# ASSESSMENT OF MORPHOLOGICAL-FUNCTIONAL STATE OF CHILDREN WITH COCHLEAR IMPLANTS

Pysanko V.M.
Institute of Otolaryngology

**Abstract.** *Purpose:* assessment of morphological-functional state of pre-school age children with cochlear implants and substantiation of need in post-operative rehabilitation in period of preparation for comprehensive school. *Material:* we tested weakly hearing children with cochlear implants (n=127, age – 5.6±0.6 years). They were the main group. Control group consisted of children with normal hearing (n=70, age – 5.7±0.4 years). Morphological-functional state was assessed by indicators of physical and biological condition, visual analyzer, posture parameters and foot arch, muscular system and level of coordination. We calculated index of integral morphological-functional state assessment. *Results:* Morphological functional state of most of children (with cochlear implants) was characterized by low physical condition indicators and disharmony. We observed delay in biological development. Index of morphological-functional state integral assessment witnesses, that such child can not study in comprehensive school. Rehabilitation program can reduce the gap between children with normal hearing and those with cochlear implants. *Conclusions:* Rehabilitation program facilitates quicker domestic and social rehabilitation of children at the account of widening the circle of communication, learning new actions and conceptions. It can permit for such children to study at school together with their healthy peers.
**Key words:** deaf, children, cochlear, implantation, rehabilitation.

## Introduction

At present the only way to full restoration of hearing in patients with sensor-nervous deafness is cochlear implantation (CI). It implies surgical operation, during which in patient's ear a system of electrodes is implanted. It ensures reception of audio information with the help of electric stimulation of hearing nerve's preserved fibers [4, 13, 15, and 20]. It is reasonable to fulfill CI up to age 4-5 years or even earlier. In later age "brain plasticity" to certain extent becomes lower; interconnection between centers of hearing and speaking inhibits and it makes training child's speech quite a problem [10, 16, and 19].

Analysis of modern domestic and foreign scientific sources permits to say that there are no researches on physical rehabilitation of such children contingent. The problem of their state correction is regarded only as a pedagogic one. The main purpose of post-operative rehabilitation is restoration of audio-speech development. Indeed child hears sounds but does not understand them and, that is why, he/she can not reproduce them consciously [11, 17, 22]. Pre-school age children's organism is formed in conditions of hearing deprivation. It results in disordering of speech development. As on the moment of operation, children's organism is characterized by the whole complex of secondary deviations in physical condition, resulted from deafness [2, 3, and 6]: delay in physical and psycho-motor development; lagging behind healthy peers by all parameters of physical fitness. All these complicate socialization process and require rehabilitation. Such children have expressed low life quality. Their rehabilitation does not permit full correction of hearing if hearing problem became heavy. But children with cochlear implants, providing full rehabilitation, can attend comprehensive school in the future. So, they have chance to become proper members of society. Actually such are conditions of favorable rehabilitation potential [5, 9, and 11]. Just study in usual school is the highest level of children's with cochlear implants adaptation. Such contingent requires examination as per usual schema, applied at entering comprehensive school. It permits to find health problems and provide effective correction.

For entering comprehensive school child shall have certain morphological-functional state (MFS) of organism. This state reflects complex characteristic of organism's intra-systems links and is regarded as health marker. Readiness for school is determined by level of child's psychic and morphological-functional development. Proper child's health will permit to adapt to requirements of systemic teaching. For such children loads shall not be excessive and will not result in social-psychological adaptation failure, reduction of teaching effectiveness and health problems [1, 7]. It is recommended to assess children's readiness for school in unified way with the help of feasible tests [7].


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So it is necessary to create physical rehabilitation program for children with cochlear implants on the base of their morphological-functional state.

*The purpose of the research:* assessment of morphological-functional state of pre-school age children with cochlear implants and substantiation of need in post-operative rehabilitation in period of preparation for comprehensive school.

**Material and methods**

*Participants:* we tested 127 pre-school age children (5.6±0.6 years) in post-operative period (installation of cochlear implants), who were the main group (MG). Control group (CG) consisted of 70 children with normal hearing of age 5.7±0.4 years, who attended pre-school educational establishments.

