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Correlation between Balance Ability and Speech-Language Development in Children

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A B S T R A C T

The longitudinal study was conducted in order to establish whether the success rate of reflexes related to maintaining balance at birth is in correlation with the success rate of maintaining balance in early childhood, as well as to examine the correlation of a certain level of speech and language development with the ability of maintaining balance at birth and at the age of 5. The main study group included 54 children of both genders, aged 5.0 to 5.4, whose balance ability and speech and language status were evaluated based on the battery of standardized tests, whereas the group of reflexes related to the function of the vestibular sense was clinically tested on the 3rd day upon birth, within the same sample of children. The data at birth and at the age of 5 were recorded by means of a digital camera, then scored and statistically and descriptively processed. The research results indicated a statistically significant correlation between the achieved level of balance ability in the newborns and five-year-olds, as well as between balance skills and a certain level of speech and language development in children at the age of 5. The importance of this research lies in new knowledge in the domain of maturation of vestubular function immediately after birth, given that this segment of physiology of a newborn has not so far been processed in such a way, as well as in the recognition of function of the vestibular sense as another parametre of a child's maturation.

Key words: *maintaining balance, newborns, vestibular sysem, speech development, child*

Introduction

The vestibular system is directly connected to the portion of the brain responsible for higher order processes such as speech, language, reading, writing, and logical thought[1]. Vestibular dysfunction in children, especially at younger age, is considered uncommon. The reason for this approach is that vestibular disorders in children very often could not be recognized, or could be replaced with some other diagnosis[2]. However, in the most recent literature, reports of vestibular deficits and related impairments in children are increasing in number[3]. There are a variety of reasons why vestibular evaluation is not routinely performed in the pediatric population[4–7]. Bilateral loss of vestibular function at or close to birth results in balance dysfunction and consequently causes the motor developmental delays[8]. Motor skills and motor abilities in general, especially in the period of growth and development has a strong impact on the complete bio-psycho-social status of children[9], as well as on the pace of speech and language development[10]. Symptoms and signs that may indicate vestibular dysfunction also include developmental and reflex delays[11]. Research on infant reflexes forms an increasingly important tool for understanding human development[12]. Until the age of five, balance reaches an adequate level, while its development is completed in later childhood[13–14]. Children with reduced vestibular function have been shown to produce reduced reading acuity scores[15]. In children with normal speech and language development, there is more homogeneity regarding proper function of vestibular apparatus. In contrast, in children with developmental dysphasia, greater individual differences in development of the vestibular system are present[16]. Hanes and McCollum identified cognitive deficits

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associated with vestibular dysfunction including short-term memory, concentration, arithmetic, and reading[17]. Reading, writing and balance can be improved by stimulating of the vestibular system throughout childhood. Absence of vestibular information early in life can lead to reduced cognitive performance in several domains[18]. Children with vestibular dysfunction since or shortly after birth do not recover function without intervention. Despite advances in clinical and diagnostic testing of vestibular function in adulst, testing of vestibular function in infants and children has not been typically done yet[19]. Stimulation of the vestibular system between the ages of three and thirteen has been shown to facilitate motor development, reading, writing, and balance activities[20]. Due to all the implications that disturbed vestibular function and balance can have on a child's development, we intend to evaluate the following: 1. Whether the success rate of reflexes related to maintaining balance at birth is in correlation with the success rate of maintaining balance in early childhood; 2. To examine the correlation of a certain level of speech-language development with the balance ability at birth and at the age of 5.

Materials and Methods

A longitudinal study was conducted at the Institute for Experimental Phonetics and Speech Pathology (IEPESP) and in the Life Activities Advancement Centre (LAAC) in Belgrade, including the research conducted at the Institute of Gynecology and Obstetrics, *Clinical Centre of Serbia* (IGO-CCS). All the tests in this study were conducted in accordance with the Declaration of Helsinki regarding biomedical research involving human subjects. The research was approved by the Ethics committee of the Clinical Centre of Serbia (No. 345/5) and all the parents of the children from the tested sample gave written consent for their children to be subjected to testing.

Testing the ability of balance and the level of speech and language development was conducted on the sample of 54 children, 5.0–5.4 of calendar age, 29 male examinees and 25 female examinees. The criteria for the selection of the tested sample were as follows:

- they belong to the group of children whose sense of balance was examined the 3rd day upon birth by clinical testing of the Moro reflex (MOR), the Vestibulo-ocular reflex (VOR), the Asymmetrical tonic neck reflex (ATNR) and the Head Righting reflex (HRR)
- they are healthy full-term babies from normal pregnancies
- they had the highest Apgar score values (9 and 10)
- at the time of testing they were not older than 5.6 years of age
- they have undergone neurological examination with the absence of any pathological findings, being completely healthy from the neurological point of view.

Testing of the ability of balance and the level of speech and language development at the age of 5 was conducted at the IEPSP and LAAC, whereas testing of the vestibular reflexes on the same sample of children, the 3rd day upon birth, was carried out at the IGO-CCS at the Neonatology Department[21]. In order to evaluate the balance ability of five-year-olds, the research instrument consisting of 15 standardized tasks was used used[22, 23].

Test description and scoring

Romberg's test

The child is asked to stand still, with his head centered, feet together and eyes closed and to remain in that position 10–15 seconds. (Since this is a test of maintaining balance without visual control, movements of the body, the arms, the legs and the feet are observed).

