

THE ASSESSMENT OF THE LONGITUDINAL ARCH OF THE FOOT IN DEAF AND HEARING CHILDREN AGED 9 TO 11 YEARS

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The aim of the study was to establish the condition of the foot arch in deaf and hearing children and to determine whether there are differences in the foot arch between children with impaired hearing and healthy children aged 9–11 years.

A group of 19 deaf children and 33 hearing children, including 23 girls and 29 boys aged 9 to 11 years were studied. Their average age was 9.9 years.

The examination of the longitudinal arch of the feet was carried out in an unloaded (in a sitting position) and in a loaded (standing) position, using a Podoskop (POSMED, Poland). In the preparation of impressions of the soles of the feet, a line method according to Wejsflog was used with the specification of an index of the longitudinal arch of the foot. It was noted that there was a statistically significant difference between the arch of the left and the right feet in loading in healthy children ($p < 0.05$). However, no statistically significant differences were noted between the studied groups of children in terms of the indicator of the arch of the foot in both an unloaded and loaded posture. It was noted however, that the condition of the arch of the foot in deaf children was characterised by a lower effectiveness of the muscular and ligament systems, which was confirmed by the values of the foot parameters of deaf children. The results of the Wejsflog index indicate that in deaf children a typical area of variables (the right foot in loading 20.55–39.85) was greater than in healthy children (the right foot in loading 17.05–34.75). Moreover, in both groups of girls greater differences were noted in the degree of foot arching than in boys. This confirms the tendency to generally a more labile body posture in girls and in the muscular and ligament system of the feet.

In conclusion, no statistically significant differences were noted between the studied groups of children in terms of the index of the arch of the foot in both a loaded and an unloaded posture.

Keywords: Medial longitudinal arch, deaf children, foot defects, podoscope.

INTRODUCTION

Epidemiological and screening tests carried out in Poland in recent years indicate that on average one in every three people has hearing problems and one in every six schoolchildren has hearing disorders. Two to four newborn babies per one thousand have serious in born hearing disorders (Association of Friends of the Deaf and Hard of Hearing Human to Human and Institute of Physiology and Pathology of Hearing, Stowarzyszenie Przyjaciół Osób Niesłyszących i Niedosłyszących Człowiek – Człowiekowi i Instytut Fizjologii i Patologii Słuchu, www.sponin.org.pl). The problem is beginning to relate to a greater and greater part of the population in Poland. In children with hearing disorders at preschool age walking anomalies appear. The change in their stereotype of walking causes changes in muscle work and the muscular strength of calves and feet may be weakened, which may affect the development of the arch of the foot during this period. The walking of deaf children may be heavy and not very springy. Body balance and

coordination of individual activities are disturbed. Also speech is impeded, which translates to the work of respiratory muscles and chest function and indirectly affects the body posture of a child (Zwierzchowska & Gawlik, 2006). The assessment of the longitudinal arch of the foot is performed in various children, both healthy and also in those with disorders and diseases. Children with hearing disorders are characterised by a weak sense of the schema of their own bodies, difficulties in telling the right side from the left side and generally weaker body motorics (Zwierzchowska & Gawlik, 2006; Maszczak, 1994). The results of the few existing studies in the area of the assessment of body posture indicated greater irregularities in body posture in deaf children than in hearing children (Grabara, 2006). Moreover, the available literature notes few studies which present results of the assessment of the longitudinal arch of the foot in deaf children (Demczuk-Włodarczyk et al., 2005). A lot of attention is devoted to the assessment of body posture and feet in obese children (Mikle et al., 2006; Villarroya et al., 2007, 2008; Wearing et al., 2004).

The hearing organ and the vestibular system located next to it are integral parts of the system of neuromuscular control, taking part in coordination and body balancing processes (Selz et al., 1999; Horak et al., 1990; Cushing et al., 2008). The foot is the base of the biokinematic chain in the body's biomechanism, and besides performing a shock-absorbing function it participates in postural control. Changes in the spatial shape of foot joints may affect the coordination of motor patterns (Mitchell et al., 2008), movement stereotypes (Lewit, 2001), muscular balance and may cause disturbances in static and/or dynamic postural control (Wiernicka et al., 2008; Cote et al., 2005). In the children who are hearing impaired it may be expected that there will be disturbances in the functioning of the above mechanisms, which may contribute to changes in the foot's structure (Demczuk-Włodarczyk et al., 2005). Thus a question arises: are deaf children's feet really not as well arched as the feet of hearing children? It should be noted that the results of the studies of maintaining a stable standing posture of hearing and deaf children showed that deaf children are characterised by a better ability to maintain a stable standing posture than hearing children (Grabara, 2006).

Thus a question arises: Do deaf children have correctly arched feet, considering the integration of the nervous and muscular system and control of the nervous system?

The aim of the study was to establish the condition of the foot arch in deaf and hearing children and to check whether there are differences in the foot arch between children with impaired hearing and healthy children aged 9–11 years.

MATERIAL AND METHOD

Deaf children from a primary school for deaf children in Poznań were included, the reference group be-

ing made up of hearing children from Poznań schools. Groups of 19 deaf children and 33 hearing children were assessed, including 23 girls and 29 boys aged 9 to 11 years (TABLE 1).

For the assessment of the correct morphological structure of the feet, a podoscope called the Podoskop (POSMED, Poland) was used.

The assessment of the children's feet was carried out under statodynamic conditions in loading with the body weight – in a standing position with two feet on the podoscope and in an unloaded setting, i.e. sitting down.

The assessment of the longitudinal arches of the feet was carried out in loading, i.e. while standing on the podoscope with a straight body, arms hanging loosely, looking forward, with equal loading of the feet. After taking a photograph of the soles of the feet in the standing position, the participant sat on the table with adjustable height situated behind him or her. When sitting down he or she tried not to move their feet placed on the podoscope. The assessment in unloading was carried out while sitting on the table with their knee and hip joints bent at 90° angles, a straight body, looking forward. In this position, a photograph of the soles of the feet in unloading was taken. The analysis of the photographs of the soles of the feet using a linear method according to Wejsflog was used and an index of longitudinal arch of the foot was established (Śliwa & Śliwa, 2002).

