Assessment of Foot Shape in Children and Adolescents with Intellectual Disability: A Pilot Study

Authors' Contribution:
Study Design A
Data Collection B
Statistical Analysis C
Data Interpretation D
Manuscript Preparation E
Literature Search F
Funds Collection G

ABCDE   **Andżelina Wolan-Nieroda**
ABCDEF **Agnieszka Guzik**
ABC   **Katarzyna Bazarnik-Mucha**
CF   **Maciej Rachwał**
B   **Justyna Drzał-Grabiec**
DF   **Ewa Szeliga**
BDEF   **Katarzyna Walicka-Cupryś**

Medical Department, Institute of Physiotherapy, University of Rzeszów, Rzeszów, Poland

Corresponding Author: Agnieszka Guzik, e-mail: agnieszkadepa2@wp.pl
Source of support: Departmental sources

Background: Available publications provide little evidence pertaining to assessment of foot shape in children with intellectual disability. The aim of this study was to assess the parameters of foot shape in children and adolescents with intellectual disability and to evaluate the relationship between the degree of disability and these parameters.

Material/Methods: The study involved 90 individuals aged 7–15 years, including 45 subjects with mild and moderate levels of intellectual disability (study group) and 45 peers with normal intellectual development (control group). Each participant was subjected to photogrammetric assessment of foot shape based on the projection moire effect.

Results: Analysis of the relationship between the disability level and the assessed parameters showed that the length of the right (p=0.006) and left (p=0.004) foot, as well as Wejsflog's rate for the right (p<0.001) and left (p<0.001) foot, were significantly higher among children with mild disability, whereas GAMMA angle of the right (p=0.028) and left (p=0.006) foot was significantly higher among children with moderate disability.

Conclusions: The findings show a significant relationship between the degree of disability and the assessed foot parameters. Significant differences between the subjects with intellectual disability and the control group were identified in the basic parameters defining foot structure.

MeSH Keywords: **Foot Bones • Foot Deformities, Acquired • Intellectual Disability**

Full-text PDF: https://www.medscimonit.com/abstract/index/idArt/905184
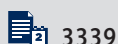
📄 3339   🎞 6   📊 1   📚 25

Background

Intellectual disability is defined as a developmental disorder with deficits in adaptive behaviors associated with insufficient or incomplete development of intellectual capacities [1]. Children with intellectual disability present with significant differences in body posture compared to their normally developing peers. Individuals in this group more often have contractures of the hip and knee and abnormal spinal curvatures in the sagittal and frontal planes, as well as lower-limb disorders. Defective positioning in the areas of the torso, pelvis, and extremities is a predictor of lateral curvatures of the spine [2]. Another interesting issue is that of altered foot shape in children and adolescents with intellectual disability. Undoubtedly, in terms of both anatomy and biomechanics, the foot is a complex structure, contributing to stable stance, ability to walk, and effective transfer of force through the lower extremities. Any changes affecting foot function can negatively impact the condition of body segments located above, starting with their abnormal development and ending with altered body posture [3]. Therefore, risk assessment related to the incidence of defective foot shapes in children with intellectual disability remains an important issue.

Research has shown that developmental delay in motor control is closely linked with intellectual disability. Children and adolescents with intellectual disability display functional deficits in various domains; for instance, they present with balance- and gait-related impairments and have serious difficulties maintaining proper posture in standing position [4–7]. Furthermore, it has been demonstrated that individuals in this group present with worse muscle strength than subjects with no disabilities [8]; therefore, many individuals with intellectual disability have behaviors and lifestyles that involve significantly lower levels of physical activity. Sedentary lifestyle and lack of sufficient exercise may in turn lead to foot deformation [9,10]; therefore, it is important to determine whether the above factors affect foot shape, leading to flat foot deformity. There are few reports on foot shape of individuals with intellectual disability. Currently available publications provide a variety of data pertaining to postural defects in children with intellectual disability. There is evidence showing that postural defects related to feet and knees dominate among children and adolescents with intellectual disability, linked with Down syndrome, and the most common problems include flat feet and knock knees [11–13]. It has also been suggested that there is no relationship between the degree of intellectual disability and flat feet in adolescents with Down syndrome [14]. However, some authors reported that individuals with intellectual disability significantly more often are have postural defects associated with the spine, and to a lesser degree with defects in lower limbs, and they report that worse intellectual disability is associated with greater potential for deficits in body posture [2]. In view of the above, the purpose of the present study was to assess the parameters of foot shape in children and adolescents with intellectual disability, and to examine the relationship between the degree of disability and the relevant foot parameters.