*Organization of the research:* the researches were conducted on the base of Institute of otolaryngology, named after prof. O.S. Kolomiychenko of national Academy of medical sciences of Ukraine. Children's morphological-functional state was assessed by indicators of physical (level, harmony) and biological (start of baby teeth replacement, "Filipino test") condition; by visual analyzer's state (binocular eyesight, visual acuity); by posture parameters (shoulder and backbone vertical curve indices) and foot arch (index of foot arch); by muscular system (static endurance, flexibility); by coordination level (static and dynamic balancing, fine motor abilities) [7]. Every indicator was assessed in points. We calculated index of morphological-functional state integral assessment by the following formula:

$$I = \Sigma a/16,$$

Where *I* is index of children's MFS; *Σa* – total points of the studied characteristics; 16 – total quantity of the considered indicators. The received index value was identified according to the following criteria [7]:

- 1.00 – 1.35 – high level – readiness for school;
- 1.36 – 2.00 – average level – presence of separate MFS deviations;
- 2.01 – 2.31 – low level – numerous MFS deviations.

In the research we used the following tests [7]:

*For physical condition, its harmony by body mass and chest circumference* we used assessment tables of physical conditions for senior pre-school age children (scale of regression by body length).

*Baby teeth replacement:* we considered all stages of permanent teeth growth. Results' assessment was: 1 point, if baby teeth replacement started by entering school; 2 points if it does not started.

*Filipino test* was carried out in the following way: child stands upright, brings his/her arm above head top and tries to touch left ear with right hand fingers or right ear with left hand fingers. Head shall be kept upright. Assessment: 1 point – finger touch the opposite ear; 2 points – fingers do not touch it.

*Testing of binocular vision:* the simplest and the most reliable for mass examinations is Reyneke's test (USA) with two pencils. Child takes sharpened pencil and is asked to drop pencil's tip by straightened arm on the sharpened tip of other pencil, kept in horizontal position by examiner. Assessment: if any problems with binocular vision, this operation will not be successful (2 points).

*Vision acuity test "Black hand":* on paper of A5 size there is a picture of human hands (table 1). The hands are under different angles. In the first row hands are of big size; in the second – they are 2 times less than in the first. In the third row hands are 2 times less than in the second. Distance between examined child and table shall be 3 meters. The purpose is determination of hand's direction on the picture. With normal visual acuity 2 years' children points correctly hands' direction in the first row; 3 years' age children – in the second row and 4-6 years' children – in the third row (1 point). If senior pre-school age child can not point correctly direction of black hands fingers in the third row it will be assessed in 2 points.

*Muscular skeletal apparatus:* posture disorders are characterized by increase or reduction of backbone natural curves; by deviation of girdle segments', torso, head and lower limbs' positions from physiological. Assessment is fulfilled by medical worker.

*Examination of right and left feet arches:* child stands barefoot on solid surface (chair). Feet are parallel at distance 10-15 cm. Position of heel bone in respect to shin and status of longitudinal and transverse arches are assessed.

Normal physiological position of foot implies being of shin axis and heel bone at one level. If child rises on tiptoes – there shall be deepening of internal and external feet arches.

*Functional state of muscular system:* determination of *back muscles' static endurance* is fulfilled from initial position lying on abdomen. Hands are on the waist, legs are fixed; upper part of torso is kept parallel to floor; head and chest are a little raised. Static endurance of back muscles is assessed in seconds with stopwatch by time of torso keeping in such position (see table 1).

**Table 1.** Static endurance of back muscles (sec.)

| Age, years | Sex | Levels of static endurance of back muscles | | | |
|---|---|---|---|---|---|
| | | Weak muscles | Average | Above average | High |
| 5 | Points | 4 | 3 | 2 | 1 |
| | Boys | ≤17.73 | 17.74-23.56 | 23.57-29.39 | ≥29.4 |
| | Girls | ≤18.48 | 18.49-23.87 | 23.88-29.28 | ≥29.29 |
| 6 | Boys | ≤21.67 | 21.68-28.07 | 28.08-34.45 | ≥34.46 |
| | Girls | ≤23.92 | 23.93-29.82 | 29.83-35.71 | ≥35.72 |

For determination of *flexibility* child shall slowly bend forward from initial position standing on gymnastic bench (arms are straightened, directed downwards, legs shall not be bent in knees). *Flexibility assessment* was carried out by measurement of distance from are of feet support (surface of gymnastic bench) to hands' fingertips with the help of rule (or measuring tape). Results are compared with table 2 data.

