Chapter 10

Balance and Physical Activity in Children with Neurodevelopmental Disorders

Büşra Candiri[1]

Amine Nur Arıkan[2]

Sanem Can Çolak[3]

Abstract

Neurodevelopmental disorder is a disorder that occurs in different ways and is diagnosed in childhood involving central nervous system abnormalities. Neurodevelopmental disorder can be explained in children with autism spectrum disorder down, intellectual disability, learning disability, attention deficit hyperactivity disorder (ADHD), cerebral palsy. Children with neurodevelopmental disorder can be affected in many dimensions developmentally, experientially and environmentally. It is known that children show special conditions in various subjects from their peers due to their physical, mental, social development and brain activities being affected. It is revealed that these special conditions affect peer relations in children's social lives, cognitive issues such as problem solving, analytical thinking, language development issues such as understanding and expression, as well as the child's balance and physical activity. By processing the information coming from visual, vestibular and proprioceptive systems together, the symptoms and characteristics of physical activities in body movements with the energy available by using the muscles in the balance and skeletal system are determined to a great extent. The characteristics of children with neurodevelopmental disorders, their assessment, the balance context and the level of physical activity are described.

1 Research Assistant, PHD, Inonu University, Faculty of Health Sciences, Department of Physiotherapy and Rehabilitation, candiri_17@hotmail.com , 0000-0001-7413-6371

2 Research Assistant, Inonu University, Faculty of Health Sciences, Department of Child Development, arkan.amine@gmail.com , nur.arikan@inonu.edu.tr , 0000-0001-6360-2357

3 Research Assistant, Inonu University, Faculty of Health Sciences, Department of Audiology, sanemcan.colak@inonu.edu.tr, 0000-0002-7566-7964

https://doi.org/10.58830/ozgur.pub305.c1255

Children with Neurodevelopmental Disorders

Neurodevelopmental disorders are a broad category of disorders that involve some form of central nervous system abnormality [1]. Neurodevelopmental disorders occur in a certain period according to any age range and developmental areas of children. These disorders greatly affect children's social emotional development as well as physical development motor movements, physical activity and balance. Neurodevelopmental disorders are a special needs group that explains cognitive, physical development in a complex and broad dimension that interferes with children's lives and thus interferes with professional and academic skills [2].

The term neurodevelopmental disorder is frequently used to describe a brain-based phenomenon that occurs in childhood and is associated with functional impairments. While the term neurodevelopmental disorder is generally used in health and medical issues and models, the term neurodevelopmental disability is mostly preferred in social studies and social fields [3].

Neurodevelopmental disorders are also referred to as a special needs condition that causes a variety of complex symptoms in the body whose symptoms are related to brain development that cause children to experience intellectual, cognitive, communication, behavioural and psychomotor deficits [4]. However, despite this, there are many diagnostic confusions in the field.

Attention deficit hyperactivity disorder, autism spectrum disorder and children of Down Syndrome are examples of neurodevelopmental disorders' that contain both psychological and neurological abnormalities [1].

Characteristics of Children with Neurodevelopmental Disorders

Children with neurodevelopmental disorders face many difficulties in the field of explanation, diagnosis and evaluation. However, it has an important role in supporting children through the development of education and intervention programmes. Although intervention programmes are role models for the child and the family, their characteristics may vary according to the type of disorder. The phenotype of children with neurodevelopmental disorders includes ongoing health and developmental symptoms. While it may be early for parents to recognise these characteristics, it becomes more difficult at times. It is therefore of great importance for staff to knowingly recognise and identify these characteristics [1, 5].

Autism spectrum disorder is described as a neurodevelopmental disorder that causes cognitive differences, health problems, social communication and behaviours in children with environmental factors, thus causing difficulty in individual behaviour in the environment. One of the prominent features is that children with autism spectrum disorder have difficulty in adapting to the environment and experiencing behavioural problems due to conditions occurring in the brain [6]. Children with autism spectrum disorder can be diagnosed at the age of 2, starting in the first years of life. At the same time, there are characteristics such as delay or regression in social skills, cognitive development, verbal and non-verbal communication such as making eye contact, not looking when their name is called, showing stereotypical movements that show less development than their peers in social communication and interaction between people, limited interests and sensory differences [7].

Down Syndrome phenotype, motor development, balance and expressive language skills delay and these delays continue throughout their lives and they have difficulties in language and social communication interaction dimension [8]. In the cognitive dimension, situations such as inability to fulfil certain mental functions and inability to learn may also occur. However, despite cognitive and social retardation, they can improve in physical activity and balance with education and support. In this way, they can be included in the social environment with physical activity. In terms of cognition, many people have asymmetrical skill profiles, with relative strengths in nonverbal reasoning and visual processing, especially when compared to verbal and auditory processing skills [9].

Learning disability is described as a neurodevelopmental disorder that differs from its peers in the acquisition and use of listening, speaking, reading-writing or mathematical skills [10]. Learning disability is divided into 4 categories: reading disability, maths disability, written expression disability and learning disorder that cannot be named otherwise [11].