Material and Methods

Participants

The assessment was carried out in a group of 90 subjects 7–15 years of age (mean age, 11.49±2.3 years), including 45 individuals diagnosed with intellectual disability (study group) and 45 subjects with normal intellectual development, matched for age (control group). The measurements were carried out in a special education school and in a primary school in the Podkarpackie Region, Poland. The entire group consisted of 39 girls (43.3%) (21 in the study group and 18 controls) and 51 boys (46.7%) (24 in the study group and 27 controls). The study group comprised 28 subjects (62.2%) with mild disability and 17 subjects (37.8%) with moderate disability. Informed consent for the children's participation in the study was obtained in writing from their parents or legal guardians. The study was approved by a local Bioethics Commission and was conducted in accordance with the World Medical Association's Declaration of Helsinki on human research. Inclusion criteria were: children with mild and moderate intellectual disability, attending a special school. Exclusion criteria were: severe intellectual disability and lower-extremity injury. The basic anthropometric characteristics are presented in Table 1.

Examination protocol

The subjects' foot shapes were assessed using photogrammetry method (a CQ-ST apparatus manufactured by Electronic System, Poland). The examination was performed by means of a podoscope using the procedure described by the manufacturer. The methodology makes use of visible light and is absolutely non-invasive. The study was performed between September and November 2016. Before scans were performed, the subjects were asked to remove their shoes and socks. Then, they were asked to step into a square in front of the panel of the device. Following the examiner's instructions, the child stepped into position on the podoscope, with the weight distributed evenly on both legs. The room was darkened during the examination. The analyses took into account: foot length (DL), foot width (SZ), foot length-to-width ratio (Wejsflog index) (DL/SZ) representing proportions of the foot, GAMMA angle representing the transverse arch of the foot (GAMMA), Clarke's angle corresponding to the longitudinal arch of the foot (CL), angle of hallux valgus (ALFA), and angle of varus of the fifth toe (BETA) (Figure 1). Analyses of foot shapes took into account

Table 1. Anthropometric characteristics of the groups.

Descriptive statistics	$\bar{\chi}$	Me	SD	Min.	Max.
Study group					
BMI [kg/m²]	19.32	19.18	4.45	12.80	31.60
Height [cm]	142.84	145.00	13.61	110.00	163.00
Weight [kg]	40.38	40.00	14.23	20.00	77.00
Control group					
BMI [kg/m²]	20.24	20.24	3.16	14.34	27.06
Height [cm]	152.33	153.25	13.5	127.00	174.00
Weight [kg]	47.79	46.90	12.85	27.00	77.50

$\bar{\chi}$ – arithmetic mean; Me – median; SD – standard deviation; Min – minimum; Max – maximum; BMI – body mass index.
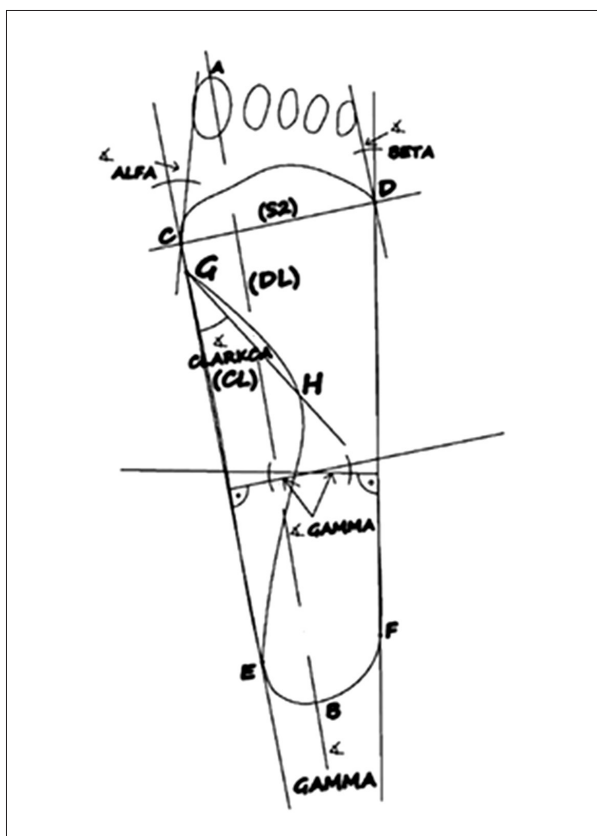

