ANNA ZWIERZCHOWSKA*,
KATARZYNA ITA BIEŃKOWSKA**, PIOTR JURCZAK***

* Jerzy Kukuczka Academy of Physical Education in Katowice,
Institute of Sports Sciences
** Maria Grzegorzewska University in Warsaw,
Department of Speech Therapy and Educational Linguistics
***John Paul II Provincial Hospital of Podkarpacie in Krosno,
Centre for Diagnostics, Treatment and Rehabilitation of Hearing,
Voice and Speech Disorders

ORCID ID: https://orcid.org/0000-0002-4284-8697; https://orcid.org/0000-0002-9325-0388

Articulatory Motor Skills, Physical Status and Efficiency of Respiratory Muscles in Children with Speech Impediments

ABSTRACT

The analysis of current research in the aspect of neurophysiological processes and development of speech functions shows that there is a relationship between the general physical status of a child and his or her perception of their body. This concerns especially the functions in the area of fine and gross motor skills, and speech sound production. This research represents the continuation of theoretical considerations on the importance of body perception, integration and sensorimotor coordination in the context of the development of realization efficiency. The aim of the study was to evaluate the differences and relationships between physical status, the functional efficiency of respiratory muscles and articulatory motor skills in children with severe and profound hearing impairments (n = 17) after cochlear implantation compared to hearing children with speech impediments (n = 29). All the participants were subjected to speech therapy at the Centre for Diagnostics, Treatment and Rehabilitation of Hearing, Voice and Speech Disorders in the John Paul II Provincial Hospital of Podkarpacie in Krosno. The presented results confirmed that the motor skills of respiratory muscles expressed in their functional efficiency combined with the changing physical status have an effect on the state of articulation, regardless of the etiopathogenesis of possible defects in this field. Therefore, the search for optimal methods of speech therapy in the field of speech impediments should include exercises integrated with respiratory muscle improvement to develop coordination motor skills. Efficient and strong respiratory muscles are an essential part of the speech executive organ which is involved in speech sound production.

Keywords: dyslalia, physical status, articulatory motor skills, breathing exercises, coordination motor skills

INTRODUCTION

The human body is an integral whole, and speaking is one of the most complex intellectual and motor activities performed by humans. This activity requires the specialization and integration of many organs and senses. The occurrence of interdependence between kinaesthetic and articulatory information, oral praxis, phonological competence and the state of realization efficiency in the process of communication in the perspective of broadly understood human motor activity, which is closely correlated with the development of morphofunctional and central nervous system (CNS), is a problem that has been explored for years in the fields of speech therapy and psychology (Shin et al., 2007). It is difficult to state, however, that this problem is fully recognized, because in real conditions, there is no single set of peripheral receptors that provide information to the brain about the location or self-identification of parts of the body. The experiences of the human body in the form of somatosensory, visual, auditory and vestibular signals are integrated and centralized in the CNS (Kułakowska, 2003). In the last decade, there has been more and more research that suggests the important role of sound perception in the processing and integration of information (Guillemot, Champoux, 2013). It has been shown that in children developing according to physiological standards (as well as in adults with no dysfunctions), hearing ability interacts with the somatosensory and motor systems. This happens during speech processing, motor activities, neuromuscular control processes that keep the body in balance, and during other utilitarian motor activities (Reynolds, Day, 2007; Gherri, Driver, Eimer, 2008; Nasir, Ostry, 2009; Kanegaonkar, Clarke, Amin, 2012).

Sound is produced by the speech apparatus, which includes respiratory, phonatory and articulation systems. The physiological role of the respiratory system is to rhythmically introduce atmospheric air into the lungs, bringing in oxygen and flushing out carbon dioxide with the exhaled air. The overriding regulatory mechanism is to maintain the physiological partial pressure of these gases in the arterial blood. In the process of voice production, the role of the respiratory apparatus is to generate a difference in pressures, used to generate a voice wave (Pruszewicz, 1992). During speaking, the exhalation phase extends with respect to the inhalation phase. Lung capacity depends on proper diaphragm function and respiratory muscle strength (Żebrowska et al., 2016). Phonation is possible due to the structure and efficiency of the larynx. Articulation, in turn, depends on the efficiency of both peripheral speech organs and motor cortical structures that program the movements of speech organs to produce a specific speech sound (Łobacz, 1996).