Assessments of Children with Neurodevelopmental Disorders

There are special criteria for the assessment of children with neurodevelopmental disorders according to certain areas. The evaluation process is seen as a challenging process for the child and parents. From the diagnosis of children, parents have problems in various issues such as acceptance and support [12]. There may be different methods for the evaluation of each child in neurodevelopmental disorders.

Considering the sub-dimensions, the evaluation of children with autism spectrum disorder is as follows according to DSM-5: utism Spesctrum disorder is included in DSM-5 and is used as an evaluation criterion. In DSM-5, autism spectrum disorder is described in two sections as limitation in social communication and interaction and limited, repetitive interests and activities and is stated as an evaluation element. In the dimension of limitations in social communication and interaction, difficulties in social-emotional, non-verbal communication and difficulties in initiating or maintaining peer relationships are detailed. In the dimension of limited and repetitive behaviours, repetitive motor movements, object use or speech, insistence on sameness, routines, rituals, limited interests, increased or decreased sensory interest or reactions are used as assessment tools in the diagnostic criteria [11].

Attention deficit hyperactivity disorder is one of the neurodevelopmental disorders and frequently occurs in preschool years. In addition to retardation in cognitive development and distractibility, children have additional symptoms such as anxiety disorders and separation anxiety [13].

According to DSM-5, the child can be diagnosed when the items specified for learning disability are observed in the child. The criteria considered in the evaluation process are as follows: Having difficulties in the academic field for at least six months, being slow in reading words and making frequent mistakes, having difficulty in reading comprehension, having phonological sound additions and subtractions, having difficulty in written expression, having difficulties in arithmetic, not having spatial awareness, having difficulty in understanding mathematical terms [14].

After the children with neurodevelopmental disorders are evaluated in general, the specialist staff carries out studies to support the child in cooperation with the parents. Supporting studies for balance and physical activity are carried out with education and intervention programmes. In this way, children can generally be adapted to social life [15]. Therefore, diagnosis and evaluation criteria are one of the important factors in neurodevelopmental disorders.

Neurodevelopmental Disorder and Balance

Balance is achieved by processing information from the visual, vestibular and proprioceptive systems together. A disorder in one of these systems causes loss of balance. Dizziness and imbalance are symptoms that can be seen in childhood [16]. In children, vestibular system disorder causes inability to maintain head and posture control, inability to perform

independent walking and sitting functions, poor motor development and delayed psychomotor skills [17]. This situation is more common when the information coming from the visual or sensory system becomes difficult. In children with vestibular disorders, in addition to postural complaints such as clumsiness, falls, injuries due to falls, step width, some disruptions in fine motor development may also be observed. If the vestibulo-ocular reflex, one of the most important reflexes of the vestibular system that ensures the stability of the visual field during head movement, is affected, motor dysfunctions may occur because hand-eye coordination cannot be achieved [18]. Studies show that vestibular disorders and cognitive skills are related [19, 20]. It has been reported that this situation arises from the connection of vestibular projections with the hippocampus [21].

It is known that the static and dynamic balance skills of children with neurodevelopmental disorders are worse than those of normally developing children [22]. Children with autism spectrum disorder may have difficulties in social and communication skills, as well as poor motor coordination skills and disorders in postural control. Disorders in postural control arise from problems in visual and somatosensory processing [14]. Morphological studies report that the disorders originate from the brainstem [23]. Disorders in postural control also affect the development of perceptual motor skills and social functionality [24]. When the vestibular functions of children with autism are evaluated, there is a decrease in their static and dynamic balance skills. In addition, oculomotor system disorders may occur and the vestibulo-ocular reflex may be negatively affected [25].

Visual-motor integration disorders, postural instability, oculomotor system disorders and vestibulo-ocular reflex involvement are observed in children with Down syndrome [26]. Children with Down syndrome cannot respond quickly to changes in the environment, so it takes longer to complete motor tasks [27]. Postural alignment is observed to maintain sway and balance during standing [28]. This situation is thought to be caused by cerebellar dysfunction, proprioceptive errors, biomechanical deficiencies, vestibular disorders or sensorimotor integration [29, 30]. Individuals with Down syndrome have lower neuron density, synaptic irregularities due to decreased neurotransmitters, and myelination abnormalities compared to their normally developing peers [31, 32].

Delays in motor development may be observed in children with intellectual disability. This situation limits functional abilities [33]. Disorders in postural control are observed due to the incomplete development of the central part that controls the somatosensory, visual and vestibular systems.

They have problems with motor coordination, muscle strength, endurance, fine and gross motor skills. It is also reported in the literature that vestibulo-ocular reflex dysfunction is observed in children with intellectual disability [34]. They may lose more postural control in situations where visual and somatosensory inputs change and become difficult, such as staying in the dark or walking on soft ground. These abnormalities are thought to result from processing deficiencies in the central mechanism of the vestibular system [35].

