EF) deficits can provide further insight into ADHD-related impairments. Individuals with ADHD frequently experience cognitive failures, struggling with executive functions, attention, inhibition, organization, problem-solving, and working memory (87,88).

2.6. Attention

Attention cannot be easily defined as a singular concept; it encompasses a range of psychological phenomena. (89) According to psychologist and philosopher William James's 1890 book The Principles of Psychology, attention "is the taking possession by the mind, in clear and vivid form of one out of what may seem several simultaneously possible objects or trains of thought..." This suggests stepping away from some things in order to handle other things well (90). Another way to put it is that it is the condition in which our minds focus on certain things while ignoring others (91). Or the mindset that developed to zero in on certain details of one's surroundings or to concentrate on one's own thoughts and actions (92).

Attention is a complex cognitive process that involves selecting, regulating, and prioritizing sensory and cognitive information to guide behavior effectively. Attention is not a single, uniform process but adapts based on whether it is dealing with external sensory input or internal cognitive demands. It is based on the type of information being processed. Perceptual attention focuses on selecting and regulating sensory input from external sources, while central/reflective attention is responsible for cognitive control, working memory structure, long-term task sets, and response selection.

Cognitive control systems function independently of sensory inputs to minimize distractions and focus on essential details for encoding and storage in working memory. Executive functions and working memory also influence visual perception and eye movement control, while perceptual attention determines what remains in working memory. When a task is simple, the brain processes unattended information later (late selection), whereas for complex tasks requiring full concentration, early selection filters out distractions immediately. Under high cognitive load, such as increased working memory demands or task switching, distractions become more noticeable, making previously ignored details more apparent (late selection) (93).

Kahneman (1973), Corbetta, and Shulman (2002) suggest that attention is shaped by the dynamic interaction between cognitive and sensory elements, which determines how stimuli are prioritized. The core functions of attention are focusing, selecting, and inhibiting stimuli, while its components divided, selective, sustained, and set-shifting attention define an individual's ability to process information while performing a task (94,95).

Cognitive processing models, based on observations of individuals without impairments, aim to explain how we process information. Mirsky et al. (1995) identified four attention components—focus-execute, sustain, encode, and shift—through factor analysis of various attention tasks. Posner and Rothbart (2006) proposed a neuroanatomical model with three attention networks: alerting (vigilance), orienting (selecting information), and executive control. Clinically, Sohlberg and Mateer (2001) outlined five core types of attention:

- **Selective Attention**: Focusing on a particular stimulus while ignoring distractions.
- **Divided Attention**: Managing and responding to multiple tasks or stimuli at the same time.
- **Sustained Attention**: Maintaining attention over time, including vigilance and working memory
- **Focused Attention**: The basic ability to respond to specific external or internal stimuli (e.g., sounds, sights, or thoughts).
- **Alternating Attention**: Shifting focus back and forth between different tasks or cognitive demands.

These models together provide a comprehensive understanding of how attention works in both typical and clinical populations (96).

2.6.1. Selective Attention

Selective attention enables individuals to concentrate on certain stimuli while disregarding others. It functions by enhancing the most important area in the environment. This enhancement is initially recorded as a map of importance based on stimuli (97,98). The brain's visual system creates low-level feature maps**,** which process basic visual details in the early stages of perception. These feature maps form a two-dimensional topographical representation of an area. Selective attention then works by creating a competition to determine the most noticeable point and directing attention to that spot (99), resulting in a saliency map that highlights the most attention-grabbing areas in a scene. Additionally, cognitive factors such as emotions, goals, and past experiences also influence selective attention. These cognitive elements integrate with stimulus-based saliency maps to form an internal motivational saliency map**,** which then generates a priority map that directs eye movements and shifts in attention (100). Shortly, selective attention focuses on only a subset of available stimuli. Focusing on some stimuli while disregarding others is fundamental for maintaining daily functioning (101).

2.6.2. Divided Attention

Divided attention is the ability to process more than one piece of information at a time (102). It also known as multitasking. It is a cognitive skill that is required to held on more than one task at the same time. It also is generally related with capacity to process information. Several tasks must be performed at the same time and the demands of the tasks may exceed processing capacity. Most studies on divided attention use dual-task designs, in which participants complete both the main task and a secondary activity simultaneously to determine whether this affects performance (103).

Attempting to pay attention to two or more things at once is something we do frequently. Examples of situations in which we split our attentional resources include listening to music when studying or doing homework, eating while attending a class or meeting, and texting while driving. Because some individuals think they are competent "multitaskers," learning is impaired when attention is split between two tasks simultaneously (104–106). Even though various forms of memory suffer from the negative consequences of split attention, many learners continue to multitask while studying important material (107).

2.6.3. Sustained Attention

Sustained attention is the capacity to remain involved in a single activity for a long time without interruption. This type of attention, called concentration, is the capacity to maintain concentration on a singular task for an extended duration. During this interval, individuals maintain their concentration on the activity and persist in the behavior till the activity is finished or a specific duration has passed (108). Sustained attention is a fundamental attentional function that influences the effectiveness of higher-order attentional processes (selective attention, divided attention) and overall cognitive ability. Cognitive neuroscience studies consistently show activity in the hemisphere's right prefrontal and parietal areas during prolonged attention tasks (109).

Impairments in the capacity to identify and choose pertinent stimuli or connections are intuitively recognized to affect contemporary life abilities, such as operating a vehicle, cognitive skills like learning new operational procedures for Machines or recognizing social signals crucial for efficient communication, and maybe awareness (109), Psychological studies regarding sustained attention have predominantly concentrated on parametric, construct-specific matters and have seldom examined the critical need for sustained attention for advanced cognitive functions such as learning and memory (110).

Starting with Mackworth's research in the 1950s, the evaluation of sustained attention (or vigilance) performance has generally involved scenarios in which an observer must monitor for subtle signals over extended durations. The preparedness to react to infrequent and unpredictable signals is defined by the overall capacity to identify these signals (referred to as the "vigilance level") and, crucially, a decline in performance over time (known as the "vigilance decrement") (111).

2.6.4. Focused Attention

Focused attention refers to the capacity to respond selectively to particular auditory, visual, or tactile inputs. It represents the most basic level of attention and serves as the foundation for more complex attentional functions. In clinical populations, focused attention is often evaluated through simple orienting or tracking tasks. Although most individuals recover this attentional capacity, it is frequently disrupted in the early stages of recovery from brain injury or coma. During this phase, individuals may respond only to strong internal stimuli, such as pain or changes in temperature, indicating minimal interaction with external environmental cues. For example; a patient turns their head when a nurse calls their name, even in a busy hospital room. This ability to detect and respond to a specific auditory cue amidst background noise is a clear demonstration of focused attention (112).

2.6.5. Alternating Attention

Alternating attention defines to the cognitive ability to shift focus flexibly between tasks or mental operations that require different cognitive demands. It reflects mental flexibility and the capacity to disengage from one task and reengage with another, allowing for control over which information is processed at any given time. Clinically, deficits in alternating attention are observed in individuals who struggle to switch between tasks or who require external cues to initiate new task demands. It is often assessed through tasks that require set-shifting or switching between different cognitive operations. For example; a student taking notes during a lecture must listen to the speaker, then shift attention to write key points, and return to listening again. This continuous back-and-forth between auditory processing and written output exemplifies alternating attention (112).

2.6.6. Attention and Adult ADHD

Sustained Attention and ADHD**:** Sustained attention, the ability to maintain focus over a prolonged period, is a core component of attention and is often impaired in individuals with ADHD. This difficulty in maintaining concentration on a single task can lead to challenges in completing tasks, following through on plans, and resisting distractions. Neuroimaging studies show that sustained attention engages the right prefrontal and parietal regions, areas often found to be functionally altered in ADHD. Impairments in sustained attention are especially pronounced in adult persons with ADHD, where inattention, rather than hyperactivity, becomes the dominant symptom.

ADHD, Sustained Attention, and Decision-Making**:** Deficits in sustained attention can directly impact decision-making (DM) processes. Effective DM requires the ability to focus on relevant information, weigh options over time, and avoid impulsive choices, all of which are compromised when sustained attention is poor. In ADHD, researches have shown that adults exhibit impaired decision-making, particularly in tasks that involve delayed rewards or risky outcomes. These impairments may stem from an inability to stay focused on long-term consequences or to maintain task-relevant goals in working memory. Moreover, deficient reward processing in ADHD, linked to poor sustained attention, may lead individuals to choose immediate gratification over more beneficial long-term outcomes.

As mentioned previously, ADHD is not anymore regarded only as a childhood disorder; it continues into adulthood for numerous individuals (113,114). Symptoms may not present equally throughout childhood and adulthood. Hyperactivity is generally more evident in pediatric patients, while inattention is the primary pathological symptom in symptomatic patients of adulthood. Athanasia M. Mowinckel et al. found that adults with ADHD exhibit attentional and DM deficits comparable in magnitude to those of healthy individuals. Therefore, whether the same DM occurs in children or adults remains uncertain, and deficits have been identified. Considering the motivational and cognitive variances among adults and younger patients, comprehending DM in adults with ADHD is unable to depend on findings derived from younger individuals predominantly. Instead, research into DM deficiencies and the mechanisms by which they occur should focus on adults who have ADHD (115). The scientific proof of decision-making deficits aligns with evaluations of life outcomes for individuals with ADHD, who indicate adverse life events linked to poor DM (115).

Cognitive impairment in ADHD is primarily linked to attention, impulsivity, and self-regulation difficulties (88). Recent research highlights deficient reward processing as both a cause and consequence of executive function deficits (116). When individuals struggle to use executive functions to achieve delayed rewards, they tend to avoid tasks that require such skills. Studies on children and adolescents with ADHD further support this link, showing poor decision-making in risky and reinforcement-based tasks (115,116).

When assessing fundamental cognitive processes**,** individuals often show slower or less accurate responses on various laboratory tests. These include tasks measuring response inhibition (Go/No-Go, Stroop Test), executive functions, and working memory (113).

Several well-established assessment tools are widely recognized for evaluating cognitive function. These tools are considered effective for assessing cognitive impairments and are widely used in both research and clinical settings, including:

- **Digit Span and Digit Symbol** (Wechsler, 1939) – measures working memory and processing speed.

- **Trail Making Test** (Reitan, 1958) – assesses cognitive flexibility and attention.