**Table 2.** Flexibility assessment (cm)

| Age, years | Sex | Flexibility | | | |
|---|---|---|---|---|---|
| | | High | Above average | Average | Insufficient |
| 5 | Points | 3 | 2 | 1 | 3 |
| | Boys | ≤ – 0.61 | – 0.60 – 3.09 | 3.10 – 6.81 | ≥ 6.82 |
| | Girls | ≤– 0.72 | – 0.71 – 2.05 | 2.06 – 4.84 | ≥ 4.85 |
| 6 | Boys | ≤– 0.31 | – 0.30 – 4.87 | 4.88 - 10.06 | ≥ 10.07 |
| | Girls | ≤– 0.64 | – 0.63 – 1.77 | 1.78 - 4.18 | ≥ 4.19 |

*Coordination and balance:* these abilities are assessed by results of two tests, which determine functional state of central nervous system. Test *"Rope":* child stands upright with one foot in front of other on one line; toe touches heel of front foot; arms are straightened forward with fingers parted and eyes closed. For convenience one can draw a line on the floor or use decorative elements of floor. Which foot (right or left) shall be in front position is up to child's opinion. Result of the test is assessed by time of keeping body position without disordering coordination (swaying, change of feet or arms position) and compared with table 3 data. Test "*Tree"* is for stability in keeping body on one leg. Foot of one leg touches the knee of other leg and this leg's knee is moved aside maximally; arms are directed upwards and then move to horizontal position; eyes are opened. Child chooses on which leg he/she will stand by him/herself. Result of the test is assessed by time of keeping body position without disordering coordination (swaying, change of feet or arms position) and compared with table 3 data.

*Fine motor abilities of hands assessment (test of N.I. Ozeretskiy):* children are offered a card with picture of several circles (central circle – of 5 cm diameter) is depicted by bold line. The task is o cut out the circle by central, bold line. Time of fulfillment (1minute) is measured with stopwatch from the start of cutting. During 1 minute not less than 8/9 of circle shall be cut out. The following deviations from bold line re admitted: 1) not more than two times, if in work one thin line is cut, 2) not more than one time, if two thin lines are cut. Assessment of the test: 1 point means high level of fine motor abilities (test fulfillment from the first attempt); 2 points – average level (two attempts); 3 points – low level – test is not fulfilled.

*Statistical analysis:* statistical processing of the received data as fulfilled with the help of standard Microsoft Excel programs. We determined Student's t-criterion for statistic verifying of hypothesis about confidence of differences between indicators of CG and MG.

**Table 3.** Assessment of coordination tests' results (seconds)

| Indicator | Coordination and balance levels | | | | | |
|---|---|---|---|---|---|---|
| | Below average | Average | Above average | Below average | Average | Above average |
| Points | 3 | 2 | 1 | 3 | 2 | 1 |
| Age, years | "Rope" test Boys | | | Girls | | |
| 5 | ≤ 7 | 8 – 12 | ≥ 13 | ≤ 9 | 10 – 14 | ≥ 15 |
| 6 | ≤ 9 | 10 – 14 | ≥ 15 | ≤ 11 | 12 – 16 | ≥ 17 |
| | "Tree" test Boys | | | Girls | | |
| 5 | ≤ 3 | 4 – 8 | | | | |
| 6 | ≤ 4 | 5 – 10 | ≥ 11 | ≤ 4 | 5 – 9 | ≥ 10 |

**Results of the research**

When assessing MFS of pre-school age children with CI and with normal hearing we found the following regularities.

Screening indicators of children's physical condition are height, mass, chest circumference. Among children with CI we found great percentage of persons, who lag behind in physical development by all tested indicators. The reasons of it are diseases, endured by a child and general somatic weakening. The same tendency was found in study of biological age (see table 4).