It is therefore indisputable that the speech sound production is a motor activity indirectly related to the high motor activity of the entire body and directly linked to oral and linguistic skills acquired (including phonemic hearing) (Polewczyk, 2013; Borowiecka, 2015). It has been accepted in speech therapy that low motor skills of articulators significantly affect the correctness of pronunciation (Styczek, 1980; Stecko, 2001; Emiluta-Rozya, 2013; Sołtys-Chmielowicz, 2016). In the development of both hearing children and those with hearing impairments, the motor skills concerning the oral cavity are primarily stimulated during primary activities such as sucking, chewing and swallowing (Pluta-Wojciechowska, 2015) and then, during the period of improvement, the activity of the respiratory, phonatory and articulatory apparatus, and thus also the improvement of phonetic and articulation skills in the subsequent stages of speech development. Phonation in the group of children with hearing impairments may be limited to varying degrees due to reduced access to the auditory field of speech. The degree of phonation and articulation limitations depends on the time of hearing defect diagnosis and auditory benefits of using hearing aids in the free speech field (Crandell, Smaldino, Flexer, 2004; Krakowiak, 2012).

However, in children with hearing difficulties, the motor ability of the articulatory system may be impaired for various reasons. The aetiological classification of articulation disorders is based on the symptomatic and causal criterion of dyslalia, which may be caused by both exogenous and endogenous factors. The following were distinguished: a) anatomical dyslalia (dysglossia), b) functional dyslalia, c) auditory (audiogenic) dyslalia, d) environmental dyslalia, e) subcortical dyslalia, f) cortical dyslalia (Emiluta-Rozya, 2008).

However, regardless of the etiopathogenesis of the speech impediment, the efficiency of the articulatory motor activity is connected with the physiological properties and level of physical development of the child, in particular the awareness of the body and effective use of its potential (Zwierzchowska, 2013). In the case of articulation, the efficiency of the respiratory muscles and the optimal use of the breathing air integrated into the movement of the peripheral part of the articulator will determine the quality of speech sounds. This thesis was also a basis for undertaking the following study.

It was assumed that the motor activity of the respiratory muscles expressed in their functional efficiency together with the changing individual physical status of a child (e.g. body weight, body height) determines its predisposition to speech development determined by the assessment of linguistic skills and articulatory motor activity. The aim of the study was to assess the efficiency of respiratory muscles in speaking children with hearing loss after cochlear implantation (CI) with audiogenic dyslalia compared to those with other articulatory disorders (Wa) with functional dyslalia. The following research questions were formulated:

1. Does the respiratory muscle efficiency differentiate between the groups of children studied?
2. Do age and physical status differ between the groups of children participating in speech therapy?

MATERIAL AND METHODS

The study used a methodology of direct (participant) observation. The study examined the group of n = 45 children at the age of x = 7.3 ±3.1 years (min = 4.9; max 10.9; median = 7.9) with hearing loss after one-sided implantation with audiogenic dyslalia and without hearing loss with functional dyslalia. The basic inclusion criterion was participation in the speech therapy program in the Centre for Diagnostics, Treatment and Rehabilitation of Hearing, Voice and Speech Disorders in the John Paul II Provincial Hospital of Podkarpacie in Krosno in 2016 and 2017. All examined children were subjected to systematic hearing and speech therapy for at least 1 year (twice a week in a rehabilitation centre, with auditory and verbal education at home).

The following inclusion criteria were also used in the study: intellectual norm, status of speech development allowing for the diagnosis of the disorders only as dyslalia (disturbance in the pronunciation of particular speech sounds, with the ability to understand and create verbal statements typical for a specific age), chronological age (after completion of the physiological process of speech development). The guardians of the children tested agreed for their participation and the children were informed that they could withdraw from the tests at any time. The project was accepted by the Bioethics Committee for Scientific Research at the Academy of Physical Education in Katowice (Resolution No. 1/2012 of 13 December 2012 and the Appendix of 11 March 2013).

Due to the cause of dyslalia, the study group was divided into two subgroups: children with profound hearing loss with cochlear implant (CI) and children with articulatory disorders (Wa). These groups were classified based on their chronological age according to the auxological methodology used during the assessment of physical development (Jopkiewicz, Suliga, 2011). According to the purposive sampling criterion, the results of children over 10 years and 6 months of age were removed from further analysis as they were considered to be 11 years old. The results of children younger than 4 years and 5 months, regarded as children 4 years old, were also removed. Consequently, three groups were subjected to further statistical analyses:

a) **CI group**: children with cochlear implants with auditory (audiogenic) dyslalia, n = 15; aged ($\bar{x}$ = 8.7 ± 1.3 (min = 6.0; max 10.1). All children in this group had a hearing loss diagnosed during screening tests, were implanted from the first year of life (hearing aids, cochlear implants) and their speech status was diagnosed as auditory dyslalia without dysprosody, dysphonia or other functional deficits.
b) **FDO group**; hearing children with articulation defects: older, with functional dyslalia, n = 18 ; aged ($\bar{x}$ = 7.9 ± 1.4 (min = 6.0; max 10.0).
c) **FDY group** - hearing children with articulation defects: younger, with functional dyslalia n = 12; aged ($\bar{x}$ = 5.0± 0.6; min = 4.6; max 6.0).