- **Stroop Color-Word Test** (Stroop, 1935) – Measures Selective attention, cognitive flexibility, interference control and evaluates response inhibition and cognitive control. Individuals with ADHD often struggle with interference control and show slower response times or higher error rates.

- **Continuous Performance Tests (CPTs)** – measures sustained attention and impulse control (117). Participants must respond to certain stimuli (e.g., letters or shapes) and withhold responses to others. Performance is analyzed based on omissions, commissions, and reaction times. (Conners' CPT-3 – Commonly used in ADHD diagnosis.)

- **Go/No-Go Task:** measuring sustained attention, response inhibition, and impulse control

- **(Significance for ADHD:** ADHD individuals often have a higher rate of false alarms (responding when they shouldn't).

- **Attention Network Test (ANT)** Quantification (Fan et al., 2002) A comparison of the three attention networks' performance in resolving conflicts: orienting, executive. (conflict resolution), and alerting. Helps identify which aspect of attention is impaired — sustained attention problems in ADHD often show up in the executive network.

2.6.7. Sustained Attention to Response Task (SART):

Maintaining focus is crucial for adapting behavior in various fields, from industry to daily life. Sustained attention enhances cognitive processing and directly impacts human performance. Therefore, studying sustained attention is essential in psychology and neuropsychology (118). The Sustained Attention to Response Task (SART) is a standardized computer-based cognitive test designed to evaluate sustained attention, an essential executive skill necessary for the execution of activities requiring prolonged oversight (119).

SART was developed by Robertson et al. (1997) as a novel continuous performance task (CPT) to assess sustained attention. Unlike traditional vigilance CPTs, SART was designed to be less prone to automatic responses, making it a more reliable measure of attentional control. It requires frequent motor responses while withholding responses to rare stimuli. Since its introduction, SART has been commonly used in research, including studies on media multitasking and working memory in social media engagement (120).

They conducted the SART on a substantial population of patients with traumatic brain injuries, likely including frontal injury, alongside matched controls (121). Errors during the test were linked with the frequency of daily attentional expires, as measured by the Cognitive Failures Questionnaire (CFQ), among the patient and control groups. The correlation between the SART and CFQ remained strong when the same subjects were tested again two years later, indicating that the assessment captures a rather persistent facet of individual variations (122). The SART has demonstrated sensitivity to everyday attentional impairments after a right hemisphere stroke in addition to its paper-and-pencil variation, such as the “Walk Don’t Walk” subtest from the Test of Everyday Attention for Children to Childhood ADHD (120).

SART assesses response inhibition and sustained attention by evaluating how well individuals can suppress automatic responses to No-Go stimuli while consistently responding to Go stimuli. It is widely used to study impulse control and cognitive processing, particularly in conditions like ADHD (122).

- Go Stimuli: Frequent signals that require a response (e.g., pressing a key).
- No-Go Stimuli: Infrequent signals where a response must be withheld (e.g., not pressing a key).

2.6.8. Types of Errors in SART

1. Error of Commission (Incorrect Response to No-Go Stimuli): Responding when one should not.

2. Error of Omission (Missed Response to Go Stimuli): Failing to respond when one should.

- Commission errors indicate poor impulse control**,** common in ADHD**.**
- Omission errors suggest difficulty maintaining attention**.**
- Longer gaps between No-Go trials increase commission errors**,** highlighting challenges in anticipatory control **(https://www.psytoolkit.org/experiment-library/sart.html).**

The SART mandates that participants refrain from responding, suggesting that the test may be more accurately characterized as a measure of "response inhibition" rather than an assessment of sustained executive control. The findings pertinent to this matter indicate a positive correlation between commission mistake rates and the duration of intervals between the presentation of no-go targets (122). This indicates that individuals progressively struggle to maintain anticipatory control as the interval between no-go trials lengthens. Periodic auditory signals to "pay attention" have been demonstrated to correlate with substantial enhancements in performance among both adults and children. Since these cues lacked predictive value for approaching events in the assignment, a significant function in sustaining top-down control in ascertaining the efficacy of response suppression in pertinent trials (123).

2.7. Postural Control (PC)

PC is a complex motor skill resulting from the collaboration of several sensory-motor systems. It is described as the capacity to sustain the movement of the center of mass between the boundaries of the base of support regardless of static or dynamic position, requiring the regulation of body positioning in space (124). PC regulates the body's posture in space to maintain balance and direction. Postural orientation includes the deliberate regulation of the body's position and muscle tone about gravity, the base of support, environmental factors, and internal references. Postural balance entails integrating sensorimotor methods to maintain the body's center of mass (CoM) throughout each self-created and externally induced change in postural stability (14,125).

CoM indicates the typical position of a person's total mass that is situated in the trunk, about in front of the lumbar vertebra, and one meter above the ankles. This position defines the length of the inverted pendulum. Therefore, the upright human posture may be shown as an inverted pendulum because of the continuous movement of CoM, commonly known as postural sway. It explained that this sway is because the support base is comparatively limited, making the posture unstable (125,126).

Postural stability is defined as an appropriate reaction to perturbations of the CoM resulting from body sway, muscular activity, or intentional contact with the environment. Balance control and PC are interconnected dynamic processes that utilize inputs from the same receptor systems and identical actuators, governing the activity of postural muscles (127). During postural sway, the body produces continually changing muscular forces, as shown in the ground response force. This force can be identified as the center of pressure (CoP). The CoP offers an indirect evaluation of postural sway alterations by measuring the body's ground response forces and applying the corresponding torque at the support surface to regulate body mass acceleration (128). The mechanical requirement for stability is preserving the center of gravity (CoG) above the base of support (BoS). It is said that the CoP movement kind of mirroring the CoG movement (129). When the CoM is neutral relative to the Bos and in line with the CoP, the body's biomechanics allow PC (125).

2.7.1. The Postural Stability System

The human body relies on the sensory and central nervous systems (CNS) to maintain proper posture in the face of environmental and gravitational forces. The control of muscles that regulate posture throughout the body, particularly in the trunk and lower extremities, relies on vestibular and visual impulses in addition to tactile somatosensory and proprioceptive stimuli. Accordingly, the CNS must coordinate the action of numerous muscles at once in response to relevant sensory data (130).

Upright posture is primarily supported by sensory inputs from the eyes, vestibular, proprioceptive, and tactile organs. Numerous studies have used various experimental techniques to investigate how each sensory input contributes to maintaining posture (130).

Although many brain regions are involved, the exact networks that regulate balance remain unknown. While initial research indicated that spinal reflexes regulated neural control of posture, current studies have highlighted the significance of cortical, subcortical, and brainstem regions. Research in humans and animals indicates that postural control engages extensive brain regions, such as the higher-level prefrontal and temporal-parietal cortices and sensorimotor and subcortical structures such as the thalamus, cerebellum, brainstem, and basal ganglia. Nonetheless, the majority of neuroanatomical and neuroimaging studies concerning imagined motor abilities focuses on locomotion, with barely any studies addressing PC (131).

For the nervous system to generate smoothly synchronized motions and stand by balance and equilibrium, it must assess and predict the various forces generated on the body, including gravitational forces, inertial coupling within body segments, and frictional forces within body segments and the support surface, among others. Motion is generated by the active forces of muscles in conjunction with all external and indirect stimuli. Coordination is attained via the optimum integration of any of these forces dynamically (132).

Maintaining equilibrium requires applying force against the base plate to position the center of mass within the stability area. Because the musculoskeletal mechanism has so many joints and potential points, the mechanical transformation from muscular contraction to forces and, ultimately, the CoM's movement is complicated. Considering the interdependent structure of the body's sections, inertial interactions allow the contraction of a single muscle to produce acceleration at distant joints that the contracted muscle did not cross (132).

2.7.2. Strategies of PC

PC strategies can be classified into three categories: reactive (compensatory), predictive (anticipatory), or a combination. Voluntary movement or increased muscular action in preparation for an expected disturbance is an example of a predictive PC strategy; a motion or reaction to an unexpected disturbance is an example of a reactive PC strategy. Such reactions may be classified as "fixed-support," where the gravity axis is displaced. At the same time, the base of support stays unchanged, or "change-in-support," where the base of support is repositioned such that the axis of gravity crosses it. Typical change-in-support strategies include swaying from the ankle or hip ('ankle strategy' or 'hip strategy') and gripping with the hand or stepping ('stepping strategy') (133).

PC is a complicated motor skill crucial for sustaining balance and facilitating movement. Traditionally regarded as reflexive responses, it is now recognized that the CNS evaluates and regulates numerous variables. These strategies adjust according to objectives and environmental contexts, rendering balance a motor skill that is enhanced through training and practice (133).

The ankle strategy is employed in a stable posture and during minimal disturbances, suggesting that the ankle plantar and dorsi flexors primarily operate to control the inverted pendulum. In more disturbed scenarios or once the ankle muscles are ineffective, a hip strategy would flex the hip to shift the center of mass posteriorly or extend the hip to advance the center of mass anteriorly. A supplementary approach, termed a hip strategy, was recognized when the ankle muscles could not react due to the foot's lateral positioning on a narrow support structure (134).

Three primary categories of movement strategies may be employed to restore the body to equilibrium in a standing position: Two strategies maintain foot stability, while an additional strategy alters the base of support through stepping or reaching actions by the individual. The ankle strategy, in which the body functions as a flexible inverted pendulum at the ankle, is suitable for holding balance during minimal sway while standing on a stable surface. The hip strategy, characterized by applying torque at the hips to rapidly relocate the body's CoM, is employed when individuals are positioned on tight or compliant surfaces that restrict sufficient ankle torque or when rapid movement of the center of mass is required. When individuals encounter an external disturbance that exceeds the capacity of the hip strategy, the body initiates a stepping strategy to restore the CoM to its original position, utilizing ankle torque (14).

2.7.3. Assessment of PC

Postural functions can be evaluated using instrumental or non-instrumental methods, with instrumental approaches further divided into kinetic and kinematic methods. Among kinetic methods, force platforms are the most widely utilized devices.

These high-precision instruments measure vertical ground reaction forces to calculate the time-series data of the CoP in the anterior-posterior (AP) and medial-lateral (ML) directions during postural assessments (135).