Figure 1. Schematic diagram showing the measurements. AB – foot length (DL); CD – foot width (SZ); GAMMA – angle representing the transverse arch of the foot; Clarke's angle corresponding to the longitudinal arch of the foot (CL); ALFA – angle of hallux valgus; BETA – angle hallux varus.

the normative for r-right foot value and l-left foot value proposed by Kasperczyk and Wejsflog [15,16]. Clarke's angle (CL) in a normal foot ranges from 42° to 54° and in a flat foot it is up to 30°; low arch ranges from 31° to 41° and high arch

starts from 55°. Wejsflog index (i.e., foot length-to-width ratio) should be 3: 1, and its value is generally 2–3 [15,16]. It is assumed that values approximating "2" reflect defective foot shape proportions, and those closer to "3" indicate perfect foot shape proportions. It was assumed that a value exceeding 2.5 represented normal foot proportions. The normal angle of the hallux valgus (ALFA) and varus of the fifth toe (BETA) is 0°–9°, the normal angle of the hallux varus is 0°–(–9°) (ALFA), and the normal GAMMA angle (GAMMA) is up to 18°, with higher values corresponding to transverse flat foot.

Statistical analysis

The acquired data were subjected to statistical analyses using Statistica 10.0 (StatSoft). The variables were examined with parametric tests and non-parametric tests. The choice of parametric test depended on the fulfilment of its basic assumptions (i.e., goodness of fit between distributions of the relevant variables and normal distribution), which were verified using the Shapiro-Wilk W test. Assessment of differences between the mean level of numerical characteristics in the 2 populations was performed using the *t* test for independent variables or with the non-parametric Mann-Whitney U test. Analysis of variables associated with qualitative data was carried out using the chi-squared test. Statistical significance was assumed at p<0.05.

Results

Initially, 52 intellectually disabled children were qualified for the study. However, the research was completed by only 45 children: 7 children failed to attend the examination and 3 children gave up due to excessive fear. Ultimately, the study involved 45 children. The control group was quantitatively matched with the study group.

Table 2. Quantitative data for the normal values and for pathology based on Clarke's angle.

Foot structure based on Clarke's angle		Study group		Control group		Significance (p)
		N	%	N	%	
Right foot	Low-arched	6	13.3%	4	8.9%	χ^2 (2)=1.20 p=0.548
	Healthy	22	48.9%	27	60.0%	
	High-arched	17	37.8%	14	31.1%	
	Total	45	100.0%	45	100.0%	
Left foot	Low-arched	7	15.6%	6	13.3%	χ^2 (2)=3.00 p=0.223
	Healthy	17	37.8%	25	55.6%	
	High-arched	21	46.7%	14	31.1%	
	Total	45	100.0%	45	100.0%	

χ^2 – chi-squared test; p – probability level.

Table 3. Wejsflog index for the right and left foot in the study group and in the controls.

Wejsflog index		Descriptive statistics						Significance (p)
		n	$\overline{\chi}$	Me	Min.	Max.	s	
Right foot	Study group	45	2.75	2.78	1.99	3.28	0.27	Z=0.96 p=0.336
	Control group	45	2.69	2.71	0.69	3.62	0.38	
Left foot	Study group	45	2.71	2.72	2.28	3.12	0.18	Z=−0.04 p=0.961
	Control group	45	2.70	2.74	1.24	3.28	0.29	

Z – normal distribution, Z-test result Z; p – probability level.

Analysis of foot shapes, taking into account Clarke's angle (CL), did not show statistically significant differences in the shape of the longitudinal arch in the right (p=0.548) or in the left foot (p=0.223) between the study and control groups (Table 2).

Analysis of Wejsflog index showed that the mean value of the relevant parameter in the study group was 2.75±0.27 for the right foot and 2.69±0.38 for the left foot, whereas the mean value of Wejsflog index in the control group was 2.71±0.18 for the right foot and 2.70±0.29 for the left foot. The mean value of Wejsflog index did not differ significantly in the 2 groups for the right (p=0.336) or the left foot (p=0.961) (Table 3).