Weak motor coordination skills, postural stability, spatial orientation and oculomotor dysfunctions can be observed in children with learning disabilities [36, 37]. They show lower postural performance compared to their typically developing peers [36]. It has been reported that these disorders occur as a result of vestibulo-cerebellar dysfunction in children with learning disabilities [38]. Disorders in postural skills may result from disruptions in the integration of information from the visual, vestibular or proprioceptive systems [39]. It is known that the vestibular system is related to attention, memory, cognitive processing and visual spatial ability. For this reason, children who have cognitive problems such as learning disabilities may experience vestibular disorders [19].

In children with attention deficit and hyperactivity disorder, poor motor performance and impaired postural control are observed compared to their normally developing peers [40, 41]. Central vestibular changes in the connections between the vestibulo-cerebellum and vestibular nuclei, deficiencies in cerebellar inhibitory functions and disorders in prefrontal functions are reported [42, 43]. At the same time, it has been reported that brain imaging studies show a decrease in the volume of the cerebellar vein. For this reason, disorders in gait control may occur [44].

In cerebral palsy, which is a common neurological disorder in childhood, there are weaknesses in static and dynamic balance as well as gross and fine motor movements. They experience balance disorders as a result of problems in the visual, vestibular and somatosensory sensory systems [45]. In order to better define the disorders in cerebral palsy, a classification was made by dividing it into five levels [46]. As the level increases, the degree of balance disorder increases. It is reported in the literature that the cause of balance disorder in cerebral palsy is due to inadequate motor and somatosensory deficiencies. At the same time, oculomotor dysfunctions are also observed in children with cerebral palsy [47].

As a result, postural instability, motor coordination disorder and oculomotor system dysfunction may be observed in children with

neurodevelopmental disorders. Children with neurodevelopmental disorders may not be able to express themselves, have difficulty communicating with their parents or caregivers, and may not be able to describe their symptoms. Vestibular disorder also negatively affects postural control, development of fine motor skills, academic success and cognitive development, emotional and social behavior skills. For this reason, children should be observed carefully, and in case of any suspicion, an expert should be consulted. Additionally, vestibular assessment tests can be challenging in children because they require good cooperation. Therefore, it is necessary to make appropriate procedural changes in evaluation tests, continue testing by taking breaks, and use a game-based approach. Vestibular rehabilitation and physical activity, after early detection of disorders through a comprehensive evaluation, is an effective approach in children with neurodevelopmental disorders and balance problems [48].

Neurodevelopmental Disorder and Physical Activity

Physical activity is body movement that results in energy expenditure using skeletal muscles [49]. Physical activity in the first years of life is important for growth and development [50]. High levels of cardiorespiratory endurance in childhood are closely related to lower cardiometabolic risk in adulthood [51]. In addition, physical activity has important benefits in terms of preventing secondary health problems that disabled children may experience and supporting communication skills, self-confidence, and psychosocial development [52]. Physical activity in the form of walking has been shown to have beneficial effects in terms of physical and subjective health (health satisfaction) in a population consisting of children with visual, hearing and physical disabilities, autism, learning disabilities and emotional disorders [53].

It is possible to talk about the different benefits of physical activity in children with various neurodevelopmental disorders. Physical activity has been found to be effective in increasing academic performance [54], decreasing anxiety and depression levels [55], and social communication [56] in children with autism. Physical activity increases self-esteem and prevents chronic diseases in children with Down syndrome [57]. In a comprehensive systematic review in 2023, 35 scientific studies conducted since 1990 investigating the effects of physical activity on children with Down syndrome were examined. Water sports, aerobic exercises, strength exercises and game training practices have been identified to increase physical activity. It has been determined that these practices generally cause improvements in maximum oxygen consumption, maximum heart rate,

upper and lower body strength, body weight and body fat percentage [58]. In individuals with intellectual disabilities, physical activity causes beneficial results in general health perception and physical fitness parameters such as strength, endurance, and body mass index [59]. In children with learning disabilities, physical activity increases their social roles, improves physical and mental health, improves academic success and reduces irritable behaviors that occur due to learning disabilities [60, 61]. In individuals with attention deficit hyperactivity disorder, physical activity supports increasing self-esteem as well as physical and general health-related parameters [62]. Other benefits include reducing impulsivity and hyperactivity, increasing attention and improving executive functions [63]. It has been shown that physical activity in children with CP (cerebral palsy) is beneficial for reducing chronic pain, fatigue and osteoporosis, supporting mental and social development, improving physical function [64], and increasing quality of life and happiness [65].

Physical Activity Deficiencies

Physical activity participation of disabled children and adolescents is affected by many factors. These; communication, transportation, costs, lack of awareness, lack of social support [66], type of disability, insufficient time, inadequate facilities, factors related to parents (fear, labeling) [67], child's lack of interest and behavioral problems [68]. In a systematic review investigating the physical activity levels of disabled children between the ages of 0-5.99, it was observed that they had low physical activity levels as a result of 21 studies included [50].