Wejsflog index:

$$Ww = \frac{|x - x_1|}{|y - y_1|} \times 100$$

The examination was carried out in two positions: with loaded feet (a standing position) and with unloaded feet (a sitting position). The analysis of the footprint parameters was performed according to the Wejsflog linear estimation index of the foot (Nowotny & Saulicz, 1993; Napolitano et al., 2000). The Wejsflog index for

TABLE 1

Anthropometric data of the assessed children

Studied group	Deaf children N = 19	Hearing children N = 33
Age [years]	9.93 +/-0.76 [9–11]	9.75 +/-0.75 [9–11]
Weight [kg]	33.75 +/-11.44 [21–55]	36.85 +/-9.83 [24–65]
Height [cm]	140 +/-14.78 [121–168]	140.70 +/-8.74 [126–166]
BMI	10.02 +/-8.68 [11.4–24.1]	18.35 +/-3.24 [13.2–27.4]
Foot width [cm]	7.72 +/-0.86 [6.1–9.4]	7.97 +/-0.86 [6.4–9.8]
Foot length [cm]	21.41 +/-1.82 [19.9–25.3]	21.96 +/-1.40 [19.5–25.4]
Hearing impairment [db]	90.77 +/-23.09 [40–111]	Not applicable

Legend:

mean +/-

standard deviation [min–max]

the scale of hearing impairment/loss:

20–40db – slight

41–70db – moderate

71–90db – significant

91–120db – deep

more than 120db – complete

a normal foot is 28–38, regardless of the experimental conditions (sitting or standing), 0–27 for a foot with a falling arch and 39–50, 51–66, 67–100 and >101 for I^o, II^o, III^o and IV^o degree of flat foot, respectively.

The assessment was carried out in the morning, after obtaining the prior written consent of the children's parents to take the measurements.

STATISTICS

The correspondence of variable distribution with normal distribution was tested using the Shapiro-Wilk test. Due to a lack of the normal distribution of results, the statistical analysis of the obtained data was carried out using non parametric tests.

The following were determined: minimum, maximum, upper quartile, lower quartile, median, quartile deviation and typical variable area.

Using the Wilcoxon's signed rank test it was checked whether significant differences were noted between the arch of the left and right foot in unloading and loading within the tested groups.

Moreover, using the Mann-Whitney U test it was checked whether statistically significant differences were noted between the index of the arch of the left and right feet in unloading and loading between the groups of deaf and hearing children.

On the basis of cross tabulation it was checked whether there were statistically significant correlations of the results between the groups of children in loading and unloading – the Spearman's rank correlation coefficient and Pearson's chi-square test were used. The level of significance $p < 0.05$ was adopted as statistically significant. Computer software Statistica 8.0 was used for computations.

RESULTS

1. In the groups of hearing and deaf girls under conditions of unloading, the largest percentage of hollow feet, both left and right, was noted (Fig. 1, 3). Under conditions of loading, the situation was slightly changed. Also for the left foot in hearing girls, a largest percentage of hollow feet was noted – 71.4% (Fig. 2) and in deaf girls 33.3% of both hollow feet and correct feet (Fig. 2).
2. In deaf girls in case of the left foot a greater difference in the arch depending on the conditions of the examination was noted (Fig. 1, 2).
3. In deaf girls in loading of the right foot, apart from hollow foot, many cases of flat foot of the 1st degree were noted – 50% (Fig. 4).
4. Under conditions of loading in deaf girls a larger percentage of correct left feet 33.3% (TABLE 2) and in hearing girls – right feet 28.6% (Fig. 4) was noted.
5. In both groups of boys the largest percentage of hollow feet in unloading – above 70% (Fig. 5, 7) and in loading around 50% of the right and left foot (Fig. 6, 8) was noted.
6. In hearing boys, a greater percentage of correct feet in loading, 21%, was noted than in deaf boys – 14.2% (Fig. 6).
7. In both groups of boys in loading a significant percentage of flat left feet of the 1st degree was noted (in hearing boys 26.3% and in deaf boys 42.8%) (Fig. 6).
8. Arching of the feet in unloading of deaf and hearing boys is very similar. Greater differences were noted in loading in terms of hollow feet in particular (in hearing boys 42.1%, in deaf boys 57.1%) (Fig. 7, 8).
9. In deaf children a greater variety of types of foot defects and a greater percentage of flat feet of the 1st and 2nd degree was noted on the left side than in hearing children in unloading (15%), in particular in loading (in total approximately 35%) (Fig. 9).
10. It should be emphasised that in loading of the right foot no case of flat foot of the 2nd degree was noted, neither in hearing or deaf children (as opposed to left feet) (Fig. 9, 10).
11. In hearing children on the right in unloading (6%) and in loading (24.2%) there are cases of a flat foot of the 1st degree and on the left in unloading no such case was noted (Fig. 9, 10).