Force platforms provide raw CoP data, which can be processed to derive various CoP variables for assessing postural function and analyzing the mechanisms underlying postural control. Commonly used static balance tests involve standing on a stable surface, with added challenges like a single-leg stance, eyes closed, or unstable surfaces to increase task difficulty. CoP data is typically represented as a statokinesigram, depicting real-time CoP movement, or a stabilogram, showing changes in AP and ML directions. Key CoP parameters—such as ellipse area, path length, amplitude, and mean speed—quantify postural stability and control efficiency, with smaller values indicating improved balance (136,137).

2.7.4. PC and Attention

PC was historically regarded as an automatic and reflexive task requiring minimal cognitive engagement; however, according to the latest studies, a significant role of attention and cognitive processing in maintaining balance, especially under complex conditions. Madli Bayot et al. concluded that attention and cognitive processes are essential for locomotion and posture in healthy elderly adults and patients with neurological disorders (95). Attentional demands for PC vary based on the specific postural assignment, the individual's age, and overall balancing capabilities. Attention is an individual's information processing ability. Each human’s information processing abilities are inherently limited, and executing any activity necessitates a specific allocation of this capacity (94,138).

Sensorimotor processes and attention also play a role in PC, which is a cognitive function. Postural control can be influenced and enhanced by emotional and psychological factors, such as anxiety and worries about falling (139). Prior research has indicated that an external focus on environmental objects influences PC during quiet standing. Postural sway diminished when participants concentrated on the movement of a paper contacted by their finger while standing still. Focusing externally, such as trying to minimize the movement of an unstable disk beneath the feet during standing, has been shown to reduce postural sway in healthy individuals. Internal or external focus can significantly affect how balance is maintained, and posture is stabilized in response to disturbances while standing (140).

Dual-task paradigms have been employed to investigate attention and PC, wherein PC is seen as the primary activity alongside a secondary task done concurrently. The degree of performance drop in either task signifies the interference between the mechanisms governing the two tasks, reflecting the level of shared attentional resources (94,141). Certain studies have asserted that when employing a dual-task paradigm, investigating the attentional demands of PC necessitates that alterations in performance be confined to the secondary task, with no modifications in the main (postural) task. Consequently, the results examine alterations in the secondary task, thereby elucidating the attentional demands linked to modifications in postural tasks. The attentional demands related to PC should not be inferred from evidence of the interaction effects of primary and secondary tasks (94).

Consistent findings emphasize the significance of examining the interaction between cognitive workload and the stability of motor performance. Although motor performance stability has traditionally been seen as instinctive or reflexive, substantial evidence indicates the necessity of attentional processing in PC. Multiple research investigations utilizing the dual-task approach have shown that the attentional demands related to balance regulation depend on the complexity of postural tasks. A decrease in performance on either task suggests that the two activities share attention, which implies a problem with cognitive and, more significantly, attentional allocation. Murian et al. (2008) highlighted that performing prolonged attention-demanding tasks can induce cognitive fatigue, which may lead to reduced postural or coordination stability due to the depletion of attentional resources. Engagement in cognitively demanding tasks (such as mental arithmetic, sustained attention tasks, dual-task paradigms, and complex decision-making) over extended periods has been shown to impair decision-making abilities and result in subsequent performance deterioration (142,143).

According to Richer et al. (2017), adopting an external focus means directing one's attention toward the outcome or effect of the movement, such as focusing on the path of a golf ball rather than on the body's motion. This approach shifts attentional resources away from the body and toward the environment, which may facilitate more automatic and efficient motor control.

An external focus has repeatedly enhanced motor learning and performance relative to internal focus and baseline conditions. The internal focus has produced motor learning and performance comparable to baseline circumstances. External focus enhances movement efficacy and efficiency compared to internal focus or initial circumstances. Nonetheless, the influence of attentional concentration on postural control has been examined to a lesser degree (144,145). The external focus resulted in enhanced cognitive performance relative to the internal focus. Reductions in sway amplitude, velocity, and variability, alongside rises in sway frequency in young, healthy adults, characterize improvements. For instance, executing working memory and mental calculation tasks in an upright position results in greater sway frequency and diminished sway amplitude. Likewise, implementing a silent backward counting exercise has diminished postural sway. External focus and cognitive tasks are believed to enhance stability by facilitating automated processes of sway. The body is posited to have mechanisms that autonomously regulate sway (144). Natalie Richer et al. claim that an external focus diminishes postural sway, while cognitive tasks contribute to additional reductions. The absence of variation in muscle activity indicates that alterations were attributable to automaticity rather than the implementation of a stiffening strategy. The external focus has shifted attention from action output, facilitating more automatic and effective control. At the same time, cognitive tasks have diverted attention from postural control entirely, enabling the body to self-regulate sway (144,146).

2.7.5. PC and ADHD

Research indicates that children with ADHD exhibit multiple deficiencies in inhibitory functions and executive motor control functions (31). These motor control deficits may be related to impairments in integrating and processing sensory inputs, including visual and vestibular stimuli (1,147). A sensory organization test showed that children with ADHD had significantly lower equilibrium scores and notably higher sway velocity while standing upright compared to healthy controls (28,148). ADHD in childhood is widely associated with deficits in coordination and balance abilities. Increased body sway velocity and sway area are indicative of impaired postural stability in children with ADHD. Furthermore, these children demonstrate deficits in active motor tasks, especially in task timing, and show greater variability in motor performance and skills. Impaired sensory-motor capabilities, reduced motor coordination, and increased latency and amplitude in skeletal muscle contractions may contribute to postural instability observed in adults with ADHD (37).

Postural stability is not governed entirely by automatic mechanisms; rather, it can be influenced by attentional resources, especially under complex dual-task conditions (149). Bucci et al. have recently reported that children with ADHD exhibit both poor PC and low-quality ocular fixation (150). There seems to be a two-way connection between the oculomotor and postural systems, since attention is known to affect the execution of eye movements as well as postural stability. Just as in children with ADHD, this connection may be modified due to deficits in attention and inhibitory control. (148).

Simona Caldani et al. and Maria Pia Bucci et al. have indicated that children with ADHD exhibit deficiencies in control of inhibitions and reduced postural stability, which are likely linked to disrupted top-down regulation caused by frontal-striatal dysfunction. Their findings also suggest that when children with ADHD, when individuals concentrate on a visual task, their postural control is compromised. (148).

Zang and Wang et al. examined the influence of sensory factors on postural abilities in children with ADHD (150,151). Both studies found significantly higher center of pressure (CoP) sway velocity in children with ADHD compared to controls, particularly under conditions such as standing with eyes closed or on a soft surface. These findings support the idea that balance control, a crucial sensorimotor function, may be impaired in children with ADHD. Additionally, these children showed poorer postural stability under both simple and dual-task conditions, supporting the notion that attention deficits disrupt PC (147). Interestingly, postural sway was found to decrease in dual-task conditions compared to single-task ones in both ADHD and control groups, suggesting that diverting attentional focus from postural control may improve its automatic execution (147). Moreover, a reduced cerebellar vermis, which plays a critical function in sensory processing and postural regulation, has been associated with ADHD (148), and evidence points to cerebellar dysfunction as a possible contributor to the postural instability seen in these children (150).

The mental effort required for PC depends on age, task complexity, and reflex functioning (94). Since postural control demands attentional engagement, children with ADHD may struggle to maintain upright posture. The cognitive demands and outcomes of performing balancing and attention-requiring tasks simultaneously differ from those of simply standing still. Performance variations are especially noticeable when individuals engage in more complex digit-span tasks compared to simpler versions (147).

ADHD begins in childhood and often carries over into adulthood. Adults with ADHD appear more prone to musculoskeletal injuries. Hove et al. recently observed increased body sway in adults with ADHD and linked these postural control deficits to reduced cerebellar gray matter volume. Previous research has also indicated that adults with ADHD show comparatively reduced cerebellar volumes (36,37).

3. METHOD

3.1. Participants:

In this study, we worked with healthy young volunteers (18–35-years) who had the potential to have ADHD. The study was conducted from February to May 2024 in the Yeditepe University Physiotherapy and Rehabilitation Department laboratory. The Marmara University Ethical Committee granted approval for the study protocol under application number “02”, as indicated in Appendix 1. Forty-two participants were selected for the research using the G*Power software. We notified all participants who met the inclusion criteria and asked them to sign an informed consent form after explaining the study and its purpose (Appendix 2). The Adult ADHD Self-Report Scale (ASRS) was distributed to the participants. (Appendix 3) to determine whether they had the potential to have ADHD According to the results, they were divided into two equal groups: ASRS>14 as group 1 (n=21) and 14>ASRS as group 2 (n=21).

Inclusion criteria:

- Volunteering and within the age range
- Experiencing no issues with balancing

Exclusion criteria:

- It has been six months since you had bodily harm
- Having any neurological disorder
- Using any medication that may affect our answers for the cognitive test.
- Having any injury at the time of the tests
- Having ankle sprain within the last 12 months
- Exercising regularly for the last 12 months

At baseline, all participants’ age, height (cm), weight (kg), body mass index (BMI), gender (female/male), and Medical History were asked by interview. The next step was for each group to complete two SART exams measuring cognitive abilities. In addition, a force plate was used to evaluate the participants' ability to maintain their balance (ProKin 252, Technobody, Italy) under three different stance conditions**:** (1) two-foot standing, (2) tandem stance, and (3) foam platform stance**.**

In each of these conditions, participants was tested under two visual conditions: eyes open and eyes closed. Additionally, each test was performed twice—once under a single-task condition (without a cognitive task) and once under a dual-task condition **(**simultaneously performing a cognitive task). The Tandem Condition (narrow support surface) is included to increase mechanical load**,** while the Foam Platform Condition (soft surface) is used to assess decreased proprioceptive sense**.** The dual-task conditions**,** applied across all stance and visual conditions, are designed to evaluate the impact of the cognitive task on postural control. Figure 3.1 presents the study's flowchart, outlining the experimental procedure.