Motor and behavioral disorders and communication problems in children with autism affect physical activity participation [69]. In a study in which the physical activity patterns of children with autism were examined with the help of an accelerometer, it was determined that the children showed insufficient physical activity and had too much sedentary time. Additionally, physical activity deficiencies were found to be more pronounced at older ages [70]. In another study conducted on a large population, it was determined that male children with autism, especially between the ages of 6 and 11, had insufficient physical activity levels compared to children in the general population [71]. In the meta-analysis in 2021, it was aimed to investigate the differences between children with autism and typically developing children in terms of moderate and vigorous physical activity. As a result of 9 studies that evaluated with the help of an accelerometer, it was analyzed that children with autism have 30 minutes less daily moderate physical activity level than normally developing children. Children also have

been shown lower physical activity performance during physical education and break hours during school education [72]. As a result of 28 studies and a comparison of the data of 805 autistic children with 1573 healthy children in 2023, it was determined that their moderate to severe physical activity levels were less than their peers [73].

In children with Down syndrome, disease-specific characteristics such as hypotonia, obesity and congenital heart problems, parental factors, coordination disorders and accessibility to physical activity affect physical activity participation [57]. The results of a systematic review conducted in 2019 have shown that the physical activity levels of participants with Down syndrome under the age of 21, assessed with the help of an accelerometer, were significantly lower than their healthy peers. It has also been determined that lack of physical activity has an impression that is inversely proportional to age [74]. It has also been documented that they have higher weight and lower physical activity performance than their healthy peers [75].

In a study conducted in Iceland, the physical activity behavior of children with mild and severe intellectual disabilities has been measured with the help of an accelerometer. It has been determined that children with intellectual disabilities are 40% less active than typically developing children matched for age and gender. Additionally, they have been found to spend 9% more sedentary time. None of the children with intellectual disabilities met the recommended daily average of 60 minutes of moderate-intensity physical activity [76]. More than 70% of children with visual, hearing, physical and mental disabilities and social development problems have been shown insufficient levels of physical activity at school. The most physical activity deficiencies were observed in children with severe mental disabilities [77].

A study conducted on young people with learning disabilities and attention deficit hyperactivity disorder found that they were significantly more obese than their healthy peers. In addition, in the examination of cases where both pathologies were seen separately and together, it was found that physical activity levels were significantly low. However, it has been determined that only individuals with learning disabilities are better at meeting their physical activity levels [78].

Reasons for the deficiencies in physical activity of children with CP include advanced age, female gender, and the presence of hip dysplasia [79]. From a general perspective, personal factors such as the child's physical abilities and psychological factors, parental factors (such as acceptance of disability), opportunities for participation in sports (such as lack of opportunity and awareness, time-related problems, financial situations), social environment

(acceptance among peers, bullying) Environmental factors such as) are obstacles to the physical activity performance of children with CP [80]. In a study examining the physical activity levels of children with CP, children's activities were recorded using an accelerometer for 4 days. As a result, it was determined that only 25% of children met the recommended daily physical activity levels [64].

Evaluation of Physical Activity

In the results of the literature research on physical activity in children with autism, evaluation methods are basically grouped as questionnaires and accelerometers. Accelerometers are mostly used with 3 axes. Surveys that provide subjective evaluation are stated as the Physical Activity Survey for Children, Godin-Shephard Leisure Survey, activity diary or surveys based on daily activity reports created by the authors [69].

No comprehensive research has been found on the methods used to evaluate physical activity in children with Down syndrome. However, it has been determined that accelerometers are mostly used as an objective method [81, 82].

Methods to evaluate physical activity in mentally retarded children aged 5-18 years are summarized.

Accordingly, classification was made as objective and subjective methods. Direct observation methods (Activity Level Observation Program, Children's Physical Activity Form, etc.), accelerometers, pedometers, accelerometers and double-labeled water method are given as objective methods. Subjective methods were based on activity diaries, surveys and parent reports. [83].

A new tool has been developed to evaluate physical activity in children with learning disabilities due to communication-related problems. Important features of the Learning Disability Physical Activity Questionnaire are that it is easy to read, has visual content, and is based on self-report. It was found to be welcomed by the participants and was also important in promoting physical activity [84].

Psychometric properties of physical activity measurements used to evaluate the physical activity level of children with cerebral palsy were examined and summarized. Basically, pedometers, accelerometers, heart rate monitors, activity monitors, armbands with sensors (based on body temperature, galvanic skin response, and accelerometer data), and monitors that can track energy expenditure have been identified. Subjective methods were investigated, including the Physical Activity Questionnaire, questionnaires

based on the Physical Activity Summary, and multimedia activity recall questionnaires for children and adults. Questionnaires have been shown to be easy to use in the clinic. However, it was also found that the correlation of these surveys with step and accelerometers was weak. In addition, the reliability of accelerometers in children with CP has not been demonstrated. There is evidence that energy expenditure monitors, activity monitors, heart rate monitors, and the Physical Activity Questionnaire are reliable [85].