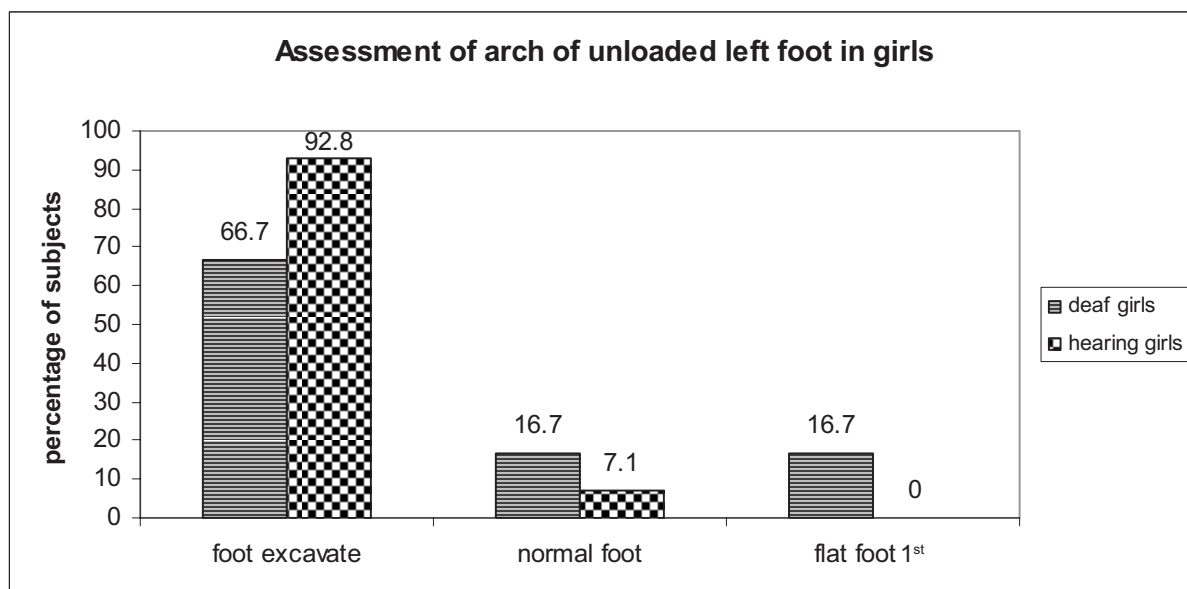
Using the Wilcoxon's test it was found that there was a statistically significant difference between the arch of the left and right foot in loading in healthy children ($p < 0.05$) (TABLE 3) which indicates a varied level of the arching of the right and left feet in individual participants.

The results showed clearly that in deaf children (depending on their IQ range) the right foot in loading was measured at 20.55–39.85, while the left foot in loading was measured at 23.7–42.9) and was therefore greater than in healthy children (in whom the right foot in loading was measured at 17.05–34.75, while the left foot in loading was measured at 11.9–32.5).

On the basis of the Mann-Whitney U test, no statistically significant differences were found between the studied groups in terms of the index of the foot arch in loading and unloading. Only the tendency towards the significance of differences in the Wejsflog index was noted for left feet in loading in healthy and deaf children ($p = 0.079$).

Fig. 1

Assessment of the arch of the unloaded left foot in girls

**Fig.2**

Assessment of the arch of the loaded left foot in girls

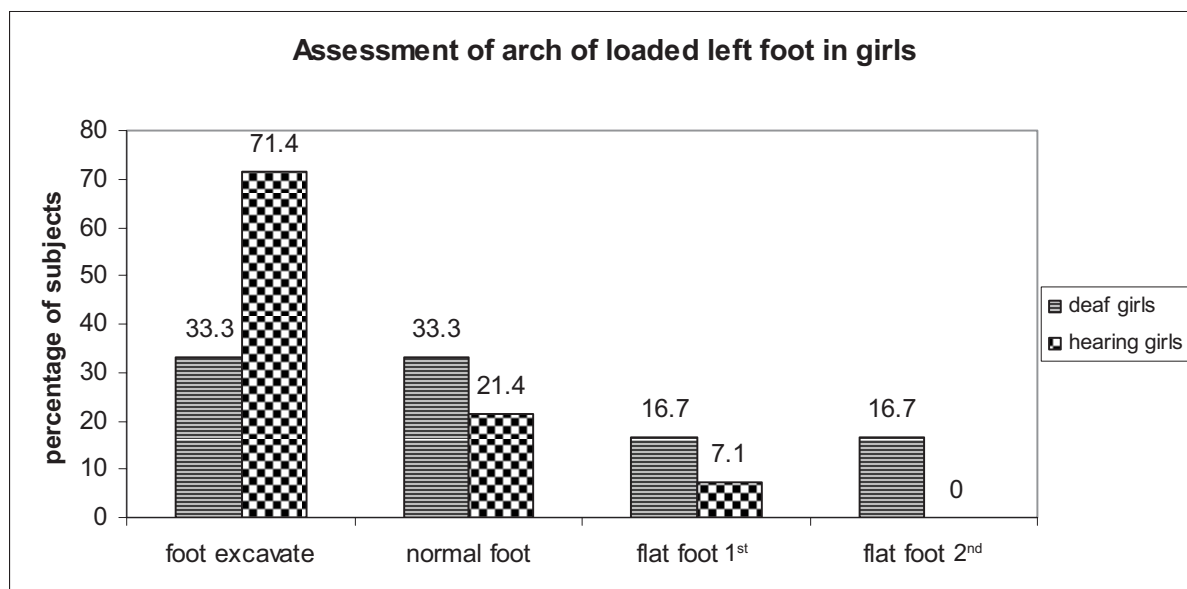
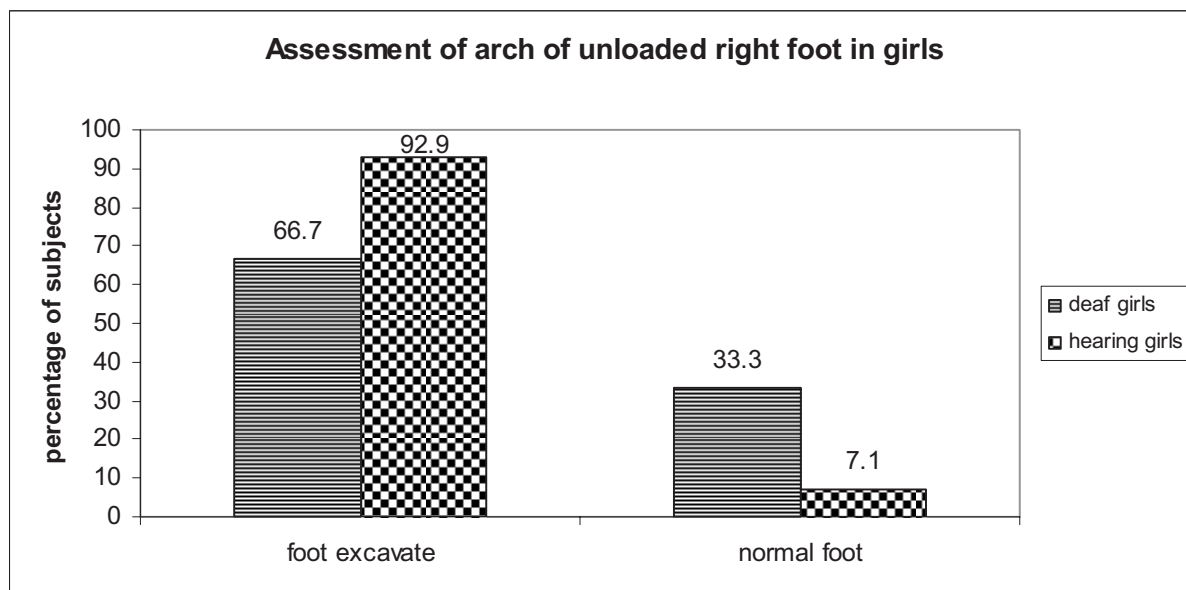