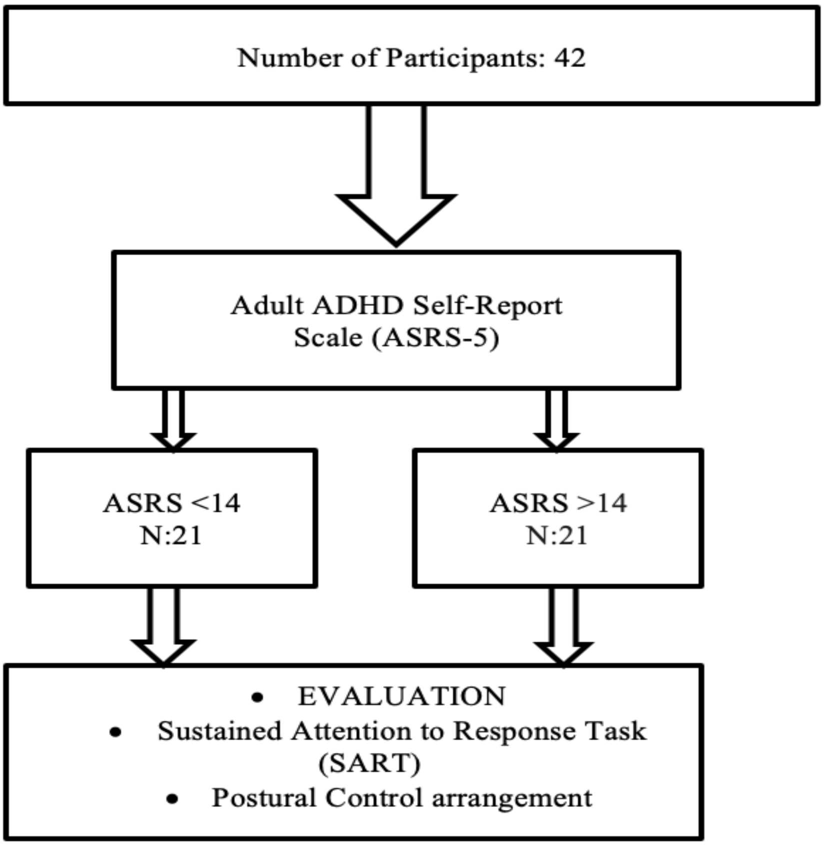

Figure 3.1. Study's Flow Chart

3.2. Evaluation Instruments:

3.2.1. Adult ADHD Screening Scale (ASRS-5):

The ASRS-5 is an ADHD screening tool aligned with the DSM-5 diagnostic criteria, introdused by the World Health Organization (WHO). This scale is a 5-point

Likert-type scale, consisting of 6 items, and underwent a validity study conducted by Üstün et al., which demonstrated strong psychometric properties (11). The original ASRS-5 exhibited a sensitivity of 91.4%, a specificity of 96%, and an area under the curve (AUC) value of 0.94. Correlations with clinical diagnoses were established in both population and clinical samples. Genç et al., translated and tested the Turkish version, confirming its reliability and validity (86). There is an appendix 4 with the Turkish version of the scale. Participants individually respond to the 6 questions, assigning scores in a 0-4 range, resulting in a total score ranging from 0-24. A score of 14 or higher suggests the possibility of ADHD.

3.2.2. Assessment of Postural Control: The Proprioceptive-Stabilometric Assessment

The ProKin 252 is a proprioceptive system used for static and dynamic balance assessment and training. The device displays several programs for balance evaluation and therapy. The "Static Stability Assessment Program" was used for this experiment to deliver thorough and accurate data for each participant while static standing on the stabilometry platform, with a sensor positioned on the trunk (152). Stabilometry enables the assessment of participants by measuring the oscillation of the CoP while static standing. The platform of the Prokin device will calculate the CoP sways of the participants, and the postural control data will be transferred to the computer screen.

The data that the system gives are as follows:

- Average Forward-Backward Velocity (mm/sec)
- Average Medium-Lateral Velocity (mm/sec)
- Perimeter (total covered distance of COP [mm])
- Ellipse area (total area, which is circumscribed by the COP [mm2]

Dual Task Procedure in Postural Control:

The assessment was done in two different conditions: two-foot standing position without stimulus (eyes open, eyes closed), and two-foot standing position with dual-task (eyes open, eyes closed). The dual-task procedure involves instructing participants to count down from 100 by 3. This method has been employed in multiple studies as a means of evaluating dual-task proficiency (153,154).

Evaluation will be done by following the steps below:

- After the assessment was explained to the participants, they were instructed to stand on the platform with bare feet in the opposite direction of the screen.
- Participants were requested to adjust their feet exactly to the reference points with a 10cm distance between feet, and their feet forming an angle of 15-30∘ degrees from the medial line to the lateral. Arms were relaxed on both sides, and the head looked forward in a neutral position.
- Throughout the assessment, participants were requested to hold their position while looking forward to a specific point for 30 seconds.
- In the eyes-open assessment, participants were requested to look at a marked point on the wall (Figure 3.3a).
- When the eyes are closed, the position of the feet remains the same as when the eyes are open, but only the eyes are closed. (Figure 3.3d)
- In the tandem position, participants placed their feet in front of each other on the center line of the platform (with the dominant foot in front), facing a marked point on the wall. They maintained the same position with eyes open (Figure 3.3b) and eyes closed (Figure 3.3e).
- Standing on the soft area, participants looked at a marked point on the wall. They maintained the same position with their eyes open (Figure 3.3c) and eyes closed (Figure 3.3f).
- All postural control assessments were performed with/without dual-task evaluations
- The dual-task process is achieved by asking the participant to count backward from 100 to 3.,
- All trails will be made in random order.
- For every condition, the assessments were carried out three times for 30 seconds. Then, the average of the three trials was recorded.
- Participants were requested to sit and rest for 1 minute between each assessment condition.
- All data were saved for later use.

- Figure 3.2 presents the study's flowchart, outlining the experimental procedure for evaluating postural control positions.