Both FDO and FDY groups were children with no additional deficits and dysfunctions (including no anatomical anomalies in the articulation apparatus). These children were included in the regular speech therapy due to functional dyslalia (diagnosed at least 1 year before the examination) (Table 1).

Table 1. Characterization of the study group

Characteristic	BH			BM			WHtR			RME		
Group	CI	FDO	FDY	CI	FDO	FDY	CI	FDO	FDY	CI	FDO	FDY
$\bar{x}$	132.5	126.2	113.7	30.2	25.2	21.5	46.4	47.8	52.0	4.1	3.2	2.8
Sd	11.9	9.1	6.3	9.0	5.2	4.1	6.7	4.8	4.2	1.9	1.1	1.0
min.	120.0	110.5	100	21.0	18.0	15.1	37.9	42.8	45.8	0.5	1.0	1.0
max.	165.0	146.	121.5	53.3	40.1	29.1	61.5	57.5	58.9	8.0	5.0	5.0

Note. BH – body height, BM – body mass, WHtR – waist-to-height ratio, RME – respiratory muscle efficiency; $\bar{x}$ – mean, sd – standard deviation; CI – group with audiogenic dyslalia; FDO – group with functional dyslalia (older); FDY – group with functional dyslalia (younger).

The status of physical development was evaluated based on basic measurements of body structure (body height – BH, body mass – BM, hip circumference (H), waist circumference (WC) and chest circumference at rest, maximum inhalation and maximum exhalation, which allowed to evaluate the level of physical development of the participants and respiratory muscle efficiency (RME).

Before the examination of articulatory motor skills, in order to exclude disturbed speech development, a structured interview with the "60 steps card" (60SC) was used to assess linguistic skills (LS) (Bieńkowska, 2011). This tool was designed based on identifiable speech development stages described in the literature. Each step is matched by the described linguistic skill. The 60SC consists of 60 items which correspond to 60 steps, i.e. 60 skills that can be achieved by a child (in the binary system), on four linguistic levels. The first level evaluates 13 pre-lingual listening abilities and those related to the concentration of attention on sounds. The second level evaluates 12 preverbal and suprasegmental skills. The third level defines 21 skills from the first word understanding stage to the complex sentence building. At the fourth level, 14 linguistic skills are tested as a tool to develop higher intellectual skills at the level of linguistic proficiency. The assessment of whether a child has reached the level of skills in the next step is facilitated by supplementary questions. The points are added up and higher scores are related to higher levels of development of linguistic skills.

Next, in all groups, the articulatory motor skills were evaluated using the "articulatory motor skills test card" (Rodak, 2002). Each test was demonstrated in a mirror. Then, the child imitated the movements of the lips (12 tests) and tongue (12 tests) performed by the examiner. Individual systems were demonstrated individually according to the principle of formula → execution. The correct execution of the movement was awarded 1 point. The maximum score was 24 points. Three degrees of efficiency of the articulators were adopted: I – healthy organs ≥ 16 points; II – average efficiency level: 12-15 points; III – significantly reduced articulatory motor skills ≤ 11 points.

STATISTICAL PROCEDURE

The results developed in MS Excel were subjected to statistical analysis (Statistica 10.0). The mean value, median, standard deviation and upper and lower quartiles were calculated. The comparative analysis was performed using the parametric test whereas the strength of the correlation was verified by means of the Pearson's test, with the level of significance set at $p < 0.05$. Correlations were interpreted according to J.Guilford's classification (King, Minium, 2009).

RESULTS

The score of the 60SC score card for the CI and FDO groups ranged from minimal to maximal values of (39–59) and the mean value with standard deviation was 49.05±4.8. In the case of the younger group with functional dyslalia, the level of development of linguistic skills in 60SC was 31–48 for min-max values, with the mean value of 41.4±5.8 (see Table 2).