Fig. 3

Assessment of the arch of the unloaded right foot in girls

**Fig. 4**

Assessment of the arch of the loaded right foot in girls

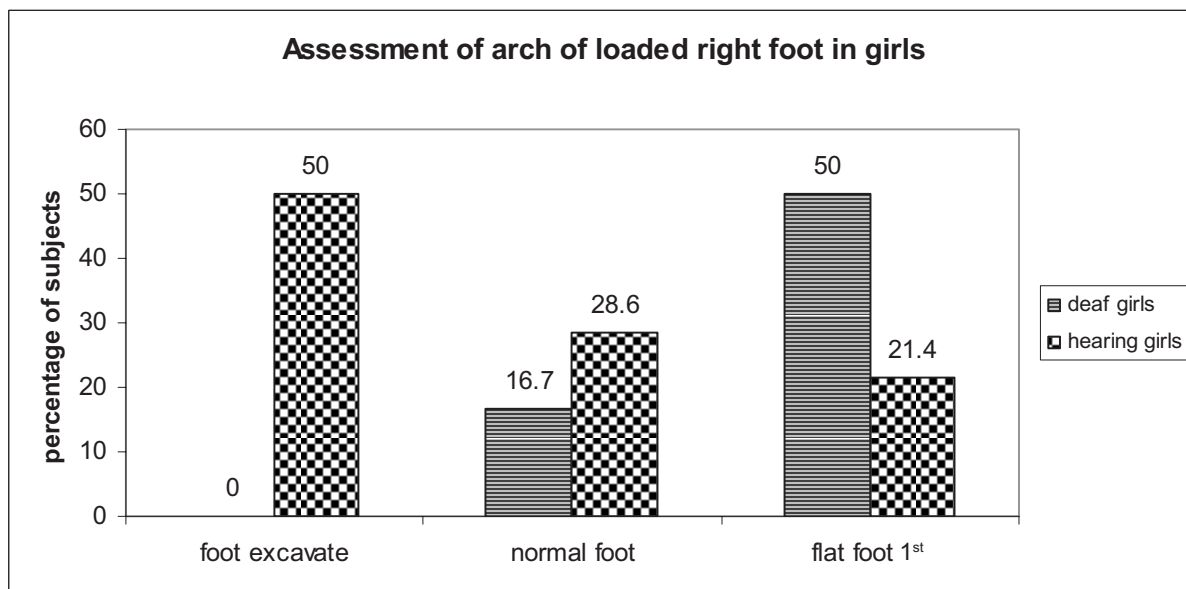
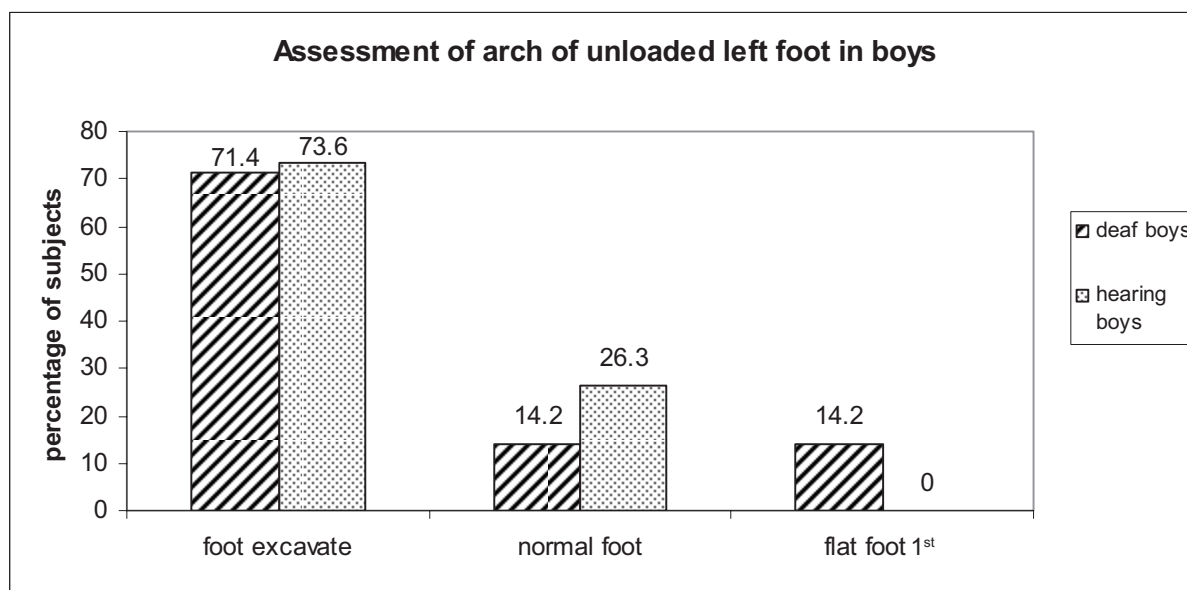