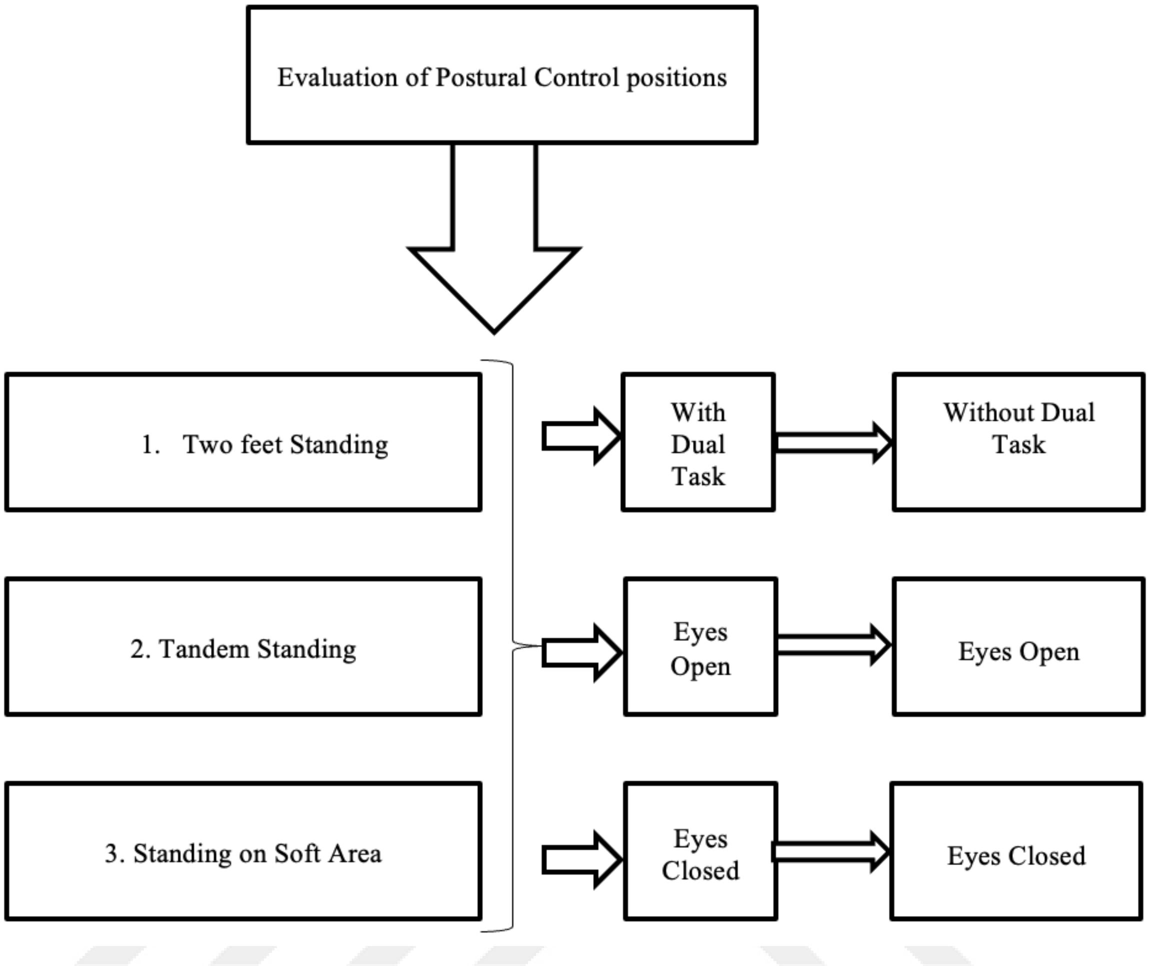

Figure 3.2. Study's Assessment Task of Postural Control

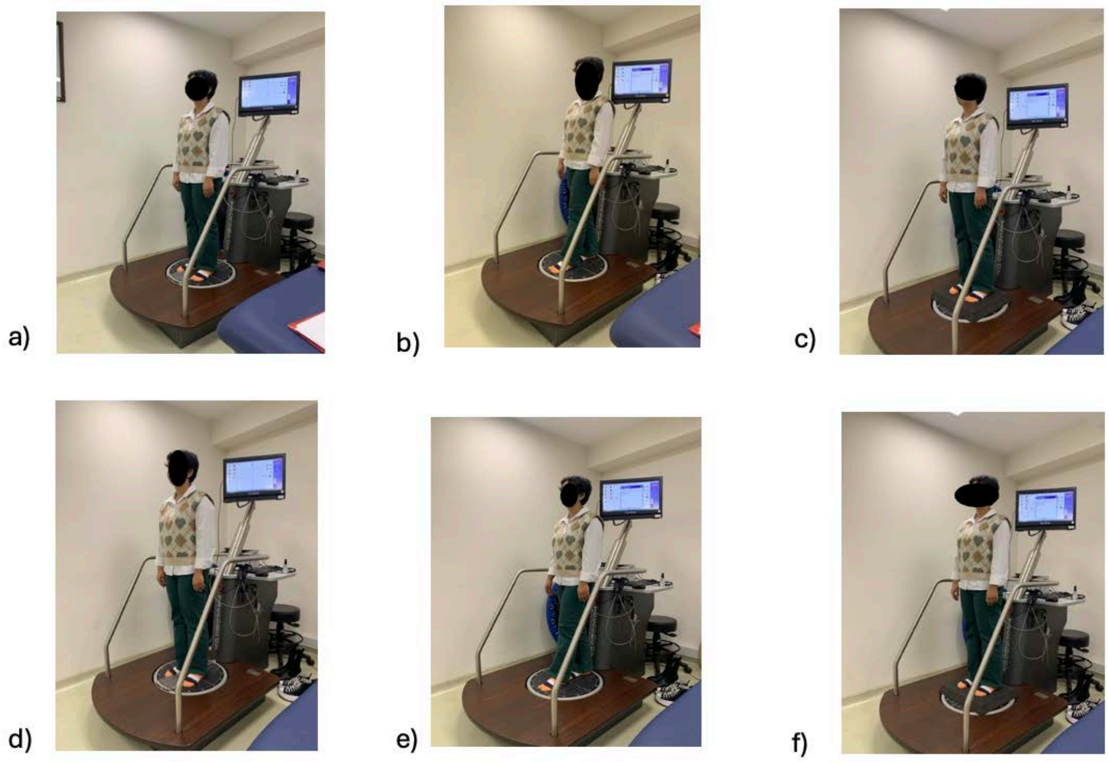

Figure 3.3. Standing With Two Feet Posture: Eyes Open (a), Eyes Closed (d), Tandem Position: Eyes Open (b), Eyes Closed (e), On The Soft Ground: Eyes Open (c), Eyes Closed (f)

3.2.3. Cognitive Test (SART):

The Sustained Attention to Response Task (SART) is a computer-based task where participants need to refrain from responding to a rare target (the digit 3) embedded within a series of more frequent non-targets (0-2, 4-9). It was designed by Robertson and colleagues in 1997 (155).

The test duration is approximately 5 minutes, and 225 single digits, including 25 of each of the nine digits, were displayed visually. For 250 milliseconds, each digit was displayed, followed by a 900-millisecond mask. Individuals were instructed to respond to each digit by pressing the space icon, with the exception of 25 times when the digit 3 appeared, which necessitated that they withhold their response. Key strikes were executed by participants using their favored hand. Throughout the 225 trials, the digit 3 was blindly interspersed.. The time between the onset of consecutive digits was 1150 milliseconds. Participants were directed to emphasize both precision and rapidity in executing the experiment. The numbers were presented in one of five randomly assigned font sizes to elevate the cognitive difficulties of understanding the numerical value instead of depending on a peripheral characteristic for selecting the no-response target. The numerals and masks were prominently shown in black on a white backdrop on the computer screen. (156). The test ran from the *PsyToolkit* website. Screenshot taken from the PsyTool website just before starting the Sart test. (Figure 3.5)

- The participant sits in front of the computer to perform the SART test.

- Before starting the test, information was given about how to perform the SART test correctly.

- The participant listens to and reads the instructions, then starts the pre-test trial by pressing the space button on the computer.

- After a short trial, the participant starts the real test.

- During the trial, participants need to press the space button for numbers 1, 2, 4, 5, 6, 7, 8, and 9, but they must NOT press the space button for number 3.

- The test takes around 5 minutes, and the participant performs 225 trials, where number 3 randomly appears.

- After the test is done, the score will be shown in front of the participant.

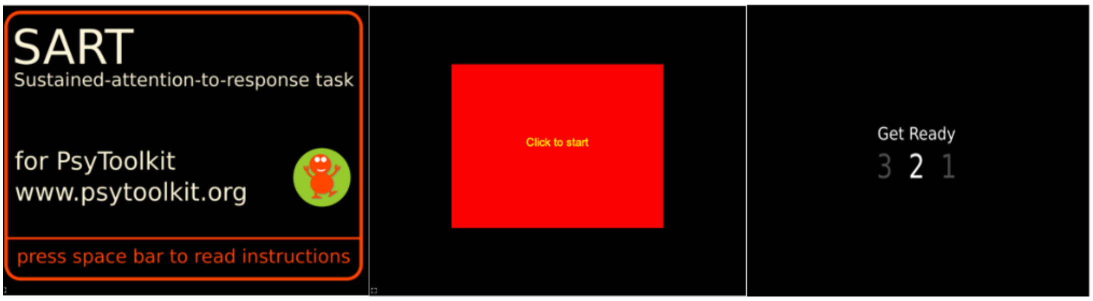

Figure 3.4. Screenshot Taken From The Psytool Website Just Before Starting The Sart Test, The Start Page of The Test When The Website is First Opened.

3.3. Statistic Analysis

Data were analyzed utilizing the statistical software IBM SPSS Statistics Standard Concurrent User V 26 (IBM Corp., Armonk, New York, USA). Descriptive statistics included the number of units (n), percentage (%), mean (X), standard deviation (SD), median (M), and interquartile range (IQR). During the judgment phase, if the absolute value of skewness is less than ±2.0 and the coefficient of kurtosis is below 7.0, it may be argued that the results are regularly distributed. (Kim, 2013). Variables included in the study were determined to be appropriate for normal distribution.

The numerical descriptive characteristics of the patients were compared across groups using an Independent Sample t-test. In contrast, Chi-square tests (Pearson chi-square/Fisher exact test) have been used to analyze the categorical descriptive features among groups.

This study compared factors according to follow-up periods using mixed-order analysis of variance (ANOVA). In the measurements, evaluations according to ADHD status (between groups) were analyzed by ANOVA, and intra-group differences (Task, Posture) were analyzed by repeated measures ANOVA. Bonferroni correction was applied for the comparison of main effects in the analyses. In η2 value, between 0.01 and 0.05 is considered as low effect size, between 0.06 and 0.013 as medium effect size, and 0.14 and above as large effect size. $p<0.05$ was considered statistically significant.

4. RESULTS

Table 4.1. shows the distribution of the descriptive characteristics of the participants according to the groups. A total of 42 participants, 21 in group 1(ASRS>14 group) and 21 in group 2 (14>ASRS group), took part in the study. The ADHD group had a median age of 22 years, whereas the 14>ASRS group had a median age of 24 years. Age, gender, body mass index, history of surgery, ear infection, sensory sensitivity, and physical activity characteristics were similar in the study groups (p>0.05). ASRS-5, total error, and ASRS>14 values were statistically higher in group 1 than in group 2 (p<0.05).

There were 11 (52.4%) people in group 1 and 3 (14.3%) people in group 2 who had medical problems, while statistically more patients in group 1 had problems (p<0.05). While there were 9 (42.9%) patients in group 1 and none in group 2 with chronic diseases, statistically, more patients in the group 1 had chronic diseases (p<0.05).

Table 4.1. Comparison of Participants' Descriptive Features by Groups (N=42)

	Group 1	Group 2	Test (*p*)
	n=21	*n*=21	
Age, (*year*)			
X ± *SS*	22.76 ± 3.25	24.38 ± 3.94	*t*=-1.451 *p*=0.155
M (*min-max*)	22 (20-33)	24 (19-33)	
ASRS-5			
X ± *SS*	16.95 ± 2.58	8.90 ± 2.90	***t*=9.510** ***p*<0.001**
M (*min-max*)	16 (14-22)	9 (4-14)	
Gender, *n* (*%*)			
Male	7 (%33.3)	10 (%47.6)	χ^2=0.889 *p*=0.346
Female	14 (%66.7)	11 (%52.4)	
Body Mass Index, (*kg/m*^{2})			
X ± *SS*	23.23 ± 4.91	24.61 ± 4.00	*t*=-0.999 *p*=0.324
M (*min-max*)	21.5 (18-35)	23.9 (19-34)	
Surgery history, *n* (*%*)			
No	20 (%95.2)	21 (%100)	χ^2=1.024 *p*=0.311
Yes	1 (%4.8)	0 (%0)	
Ear infection, *n* (*%*)			
Yok	20 (%95.2)	19 (%90.5)	χ^2=0.359 *p*=0.549
Var	1 (%4.8)	2 (%9.5)	

Sensory sensitivity, *n (%)*			
No	17 (%81)	18 (%85.7)	χ^2=0.171 *p*=0.679
Yes	4 (%19)	3 (%14.3)	
Physical activity, *n (%)*			
No	14 (%66.7)	13 (%61.9)	χ^2=0.104 *p*=0.747
Yes	7 (%33.3)	8 (%38.1)	

Chi-Square Test (χ2); Dependent Sample t Test (t); The following are the descriptive statistics: mean (X), standard deviation (SD), median (M), minimum (min), maximum (max), number (n), and percentage (%). Statistical significance is indicated by bolded sections (p<0.05).

Table 4.2 Group 1 had significantly lower mean values for total mistakes, Go Correct RT, and reaction time than group 2 (p<0.05). Both groups did not differ significantly regarding the No-Go Wrong RT or limit of stability metrics (p>0.05).

Table 4.2. Comparison of (SART Reports) Attention Measurements by Groups (N=42)

	Groups		Test (*p*)
	Group 1	Group 2	
	n=21	*n*=21	
Total Errors			
X ± SS	9.00 ± 4.35	4.62 ± 3.99	***t*=3.401 *p*=0.002**
M (*min-max*)	10 (1-17)	3 (0-15)	
No-Go Wrong RT (0,0)			
X ± SS	113.30 ± 53.30	127.58 ± 96.77	*t*=-0.592 *p*=0.557
M (*min-max*)	110.1 (6-186)	93.4 (0-361)	
Go Correct RT (1,1)			
X ± SS	184.39 ± 60.78	233.44 ± 84.20	***t*=-2.164 *p*=0.036**
M (*min-max*)	164.6 (93-304)	235.7 (88-371)	
RT Mean			
X ± SS	240.89 ± 61.66	289.35 ± 88.93	***t*=-2.052 *p*=0.047**
M (*min-max*)	223.9 (146-361)	292.9 (142-427)	
Limit of Stability			
X ± SS	83.94 ± 5.77	82.68 ± 15.81	*t*=0.344 *p*=0.733
M (*min-max*)	84.6 (67-91)	87 (18-95)	

"RT" stands for "Reaction Time." The independent sample t test (t) is performed. Mean (X), standard deviation (SD), median (M), minimum (min), and maximum (max) values are provided as descriptive statistics. Statistical significance is indicated by the bolded sections (p<0.05).