Table 2. Efficiency of articulatory motor skills, age, level of linguistic skills

Articulatory motor skills						
Group	CI n = 15		FDO n = 18		FDY n = 12	
age	$\bar{x}$ = 8.7 ± 1.3		$\bar{x}$ = 7.9 ± 1.4		$\bar{x}$ = 5.0± 0.6	
test	LS – 60SC	AMS	LS – 60SC	AMS	LS – 60SC	AMS
mean	48.7	21.1	49.4	16.3	41.4	11.8
sd	5.6	3.3	4.0	4.6	5.8	3.7
curtosis	0.0	2.1	1.0	0.5	-0.4	-0.3
min	39.0	13.0	40.0	5.0	31.0	5.0
max	59.0	24.0	55.0	23.0	48.0	18.0

Note. AMS – articulatory motor skills; LS – 60SC linguistic skills tested using the “60 steps card”; CI – group with audiogenic dyslalia; FDO – group with functional dyslalia (older); FDY – group with functional dyslalia (younger)

Source: Own study.

Comparative analysis of selected features, indices and parameters evaluating the group studied in terms of their physical and functional state and articulatory motor skills showed a statistically significant difference only in the case of articulatory motor skills (AMS) for the compared CI and FDO groups. There were no statistically significant differences in the assessment of linguistic skills (60SC). Physical status and respiratory muscle efficiency did not differentiate between CI and FDO groups (Figure 1).

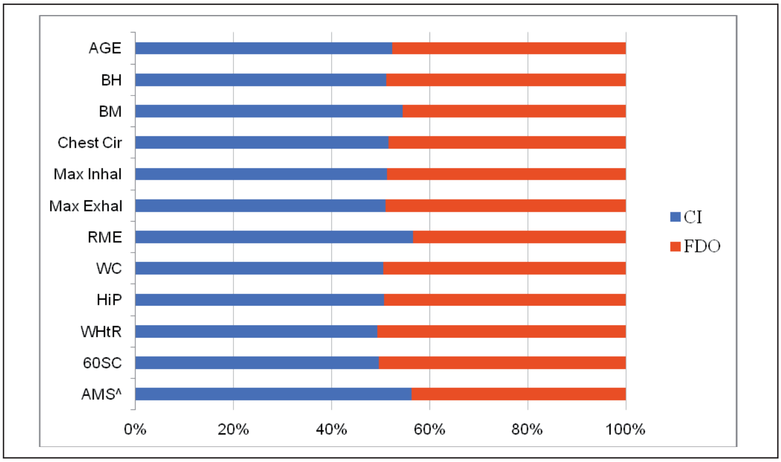

Figure 1. Differentiation of somatic characteristics, indices and functional parameters in CI and FDO groups

Note. BH – body height; BM – body mass; RME – respiratory muscle efficiency; WC – waist circumference, HiP – hip circumference; WHtR – waist-to-height ratio according to Nawarycz and Ostrowska-Nawarycz (2007); 60SC – 60 steps card; AMS – articulatory motor skills). The symbol ^ in all figures indicates statistical significance at the level of $p \geq 0.05$.

Source: Own study.

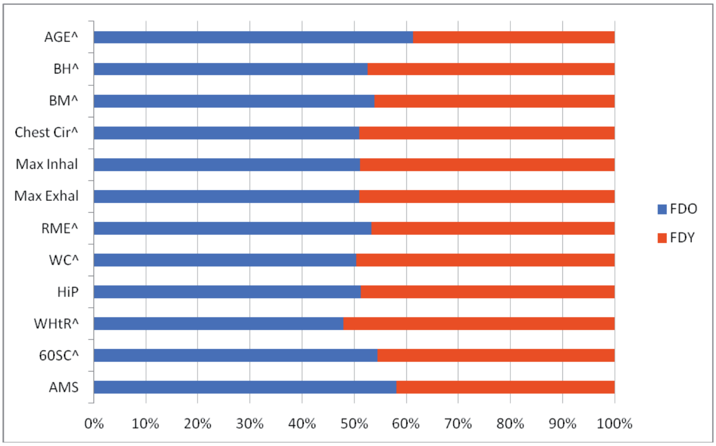

Figure 2. Differentiation of somatic characteristics, indices and functional parameters in FDO and FDY groups

Note. BH – body height; BM – body mass; RME – respiratory muscle efficiency; WC – waist circumference, HiP – hip circumference; WHtR – waist-to-height ratio according to Nawarycz and Ostrowska-Nawarycz (2007); 60SC – 60 steps card; AMS – articulatory motor skills). The symbol ^ in all figures indicates statistical significance at the level of $p \geq 0.05$.

Source: Own study.