Fig. 5

Assessment of the arch of the unloaded foot in boys

**Fig. 6**

Assessment of the arch of the loaded left foot in boys

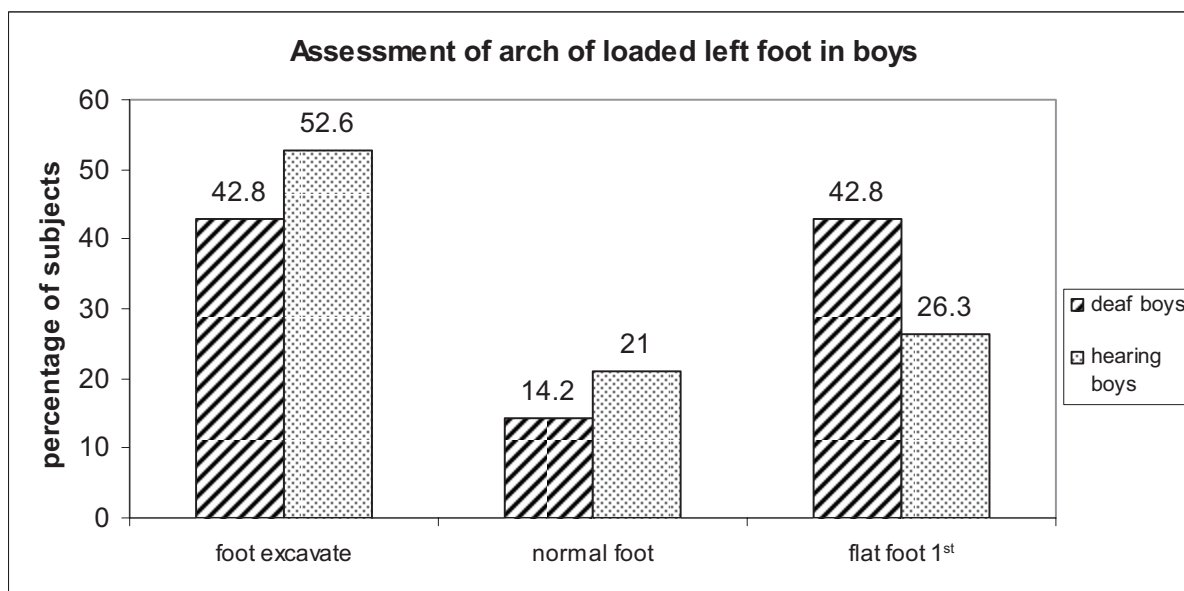


Fig. 7
Assessment of the arch of the unloaded right foot in boys