In Table 4.3. indicates no statistically significant difference in A-P velocity assessment taken with eyes closed in group 1 and group 2 in normal and dual task conditions ($p>0.05$). A-P velocity measurements on soft surfaces were statistically elevated compared to those on other circumstances, but A-P velocity measurements in a two-foot standing position were significantly diminished relative to other situations ($p<0.05$). No statistically significant difference was seen in A-P velocity measurements with eyes open between group 1 and group 2 under normal and dual task circumstances during tandem standing and soft surface standing postures ($p>0.05$).

The findings indicated no statistically significant change in A-P velocity measurements between the normal and dual task circumstances during two-foot standing postures with eyes open in group 2 ($p>0.05$). In group 1, A-P velocity measurements with eyes open were significantly lower in the normal task condition compared to the dual task condition when standing on two feet ($p<0.05$). In groups 1 and 2, A-P velocity measurements obtained in the two-foot standing posture with eyes open were significantly lower than those recorded under other circumstances ($p<0.05$).

In Table 4.4. in both eyes closed and eyes open conditions, there were no statistically significant differences in M-L velocity between group 1 and group 2 groups in any of the posture or task conditions ($p > 0.05$). However, there were significant diffrence in sway velocity across different postural surfaces and task conditions within each group **(**$p<0,001$).

Table 4.3. Evaluation of A-P Velocity Data Within and Between Groups

		Groups		
		Group1	Group 2	Between-group comparison
		n=21	*n*=21	P, η2
A-P Velocity (Eyes Closed)				
Two Feet Standing	Normal Task	9.57 ± 2.87 C	10.81 ± 2.68 C	p=0.156 η2=0.050
	Dual Task	11.48 ± 5.07 C	11.43 ± 3.03 C	p=0.971 η2=0.001
Tandem Standding	Normal Task	21.78 ± 7.08 B	19.60 ± 4.90 B	p=0.254 η2=0.032
	Dual Task	21.51 ± 9.09 B	19.40 ± 6.36 B	p=0.389 η2=0.019
Standing on Soft Surface	Normal Task	26.87 ± 7.78 A	28.38 ± 6.95 A	p=0.511 η2=0.011
	Dual Task	27.43 ± 9.16 A	26.21 ± 6.01 A	p=0.612 η2=0.006
Test Statistics ϕ		**p<0.001 η2=0.871**	**p<0.001 η2=0.844**	
A-P Velocity (Eyes Open)				
Two Feet Standing	Normal Task	6.92 ± 1.26 C	7.43 ± 1.73 BC	p=0.283 η2=0.029
	Dual Task	10.67 ± 6.59 B	8.94 ± 2.12 B	p=0.259 η2=0.032
Tandem Standding	Normal Task	14.59 ± 4.24 A	14.03 ± 2.71 A	p=0.616 η2=0.006
	Dual Task	16.70 ± 8.87 A	14.13 ± 2.65 A	p=0.211 η2=0.039
Standing on Soft Surface	Normal Task	13.67 ± 2.62 A	15.03 ± 5.89 A	p=0.338 η2=0.023
	Dual Task	15.83 ± 6.31 A	15.14 ± 4.05 A	p=0.679 η2=0.004
Test Statistics ϕ		**p<0.001 η2=0.793**	**p<0.001 η2=0.763**	

Effect size (η^2), ϕ Intragroup comparison, Descriptive statistics are presented as mean (X) and standard deviation (SD). Highlighted areas are statistically significant ($p<0.05$). A>B>C: The disparities among distinct letters in the same row or column are statistically significant (Bonferroni $p<0.05$).

Table 4.4. Intra-Group and Inter-Group Evaluation of M-L Velocity Measurements

		Groups		
		Group 1	Group 2	Between-group comparison
		n=21	*n*=21	P, η2
M-L velocity (Eyes Closed)				
Two Feet Standing	Normal Task	5.38 ± 1.72 D	5.70 ± 1.98 D	p=0.582 η2=0.008
	Dual Task	5.90 ± 2.42 D	5.81 ± 1.97 D	p=0.890 η2=0.001
Tandem Standding	Normal Task	18.84 ± 4.94 A	16.65 ± 3.31 AB	p=0.099 η2=0.066
	Dual Task	18.73 ± 5.74 A	16.51 ± 4.80 AB	p=0.181 η2=0.044
Standing on Soft Surface	Normal Task	14.67 ± 4.14 BC	16.48 ± 5.28 B	p=0.223 η2=0.037
	Dual Task	14.71 ± 5.79 BC	14.21 ± 4.34 C	p=0.749 η2=0.003
Test Statistics ϕ		**p<0.001 η2=0.908**	**p<0.001 η2=0.874**	
M-L Velocity (Eyes Open)				
Two Feet Standing	Normal Task	4.81 ± 1.68 C	4.54 ± 1.50 C	p=0.586 η2=0.007
	Dual Task	5.37 ± 1.79 C	4.81 ± 1.31 C	p=0.259 η2=0.032
Tandem Standding	Normal Task	11.02 ± 3.29 AB	10.29 ± 2.29 AB	p=0.409 η2=0.017
	Dual Task	12.56 ± 3.86 A	11.00 ± 1.97 A	p=0.108 η2=0.063
Standing on Soft Surface	Normal Task	9.63 ± 2.33 B	9.68 ± 2.59 AB	p=0.950 η2=0.001
	Dual Task	9.59 ± 3.00 B	8.67 ± 2.12 B	p=0.257 η2=0.032
Test Statistics ϕ		**p<0.001 η2=0.812**	**p<0.001 η2=0.787**	

ϕ, effect size, (η2) comparison of two groups, Descriptive statistics are represented as the mean (X) and standard deviation (SD). Statistical significance is indicated by bolded sections (p<0.05). A>B>C>D: The Bonferroni test indicates that there are significant differences between letters in the same row or column (p<0.05).

Table 4.5. On both normal and dual task situations with closed eyes, the Ellipse Area was significantly higher in group 1 while they were in the Tandem posture (p=0.040 and p=0.020, respectively). In the eyes-open condition, the group 1 group also showed significantly higher sway area in the two feet standing position under dual task (p=0.048) and in the Tandem stance under dual task (p=0.047). Other comparisons did not show

significant group differences (p > 0.05). There were significant differences in the ellipse area across different postural surfaces and task conditions within each group **(**p<0,001).

Table 4.5. Intra-group and Inter-group Evaluation of Ellipse Area Measurements

		Grup		
		Group 1	Group 2	Between-group comparison
		n=21	*n*=21	P, η2
Eilipse Area (Eyes Closed)				
Two Feet Standing	Normal Task	283.52 ± 228.44 D	211.48 ± 105.46 D	p=0.197 η2=0.041
	Dual Task	307.08 ± 338.14 D	233.19 ± 137.19 D	p=0.359 η2=0.021
Tandem Standding	Normal Task	1041.22 ± 678.33 B	745.49 ± 329.07 C	**p=0.040 η2=0.077**
	Dual Task	888.81 ± 724.29 B	493.19 ± 180.39 D	**p=0.020 η2=0.129**
Standing on Soft Surface	Normal Task	1558.87 ± 1025.99 A	1525.57 ± 570.20 A	p=0.897 η2=0.001
	Dual Task	1453.79 ± 1470.97 AB	1172.65 ± 482.69 BC	p=0.410 η2=0.017
Test Statistics ϕ		**p<0.001 η2=0.706**	**p<0.001 η2=0.720**	
Eilipse Area (Eyes Open)				
Two Feet Standing	Normal Task	191.51 ± 163.32 D	162.40 ± 77.93 D	p=0.465 η2=0.013
	Dual Task	300.78 ± 327.60 C	167.68 ± 82.10 D	**p=0.048 η2=0.075**
Tandem Standding	Normal Task	515.02 ± 285.15 AB	406.30 ± 140.83 BC	p=0.125 η2=0.058
	Dual Task	573.06 ± 792.36 AB	329.38 ± 106.42 CD	**p=0.047 η2=0.074**
Standing on Soft Surface	Normal Task	681.49 ± 381.30 A	612.57 ± 315.32 A	p=0.527 η2=0.010
	Dual Task	734.49 ± 827.24 A	532.51 ± 229.22 AB	p=0.287 η2=0.028
Test Statistics ϕ		**p<0.001 η2=0.709**	**p<0.001 η2=0.617**	

Number of effects (η2), ϕ comparing different groups. The mean (X) and standard deviation (SD) are the two main pieces of descriptive statistics. The bolded parts show statistical significance (p<0.05). If there are substantial differences between letters in the same row or column, then A>B>C>D (Bonferroni p<0.05)

5. DISCUSSION

This research aimed to determine whether there was a connection between postural control and sustained attention in people with pADHDt. To address this aim, we implemented a series of sensorimotor perturbations, including the presence or absence of visual stimuli and the alteration of proprioceptive input through the use of a soft surface under the feet. Furthermore, we assessed postural responses under physically demanding tasks and dual-task conditions in order to better understand how attentional influences balance performance in this population. Participants who scored above 14 on the ASRS-5 were classified as individuals with pADHDt, reflecting subclinical levels of inattention and/or hyperactivity-impulsivity.

SART is a task that assesses individuals' ability to sustain attention. In this task, participants are expected to respond to certain stimuli and withhold responses to others. Individuals with pADHDt tend to make more errors on this task. In particular, they often exhibit elevated rates of commission errors—responding to stimuli when they should not—and omission errors—failing to respond when they should. These patterns are typically interpreted as behavioral markers of attentional lapses and impulsivity. Gau (2022) found that adult persons with ADHD traits committed considerably more mistakes on the SART, especially in connection with increased mind-wandering and cognitive interference during task execution (157). Similarly**,** Thomson (2020) found that children and adolescents with ADHD showed elevated omission error rates and response time variability across longitudinal assessments, highlighting the persistent nature of sustained attention difficulties in this population (158). The pADHDt group exhibited significantly poorer performance on the sustained attention test, as shown by increased commission and omission errors and prolonged reaction times. These findings are consistent with previous research suggesting that individuals with potential ADHD who are frequently show impairments in sustained attention and inhibitory control (121,122). Originally demonstrated that ADHD participants make more errors and exhibit greater response variability in SART, patterns echoed by Dockree (2009), who linked such deficits to impulsivity and executive dysfunction. More recently, Machida (2022). confirmed that SART-based metrics—including commission and omission errors and reaction time variability—can serve as reliable indicators in ADHD from non-ADHD individuals(159,160). These patterns were also observed in the current study, supporting the robustness of SART as a tool for detecting attentional control limitations in ADHD.