Statistically significant age differentiation was found in the functional dyslalia group (FDO and FDY) for most of the analysed characteristics, except for differences in max inhalation and max exhalation function and in the evaluation of articulatory motor skills (AMS) (Figure 2).

Similar age differentiation in characteristics, indices and parameters was observed in the comparative analysis of the younger group with functional dyslalia and the group with CI. In this case, however, only the max exhalation phase did not differ between the CI and FDY groups (Figure 3).

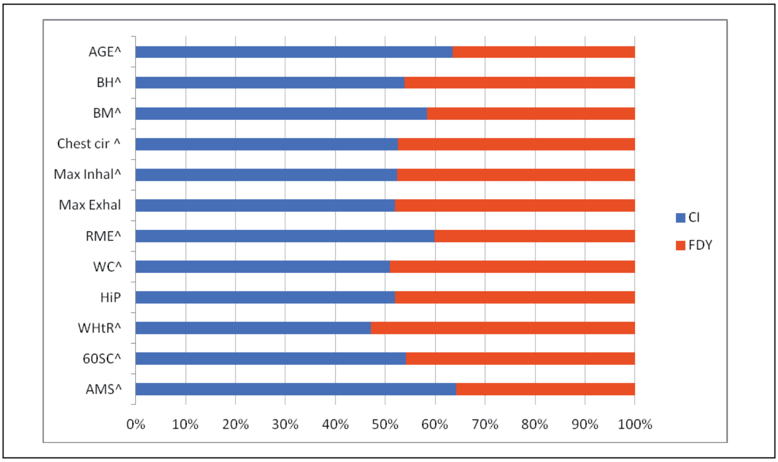

Figure 3. Differentiation of somatic characteristics, indices and functional parameters in CI and FDY groups

Note. BH – body height; BM – body mass; RME – respiratory muscle efficiency; WC – waist circumference, HiP – hip circumference; WHtR – waist-to-height ratio according to Nawarycz and Ostrowska-Nawarycz (2007); 60SC – 60 steps card; AMS – articulatory motor skills). The symbol ^ in all figures indicates statistical significance at the level of $p \geq 0.05$.

Source: Own study.

A high correlation between articulatory motor skills (AMS) and respiratory muscle efficiency was demonstrated for audiogenic dyslalia CI ($r = 0.8$; $p < 0.05$), whereas moderate correlation was found in the case of functional dyslalia in the older FDO group ($R = 0.5$; $p < 0.05$). There was no statistically significant correlation between respiratory muscle function and articulatory motor skills and linguistic skills for subjects with hearing loss with audiogenic dyslalia. There were also no statistically significant relationships between 60SC and AMS in the younger group with functional dyslalia (Figure 4).

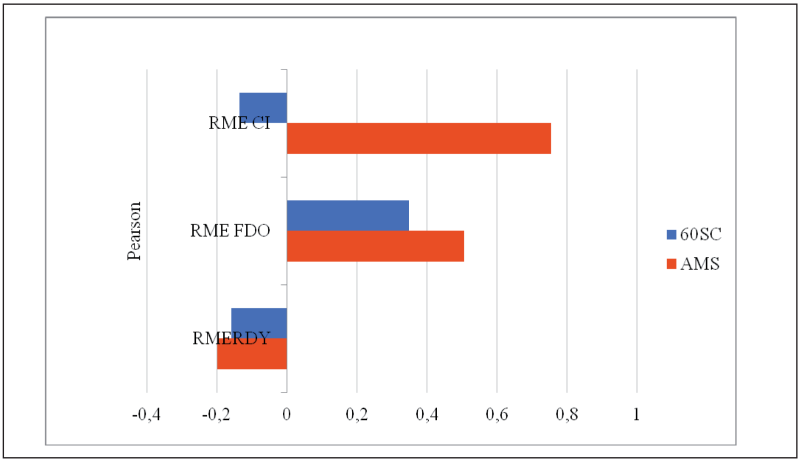

Figure 4. Respiratory muscle efficiency and assessment of linguistic skills (60SC) and articulatory motor skills (AMS)

DISCUSSION

A healthy hearing child learns to speak during the first five to six years of life, when he or she gradually learns to coordinate the activity of the muscles responsible for articulation. The important role of respiratory and phonatory muscle activity combined with the development of articulatory motor skills is emphasized in subsequent stages of speech (Stecko, 2001; Kielar-Turska, 2002; Sochacka, 2016). As described in the meta-analysis performed by Houde et al. (2016), authors of many papers, more and more often indicate that the brain develops with the stimuli coming from the body (the body-brain feedback is formed in areas of gross-fine motor skills, praxis and kinaesthesia). Children with articulatory defects can hear and speak, but the flow of movement stimuli is not synchronized, which was confirmed in our study. Linguistic skills differentiated between the FDO and FDY groups, but both inhalation and exhalation phases and articulatory motor skills did not differentiate the younger and older groups from the group with functional dyslalia. Although the opposite result was expected, the study showed that the age and stage of speech development were not adequate for the development of articulatory motor skills and functional efficiency of respiratory muscles in the CI group (negative correlation). However, there were differences in favour of CI group compared to the younger group with functional dyslalia, thus demonstrating the importance of the morphofunctional factor (especially the early intervention exercises for children with hearing loss) (Figures 2 and 3).