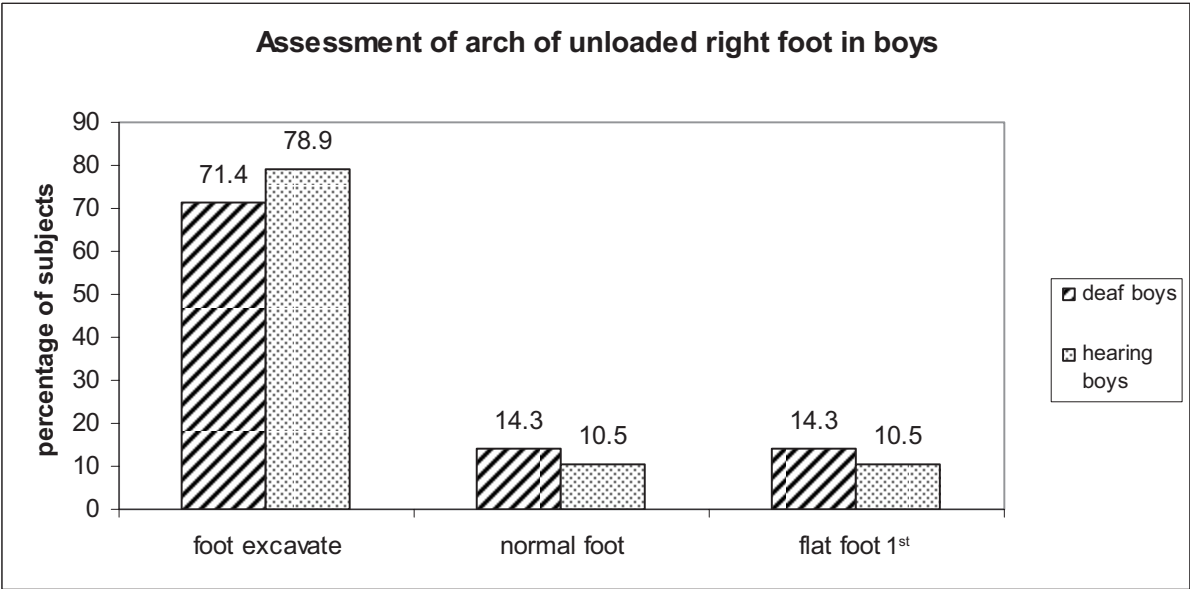


Fig. 8
Assessment of the arch of the loaded right foot in boys

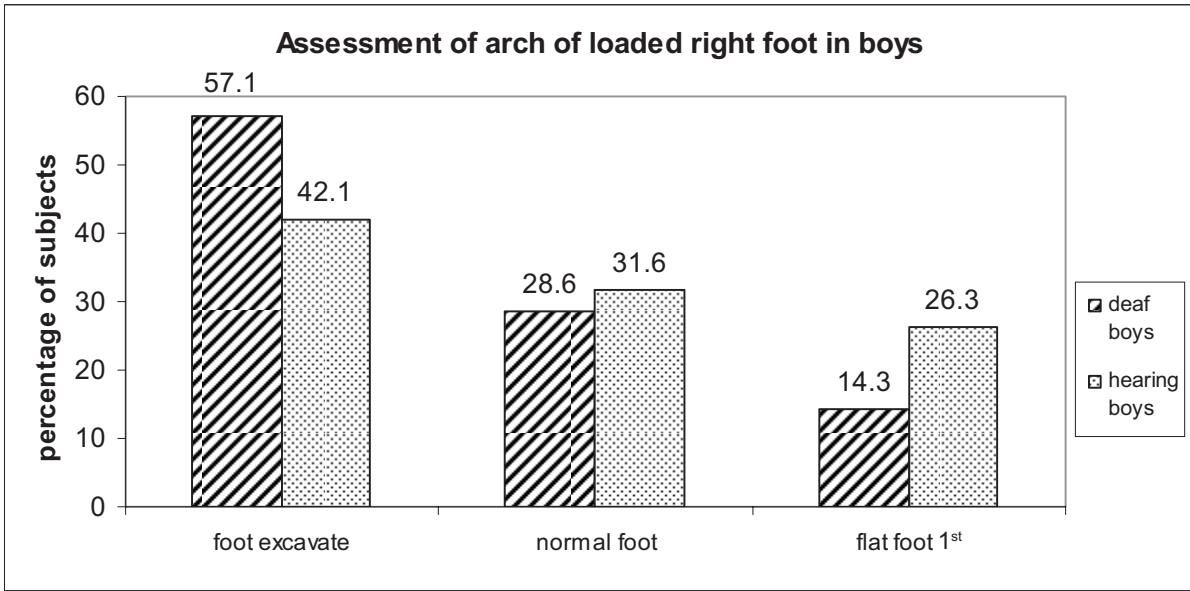
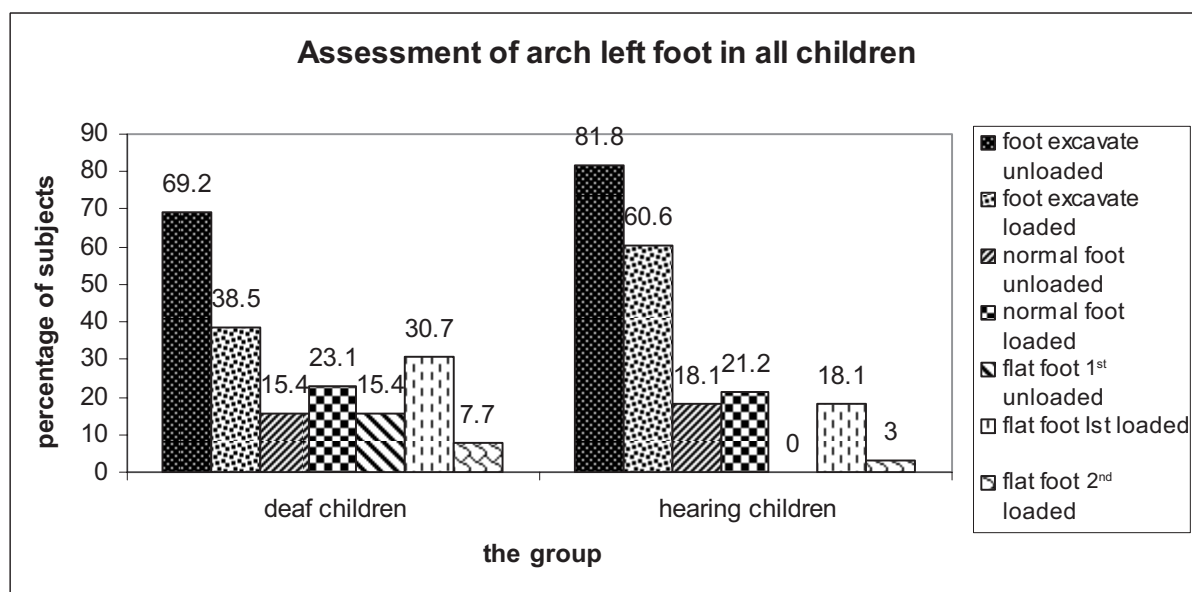