The accelerometer used in the objective evaluation of physical activity must be used for at least 10 hours a day. For appropriate evaluation in children and adolescents, it is recommended that follow-up be done between 4-9 days [86].

Promoting Physical Activity

World Health Organization guidelines encourage an average of 60 minutes of moderate-intensity physical activity per day, including for children with disabilities [87, 88].

A recent systematic review examined the impact of digital health applications on promoting physical activity in children with autism and intellectual disabilities. It has been observed that there are active video games, e-learning methods and social media-based interventions. Positive results have been reported for many of these interventions [89].

Physical activity has an important place in children with Down syndrome due to the high potential for weight gain [90]. Providing cycling training to children, increasing strength training during adolescence, encouraging participation in special Olympics, adapting sports programs, providing educational programs by physiotherapists including families, community programs and practices aimed at improving physical activity in schools are encouraging practices in terms of increasing physical activity [91].

It is generally reported that practices to encourage physical activity in children with attention deficit hyperactivity disorder are limited. For this purpose, studies have been carried out on cooperation through various organizations and revealing a common recipe. Further studies are needed to promote physical activity [92].

A systematic literature review in children with CP found that leisure-time physical activity procedures resulted in beneficial outcomes for musculoskeletal strength, cardiorespiratory fitness, quality of life, spasticity, participation, and physical function. It has been stated that the most effective interventions are exercise training, active video games, recreational activities, behavioral coaching and motor skill training [93].

REFERANSLAR

1. Thapar, A., M. Cooper, and M. Rutter, *Neurodevelopmental disorders.* Lancet Psychiatry, 2017. **4**(4): p. 339-346.
2. Jung, Y., G.M. Ibrahim, and P.J. McDonald, *Invasive neurotechnology for neurodevelopmental disorders.* 2023.
3. Morris, C., et al., *Towards a definition of neurodisability: a Delphi survey.* Dev Med Child Neurol, 2013. **55**(12): p. 1103-8.
4. Cardoso, A.R., et al., *Essential genetic findings in neurodevelopmental disorders.* Hum Genomics, 2019. **13**(1): p. 31.
5. O'Connor, A.B., B. Carpenter, and B. Coughlan, *Confident championing: A grounded theory of parental adjustment following a child's diagnosis of developmental disability.* British Journal of Learning Disabilities, 2021. **49**(2): p. 247-258.
6. McIntyre, L.L. and M. Kunze, *Family-focused interventions as prevention and early intervention of behavioral problems in children with autism spectrum disorder.* International Review of Research in Developmental Disabilities, 2021. **61**: p. 159-191.
7. Lord, C., et al., *Autism spectrum disorder.* Nat Rev Dis Primers, 2020. **6**(1): p. 5.
8. Bull, M.J., *Down Syndrome*. N Engl J Med, 2020. **382**(24): p. 2344-2352.
9. Startin, C.M., et al., *Health comorbidities and cognitive abilities across the lifespan in Down syndrome*. J Neurodev Disord, 2020. **12**(1): p. 4.
10. Kirk, S.A., J. Gallagher, and M.R. Coleman, *Özel gereksinimli çocukların eğitimi*. 2017: Nobel Akademik Yayıncılık.
11. Vahia, V.N.J.I.j.o.p., *Diagnostic and statistical manual of mental disorders 5: A quick glance*. 2013. **55**(3): p. 220.
12. Simon, J., et al., *The diagnostic journey of genetically defined neurodevelopmental disorders.* J Neurodev Disord, 2022. **14**(1): p. 27.
13. Weiss, M., L. Hechtman, and G. Weiss, *ADHD in parents.* J Am Acad Child Adolesc Psychiatry, 2000. **39**(8): p. 1059-61.
14. Abdel Ghafar, M.A., et al., *Quantitative Assessment of Sensory Integration and Balance in Children with Autism Spectrum Disorders: Cross-Sectional Study.* Children (Basel), 2022. **9**(3).
15. Tortorelli, C., P. Choate, and D. Badry, *Disrupted life narratives of children in care with neurodevelopmental disabilities: Whose story is it?* 2023.
16. Li, C.M., et al., *Epidemiology of Dizziness and Balance Problems in Children in the United States: A Population-Based Study.* J Pediatr, 2016. **171**: p. 240-7.e1-3.