The results of the study are part of the theory of the importance of heard, felt and produced sounds on the regulation of movement behaviours of a human

(Mainel, Schnabel, 1987), which may contribute to a change in the organization of sensory functions and motor control (in this study: fine motor skills). It was found that the CI and FDY groups only differentiated between the articulatory motor skills in favour of CI (Figure 1). On the other hand, the other characteristics, functional indices and level of linguistic skills did not differentiate between two groups (CI and FDO): homogeneous in terms of chronological and developmental age. Consequently, it can be concluded that with early intervention, the speech of children with CI was developed into the normal level and is only characterized by symptoms in the phonic area associated with the limited hearing of the speech field in terms of both loudness and frequency. The state of speech in this group can therefore be described as audiogenic dyslalia (Emiluta-Rozya, 2017). At the same time, the early intervention in the group CI allowed for the compensation of possible development deficits, also in the area of motor skills. Therefore, the current status of the CI group can be described as being within the developmental norm for the organization of sensory functions and motor control (fine motor skills), which cannot be observed in the group of children with functional dyslalia.

The childcare program after the implantation of the speech processor includes a therapy based on auditory training (perception of sounds and speech), which at a later stage allows for building communication and linguistic competence (Allum, 1996; Szkiełkowska et al., 2008). Studies on older groups of children indicate that in children with hearing loss, the functions of the respiratory apparatus may be characterized by disorders, which affects speech development, particularly in terms of phonation and articulation (Żebrowska et al., 2016). In order to achieve proper speech development of a child with hearing defects, exercises are conducted, from the very beginning of the therapy, to consciously coordinate breathing, phonation and articulation (Zwierzchowska, Bieńkowska, 2016). The present study additionally addresses the problem of the importance of physical status and respiratory muscle efficiency in relation to children with speech impediments. Significantly better results in the evaluation of articulatory motor skills were found among children with CI compared to those with functional dyslalia. This confirms the importance of not only preventive early intervention in groups of children at risk of functional dyslalia, but also the effectiveness of actions in the group with audiogenic dyslalia (CI) (phenomena of developmental plasticity and/or deficit compensation).

The results presented in this paper are in a certain contradiction to those presented in other studies (Zwierzchowska, 2009; 2013; Houde et al., 2016). Previous studies have emphasized the occurrence of disturbances in motor coordination: sequential movement of limbs, movement rhythmization, body sensation and posture of children and adolescents with hearing loss compared to hearing peers. It seems, however, that differences in results may be caused by the differences in the chronological age and duration of treatment. Previous observations concerned the groups of children without early intervention. The therapeutic measures used in these groups were rather aimed at the compensation of hearing and speech disorders. They did not take into account the versatility of activities aimed to meet the need for motor development. Furthermore, the CI group presented in this paper underwent comprehensive therapy from the moment of diagnosis of hearing impairment in infancy with consideration for the needs of multisensory learning.

Physical activity, both stimulated and spontaneous, allows children and adolescents to participate in verbal interactions naturally, thus developing their linguistic skills and the efficiency of the respiratory and phonation apparatus. The results of our study indicate a high correlation between respiratory muscle function and articulatory motor skills ($r = 0.8$; $p < 0.05$) and no correlation with general linguistic skills (60SC) in children with CI and audiogenic dyslalia compared to moderate correlation for motor skills and linguistic skills level in the FDO group (functional dyslalia). Undoubtedly, this requires confirmation in further research, which will contribute to a full understanding of the importance of comprehensive sound perception for human development.

CONCLUSIONS

1. Chronological age differentiates the level of linguistic communication among children with audiogenic and functional dyslalia.
2. Respiratory muscle efficiency differentiates the groups only based on age, but not based on the type of dyslalia.

With improved respiratory muscle efficiency, better results were reported for articulatory motor skills regardless of the type of dyslalia. However, the strength of the association (RME – AMS) was higher in the group of CI children with audiogenic dyslalia (treated since early childhood) than in children of the same age with similar physical parameters with functional dyslalia.

