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Comprehensive assessment of motor skills in children with autism spectrum disorders

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Abstract

Background: Autism is a neurodevelopmental disorder that affects many spheres of life. Apart from the psychological area of social contacts, it also has a negative effect on motor functions. People with the autism spectrum are characterized by lower motor skills compared to their neurotypical peers. Motor disorders often precede a later diagnosis of autism. The identified difficulties are visible and persistent in relation to everyday functioning. They also have a negative impact on the quality of life.

The aim of the study was to assess the motor skills of people with autism spectrum disorders, taking into account: the strength of the upper limbs, explosive strength of the lower limbs, gait, postural stability and gross motor skills. The specific aim was to compare the parameters of the above-mentioned areas with the results of neurotypical children.

Material and methods: The study was conducted on female and male children aged 6–11 years. The research group included 30 children with autism spectrum disorders, the control group consisted of 30 neurotypical children. Upper limb strength was assessed using a hand dynamometer, lower limb explosive strength was assessed using the Standing Long Jump Test, biomechanical assessment of postural stability parameters and child's gait using a

dynamographic platform and gross motor skills assessment using the Polish version of the TGMD-3 test.

Results: The results showed no significant differences in the strength of upper limbs measured with a dynamometer between children developing neurotypically and children with autism spectrum disorder (ASD). Children with ASD had significantly lower results than those developing neurotypically, in terms of the maximum pressure of both lower limbs. People with spectrum disorder showed lower gross motor skills compared to the neurotypical population.

Conclusions: Gross motor skills and gait quality are lower in neuro-typical individuals. People on the autism spectrum should receive support focused on motor skills, especially on the gait pattern. Probably, the diagnosis of ASD does not affect the strength of the upper limbs.

Key words: autism; motor skills; gait pattern; TGMD-3

Introduction

Autism spectrum disorder (ASD) is classified as a neurodevelopmental disorder. The clinical picture of people with ASD is very diverse and heterogeneous. Despite the recognition of the same unit described under the symbol 299.00 by Diagnostic and Statistical Manual of Mental Disorders 5th (DSM-5), which stands for Autism Spectrum Disorder, the picture of a child may differ significantly from that of a child with the same diagnosis. Scientific literature characterizes the triad of symptoms, i.e., a deficit in both verbal and non-verbal communication, social difficulties and the occurrence of stereotypical behaviors. Despite listing these symptoms, each child presents an individual series of abnormalities. The cause influencing the formation of ASD has not been known so far. This discovery would be a breakthrough, as it would allow the establishment of preventive measures, as well as the creation of an individual ASD probability profile[1]. Autism scientists mention a multifactorial etiopathogenesis [2]. Currently, the diagnostic process is based on observations, tests, measurements and analyzes [3]. Early intervention for autism improves the prognosis of these people in the future and also affects the quality of life. Early introduction of therapy (between 2 and 4 years of age) is most justified, among others, due to the high plasticity of the brain [4].

Children with autism spectrum disorders are characterized by impaired motor coordination. As many as 86.9% of them are at risk of motor problems [5]. A lower quality of movements is observed as compared to neurotypical children [6]. In children from 1 to 5

years of age, 6.7% have significant problems with gross motor skills, 38.5% have gross motor impairment. Motor delays are more prominent in older children [7]. Early detection of motor disorders at a young age and a spectrum diagnosis in later years are common. This proves how important the motor sphere is in children. It is recommended to observe and take action in the event of any irregularities [8]. There are reports on the validity of introducing motor difficulties as a diagnostic criterion for autism. Interventions targeting motor deficits can also positively influence the improvement of social functioning [9]. Moderate to vigorous physical activity in the early school years may aid motor function in children with autism. It is also important to engage in physical education classes, which should be adapted to people with motor impairments with ASD [10].

Aim

The aim of the work is to verify the assumed research hypotheses:

1. The strength of the upper limbs in children with autism spectrum disorder is lower compared to their peers developing neurotypically
2. The explosive strength of the lower limbs in children with autism spectrum disorder is lower compared to their peers developing neurotypically
3. Children with ASD show greater gross motor disorders than children without a diagnosis of autism

Material and methods

Study participants

Thirty-nine children from 6 years of age were examined in the study up to 11 years of age, including 19 with autism spectrum disorder and 20 developing neurotypically, and 12 (30.8%) girls and 27 (69.2%) boys.

Table 1. Characteristics of the studied group

Variables	**Study group** (n = 39) (%)
Dominant hand	
L	6 (15.4)
N	4 (10.3)
P	26 (667)

Dominant foot	
L	4 (10.3)
N	8 (20.5)
P	24 (61.5)

Procedure

All parents consented to the participation of their children in the study. After obtaining the consent, the research began. Therapists in the large room set up positions where the test was performed. Children, on the basis of the station circuit, were tested with the tools used for this work.