The identified GAMMA angle parameters made it possible to determine the number of feet with normal shape and the number of feet with symptoms of pathology in the study and control groups. The findings showed no statistically significant differences in the number of normal feet or those with abnormalities, either right (p=0.651) or left (p=0.899), between the study group and the control group. Normally-shaped right feet were identified in 16 (35.6%) subjects from the study group and in 19 (42.2%) controls. Right feet with high transverse arch were identified in 20 (44.4%) subjects from the study

group and in 20 (44.4%) controls. Right transversely flat feet were found in 9 (20.0%) children in the study group and in 6 (13.3%) controls. Left feet with normal shape were observed in 19 (42.2%) subjects in the study group and in 17 (37.8%) children in the control group. Left feet with high transverse arch were identified in 20 (44.4%) subjects in the study group and in 21 (46.7%) controls. Left transversely flat feet were found in 6 (13.3%) subjects in the study group and 7 (15.6%) controls.

The obtained ALFA angle parameters made it possible to identify the rates for normally-shaped big toes, hallux valgus, and hallux varus in the study and the control groups. There were no statistically significant differences in the number of hallux varus, hallux valgus, and normally-shaped big toes, either right (p=0.750) or left (p=0.367), between the 2 groups. Normal right big toe shape was identified in 23 (51.1%) subjects in the study group and in 26 (57.8%) controls. Normally-shaped left big toes were found in 16 (35.6%) subjects in the study group and 21 (46.7%) controls.

Analysis of BETA angle made it possible to identify the number of normally-shaped fifth toes, as well as the number of valgus and varus deformities of fifth toes, in the study group

Table 4. Quantitative data for the norm and for pathology based on Beta angle.

Foot structure based on Beta angle		Study group		Control group		Significance (p)
		N	%	N	%	
Right foot	Normal position of fifth toe	16	35.6%	7	15.6%	χ² (1)=4.73 (p= 0.029)
	Varus of fifth toe	29	64.4%	38	7.8%	
	Total	45	100.0%	45	100.0%	
Left foot	Normal position of fifth toe	7	15.6%	6	13.3%	χ² (1)=0.08 p=0.688
	Varus of fifth toe	38	84.4%	39	86.7%	
	Total	45	100.0%	45	100.0%	

χ² – chi-squared test; p – probability level.

Table 5. Comparison of feet parameters in the study group, relative to the degree of disability.

Study group	Mild disability n=28			Moderate disability n=17			Significance (p)	
	$\bar{x}$	Me	SD	$\bar{x}$	Me	SD	t*/U	p
DLp	210.64	211.00	21.36	192.12	197.00	20.29	*2.87	0.006
DLl	212.14	211.00	19.68	192.88	196.00	21.45	*3.08	0.004
DL(p-l)	−1.64	−1.00	5.96	−0.59	0.00	5.03	201.00	0.397
DL(%)	−0.94	−0.55	3.24	−0.31	0.20	2.54	204.50	0.437
SZp	74.57	74.00	9.39	74.47	75.00	9.16	*0.04	0.972
SZl	76.07	75.00	8.06	74.88	77.00	8.23	*0.48	0.637
SZ(p-l)	−1.57	−2.00	4.79	−0.41	−2.00	5.42	*−0.75	0.458
SZ(%)	−2.41	−2.55	6.70	−0.86	−2.40	7.41	*−0.73	0.472
DL/SZp	2.84	2.85	0.25	2.59	2.60	0.22	86.00	<0.001
DL/SZl	2.80	2.79	0.14	2.58	2.58	0.14	*5.04	<0.001
(DL/SZ)(p-l)	1.01	2.25	7.59	0.05	0.50	7.33	209	0.509
ALFAp	6.18	6.30	13.43	6.72	4.70	6.55	209.00	0.509
ALFAl	4.73	5.75	7.85	6.47	7.10	8.40	*−0.70	0.487
BETAp	7.71	8.85	9.18	9.68	8.20	12.09	231.50	0.880
BETAl	11.90	12.00	5.80	11.81	11.50	9.78	*0.04	0.971
GAMMAp	14.38	14.05	3.54	16.98	16.60	4.01	*−2.28	0.028
GAMMAl	13.99	14.50	2.65	16.58	16.10	3.52	122.00	0.006
CLp	45.84	48.30	13.13	40.75	44.00	16.62	190.00	0.269
CLl	48.27	52.05	13.05	41.43	47.30	18.00	169.00	0.109