IMPLICATIONS FOR SPEECH THERAPY PRACTICE

1. Children with functional dyslalia should be introduced as early as possible to improve not only the articulatory motor skills, but above all to improve general motor skills and to develop coordination motor skills. Especially valuable are respiratory exercises and mixed respiratory and phonation exercises carried out during spontaneous and stimulated physical activity with the use and acquisition of coordination skills (in motion).
2. For children with CI in the process of designing and performance of tasks in the field of articulatory improvement, it is necessary to introduce global

movement tasks with a complex structure, which can significantly support the acquisition of not only motor but also linguistic skills. Furthermore, breathing exercises involving both gross and fine motor skills are also critical. Therefore, it is advisable to perform exercises not only extending the exhalation phase, but also the inhalation phase (and then exhalation coordinated with proper work of arms and legs).

3. Logorhythmics and/or psychomotor classes should be an obligatory element of speech therapy for children with hearing impairments and functional dyslalia.
4. It is recommended that the program of speech therapy (used to treat functional dyslalia) should incorporate the exercises to develop body awareness coordinated with breathing exercises (passive and active exercises, assisted exercises, exercises using gravity and with an additional load to activate both abdominal and thoracic breathing modes). The movement associated with body awareness and breathing exercises during speech development seems to be critical in the articulatory therapy process.

ACKNOWLEDGEMENTS

The authors would like to thank both children and their parents who agreed to participate in the research. We would like to express special thanks to the employees of the Centre for Diagnostics, Treatment and Rehabilitation of Hearing, Voice and Speech Disorders in the John Paul II Provincial Hospital of Podkarpacie in Krosno for their help in conducting the examinations: Katarzyna Skrobek – Chmurska, Izabela Kowalik, Marzena Głowińska, Ilona Bar, Dominika Such. Also special thanks to Danuta Emiluta-Rozya for her help and valuable professional comments.

REFERENCES

Allum D.J., 1996, *Cochlear implant rehabilitation in children and adults*, Whurr Publishers Ltd, London.

Bieńkowska K.I., 2011, *Słucham, mówię, jestem... Program 60 kroków do oceny i terapii dzieci z wada słuchu*. III, Stowarzyszenie Rodziców i Przyjaciół Dzieci z Wadą Słuchu, Krosno.

Borowiecka R., 2015, *Dziecko w równowadze. Koordynacja i słuch*, Centrum Diagnozy i Terapii Psychologiczno-Pedagogicznej, Warszawa.

Crandell C.C., Smaldino J., Flexer C., 2004, *Sound Field Amplification: Applications to Acoustics and Speech Perception*, Delmar Cengage Learning, http://www.amazon.co.uk/Sound-Field-Amplification-Applications-Perception/dp/1401851452/ref=sr_1_1?ie=UTF8&qid=1447667101&sr=8-1&keywords=Flexer (access: 20.11.2019).

Emiluta-Rozya D., 2008, *Modyfikacja zestawienia form zaburzeń mowy H. Mierzejewskiej i D. Emiluty-Rozya*, [in:] *Diagnoza i terapia w logopedii*, VII:25–36. Z prac Towarzystwa Kultury Języka, Dom Wydawniczy ELIPSA, Warszawa.

Emiluta-Rozya D., 2013, *Całościowe badanie logopedyczne z materiałem obrazkowym*, Wyd. Akademii Pedagogiki Specjalnej, Warszawa.

Emiluta-Rozya D., 2017, *Surdologopedia dawniej i dziś*, [in:] *Język i komunikacja – perspektywa lingwistyczna i logopedyczna*, Dom Wydawniczy ELIPSA, Warszawa, 138–153.

Gherri E., Driver J., Eimer M., 2008, *Eye movement preparation causes spatially-specific modulation of auditory processing: new evidence from event-related brain potentials*, "Brain Research", 1224–1288.

Guillemot J.P., Champoux F., 2013, *Temporary deafness can impair multisensory integration: A study of cochlear-implant users landry SP 1*, "Psychological Science", 24(7): 1260–1268.

Houde, M.S., Landry S.P., Pagé S., Matheu M., 2016, *Body perception and action following deafness*, "Neural Plasticity", 5260671.

Jopkiewicz A., Suliga E., 2011, *Biomedyczne podstawy rozwoju i wychowania*, Wyd. Instytutu Technologii Eksploatacji – PIB, Radom–Kielce.