**Table 4.** Children's MFS

| № | MFS indicators | Characteristics | Points | CG, % of found persons | MG, % of found persons |
|---|---|---|---|---|---|
| 1 | ***Physical condition*** | | | | |
| 1.1 | Physical condition level | Average level | 1 | 78.57 | 54.33 |
| | | Body length indicator from above average to high level | 2 | 14.29 | 6.35 |
| | | Body length indicator from below average to low level | | 7.14 | 39.32 |
| 1.2 | Harmonious of physical condition by body mass | Harmonious by body mass | 1 | 72.86 | 40.94 |
| | | Disharmony at the account of insufficient or excessive body mass | 2 | 27.14 | 59.06 |
| 1.3 | Harmonious of physical condition by chest circumference (CC) | Harmonious by CC | 1 | 87.14 | 39.37 |
| | | Disharmony at the account of excessive or insufficient CC | 2 | 12.86 | 60.63 |
| 2 | **Biological condition** | | | | |
| 2.1 | Start of baby teeth replacement by permanent | Baby teeth replacement started | 1 | 77.14 | 66.93 |
| | | Baby teeth replacement did not start | 2 | 22.86 | 33.07 |
| 2.2 | "Filipino test" | Fulfills | 1 | 88.57 | 62.99 |
| | | Not fulfills | 2 | 11.43 | 37.01 |
| 3 | **Visual analyzer assessment** | | | | |
| 3.1 | Assessment of binocular vision | Child connects tips of pencils | 1 | 97.14 | 88.19 |
| | | Child does not connect tips of pencils | 2 | 2.86 | 11.81 |
| 3.2 | Assessment of vision acuity by "Black hand" test | No mistakes | 1 | 91.43 | 82.68 |
| | | Mistakes are present | 2 | 8.57 | 17.32 |
| 4 | ***Functional state of posture*** | | | | |
| 4.1 | Assessment of posture in sagittal plane by shoulder index (SI) | *Physiological posture* (PP 90 – 100 %) | 1 | 91.43 | 69.29 |
| | | Kyphosis of posture (SI up to 90 %) | 2 | 8.57 | 30.71 |

| № | MFS indicators | Characteristics | Points | CG, % of found persons | MG, % of found persons |
|---|---|---|---|---|---|
| 4.2 | Assessment of posture in frontal plane by index of backbone vertical curve (BVC) | Physiological posture (BVC 90 – 100%) | 1 | 97.14 | 93.70 |
| | | Scoliosis of posture (BVC is more than 110% or less than 90%) | 2 | 2.86 | 6.30 |
| 5 | ***Foot arch*** | | | | |
| 5.1 | Assessment of right foot arch by index of foot arch | Normal foot arch | 1 | 87.14 | 75.59 |
| | | Flat or increased foot arch | 2 | 11.43 | 21.26 |
| | | Flat foot or foot with voids | 3 | 1.43 | 3.15 |
| 5.2 | Assessment of left foot arch by index of foot arch | Normal foot arch | 1 | 85.71 | 74.80 |
| | | Flat or increased foot arch | 2 | 12.86 | 21.26 |
| | | Flat foot or foot with voids | 3 | 1.43 | 3.94 |
| 6 | ***Functional state of muscular system*** | | | | |
| 6.1 | Static endurance of back muscles | High | 1 | 4.29 | |
| | | Above average | 2 | 10.00 | |
| | | Average | 3 | 82.86 | 68.50 |
| | | Weak muscles | 4 | 2.86 | 31.50 |
| 6.2 | Flexibility | Average | 1 | 84.29 | 56.69 |
| | | Increased flexibility | 2 | 10.00 | |
| | | Insufficient or excessive flexibility | 3 | 5.71 | 43.31 |
| 7 | ***Coordination*** | | | | |
| 7.1 | Test “Tree” | Above average | 1 | 11.43 | |
| | | Average | 2 | 88.57 | 11.81 |
| | | Below average | 3 | | 88.19 |
| 7.2 | Test “Rope” | Above average | 1 | 10.00 | |
| | | Average | 2 | 90.00 | 11.81 |
| | | Below average | 3 | | 94.49 |
| 7.3 | Fine motor abilities (by Ozeretskiy’s test) | Fulfillment of test from first attempt | 1 | 91.43 | 7.87 |
| | | Fulfillment of test from second attempt | 2 | 8.57 | 81.10 |
| | | Test has not been fulfilled | 3 | | 11.02 |

When assessing visual analyzer we found that children with CI lagged behind healthy children by vision acuity and binocular vision. Posture disorders are evidences of muscular system’s weakening and general somatic weakness (by indices of posture and backbone vertical curve) as well as bent to platypodia (by index of foot arch). CI children’s physical qualities were characterized by low endurance of back muscles and insufficient flexibility.