n – number of observations; $\bar{x}$ – arithmetic mean; Me – median; SD – standard deviation; t* – result of Student's t-test for independent variables; U – result of Mann-Whitney test; p – probability level; DL – foot length; SZ – foot width; DL/SZ – foot length-to-width ratio (Wejsflog index); ALFA – angle of hallux valgus; BETA – angle of toe varus; GAMMA – gamma angle reflecting transverse arch of foot; CL – Clarke's angle for longitudinal arch of foot; p – right foot; l – left foot.

Table 6. Comparison of foot parameters in the study and control groups.

Girls and boys	Study group n=45			Control group n=45			Significance (p)	
	Me	SD	$\bar{\chi}$	Me	SD	t*/U	p
DLp	203.64	204.00	22.63	214.38	214.00	21.96	*−2.28	0.024
DLl	204.87	205.00	22.23	213.87	218.00	19.96	*−2.02	0.046
DL(p-l)	−1.24	−1.00	5.59	0.49	0.00	8.63	−1.12	0.264
DL(%)	−0.70	−0.50	2.98	0.08	−0.10	3.64	−1.17	0.244
SZp	74.53	75.00	9.20	82.98	79.00	26.50	−2.59	0.010
SZl	75.62	75.00	8.05	80.29	79.00	12.12	−1.93	0.053
SZ(p-l)	−1.13	−2.00	5.01	2.73	1.00	31.19	−1.47	0.142
SZ(%)	−1.83	−2.40	6.94	−1.54	0.80	27.19	−1.52	0.128
DL/SZp	2.75	2.78	0.27	2.69	2.71	0.38	0.96	0.337
DL/SZl	2.71	2.72	0.18	2.70	2.74	0.29	−0.05	0.961
(DL/SZ)(p-l)	0.65	1.80	7.42	−6.28	−0.10	48.32	1.25	0.212
ALFAp	6.38	6.30	11.24	4.22	6.10	8.00	0.29	0.775
ALFAl	5.39	6.30	8.01	5.66	5.20	11.62	0.79	0.431
BETAp	8.46	8.20	10.28	17.70	13.90	28.56	−3.14	0.002
BETAl	11.86	11.90	7.44	14.51	14.80	7.73	−1.87	0.061
GAMMAp	15.36	15.00	3.89	13.89	15.40	9.32	−0.08	0.932
GAMMAl	14.97	15.20	3.23	14.81	15.20	3.74	−0.16	0.872
CLp	43.92	47.80	14.57	42.69	43.40	12.24	1.23	0.217
CLl	45.68	48.00	15.28	50.74	47.10	35.59	0.79	0.431

n – number of observations; $\bar{\chi}$ – arithmetic mean; Me – median; SD – standard deviation; t* – result of Student's t-test for independent variables; Z – result of Mann-Whitney test; p – probability level; DL – foot length; SZ -– foot width; DL/SZ – foot length-to-width ratio (Wejsflog index); ALFA – angle of hallux valgus; BETA – angle of toe varus; GAMMA – gamma angle reflecting transverse arch of foot; CL – Clarke's angle for longitudinal arch of foot; p – right foot; l – left foot.

and in the control group. The findings show statistically significant differences in the number of right fifth toes with normal shape and varus deformity (p=0.029) in both groups. A normally-shaped right fifth toe was found in 16 (35.6%) subjects in the study group and 7 (15.6) controls. A normally-shaped left fifth toe was identified in 7 (15.6%) children from the study group and in 6 (13.3%) controls. In the left toes, there were no statistically significant differences between the groups (p=0.688) (Table 4).

Analysis of the data related to degree of disability and the examined parameters showed statistically significant differences related to DL r (p=0.006), DL l (p=0.004), DL/SZ r (p<0.001), DL/SZ l (p<0.001), GAMMA r (p=0.028), and GAMMA l (p=0.006) among the mildly and moderately intellectually disabled children from the study group. The DL r, DL l, DL/SZ r, and DL/SZ l parameters were higher in the children with mild disability, while GAMMA r and GAMMA l were higher in children with moderate disability. The remaining parameters did not significantly differ among the children in the 2 groups (Table 5).