Kanegaonkar, R.G, Clarke M., Amin K., 2012. *The contribution of hearing to normal balance*, "Journal of Laryngology and Otology", 126(10): 984–988.

Kielar-Turska M., 2002, *Psychologiczne i psycholingwistyczne badania nad mową dziecka. Retrospekcja i obszary aktualnych badań*, [in:] *Zaburzenia mowy*, red. S. Grabias, Wyd. UMCS, Lublin.

King B., Minium E., 2009, *Statystyka dla psychologów i pedagogów*, PWN, Warszawa.

Krakowiak K., 2012, *Dar języka. Podręcznik metodyki i wychowania językowego dzieci i młodzieży z uszkodzeniami narządu słuchu*, Wyd. KUL Lublin.

Kułakowska Z., 2003, *Wczesne dojrzewanie uszkodzonego mózgu. Od neurofizjologii do rehabilitacji*, FOLIUM, Lublin.

Łobacz P., 1996, *Polska fonologia dziecięca. Studia fonetyczno-akustyczne*, Energeia, Warszawa.

Mainel K., Schnabel G., 1987, *Movement theory – sport motor system*, Sportverlag, Berlin.

Nasir S.M, Ostry D.J., 2009, *Auditory plasticity and speech motor learning*, "Proceedings of the National Academy of Sciences of the United States of America", 106(48): 20470–20705.

Nawarycz T., Ostrowska-Nawarycz L., 2007, *Rozkłady centylowe obwodu pasa u dzieci i młodzieży*, „Pediatria polską", 82 (5–6): 418–424.

Pluta-Wojciechowska, D., 2015, *Zaburzenia czynności prymarnych i artykulacji*, Wyd. Ergo-Sum, Bytom.

Polewczyk, I., 2013, *Diagnozowanie i stymulowanie rozwoju percepcji słuchowej dzieci w wieku przedszkolnym*, Wyd. Akademickie Żak, Warszawa.

Pruszewicz A., 1992, *Foniatria kliniczna*, I. PZWL, Warszawa.

Raczek, J., Mynarski W., Ljach W., 1998, *Teoretyczno-empiryczne podstawy kształtowania i diagnozowania koordynacyjnych zdolności motorycznych*, AWF, Katowice.

Reynolds R.F., Day B.L., 2007, *Fast visuomotor processing made faster by sound*, "The Journal of Physiology", 583(3): 1107–1115.

Rodak H., 2002. *Karta badania motoryki artykulacyjnej*, [in:] *Terapia dziecka z wadą wymowy*. IV,UW, Warszawa.

Shin M.S., Kim, S.K, Kim S.S., Park M.H., Kim C.S., Oh S.H., 2007, *Comparison of cognitive functionin deaf children between before and after cochlear implant*, "Ear Hear", 28(2 (suppl)): 22S–28S.

Sochacka I., 2016, *Sprawność narządów artykulacyjnych u dzieci w wieku przedszkolnym – doniesienia z badań*, „Zeszyty Naukowe Pedagogika", 2(12): 121–133.

Sołtys-Chmielowicz A., 2016, *Zaburzenia artykulacji*. V, Impuls, Kraków.

Stecko E., 2001, *Ocena dojrzałości motorycznej aparatu artykulacyjnego u dzieci*, [in:] *Zaburzenia mowy. Mowa, teoria, praktyka*, Wyd. UMCS Lublin.

Styczek I., 1980, *Logopedia*, PWN, Warszawa.

Szkiełkowska A., Skarżyński H., Piotrowska A., Lorens A., Szuchnik J., 2008, *Postępowanie u dzieci ze wszczepami ślimakowymi*, „Otorynolaryngologia", 7(3): 121–28.

Zwierzchowska A., 2009, *Głuchota a uwarunkowania rozwoju morfofunkcjonalnego i motorycznego dzieci i młodzieży*, Wyd. AWF, Katowice.

Zwierzchowska A., 2013, *Zmienność morfologiczna a rozwój funkcjonalny dzieci i młodzieży niesłyszącej*, Katowice.

Zwierzchowska A., Bieńkowska K.I., 2016, *Znaczenie interdyscyplinarnej terapii – sprawozdanie z turnusu rehabilitacyjnego dla dzieci z wadą słuchu w Sarbinowie 2016*, „Niepełnosprawności i rehabilitacja", 16(3): 153–65.

Żebrowska A., Zwierzchowska A., Manowska B., Krużyńska A., Kempa K., 2016, *Respiratory function and language abilities of profoundly deaf adolescents with and without cochlear implants*, "Advances in Experimental Medicine and Biology", 912: 1–9.