Fig. 9

Assessment of the arch of the unloaded and loaded left foot in all children

**Fig. 10**

Assessment of the arch of the unloaded and loaded right foot in all children

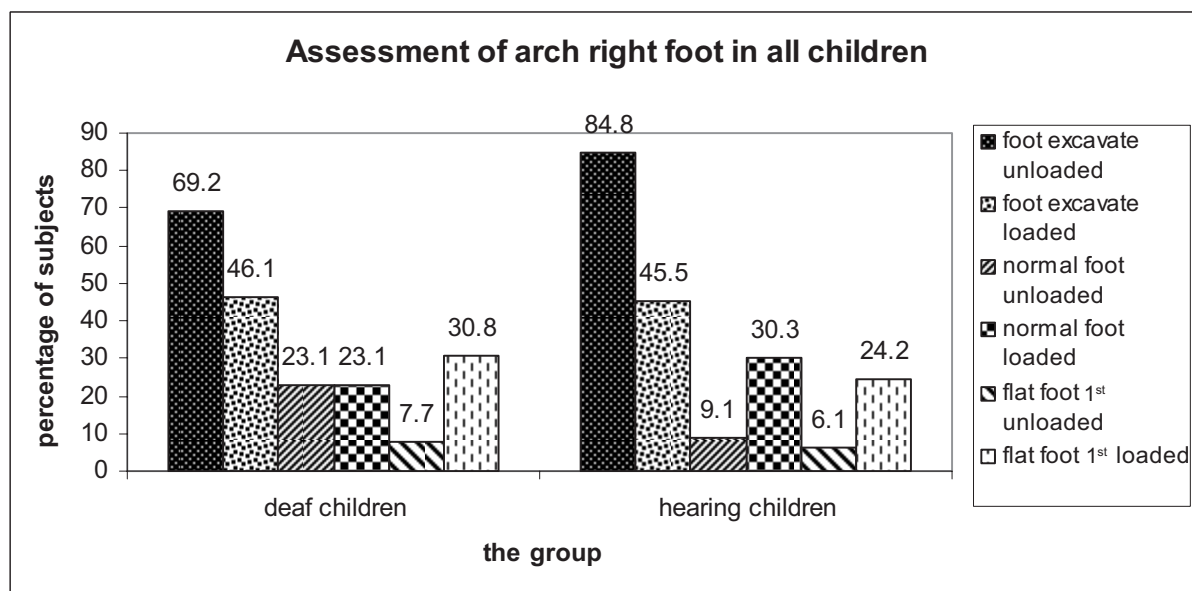


TABLE 2

The Wejsflog index in individual groups under both sets of test conditions for each foot

Variable	Group	Median	Minimum	Maximum	Q ₁	Q ₃	IQ range	Wilcoxon paired test
Wejsflog index loaded left foot	hearing children	22.2	2.0	77.4	12.2	32.8	11.9–32.5	p < 0.05
Wejsflog index loaded right foot		25.9	1.6	59.0	17.8	35.5	17.0–34.7	
Wejsflog index loaded left foot	deaf children	33.3	0.8	52.6	22.4	41.6	23.7–42.9	n. s.
Wejsflog index loaded right foot		30.2	11.6	45.3	20.6	39.9	20.5–39.8	
Wejsflog index unloaded left foot	hearing children	7.7	0.7	47.4	2.7	16.0	1.0–14.3	n. s.
Wejsflog index unloaded right foot		7.6	1.8	47.0	3.8	14.0	2.5–12.7	
Wejsflog index unloaded left foot	deaf children	18.3	2.0	46.7	2.3	30.8	4.0–32.5	n. s.
Wejsflog index unloaded right foot		15.3	2.2	38.7	2.6	30.1	1.5–29.0	

Legend:

n. s. – not significant

The analysis of relations between the properties describing the feet of deaf and healthy children (individual types of feet) using a Spearman's rank correlation coefficient showed a significant relation between the results of the assessment of the left feet in unloading $p = 0.031$, whereas under conditions of loading it showed a tendency to significance $p = 0.091$. Specifying the correspondence of properties using the Pearson's chi-square test showed us a tendency to significance $p = 0.094$, also in the case of the analysis of the results obtained for left feet in unloading. The results of the analysis of statistical correlations showed a similar distribution for typical left feet in unloading and a tendency to similarity of these types of feet in loading in both studied groups. No positive correlations nor any tendency towards similarities were noted for the right feet in neither test conditions nor in neither group.

DISCUSSION

In the analysis of the results of the tests it can be noted that deaf children had worse values of the parameters of the foot arch in both loading and unloading. However, in the comparison of both studied groups under both sets of test conditions, no statistically significant differences were noted.

Available literature includes only the results of the work of Demczuk-Włodarczyk et al. (2005) on the examination of feet in deaf children. In this work, a photometric method was used for the assessment of the

correct structure of feet using the Mora effect. The longitudinal arch was examined on the basis of the height of the arching of five longitudinal arches according to the author's own typology and transverse arching on the basis of the analysis of the pressure of the metatarsal bones and toes on the podoscope panel (Demczuk-Włodarczyk et al., 2005). For the assessment of feet in the current study, a podoscope was used and feet were assessed under conditions of loading and unloading using a line method, according to Wejsflog, specifying an indicator of the longitudinal arch of the foot. The results of the quoted study and the current study should not, however, be compared, due to different methodologies as well as due to the range of age of the examined children (9–19 years). These are, however, the only recent studies of Polish children in Poland.

In the work of Demczuk-Włodarczyk regarding deaf children, the longitudinal arch of the foot was classified as being the correct arching of the foot and one threatened with developing into flat feet. No excessively arched feet and flat feet were noted in deaf children as opposed to the current study where a very high percentage (of hollow feet) was noted in unloading in both groups of examined children. In loading the situation changed. In hearing girls regarding the left foot, the highest percentage of hollow feet was noted (71.4%) and in deaf girls, 33.3% of hollow and correct feet, respectively. In both groups of boys in loading, over 50% of hollow feet were noted and in hearing boys a higher percentage of correct feet than in deaf boys was noted. Greater differences in arching in both groups were noted in girls than in boys.

The greatest variety of types of feet depending on the conditions of the conducted examinations were noted in the groups of deaf girls on the left side. Under loading conditions in deaf girls a higher percentage of correct left feet was noted and in hearing girls a higher percentage of the right feet. The presented results are in line with the results of Demczuk-Włodarczyk in terms of the differences between sexes, i.e. the irregularities relate to girls more often than to boys (Demczuk-Włodarczyk et al., 2005). Moreover, the results of the above work indicate that the majority of changes in the structure of feet relate to the left side both in boys and in girls, not to the right side. The results of the study of Schilling (1985) confirm also that changes in the structure of feet relate more often to girls. The author found also that medium longitudinal plantar arch is smaller in children with hypertrophy of the knee joints and hypermobility of the foot joints.

The results of the study of Demczuk-Włodarczyk also inform us that, in deaf children, there has been a lowering of the longitudinal arch and the appearance of disorders in the front segments of the foot. Grabara, in the assessment of the body posture in deaf children, noted a forward bending of the trunk (Grabara, 2006). This is a compensation mechanism which occurs in body balance disorders (Błaszczuk & Czerwosz, 2005). Deaf children may move their body weight towards the metatarsus and, therefore, a greater loading of the front segments of the foot was noted. The results of the study of Sipko and Skolimowski (1998) indicate that changes in the morphological build of all segments of feet in deaf children are a consequence of the impairment of the coordination processes of postural muscle function and fitness of balancing reactions. Some scholars claim that there is a statistical relationship between the type of feet and the BMI (Mikle et al., 2006; Morrison et al., 2007; Mauch et al., 2008).