17. Inoue, A., et al., *Effect of vestibular dysfunction on the development of gross motor function in children with profound hearing loss.* Audiol Neurootol, 2013. **18**(3): p. 143-51.
18. O'Reilly, R., et al., *Development of the vestibular system and balance function: differential diagnosis in the pediatric population.* Otolaryngol Clin North Am, 2011. **44**(2): p. 251-71, vii.
19. Bigelow, R.T. and Y. Agrawal, *Vestibular involvement in cognition: Visuospatial ability, attention, executive function, and memory.* J Vestib Res, 2015. **25**(2): p. 73-89.
20. Besnard, S., et al., *Editorial: The Vestibular System in Cognitive and Memory Processes in Mammalians.* Front Integr Neurosci, 2015. **9**: p. 55.
21. Brandt, T., et al., *Vestibular loss causes hippocampal atrophy and impaired spatial memory in humans.* Brain, 2005. **128**(Pt 11): p. 2732-41.
22. Bucci, M.P., et al., *Postural Instability in Children with ADHD Is Improved by Methylphenidate.* Front Neurosci, 2016. **10**: p. 163.
23. Ogawa, T., *[Neurophysiological study of autistic children].* No To Hattatsu, 1989. **21**(2): p. 163-9.
24. Casartelli, L., M. Molteni, and L. Ronconi, *So close yet so far: Motor anomalies impacting on social functioning in autism spectrum disorder.* Neurosci Biobehav Rev, 2016. **63**: p. 98-105.
25. Oster, L.M. and G. Zhou, *Balance and Vestibular Deficits in Pediatric Patients with Autism Spectrum Disorder: An Underappreciated Clinical Aspect.* Autism Res Treat, 2022. **2022**: p. 7568572.
26. Costa, A.C., *An assessment of optokinetic nystagmus (OKN) in persons with Down syndrome.* Exp Brain Res, 2011. **214**(3): p. 381-91.
27. Galli, M., et al., *Postural control in patients with Down syndrome.* Disabil Rehabil, 2008. **30**(17): p. 1274-8.
28. Aruin, A.S. and G.L. Almeida, *A coactivation strategy in anticipatory postural adjustments in persons with Down syndrome.* Motor control, 1997. **1**(2): p. 178-191.
29. Latash, M.L. and J.G. Anson, *Synergies in health and disease: relations to adaptive changes in motor coordination.* Phys Ther, 2006. **86**(8): p. 1151-60.
30. Koo, B.K., et al., *Magnetic resonance imaging evaluation of delayed myelination in Down syndrome: a case report and review of the literature.* J Child Neurol, 1992. **7**(4): p. 417-21.
31. Wu, J., et al., *Strategy adoption and locomotor adjustment in obstacle clearance of newly walking toddlers with Down syndrome after different treadmill interventions.* Exp Brain Res, 2008. **186**(2): p. 261-72.

32. Agulló, I.R. and B.M. González, *Factores que influyen en el desarrollo motor de los niños con síndrome de Down.* Revista Médica Internacional sobre el sindrome de Down, 2006. **10**(2): p. 18-24.
33. Bahiraei, S., E. Hosseini, and R.A.J. Lou, *The test-retest reliability and limits of agreement of the balance evaluation systems test (BESTest) in young people with intellectual disability.* Sci Rep, 2023. **13**(1): p. 15968.
34. Zur, O., et al., *Vestibulo-ocular response and balance control in children and young adults with mild-to-moderate intellectual and developmental disability: a pilot study.* Res Dev Disabil, 2013. **34**(6): p. 1951-7.
35. Van Hecke, R., et al., *Vestibular Function in Children with Neurodevelopmental Disorders: A Systematic Review.* J Autism Dev Disord, 2019. **49**(8): p. 3328-3350.
36. Razuk, M., et al., *Eye movements and postural control in dyslexic children performing different visual tasks.* PLoS One, 2018. **13**(5): p. e0198001.
37. Lukasova, K., I.P. Silva, and E.C. Macedo, *Impaired Oculomotor Behavior of Children with Developmental Dyslexia in Antisaccades and Predictive Saccades Tasks.* Front Psychol, 2016. **7**: p. 987.
38. Stoodley, C.J. and J.F. Stein, *Cerebellar function in developmental dyslexia.* Cerebellum, 2013. **12**(2): p. 267-76.
39. Bucci, M.P., et al., *The influence of oculomotor tasks on postural control in dyslexic children.* Front Hum Neurosci, 2014. **8**: p. 981.
40. Kim, S.M., et al., *Balance Deficit and Brain Connectivity in Children with Attention-Deficit/Hyperactivity Disorder.* Psychiatry Investig, 2017. **14**(4): p. 452-457.
41. Tervo, R.C., et al., *Children with ADHD and motor dysfunction compared with children with ADHD only.* Dev Med Child Neurol, 2002. **44**(6): p. 383-90.
42. Lotfi, Y., et al., *Rotational and Collic Vestibular-Evoked Myogenic Potential Testing in Normal Developing Children and Children With Combined Attention Deficit/Hyperactivity Disorder.* Ear Hear, 2017. **38**(6): p. e352-e358.
43. O'Halloran, C.J., G.J. Kinsella, and E. Storey, *The cerebellum and neuropsychological functioning: a critical review.* J Clin Exp Neuropsychol, 2012. **34**(1): p. 35-56.
44. Seidman, L.J., E.M. Valera, and N. Makris, *Structural brain imaging of attention-deficit/hyperactivity disorder.* Biol Psychiatry, 2005. **57**(11): p. 1263-72.
45. Rosenbaum, P., et al., *A report: the definition and classification of cerebral palsy April 2006.* Dev Med Child Neurol Suppl, 2007. **109**: p. 8-14.
46. Rosenbaum, P.L., et al., *Prognosis for gross motor function in cerebral palsy: creation of motor development curves.* Jama, 2002. **288**(11): p. 1357-63.