Analysis of differences in the relevant parameters within the study group and the control group showed statistically significant differences in the parameters DL r (p=0.024), DL l (p=0.046), SZ r (p=0.010), and BETA r (p=0.002) among children in the study group and the controls. All of these parameters were higher in the children from the control group (Table 6).

Discussion

In recent years, more and more studies have focused on assessment of body posture in children with intellectual disability [1,2,4,10–14,17–20]. Some publications have discussed foot shapes in children and adolescents with intellectual disability associated with Down syndrome [11–14], but there are few reports related to parameters of longitudinal and transverse foot arch in children and adolescents with intellectual disability treated globally, without differentiation into specific disease entities [2,10]. This observation inspired the present study.

The findings of the present study acquired during analysis of foot shapes, based on Clarke's angle, did not show statistically significant differences between the study group and the controls in the longitudinal arch shape of the right (p=0.548) or left foot (p=0.223), but low-arched and high-arched feet were more common in the study group than in the controls, and healthy foot shapes were more often found in the children from the control group. Similarly, the obtained values of Wejsflog index showed normal transverse foot arch in the children from both the study and the control group. No significant differences between the groups were identified in this parameter in either the right (p=0.336) or left foot (p=0.961).

Analysis of GAMMA and ALFA angles also did not show any significant differences in the number of normal feet and feet with abnormalities, either right (GAMMA p=0.651, ALFA p=0.750) or left (GAMMA p=0.899, ALFA p=0.367), identified in the study group and in the controls. However, assessment of BETA angle showed significant differences between the groups in the number of right fifth toes with valgus deformity, normal shape, and varus deformity (p=0.028). Analysis of relationships between the degree of disability and these parameters showed that right foot length (p=0.006) and left foot length (p=0.004), as well as Wejsflog index for the right (p<0.001) and left foot (p<0.001), were significantly higher in children with mild disability, and GAMMA angle, reflecting the transverse angle in the right (p=0.028) and left foot (p=0.006), was significantly higher in children with moderate disability.

Similarly, Przysada et al. focused on assessing the prevalence of foot abnormalities in children with intellectual disability. These authors investigated the relationship between the degree of intellectual disability and the type of foot defects, and compared shapes of the right and the left foot in children with intellectual disability. The study examined 66 subjects with various levels of intellectual disability, aged 7–15 years. Foot arch was examined using plantoconturography method. Foot deformities were found in a significant majority (80%) of the subjects, with comparable rates identified in girls and boys. Children with moderate and severe disability were more likely to have flat feet (53%) and low-arched feet (40%), and were

less likely to have with high-arched feet (7%). In the group of children with mild disability, the percent distribution of these deformities was similar. High-arched feet were found in 33% of the subjects with abnormal longitudinal arch. No correlation was found between the degree of intellectual disability and the type of foot deformity. Differences in the structure of the right and left foot were only found in the longitudinal foot arch, which was linked with fallen left-side longitudinal arch in 64% of the subjects with foot deformity [10]. Body posture in subjects with intellectual disability was also assessed by Momola and Czarny, who studied a group of 201 subjects, aged 12–18 years, presenting with severe intellectual disability. The assessment focused on body posture in frontal and sagittal plane, as well as position of the lower limbs; the latter was examined for defects such as knocked knees, bow legs, low-arch foot, flat foot, and flat foot with valgus deformity. Morphological structure of feet was examined using plantographic method. The authors demonstrated that intellectually disabled children tend to present with poor body posture. In the entire group, regardless of the degree of disability, only 7.7% of boys and 7.1% of girls had good body posture, while the remaining subjects had poor posture or posture-related defects, and 65.5% had bad posture. The authors also reported that postural defects were significantly more often associated with the spine, and less frequently with the lower limbs. Most of the boys and girls, with either moderate or severe disability, presented with abnormal lateral curvatures of the spine. However, abnormalities in the lower limbs, including foot deformities, were found in 44.4% of the boys and in 61.9% of the girls [2]. Momola also assessed body posture and foot shapes in a group of girls with mild or severe intellectual disability. The study group consisted of 426 girls, ranging in age from 8 to 18 years. Foot shapes were assessed using plantograms. The author showed that most of the severely disabled girls (over 45%) had flat feet and poor body posture, while the girls with moderate intellectual disability had better body posture; however, flat feet were identified in over 36% of these subjects [19]. Our findings in the present study are consistent with those reported by the above authors. Analysis of foot-related body posture shows that a greater degree of intellectual disability tends to coincide with a higher proportion of defective foot shape and with lower transverse arch. Similar issues were investigated in a study by Kuzdzal et al., who assessed body posture in a group of 108 intellectually disabled students, aged 11–13 years, confirming that children with intellectual disability frequently present abnormalities in body posture [18].