The research was carried out, among others at the Primary School in Tulce in 2021.

Tools

The children's physiotherapeutic assessment included:

- assessing child's upper limb strength: upper limb strength was performed using the Handgrip Strength Test using a digital hand dynamometer (dynamometer) — 08–010201. Starting position: standing position, non-dominant upper limb lowered along the body, dominant upper limb lowered along the body, bent at the elbow to 90 degrees, elbow touching the body, forearm and wrist in neutral position, feet hip-width apart, eyes open, eyes directed straight ahead. Test: During the test, the child was asked to take a hand dynamometer with his dominant hand. Then, each participant was given a demonstration of the task and made an initial test trial. After the verbal command "squeeze as hard as possible", the child squeezed the dynamometer with all its strength for 2 seconds. Then the non-dominant limb was measured. Each subject had to perform 3 trials on each hand. The test result is given as the average of three measurements.
- biomechanical assessment of the parameters of the child's postural stability and gait The study of maintaining the balance was carried out with the use of the Zebris FDM-S platform. Each child made a 30-second attempt to calmly stand in a neutral position, without footwear, arms lowered along the torso, feet hip-width apart, eyes open, eyes directed straight ahead, without any additional movements. The gait was assessed using the following variables: "maximum pressure force of the right leg" (specifying the foot areas, "maximum pressure force on the forefoot of the right leg", "maximum pressure force metatarsus of the right leg ", "maximum pressure force on the heel of the right leg")

and “maximum pressure of the left leg” (specifying the areas of the foot — "Maximum pressure force on the left forefoot”, “maximum pressure force metatarsus of the left leg”, “maximum pressure force on the heel of the left leg”);

- gross motor skills study. The study of gross motor skills using the Polish version of the non-invasive TGMD-3 test was carried out on a group of 30 children diagnosed with autism spectrum disorder without comorbidities and a control group: 30 healthy children, without a diagnosis of autism and without comorbidities. The inclusion criteria are: compensated vision defect, health condition enabling participation in the study (no dizziness, fresh injuries, sprains, fractures, no plaster dressing, no developmental disorders in the upper and lower limbs).

Results

Descriptive statistics of variables

The results of the Kolmogorov-Smirnov test, carried out in order to select appropriate statistical methods, indicate that the variables concerning the strength of the upper and lower limbs as well as the variables concerning the maximum pressure forces of the left and right leg were normally distributed, while the variables concerning gross motor skills did not have a normal distribution. In order to verify the research hypotheses, both parametric (Student's t) and non-parametric (Mann-Whitney U) tests performed with the SPSS Statistics program will be used.

Verification of research hypotheses

Hypothesis 1: The strength of the upper and lower limbs in children with autism spectrum disorder is lower compared to their peers developing neurotypically.

Table 2. Study group and the strength of upper and lower limbs — t-test for independent data

Variable	**Group**				***t***	***p***
	Neurotypical (n = 20)		**Autism spectrum (n = 19)**			
	M	**SD**	**M**	**SD**		
The strength of the upper	12.64	3.21	9.39	7.99	1.61	0.122

limbs						
The strength of the lower limbs	0.30	1.34	0.00	0.00	1.00	0.330

*p < 0.05, **p < 0.01

The results of the Student's t-test for independent data presented in Table 2 show no significant differences between children with autism spectrum disorder and children developing neurotypically.

Hypothesis 2: The quality of gait in children with autism spectrum disorder is lower compared to their peers developing neurotypically.

Table 3. Study group and gait quality — t-test for independent data

Variable	**Group**					
	Neurotypical (n = 20)		**Autism spectrum (n = 19)**		**t**	**p**
	M	**SD**	**M**	**SD**		
Maximum pressure on the left leg	340.25	69.16	218.98	154.63	3.06**	0.004
Maximum pressure on the forefoot of the left leg	327.97	61.28	210.56	135.04	3.38**	0.002
Maximum pressure on the metatarsus of the left leg	71.41	33.80	83.63	55.71	–0.79	0.435
Maximum pressure force on the heel of the left leg	246.91	50.33	137.36	80.23	4.87**	< 0.001
Maximum pressure on the right leg	330.98	69.25	230.26	157.84	2.50*	0.018
Maximum pressure on the forefoot of the right leg	332.46	62.98	215.00	146.46	3.16**	0.003
Maximum pressure on the	76.35	40.97	80.68	63.88	–0.24	0.812

metatarsus of the right leg						
Maximum pressure force on the heel of the right leg	238.60	45.68	155.89	98.04	3.26**	0.003

*p < 0.05, **p < 0.01

The results of the Student's t-test for independent data presented in Table 3 show that children with autism spectrum disorder have significantly lower results than neurotypically developing children in terms of the maximum pressure force of the left leg, the maximum pressure force on the left forefoot, and the maximum pressure force on the heel. on the left leg, maximum pressure on the right leg, maximum pressure on the forefoot of the right leg, and maximum pressure on the heel of the right leg. No significant results were obtained for the remaining measurements.