However, not all studies have found consistent results. Chan (2001) reported no significant differences in SART performance between ADHD and control groups (118).

Postural control involves complex regulation and should not be considered in the same way as balance assessment. Postural control involves biomechanics, motor coordination, and sensory organization. In the sensory organization part, there is flexibility in the somatosensory, visual, and vestibular senses to function in place of each other as needed. The present study is the first to examine static postural stability across multiple conditions and under added cognitive challenges in adults with pADHDt, comparing them to typically developing adults. The existing literature on this topic is limited, and most prior research has focused on children.

In the study, both groups showed a similar pattern of change within themselves. When ranked by the most significant changes within each group based on anterior-posterior (A-P) sway, the order was soft ground, tandem stance, and two-foot upright stance. In contrast, medio-lateral (M-L) sway velocities showed a different ranking from A-P sway velocities within both groups. Both groups showed a similar pattern, with M-L sway velocities differing significantly in the following order: tandem stance, soft ground, and two-foot upright stance. The results of M-L and A-P velocities indicated no significant differences between individuals with pADHDt and normally developing individuals in both eyes-open and eyes-closed postures under normal and dual task situations. The existing literature on sway velocity is limited, with only one relevant study identified in adults by Jansen (2019), who reported that adults with ADHD exhibited higher spontaneous sway amplitude and velocity than healthy controls (37).

However, studies on children were more numerous, as some studies in the literature also report findings consistent with our results. They demonstrated increased body sway velocity in children with ADHD. Starting with Bucci (2016), who found that children with ADHD exhibit higher mean sway velocities than controls under both stable and unstable surfaces, improving performance after methylphenidate treatment (161). Further support comes from Caldani (2019), who observed increased CoP mean velocity in children with ADHD, particularly under dual-task and unstable platform conditions. Based on these results, they suggest that this finding highlights the role of frontal-striatal dysfunction in reduced attentional flexibility (148). However, some studies have reported compensatory or paradoxical effects. Shorer (2012) and Bucci (2014) noted that dual-task conditions could sometimes reduce sway in ADHD groups, possibly due to the activation of more automatic control processes when attention is shifted away from posture (147,150).

When examining the CoP area within groups, both groups showed significant changes within themselves in both open-eye and closed-eye conditions (the largest areas were, in order: soft ground, tandem stance, and two-foot upright stance). Regarding the CoP area with eyes open, the dual task significantly increased the CoP area in the pADHDt in the upright stance; that is, no significant difference was found in the group considered normal, as in this group, the dual task significantly reduced the CoP area. In the eyes closed condition, In the normal group, CoP area decreased significantly in both tandem stance and soft surface dual task conditions, while no difference was found between tasks in the pADHDt.

When comparing the pADHDt group to the control group, statistically significant differences were seen. Under eyes-open condition, the potential ADHD group exhibited a significantly larger CoP area during the dual-task in both the two-foot and tandem stances compared to the normal group. In contrast, under the eyes-closed condition, the potential ADHD participants showed a significant increase in CoP area only in the tandem stance, in both the normal and dual-task conditions.

The same literature limitation has been faced regarding the sway area difference between possible ADHD traits and normal adults. The previously mentioned Jansen (2019) study also showed larger body sway in adult ADHD compared to normal (37). Hove (2015) compared adults with ADHD with normal people by testing their postural stability in four conditions: eyes open, feet shoulder-width apart; eyes closed, feet shoulder-width apart; eyes open, feet together; and eyes open, feet apart, barefoot. The results showed that the ADHD group was far more swayed than the healthy control group. The two situations having the most significant sway were noted under (eyes-open/feet-together and eyes-closed/feet-apart). Our study also showed that potential ADHD group had larger area but didn't reach to the significant level until it combined with dual task in eyes open. Rather than feet apart, we did tandem stand and also showed larger area in the pADHDt but reached to the significant level in eyes closed condition only. Hove (2015) suggested that this significant increase in sway observed in adults with ADHD is attributable to impairments associated with reduced cerebellar grey matter volume (36).

Studies on children also showed some differences in different conditions and challenges. This research aimed to determine whether there was a connection between postural control and sustained attention in people with pADHDt. Bucci (2016) measured the CoP region on both stable and unstable platforms under three visual conditions: eyes open and fixated on a target, eyes closed, and eyes open with disrupted vision (dual task) (161). They demonstrated that children with ADHD have deficient postural control, which deteriorates in dynamic settings and when visual information is disrupted, as the CoP surface area was consistently significantly larger than in controls. Similar testing conditions were done in a study by Caldani (2019), which showed that individuals with ADHD have worse postural stability when tested on the unstable platform, both with and without a dual task, in comparison to typically developing children (148). These results support ours, as we also found that tandem stance (unstable) and dual task (verbal cognitive challenge) worsened postural stability in our adult participants with pADHDt when compared with normal. Bucci (2014) tested children CoP area with ADHD (both on and off methylphenidate medication) vs. control children in different eye movements: fixation, pursuits, pro-/anti-saccades affects postural sway (CoP surface and mean velocity). The results showed that ADHD children without medication had significantly worse postural stability (larger CoP surface) than controls and ADHD children on methylphenidate showed postural sway similar to controls (150). Shorer (2012) compared M-L, A-P, and total area of ADHD people with normal children in eyes open with and without an auditory-memory-demanding task. The normal eyes open postural stability test without any extra tasks showed only that M-L sway is larger significantly, while with the demanding task both M-L and A-P sway areas were larger significantly in the ADHD group. Similarly to our study, within group changes showed that the normal group changes showed a significant decrease in the M-L, A-P and total sway area with the demanding task in comparison to without while the changes in ADHD group were not significant except the M-L sway decreased with the cognitive demand (147). Yuanchun (2014) compared standing balance and sensory information processing among children with ADHD subtypes and normally developing children. Postural control was tested under six sensory conditions to assess the effects of visual, vestibular, and proprioceptive inputs. The results showed that ADHD boys had generally weaker balance, poorer static postural control, and impaired processing of visual and vestibular information compared to controls (162). In the study the variables revealed that participants with the pADHDt exhibited greater changes under challenging conditions, differently during dual-task paradigms with eyes open and eyes closed.

Maintaining upright posture is not a purely automatic process; rather, it requires attentional resources. This demand for attention in regulating postural sway becomes particularly evident when an individual performs a concurrent secondary task. The literature has shown that the direction of attention affects motor performance (25,163). In this study, backward counting was used as a verbal dual task as a cognitive load. The verbal dual task used diverted attention away from the physical task being performed. The literature discusses two approaches to how the direction of attention and cognitive control affect performance. These are the Reinvestment Theory and the Constrained Action Hypothesis (25,163). Both approaches emphasize the negative effects of conscious attention and control on motor performance (25,163). Based on this information, it was expected that postural stability would be better in the verbal backward counting dual task because conscious attention was focused on the cognitive task. However, in the current study, it was observed that the dual task did not improve motor performance by diverting attention away from the motor task in individuals with the pADHDt. In other words, the pADHDt, participants had difficulty directing their attention outward. These observations align with prior theoretical frameworks, as suggested by Masters (1992), Wulf (2001), and Seidler (2010), which emphasize that while external attentional focus or dual-task conditions typically enhance automatic motor control, individuals with the pADHDt may struggle to effectively redirect their attention, limiting the expected performance benefits under such conditions (25,163,164). Previously mentioned studies with children with ADHD have supported these theories.

Moreover, the interaction between cognition and postural regulation is influenced by several factors, including age, individual differences in sensorimotor functions, the complexity of the postural task, and the type of the cognitive task. Individual differences in cognitive functioning, such as the presence of attentional deficits, Individuals with ADHD or pADHDt may struggle more in dual-task conditions, as their capacity to allocate attention flexibly between motor and cognitive tasks is often impaired or more limited (157,158,165). Neuroscientific evidence suggests that postural control is not solely dependent on peripheral sensory and muscular systems but also involves higher-order cortical regions responsible for integrating spatial representations of the body. In individuals with ADHD, several studies have identified cerebellar abnormalities as a key contributor to impaired motor function. Relative to controls, decreased cerebellar volume has been observed in individuals with ADHD, including children, adolescents, and adults (166–169).

Given the seemingly paradoxical pattern of findings in the literature and the absence of studies focused on adults with ADHD, the motivation of this study was to better understand how concurrent cognitive processing affects postural control in adults with attentional problems. In our current study, sway velocity changes did not show significant differences between the control group and participants with pADHDt across all conditions. However, the pADHDt group exhibited slightly greater, though not statistically significant, A-P sway velocity under dual-task conditions compared to single-task conditions during the eyes-open stance. The sway area in the pADHDt group was significantly larger under dual-task conditions, particularly in the tandem stance. More specifically, during the eyes-closed condition, the pADHDt group had a larger sway area in the tandem stance (both with and without the dual task) compared to the control group. Within-group comparisons revealed that in the control group, CoP area significantly decreased in both the tandem stance and soft surface conditions during dual-task performance. However, in the pADHDt group, there was no significant difference between single and dual-task conditions. During the eyes-open condition, the sway area was significantly higher in the pADHDt group under dual-task conditions, both in two-feet standing and tandem stance, compared to the control group. Within-group analysis showed that dual-tasking significantly increased the CoP area in the upright stance for the pADHDt group. In contrast, the control group showed a significant decrease in CoP area under dual-task conditions. The expected benefit of automatic motor control through externally directed attention—often seen in typical individuals—was not observed in the pADHDt group. These results support the view that attentional deficits in ADHD impair the coordination of motor and cognitive demands, reinforcing previous theoretical frameworks. They also highlight the need for further ADHD-specific research on postural control under cognitive load. The inability of the pADHDt group to meet increased attentional demands likely reflects impairments in executive control and reduced automaticity, as previously described in ADHD (170,171). The difficulties in sustained attention and inhibitory control observed in the pADHDt group were accompanied by increased postural instability during dual-task conditions, suggesting that the extra cognitive load imposed by the dual-task interfered with their ability to maintain balance.