In the present study, children with Down syndrome accounted for 6.66% of the study group. It has been reported that musculoskeletal impairments related to the feet are a serious challenge for young people with Down syndrome, affecting their daily functioning and mobility [21,22]. According to Lim et al.,

foot deformities and flat feet are common in this group of patients. The authors examined foot structure in 50 subjects with Down syndrome, age 5–18 years (mean age 10.6 years). They reported flat foot, hallux valgus, and lesser toe deformities in 76%, 10%, and 12% of the subjects, respectively [11]. Pau et al. assessed the main parameters related to foot-ground interaction in standing position, as well as age-related evolution of feet in young people with Down syndrome. The study was conducted in a group of 99 children with Down syndrome, aged 6–11 years (mean age 9.7 years), as well as 99 healthy controls matched for age and sex. The examined factors included rearfoot, midfoot, and forefoot contact area, the overall foot-ground contact area, and average contact pressure. The acquired values were compared to those identified in the control group. The authors found higher average contact pressure in the midfoot and forefoot in the children with Down syndrome, confirming the widespread incidence of flatfoot deformity linked with hypotonia and ligamentous laxity in this group of patients [13].

The present study has shown significant differences in the basic parameters defining foot structure (i.e., foot width and length) between subjects with intellectual disability and the control group. Length of the right (p=0.024) and left foot (p=0.046), as well as width of the right foot (p=0.010), were significantly greater in the control subjects. These findings are consistent with numerous studies reporting differences in foot length, and, more specifically, short foot length, as a diagnostic marker of Down syndrome [23–25], but in the present study, children with Down syndrome constituted only 7% of the study group.

In summary, the above considerations show that the results of the present study do not confirm findings available in the literature, as our findings suggest there are no statistically significant differences in foot shapes between children and adolescents with and without intellectual disability. Therefore, to verify these findings, it will be necessary to conduct further research involving a larger group of subjects and designed to additionally assess foot shape in children and adolescents with severe intellectual disability.

Our study shows tendencies in the changes of parameters reflecting foot architecture in individuals with a disability; these findings enable quick and accurately targeted preventive and corrective action. It has been determined that worse intellectual disability is associated with decreased proportions in foot shape and lower transverse arch. Therefore, rehabilitation treatments designed for individuals with disabilities should particularly focus on the forefoot and include exercises aimed at increasing the height of the transverse arch.

Conclusions

Our study did not find statistically significant differences in most of the examined parameters of foot shape in the children and adolescents from the study group and control group. Only the BETA angle-based measure showed statistically significant differences in the number of right fifth toes with normal shape and varus deformity between the 2 groups. Moreover, a significant relationship was found between the degree of disability and the examined foot parameters. Right and left foot length, as well as Wejsflog index, for the right and left foot were significantly greater in the group of children with mild disability, and the GAMMA angle of the right and left foot was significantly greater in the group of children with moderate disability. Significant differences between the subjects with intellectual disability and the control group were identified in the basic parameters defining the foot structure (i.e., foot length and width).