Hypothesis 3: Gross motor disorders in children with autism spectrum disorder are greater compared to their peers developing neurotypically

Table 4. Study group and gross motor disorders — Mann-Whitney U test

Variable	**Group**					
	Neurotypical (n = 20)		**Autism spectrum (n = 19)**		**U Mann-Whitney**	**p**
	M	**SD**	**M**	**SD**		
Gross motor skills disorders	49.80	25.61	82.58	20.44	–4.13**	< 0.001
Locomotion	25.40	13.87	41.47	10.42	–4.19**	< 0.001
Run	5.60	2.21	7.11	1.91	–2.62**	0.009
Gallop	3.95	3.05	6.84	2.03	–3.12**	0.002
Jumping	3.90	3.71	7.58	1.84	–3.66**	< 0.001
Jumping with forepasses of hands	1.60	2.37	4.89	2.02	–3.71**	< 0.001
Long jump	4.95	3.17	7.47	1.84	–3.47**	0.001
Extension and delivery	5.40	3.32	7.58	1.84	–2.91**	0.004

step						
Tasks with the ball	24.40	13.62	41.11	11.02	–4.02**	< 0.001
Hitting the ball with both hands	4.45	3.09	7.63	2.93	–3.21**	0.001
Reflection and impact	2.50	2.84	6.84	2.12	–4.08**	< 0.001
One-handed ball dribbling	1.10	1.83	2.95	2.22	–2.55**	0.011
Catch a ball with both hands	3.80	2.12	5.47	1.43	–3.18**	0.001
Kick a lying ball	4.15	2.56	5.89	2.16	–2.12*	0.034
Overhead ball throw	3.85	2.62	5.68	2.77	–2.16*	0.031
Bottom throw of the ball	4.55	2.70	6.63	1.98	–2.73**	0.006

*p < 0.05, **p < 0.01

The results of the Mann-Whitney U test presented in Table 4 show that children with autism spectrum disorder have significantly higher results than children developing neurotypically, in terms of gross motor disorders, including the dimension of locomotion along with the following skills: running, galloping, jumping, jumping with foreplay of hands, long jump and extension step as well as the dimension of the task with the ball along with the skills: hitting the ball with both hands, bouncing and hitting the ball, dribbling the ball with one hand, catching the ball with both hands, kicking the lying ball, overhead throw and downward throw of the ball.

Discussion

Autism is a neurodevelopmental disorder, the underlying cause of which has not yet been established. Commonly known symptoms are listed, but each child may present a different clinical picture. On a daily basis, people on the autism spectrum face many difficulties, which distinguishes them from neurotypical people. Almost 90% of people with ASD present with sensory processing disorders that can cause social withdrawal, communication problems or unusual play behavior [11].

Perin et al. (2020) decided to conduct an assessment of postural abilities in children and adolescents with ASD in comparison with neurotypical people in different age groups. They used the Physiological Profile Assessment (PPA), which examines the following areas:

vision, reaction time, peripheral sensation, lower limb strength, and balance. The effects of tests of people with autism were examined in relation to the percentiles of neurotypical people. Participants with ASD scores were above the 90th percentile (poor scores) on most sensory, motor, and balance parameters. All PPA tests, with the exception of sensitivity to edge contrast, proprioception and rocking on the floor with open and closed eyes, significantly correlated with age, which was not the case in the group of people with ASD [12].

Apart from the postural difficulties mentioned above, people with autism present disorders in the area of social and verbal and non-verbal communication. Dadgar et al. (2017) undertook a study evaluating the relationship between motor and imitation skills and social communication skills in children with ASD. Both parameters were found to influence the social behavior of people on the autism spectrum. In addition, it is believed that a positive impact would be the inclusion of gross motor skills and mimicry in early intervention programs [13].