It is likely that trying to handle both the cognitive task and postural control simultaneously exceeded their available attentional resources, resulting in less efficient motor coordination (94,111). These findings underline the importance of integrated interventions that incorporate dual-task balance training, aiming to improve both postural control and attentional flexibility in everyday life.

This study possesses various limitations that must be considered when interpreting the results. First, participants were categorized based on the pADHDt using a self-report screening tool, rather than through formal clinical diagnosis. While such screening tools are useful for identifying probable cases, they do not replace detailed clinical assessments and may introduce variability in how ADHD-related traits are represented. Because we don't have direct contact with the Clinic to take participants who have an official diagnosis of ADHD. Second, the study's cognitive load was introduced through a single type of dual-task (verbal backward counting). However, different types of secondary tasks, such as visual or motor tasks, might affect postural control in unique ways. Exploring various dual-task conditions in future research could offer a more comprehensive understanding of attentional demands. Finally, while this research contributes valuable data on adults with the pADHDt—a group less frequently studied than children—the limited availability of comparable adult studies makes it difficult to place these results fully within the existing research landscape. Continued research in adult populations is needed to build a more complete picture.

6. CONCLUSION

- The individuals with the pADHDt have difficulty directing their attention.
- The positive effect of dual task, consciously directing attention elsewhere, was not observed in the pADHDt participants.
- The participants with the pADHDt were not affected by verbal stimuli or difficult postural tasks while directing their attention elsewhere.
- This study provides initial evidence that adults with pADHDt experience increased postural instability under cognitive load, highlighting the interaction between attention and motor control.
- These findings underscore the need for further research on postural regulation in adult ADHD populations.

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8. APPENDICES

8.1.Appendix 1. Ethical Approval Document

T.C.
MARMARA ÜNİVERSİTESİ
Sağlık Bilimleri Fakültesi
Girişimsel Olmayan Klinik Çalışmalar Etik Kurulu

PROJENİN ADI	: "Dikkatin Postüral Kontrol Üzerindeki Etkisi"
PROJENİN YÜRÜTÜCÜSÜ	: Dr. Öğr. Üyesi Çiğdem YAZICI MUTLU
PROJEDEKİ ARAŞTIRICILAR	: Can SEÇİNTİ
ONAY TARİHİ VE SAYISI	: 25.01.2024/02

Sayın: Dr. Öğr. Üyesi Çiğdem YAZICI MUTLU

"02" protokol numaralı "Dikkatin Postüral Kontrol Üzerindeki Etkisi" İsimli projeniz Fakültemiz Etik Kurulu tarafından incelenmiş oy birliği ile etik yönden uygun olduğuna karar verilmiştir.

Marmara Üniversitesi Sağlık Bilimleri Fakültesi 34854 Başıbüyük/Maltepe /İSTANBUL
0 (216) 399 62 42 (Faks)
0 (216) 777 57 86
Ayrıntılı bilgi için: Melek KARADAĞ AKYOL
sbfetikkurul@gmail.com
http://sbf.marmara.edu.tr

8.2.Appendıx 2. Consent Form

BİLGİLENDİRİLMİŞ ONAM FORMU

Araştırmanın Adı: Dikkatin Postüral Kontrol Üzerindeki Etkisi

Sayın Katılımcı,

Yukarıda adı yazılı araştırmaya katılmak üzere davet edilmiş bulunmaktasınız. Bu araştırmada yer almayı kabul etmeden önce, araştırmanın ne amaçla yapılmak istendiğini anlamanız ve bu bilgilendirme sonucunda kararınızı vermeniz gerekmektedir. Aşağıdaki bilgileri lütfen dikkatlice okuyunuz, sorularınız olursa sorunuz ve açık yanıtlar isteyiniz.

Bu araştırma ile Dikkatin Postüral Kontrol Üzerindeki Etkisinin ölçülmesi amaçlanmıştır. Bu araştırma, Bu araştırma, ASRS (Erişkin DEHB Öz Bildirim Tarama Ölçeği) testinden 14 puan üstü ve altında alan kişilerde, farklı duyusal girdiler ve ikili görevdeki durumunda postüral kontrollerindeki değişimin belirlenmesine olanak sağlayacaktır. Araştırma için Yeditepe Üniversitesinden izin alınmıştır. Postüral Kontrollerinin değerlendirilmesi, üç farklı koşulda (fiziksel yük, duyusal yük ve bilişsel yük) bir güç platformu (ProKin 252, technobody, İtalya) kullanılarak gerçekleştirilecektir: Birinci test ayakta dik duruş pozisyonunda (gözler açık, gözler kapalı) ve ayrıca ikili görev eklenerek, ikinci test; Tandem pozisyonu (gözler açık, gözler kapalı) ve ayrıca ikili görev eklenerek ve üçüncü test; yumuşak zemin (gözler açık, gözler kapalı) ve ayrıca ikili görev ile birlikte. Buna ek olarak, sürekli dikkati ölçmek için PsyToolkit web sitesinde Tepkiye Sürekli Dikkat Görevi (SART) testi uygulanacaktır. **Bu işlem yaklaşık 60 dakikanızı alacaktır. Bunun size ve yakınlarınıza hiçbir zararı olmayacaktır. Çalışmaya katılmakla parasal yük altına girmeyeceksiniz ve size de herhangi bir ödeme yapılmayacaktır. Bu araştırmaya katılıp katılmamakta tümüyle özgürsünüz. Gerek duyduğunuz tüm bilgileri istemeye ve doğru, açık, anlaşılır bilgi almaya hakkınız vardır. Araştırmaya katılmayı istemezseniz burada size verilen hizmet olumlu veya olumsuz şekilde etkilenmeyecektir. Gerekli gördüğü takdirde araştırmanın herhangi bir kısmında katılımcı araştırmadan çıkabilir, araştırmacı çalışmayı sonlandırabilir. Araştırmanın tüm aşamalarında kimlik bilgileriniz gizli tutulacaktır. Araştırma kapsamında elde edilen bilgiler bilimsel amaçlarla kullanılabilir gizlilik kurallarına uyulmak kaydıyla sunulabilir ve yayınlanabilir.**

Araştırma ile ilgili daha fazla bilgiye ihtiyaç duyarsanız araştırmacıya e-posta adresi veya numaralı telefondan ulaşabilirsiniz.

Yukarıda yer alan ve araştırmaya başlanmadan önce katılımcılara verilmesi gereken bilgileri içeren metni okudum (ya da sözlü olarak dinledim). Araştırma kapsamında elde edilen şahsıma ait bilgilerin bilimsel amaçlarla kullanılmasını, gizlilik kurallarına uyulmak kaydıyla sunulmasını ve yayınlanmasını, hiçbir baskı ve zorlama altında kalmaksızın, kendi özgür irademle kabul ettiğimi beyan ederim

İmza/Tarih	**İmza/Tarih**
Katılımcının adı soyadı	**Sorumlu Araştırmacının adı soyadı**

8.3.Appendix 3. Adult Adhd Self-Report Screening Scale For DSM-5 (ASRS-5)

DSM 5 için Erişkin DEHB Öz Bildirim Tarama Ölçeği (ASRS-5)

from Composite International Diagnostic Interview 5.0 (CIDI-5.0)

Tarih

Son 6 ay içerisinde nasıl hissettiğinizi ve davrandığınızı en iyi tanımlayan seçeneği işaretleyiniz. Lütfen tamamlanmış anketi bir sonraki randevunuzda sağlık çalışanınıza teslim ediniz ve sonuçları tartışınız.	Hiçbir zaman	Nadiren	Bazen	Sıklıkla	Çok sık
1. Doğrudan sizinle konuşuyor olsalar bile, insanların söylediklerine odaklanmakta ne sıklıkla güçlük çekersiniz?					
2. Toplantılarda veya yerinizden kalkmamanız beklenen diğer durumlarda ne sıklıkla yerinizden kalkarsınız?					
3. Kendinize zaman ayırdığınızda gevşemekte ve rahatlamakta ne sıklıkla güçlük çekersiniz?					
4. Sohbet esnasında kendinizi, ne sıklıkla karşınızdaki kişiler sözünü bitiremeden onların cümlesini tamamlarken bulursunuz?					
5. İşleri ne sıklıkla son dakikaya kadar ertelersiniz?					
6. Yaşamınızı düzende tutmaları ve detaylarla ilgilenmeleri için ne sıklıkla başkalarına ihtiyaç duyarsınız?					

9. CURRICULUM VITAE

Kişisel Bilgiler

Adı	Can	**Soyadı**	Seçinti
Doğum Yeri		**Doğum Tarihi**	
Uyruğu		**TC Kimlik No**	
E-mail		**Tel**	

Öğrenim Durumu

Derece	**Alan**	**Mezun Olduğu Kurumun Adı**	**Mezuniyet Yılı**
Doktora			
Yüksek Lisans		**Yeditepe University**	
Lisans		**Semmelweis University**	
Lise	-		

Başarılmış birden fazla sınav varsa(KPDS, ÜDS, TOEFL; EELTS vs), tüm sonuçlar yazılmalıdır

Bildiği Yabancı Dilleri	**Yabancı Dil Sınav Notu (#)**

İş Deneyimi (Sondan geçmişe doğru sıralayın)

Görevi	**4.1.1. Kurum**	**Süre (Yıl - Yıl)**
		-
		-

Bilgisayar Bilgisi

Program	**Kullanma becerisi**

***Çok iyi, iyi, orta, zayıf olarak değerlendirin**

Bilimsel Çalışmaları

SCI, SSCI, AHCI indekslerine giren dergilerde yayınlanan makaleler

Diğer dergilerde yayınlanan makaleler

Uluslararası bilimsel toplantılarda sunulan ve bildiri kitabında (*Proceedings*) basılan bildiriler

Hakemli konferans/sempozyumların bildiri kitaplarında yer alan yayınlar

Diğer (Görev Aldığı Projeler/Sertifikaları/Ödülleri)