47. Ego, C., et al., *Spontaneous improvement in oculomotor function of children with cerebral palsy.* Res Dev Disabil, 2015. **36c**: p. 630-644.
48. Lotfi, Y., et al., *Preliminary evidence of improved cognitive performance following vestibular rehabilitation in children with combined ADHD (cADHD) and concurrent vestibular impairment.* Auris Nasus Larynx, 2017. **44**(6): p. 700-707.
49. Caspersen, C.J., K.E. Powell, and G.M. Christenson, *Physical activity, exercise, and physical fitness: definitions and distinctions for health-related research.* Public health reports, 1985. **100**(2): p. 126.
50. Taylor, L.G., et al., *Physical Activity Among Young Children With Disabilities: A Systematic Review.* Adapt Phys Activ Q, 2023: p. 1-22.
51. Azmi, N.A., et al., *Correlation of Physical Activity Level with Physical Fitness and Respiratory Function amongst Undergraduates.* Trends in Sciences, 2021. **18**(19): p. 24-24.
52. Ross, S.M., et al., *Physical Activity Participation of Disabled Children: A Systematic Review of Conceptual and Methodological Approaches in Health Research.* Frontiers in Public Health, 2016. **4**.
53. Selanon, P. and W. Chuangchai, *Walking activity increases physical abilities and subjective health in people with seven different types of disabilities.* Front Public Health, 2023. **11**: p. 1120926.
54. Oriel, K.N., et al., *The effects of aerobic exercise on academic engagement in young children with autism spectrum disorder.* Pediatr Phys Ther, 2011. **23**(2): p. 187-93.
55. Accardo, A.L., N.M.H. Pontes, and M.C.F. Pontes, *Greater Physical Activity is Associated with Lower Rates of Anxiety and Depression Among Autistic and ADHD Youth: National Survey of Children's Health 2016-2020.* J Autism Dev Disord, 2023.
56. Jia, S., et al., *The effect of physical exercise on disordered social communication in individuals with autism Spectrum disorder: a systematic review and meta-analysis of randomized controlled trials.* Front Pediatr, 2023. **11**: p. 1193648.
57. Barr, M. and N. Shields, *Identifying the barriers and facilitators to participation in physical activity for children with Down syndrome.* Journal of Intellectual Disability Research, 2011. **55**(11): p. 1020-1033.
58. Ballenger, B.K., et al., *Health Outcomes of Physical Activity Interventions in Adults With Down Syndrome: A Systematic Review.* Adapt Phys Activ Q, 2023. **40**(2): p. 378-402.
59. Golubović, Š., et al., *Effects of exercise on physical fitness in children with intellectual disability.* Research in Developmental Disabilities, 2012. **33**(2): p. 608-614.

60. Demirci, N., A.O. Engin, and A. Özmen, *The Influence of Physical Activity Level on the Children's Learning Ability of Disabled Children Having Difficulties in Learning*. Procedia-Social Behavioral Sciences, 2012. **69**: p. 1572-1578.

61. Hallawell, B., J. Stephens, and D.J.B.J.o.N. Charnock, *Physical activity and learning disability*. 2012. **21**(10): p. 609-612.

62. Lancaster, G.J.B.J.o.G.S.i.E., *Attention Deficit Hyperactivity Disorder and Physical Activity*. p. 11.

63. Mehren, A., et al., *Physical exercise in attention deficit hyperactivity disorder - evidence and implications for the treatment of borderline personality disorder*. Borderline Personal Disord Emot Dysregul, 2020. **7**: p. 1.

64. Mitchell, L.E., J. Ziviani, and R.N. Boyd, *Habitual Physical Activity of Independently Ambulant Children and Adolescents With Cerebral Palsy: Are They Doing Enough?* Physical Therapy, 2015. **95**(2): p. 202-211.

65. Maher, C.A., M. Toohey, and M. Ferguson, *Physical activity predicts quality of life and happiness in children and adolescents with cerebral palsy*. Disability and Rehabilitation, 2016. **38**(9): p. 865-869.

66. Wilson, O.W.A., et al., *Inequities in the physical activity of disabled young people in Aotearoa New Zealand: a stakeholder SWOT analysis of the physical activity sector*. N Z Med J, 2023. **136**(1577): p. 12-21.

67. Alghamdi, S. and R. Alsaigh, *Determinants of Physical Activity among Children with Disabilities*. Healthcare (Basel), 2023. **11**(4).

68. Yazdani, S., C.T. Yee, and P.J. Chung, *Factors predicting physical activity among children with special needs*. Prev Chronic Dis, 2013. **10**: p. E119.

69. López-Valverde, P., et al., *Instruments to Assess Physical Activity in Primary Education Students with Autism Spectrum Disorder: A Systematic Review*. Int J Environ Res Public Health, 2021. **18**(9).