Many authors have tried to show what motor deficits are faced by children on the autism spectrum. Among them, we can distinguish imbalances, coordination or strength in combination with developmental delays in the field of fine and gross motor skills. In the studies by Laurenco et al. (2020) children with ASD obtained poorer results in terms of fine motor precision, manual dexterity, balance, speed and agility as well as strength, compared to children developing neurotypically [14]. In turn, Turkish researchers (2022) proved that the pressure of the hand increases with age. Considering the grip strength of children with autism spectrum disorders, it is lower than in typically developing children. This may be related to the low level of active use of motor skills. Moreover, the strength of the right hand was higher than that of the left hand in both groups [15]. Similar results were obtained by Morrison et al. (2018), who showed that adults with ASD are characterized by a reduced strength of the upper limbs [16]. In our study, no significant difference in the strength of the upper limbs was found between children with autism spectrum disorder and children developing neurotypically.

Another aspect that makes it difficult for people on the autism spectrum to function in everyday life are irregularities in the way they move. This is exactly what Lim et al. (2019) did in an attempt to explain the causes of impaired postural control on the basis of incorrect weighting of visual information. A group of neurotypical children and people with ASD was assessed with the use of optical flow. They have been examined in and between the visual illusion trials. The study did not show significant differences between the groups; therefore it

cannot be concluded that the reason for the incorrect walking posture in people with ASD is incorrect sensory weighing [17].

Research on the gait of people on the autism spectrum is growing all the time. For its evaluation, a study was also carried out using 3D motion analysis with a treadmill (2018). It consisted of a six-minute walk, recording 20 steps first as a baseline, then participants had 20 attempts to complete the task. Patients with autism were characterized by increased pelvic anterior tilt, also demonstrated a reduction in the moment of ankle flexion and an increase in the flexion of the hip joint. The most important, however, was the differentiated knee extension parameter, which the researchers considered the leading difficulty in walking in children with ASD [18].

In 2017, Hasan and co-authors conducted a study to determine whether the 3D components of the ground reaction forces (maximum braking force, relative time to reach the maximum braking force, relative time to reach zero force during intermediate stance, the second peak of vertical ground reaction forces in the final stage of standing) differ between autistic and neurotypical people. It has been documented that children with autism have significant difficulties with weight bearing and experience gait instability during the standing phase [19]. Our observations show that both the pressure force on the forefoot and the heel in both lower limbs are much higher in children with ASD than in children developing neurotypically. This could have had a significant impact on the stability and the quality of the gait presented.

In a review study, Kindregan et al. (2015) analyzed abnormalities in the gait of people with ASD. Children with autism support their stability by shortening the stride length, increasing the stride width and the support plane, and also by extending the standing phase. Demonstrate reduced ranges of motion in the knee and ankle joints when walking while increasing hip flexion [20].

In 2020, Armitano and co-authors performed an analysis to investigate the space-time characteristics and acceleration pattern of the torso, neck and head while walking and in autistic and neurotypical people. It was found that adults with ASD moved more slowly. Despite this, they were unable to suppress the acceleration associated with gait, exhibiting large fluctuations from torso to head [21].

Last year, Li and co-authors conducted a study to evaluate the kinematics and symmetry of gait according to the age of children with autism. They found that older children presented lower ankle and knee dorsiflexion angles at heel strike. Moreover, they were characterized by a reduced range of axial rotation of the pelvis and thorax, and an increased range of flexion and extension of the arms. Age had no effect on gait symmetry [22].

In neurotypical individuals, gait is usually characterized by stability, symmetry, and smooth contact between the heel and the ground. The study by Gong et al. (2020) used ground pressure analysis, which made it possible to more accurately assess the interaction between the foot and the ground. It was shown that children with autism moved in a characteristic pattern of foot contact with the ground, with inadequate contact force and high variability of steps. There is a close relationship between atypical motor coordination and the main symptoms of autism. [23]. The own study also confirmed that the first phase of walking in children with ASD is characterized by a significant pressure of the heel on the ground.

Allen et al. (2017) used the TGMD-3 test. According to their observations, children with ASD achieved much more severe results compared to typically developing peers who were matched according to gender and age [24]. The presented publication is consistent with our research, according to which children with ASD are characterized by reduced competences in the field of basic motor skills.

Conclusions

1. ASD affects many areas of everyday life, including motor aspects.
2. On the basis of the above results, it is concluded that neuro-typical persons may exhibit lower gross motor skills.
3. The quality of gait measured with the use of a dynamometric platform also differs from neurotypical people.
4. Developmental difficulties such as autism did not affect the strength of the upper limbs in the subjects.
5. It is recommended that people diagnosed with developmental disorders receive specialist care, taking into account motor aspects.
6. A low level of gross motor skills as well as an incorrect gait pattern may affect the quality of life, reducing it.

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