Lin et al. (2006) examined hearing children (64 children) aged 4–5 years and 8–10 years. The relationships between six parameters of foot and postural stability were studied. The results of the study showed that, in younger children with a decreased height of the longitudinal arch of the foot, the range of body sway was smaller and these children had a better control of their posture, even only with their eyes closed. The authors explain it with a degree of compensation on the part of skin receptors in these children or the elasticity of the biomechanical structure of the feet under conditions of standing (statics). They also claim that the relationship between the parameters of foot structure and the range of sway is very subtle. Demczuk-Włodarczyk claims that the change in the shape of the foot disturbs the deep sensibility of the impairing muscular balance and coordination of motor patterns (Demczuk-Włodarczyk et al., 2005). However, the results of the study of Wierzbicka-

Damska et al. (2005) contradict this theory. The stability of posture in boys with hearing impairment and healthy boys aged 10–12 and 14–16 was also studied (Posturograf PE-90). All parameters describing the stability of their free straight posture were lower – better in deaf children than in healthy children. The results turned out to be surprising, also due to the fact that the control group consisted of boys practising shooting, which requires the best mechanisms controlling a stable posture. Probably the information from proprioceptors and skin receptors is so perfect that it compensates for any disturbances in the reception of information from the organs controlling balance. This is supported by the fact that the performance of the test with eyes closed resulted in a lowering of the value of the measured parameters.

The above results of the study indicate a greater degree of the occurrence of disorders in the morphological structure of feet in deaf children, in particular in girls. Boys, on the other hand, who, in the current study, did not differ significantly in terms of the arching of the foot, are better able to control and maintain a stable standing posture, according to Wierzbicka-Damska et al. (2005). Moreover, the relationship between the structure of the feet and control of their standing position turned out to be subtle, as described by Lin et al. (2006) in their work.

This requires further verification, thus there is a need to examine foot arching in all children and body balance and symmetry of the loaded sides of the body (Wiernicka et al., 2007; Lewit, 2001). At the present time, diagnostic and training devices are available on the market, which can be used for examinations that would answer the question as to whether a child or an adult has a disturbance of the control of their posture under static or dynamic conditions, with open or closed eyes. Also in the therapy tests of sensomotoric control presented in the table below, the following can be used: (TABLE 1) – short foot training (Greenman, 1996) and Duncan's test, used for the assessment of body balance (Błaszczuk, 2004).

To sum up, in all children attention should also be paid to the position of the head in space. Reflex reactions, affecting the position of other body parts by tonic vestibular reflexes and neck reflexes are responsible for it. They regulate in this way the position of the trunk and lower limbs, including the feet.

CONCLUSIONS

1. No statistically significant differences between the studied groups of children were noted in terms of the indices of the foot arch in unloading and loading.

2. It was noted however, that the condition of the foot arch in deaf children was characterised by a lower effectiveness of the muscular and ligament system, which was confirmed by values of the foot parameters of deaf children in the test of feet in unloading and loading.
3. Moreover, in both groups of tested girls, greater differences in the degree of foot arching were noted than in boys. This confirms the tendency to a generally labile body posture of girls and their muscular and ligament systems of the feet.

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HODNOCENÍ PODÉLNÉ KLENBY NOHY U HLUCHÝCH A SLYŠÍCÍCH DĚTÍ VE VĚKU OD 9 DO 11 LET (Souhrn anglického textu)

Cílem studie bylo zjistit stav klenby nohy u hluchých a slyšících dětí a určit, zda existují rozdíly mezi klenbou nohy u dětí s poškozením sluchu a u zdravých dětí ve věku 9–11 let.

Studie proběhla na skupině 19 hluchých dětí a 33 slyšících dětí, z nichž bylo 23 dívek a 29 chlapců ve věku 9 až 11 let. Jejich průměrný věk byl 9,9 let.

Vyšetření podélné klenby nohy bylo provedeno v poloze nezatížené (v sedě) a zatížené (ve stoje), za použití podoskopu (POSMED, Polsko). Při přípravě otisků chodidel byla použita lineární metoda dle Wejsfloga se specifikací ukazatele podélné klenby nohy. Byl zjištěn statisticky významný rozdíl mezi klenbou levé a pravé nohy v zatížené poloze u zdravých dětí ($p < 0,05$). Nebyly ovšem zjištěny žádné statisticky významné rozdíly mezi zkoumanými skupinami dětí, pokud jde o ukazatele klenby v nezatížené i zatížené poloze. Nicméně bylo zjištěno, že stav klenby nohy u hluchých dětí byl charakterizován nižší efektivitou svalového a vazivového systému, což potvrdily hodnoty parametrů nohou u hluchých dětí. Výsledky Wejsflogova ukazatele svědčí o tom, že u hluchých dětí byla typická oblast proměnných (pravá noha v zatíženém stavu 20,55–39,85) větší než u zdravých dětí (pravá noha v zatíženém stavu 17,05–34,75). Navíc byly u obou skupin dívek zjištěny větší rozdíly ve stupni klenutí nohy než u chlapců. Toto potvrzuje tendenci k všeobecně labilnějšímu držení těla u dívek a ve svalovém a vazivovém systému nohy.

Závěr: nebyly zjištěny žádné statisticky významné rozdíly mezi zkoumanými skupinami dětí, pokud jde o ukazatele klenby v nezatížené i zatížené poloze.

Klíčová slova: mediální podélná klenba, hluché děti, vady nohou, podoskop.

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First-line publications

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