70. MacDonald, M., P. Esposito, and D. Ulrich, *The physical activity patterns of children with autism*. BMC Research Notes, 2011. **4**(1): p. 422.

71. Gehricke, J.G., et al., *Physical activity rates in children and adolescents with autism spectrum disorder compared to the general population*. Res Autism Spectr Disord, 2020. **70**.

72. Rostami Haji Abadi, M., et al., *Children with Autism Spectrum Disorder Spent 30 Min Less Daily Time in Moderate-to-Vigorous Physical Activity than Typically Developing Peers: a Meta-Analysis of Cross-sectional Data*. Review Journal of Autism and Developmental Disorders, 2023. **10**(1): p. 144-157.

73. Liang, X., et al., *Age-Related Differences in Accelerometer-Assessed Physical Activity and Sleep Parameters Among Children and Adolescents With and Without Autism Spectrum Disorder: A Meta-Analysis*. JAMA Netw Open, 2023. **6**(10): p. e2336129.

74. Fox, B., et al., *Physical Activity Levels of Children With Down Syndrome*. Pediatric Physical Therapy, 2019. **31**(1).

75. Whitt-Glover, M.C., K.L. O'Neill, and N. Stettler, *Physical activity patterns in children with and without Down syndrome*. Pediatric Rehabilitation, 2006. **9**(2): p. 158-164.

76. Einarsson, I., et al., *Differences in physical activity among youth with and without intellectual disability*. Med Sci Sports Exerc, 2015. **47**(2): p. 411-8.

77. Sit, C.H., et al., *Physical Activity and Sedentary Time among Children with Disabilities at School*. Med Sci Sports Exerc, 2017. **49**(2): p. 292-297.

78. Cook, B.G., D. Li, and K.M. Heinrich, *Obesity, Physical Activity, and Sedentary Behavior of Youth With Learning Disabilities and ADHD*. Journal of Learning Disabilities, 2014. **48**(6): p. 563-576.

79. Van Eck, M., et al., *Physical activity level and related factors in adolescents with cerebral palsy*. 2008. **20**(1): p. 95-106.

80. Verschuren, O., et al., *Identification of Facilitators and Barriers to Physical Activity in Children and Adolescents with Cerebral Palsy*. The Journal of Pediatrics, 2012. **161**(3): p. 488-494.

81. Izquierdo-Gomez, R., et al., *Objective assessment of sedentary time and physical activity throughout the week in adolescents with Down syndrome. The UP&DOWN study*. Res Dev Disabil, 2014. **35**(2): p. 482-9.

82. Phillips, A.C. and A.J. Holland, *Assessment of objectively measured physical activity levels in individuals with intellectual disabilities with and without Down's syndrome*. PLoS One, 2011. **6**(12): p. e28618.

83. Hinckson, E.A. and A. Curtis, *Measuring physical activity in children and youth living with intellectual disabilities: A systematic review*. Research in Developmental Disabilities, 2013. **34**(1): p. 72-86.

84. Pakravan, A., M. Ghazirad, and F. Shaddel, *Development of the learning disability physical activity questionnaire (LDPAQ)*. Tizard Learning Disability Review, 2022. **27**(2): p. 112-121.

85. Mitchell, L.E., et al., *A systematic review of the clinimetric properties of measures of habitual physical activity in primary school aged children with cerebral palsy*. Research in Developmental Disabilities, 2013. **34**(8): p. 2419-2432.

86. Trost, S.G., et al., *Conducting accelerometer-based activity assessments in field-based research*. 2005. **37**(11): p. S531.

87. Supramaniam, N., A. Zanudin, and N.A. Azmi, *Body Mass Index, Physical Activity, Cardiorespiratory Endurance and Quality of Life among Children with Physical Disabilities*. Children (Basel), 2023. **10**(9).

88. Organization, W.H., [(accessed on 1 November 2022)];Physical Activity and Young People. 2022 Available online: https://www.who.int/news-room/fact-sheets/detail/physical-activity.

89. Van Biesen, D., et al., *A Systematic Review of Digital Interventions to Promote Physical Activity in People With Intellectual Disabilities and/or Autism*. Adapt Phys Activ Q, 2023: p. 1-21.

90. Alesi, M. and A. Pepi, *Physical Activity Engagement in Young People with Down Syndrome: Investigating Parental Beliefs*. Journal of Applied Research in Intellectual Disabilities, 2017. **30**(1): p. 71-83.

91. Wentz, E.E., et al., *Promoting Participation in Physical Activity in Children and Adolescents With Down Syndrome*. Physical Therapy, 2021. **101**(5): p. pzab032.

92. Lydell, M., L. Kristén, and M. Nyholm, *Health promotion partnership to promote physical activity in Swedish children with ASD and ADHD*. Health Promot Int, 2022. **37**(6).

93. Lai, B., et al., *Leisure-time physical activity interventions for children and adults with cerebral palsy: a scoping review*. Developmental Medicine & Child Neurology, 2021. **63**(2): p. 162-171.