References:

1. Lee K, Lee M, Song C: Balance training improves postural balance, gait, and functional strength in adolescents with intellectual disabilities: Single-blinded, randomized clinical trial. Disabil Health J, 2016; 9(3): 416–22

2. Momola I, Czarny W: Body posture and energetic predisposition of the intellectually disabled. Gen Med Health Sci, 2011; 17(2): 57–63

3. Dawe EJC, Davis J: Anatomy and biomechanics of the foot and ankle. Orthop Trauma, 2011; 25(4): 279–86

4. Kachouri H, Borji R, Baccouch R et al: The effect of a combined strength and proprioceptive training on muscle strength and postural balance in boys with intellectual disability: An exploratory study. Res Dev Disabil, 2016; 53–54: 367–76

5. Zur O, Ronen A, Melzer I, Carmeli E: 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: 1951–57

6. Enkelaar L, Smulders E, van Schrojenstein Lantman-de Valk H et al: A review of balance and gait capacities in relation to falls in persons with intellectual disabilities. Res Dev Disabil, 2012; 33(1): 291–306

7. Vuijk PJ, Hartman E, Scherder E, Visscher C: Motor performance of children with mild intellectual disability and borderline intellectual functioning. J Intellect Disabil Res, 2010; 54: 955–65

8. Borji R, Zghal F, Zarrouk N et al: Individuals with intellectual disability have lower voluntary muscle activation level. Res Dev Disabil, 2014; 35: 3574–81

9. Ayán Pérez C, Martínez-Lemos I, Lago-Ballesteros J et al: Reliability and validity of physical fitness field-based tests in Down syndrome: A systematic review. J Policy Pract Intellect Disabil, 2016; 13(2): 142–56

10. Przysada G, Luszowska A, Drużbicki M et al: Foot deformities in children with intellectual disability. J Sports Sci Ukr, 2010; 3: 163–68

11. Lim QXP, Shields N, Nikolopoulos N et al: The association of foot structure and footwear fit with disability in children and adolescents with Down syndrome. J Foot Ankle Res, 2015; 8: 4

12. Sadowska L, Myslek-Prucnal M, Choińska AM, Mazur A: Diagnostics and therapy for children with Down syndrome in the range of own research and literature review. Prz Med Uniw Rzesz, 2009; 1: 8–30

13. Pau M, Galli M, Crivellini M, Albertini G: Foot-ground interaction during upright standing in children with Down syndrome. Res Dev Disabil, 2012; 33(6): 1881–87

14. Jankowicz-Szymanska A, Mikolajczyk E, Wojtanowskia W: The effect of the degree of disability on nutritional status and flat feet in adolescents with Down syndrome. Res Dev Disabil, 2013; 34: 3686–90

15. Kasperczyk T: Body posture abnormalities. 1st ed. Kraków (PL): Kasper s.c. Publishers, 1994

16. Wejsflog G: Posture – examination and clinical documentation. Pol Orthop Traumatol, 1956; 21(2): 113–20

17. Wang HY, Long IM, Liu MF: Relationships between task-oriented postural control and motor ability in children and adolescents with Down syndrome. Res Dev Disabil, 2012; 33: 1792–98

18. Kużdżał A, Magoń G, Cieślar G: Physical development and body posture of mentally disabled children, with reference to the latest population norms. Sports Med, 2004; 4: 199–204

19. Momola I: Somatic development, body posture and motor abilities in mentally disabled girls. 1st ed. Rzeszów (PL): University of Rzeszów Publishers, 2007

20. Choińska AM, Sadowska L: Synthetic evaluation of physical and psychomotor development in children with Down Syndrome in age from 0–3 years, who were treated by Wrocław Rehabilitation Model (WRM). Prz Med Uniw Rzesz, 2007; 2: 127–36

21. Acharya K: Prenatal testing for intellectual disability: misperceptions and reality with lessons from Down syndrome. Dev Disabil Res Rev, 2011; 17(1): 27–31

22. Pikora TJ, Bourke J, Bathgate K et al: Health conditions and their impact among adolescents and young adults with Down syndrome. PLoS One, 2014; 9(5): e96868

23. Suresh S, Vijayalakshmi R, Indrani S, Lata M: Short foot length: A diagnostic pointer for harlequin ichthyosis. J Ultrasound Med, 2004; 23(12): 1653–57

24. Grandjean H, Sarramon MF: Femur/foot length ratio for detection of Down syndrome: Results of a multicenter prospective study. The Association Française pour le Dépistage et la Prévention des Handicaps de l'Enfant Study Group. Am J Obstet Gynecol, 1995; 173(1): 16–19

25. Johnson MP, Barr M Jr., Treadwell MC et al: Fetal leg and femur/foot length ratio: A marker for trisomy 21. Am J Obstet Gynecol, 1993; 169(3): 557–63