The most expressed were disorders in coordination: no CI children could fulfill tests “Rope” and “Tree” at above average level. Most of them could not fulfill these tests at all or fulfilled at level “below average”. It witnesses about deep functional disorders in vestibular-cochlear apparatus. Fine motor abilities were regarded as preparation for writing. This indicator in CI children was also unsatisfactory: part of children could not fulfill Ozeretskiy’s test at all.

Index of MFS integral assessment was 1.44±0.23 conv.un. (average level) in group of healthy children. These children physically are ready for school but they require consultations of appropriate specialists and application of correcting measures.

Result of calculation of MFS integral assessment index for CI children was 2.21±0.15 conv.un. (low level) ($p<0.05$ in respect to CG indicator). Such children physically are not ready for school. They require profound examination of specialists, working out individual rehabilitation programs, application of prophylaxis-correction measures. It proves the idea that such children shall endure psychological, audio-speech and intensive physical rehabilitation. Improvement of such children’s physical condition and functional parameters is impossible with the help of only pedagogic methodic.

**Discussion**

MFS reflects complex characteristic of organism's intra-systems' links and is regarded as a health marker. The level of certain progress of 5-6 years' age child's organism for systemic studying at school is the basis of health preservation. Readiness for school is determined by organism's psychic and morphological-functional condition, under which requirements of systemic studying will not be excessive and will not result in social-psychological adaptation failure and reduction of education effectiveness and child's health worsening [7]. So, the found in our research disorder in CI children health (if no their correction) can result in posture disorders, platypodia, eyesight worsening in the future. They can complicate mastering of writing and reading; result in disordering of other organs' functioning [3, 9].

The raised by us problem of CI children rehabilitation is closely interconnected with the data of domestic and foreign studies [9, 12, 16, 21].

Results, received in the process of our research, prove and supplement the data about lagging behind in physical and psych-motor development, in parameters of children's with hearing problems physical fitness, comparing with their healthy peers [2, 3, 6, 14].

CI children are, indeed, new contingent of physical rehabilitation. The obtained by us results are new approach to CI children rehabilitation as well as they are a substantiation of the fact that the worked rehabilitation programs shall be based on detected MFS disorders and assessed by a number of standard tests for entering comprehensive schools. The recommended means of physical rehabilitation are massage (for strengthening muscular system), kinesis-therapy (as independent (with parents) trainings and trainings with instructor.

The assumption about possibility of physical load's positive influence on physical development of children with hearing problems is based on the data of other researches. Their authors say that in such children physical activity reduces secondary disorders [2, 3 6].

As on the present time, in Ukraine there is no unified rehabilitation program for children with cochlear implants. In the list of recommendations of implants for post-operative rehabilitation producers only audio-speech correction is mentioned. No attention is paid to physical rehabilitation [8, 11, 18].

Pre-school age is characterized by quick growth of children's physical activity indicators. It is important for their complete development. That is why out rehabilitation program can reduce CI children's lagging behind in physical progress from their healthy peers. Such program facilitates quicker domestic and social rehabilitation at the account of widening of communication circle; mastering new actions and conceptions. Rehabilitation of such children shall be complex. Collective of specialists shall compulsory have a specialist in physical rehabilitation. It will permit to recreate deaf child as valuable member of society with normal hearing and normal physical condition. CI children's entering comprehensive school in proper time will improve their life quality; reduce psycho-emotional tension in their families and social-economic expenses of the state for their rehabilitation and their financial support.

**Conclusions**

Pre-school age children with cochlear implants lag behind their healthy peers by parameters of organism's morphological-functional state (indicators of physical and biological condition, visual analyzer; parameters of posture and feet arch; muscular system and coordination). All these make impossible such children's studying in comprehensive school and requires physical rehabilitation.

The prospects of further researches imply creation of physical rehabilitation programs for different age children after cochlear implantation.

**Conflict of interests**

The author declares that there is no conflict of interests.

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**Information about the author:**

**Pysanko V.M.;** http://orcid.org/0000-0002-5117-7768**;** zastavnaolya@mail.ru**;** Institute of Otolaryngology; Str. Zoological, 3, Kiev, 04119, Ukraine.

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