Scoring:

2 – good balance without movement

1 – balance possible only when gently moving the ankles, the toes, or the whole body

0 – the lack of balance with eyes closed, the child moves the feet to one side to prevent the fall.

Evaluation of standing balance

The child is asked to stand still, with the head centered, arms by the sides and the feet 5cm apart. The examiner gently pushes the child's shoulder to one side and then to the other. The intensity is graded according to the child's age. The whole procedure is repeated 3 times to the left and 3 times to the right. (The child should remain upright, without moving the legs to the contralateral side. The child will try to maintain balance changing the position of the body towards the ipsilateral side. If he does not succeed, he may lean to the contralateral side with arms abducted, or may even take a step sideways. Holding his free hand on the contralateral side, the examiner, standing at a certain distance from the child, might prevent the child with poor balance from falling).

Scoring:

2 – maintains balance, does not move except to prevent certain sudden swaying movements

1 – steps sideways or abducts arms and shoulders

0 – falls sideways and the examiner must hold him.

Evaluation of walking in a straight line

The child is asked to walk along a straight line, 20 steps forward and then come back to the starting position. The toes of one leg do not have to strictly touch the heel of the other leg. At 5–7 years of age, 3 deflections are allowed. (Walking in the straight line is tested after the age of 5. Difficulties in conducting this test may be caused by: muscle hypotonia or hypertonia, cerebral or sensory disorders, or uncoordinated movements).

Scoring:

2 – walks without a deflection from the line

1 – has 4–6 deflections from the line

0 – cannot walk on the line, has more than 6 deflections from the line.

Standing on one foot

The child is asked to stand on one foot for 20 seconds, with arms extended forward and palms facing upwards. The same procedure is repeated 3 times, on the left and the right foot. (It is necessary to determine possible symmetry, as well as involuntary choreiform or tremor movements. The inability to stand on one foot, without dyskinesia, suggests the delay in functional maturation; it can also be the consequence of generalized hypotonia, cerebral or sensory dysfunction).

Scoring:

2 – stands on one foot with stability for 10–12 seconds or more

1 – tries to stand on one foot, but puts the foot on the floor, manages to stand up to 3 seconds

0 – cannot stand on one foot.

Finger to finger test

The child is in the sitting position, with the arm bent in the elbow at 90°. The examiner points his extended index finger towards the child and asks the child to touch it with the tip of his index finger. The distance between the examiner and the child must be sufficient so that the child always extends and bends the arm at the elbow when touching the examiner's finger. During the test, the examiner's finger remains static at all times. The precision with which the child touches the examiner's finger is observed. The procedure is repeated 3 times for one hand and 3 times for the other. (Deviation in touching the finger always towards one side suggests the dysfunction of the vestibular or cerebral origin).

Scoring:

2 – touches the examiner's finger with precision

1 – touches with insecurity and there is 1 failure

0 – misses the examiner's finger, the child's finger goes to one or the other side.

Evaluation of the vestibulo-ocular reflex

For right and left head movement:

The child is seated on the examination table to be level with the examiner. The examiner holds the child's head, placing his hands on the sides of the head at ear level. The child's chin gently bends down for 30º. During the test, the child has to look at the tip of the examiner's nose. The child's head is then gently and quickly turned to the right for 20º. The eyes must briefly go to the left, opposite to the direction of the head. When this procedure is completed, the child's head is turned gently but quickly to the left, whereas the eyes shift to the right. The whole procedure is repeated 3 times to one side and 3 times to the other. The pause between each attempt is 5 seconds.

Scoring:

2 – present (the eyes move and shortly remain looking at the side opposite to the direction of the head)

1 – incomplete (the so-called corrective saccade indicates a dysfunction of the vestibular paths on that side. This happens when the head is turned and the expected position of the eye is not achieved immediately, but with a short delay

0 – absent (it does not go opposite to the side to which the child's head is turning and does not remain in that position, but is shifted towards the nose).

For upward and downward head movement:

The examiner holds the child's head, placing his hands on the sides of the head, at ear level, moving it downwards gently and quickly expecting the upwardd eye movement. And the contrary, when the child's head is moved upwards, his eyes should be directed downwards. During the test, the child looks at the examiner's nose tip at all times.

Scoring:

2 – present

1 – incomplete

0 – absent.

The final score was the sum of the results of both tests.

Evaluation of body and head posture in the sitting position

The child is seated on the examination table. He is not allowed to lean his hands on the table or to rest his feet on the floor (it is for this reason that the child is seated on the table, so that his legs are in a hanging position).

The child is then asked to look straight at the examiner. The examiner observes whether the child holds his head in the normal position, whether the body posture is symmetrical, or the head and the body lean sideways.

In the expected correct posture, the head is centred and the body and extremities are symmetrical.

Scoring:

2 – complete symmetry of the head and the body

1 – the head tilts to one side

0 – leaning or fall of the head or the head and the body together, to the side or back.

Balance reaction in the sitting position

The child is seated on the examination table, with his arms relaxed on his knees. The head is centered. The examiner gently pushes the child's shoulder to one side, observing the way the child maintains balance in the sitting position. Median line abduction is 30º, and the pushing intensity is graded according to the child's age and his body weight. During the procedure, the care is taken so that the child does not fall. The procedure is repeated 3 times to one and 3 times to the other side.

Scoring:

2 – maintains balance without moving arms or hands

1 – raises his arms or hands from his knees or uses the opposite hand for lateral support in order to maintain balance

0 – cannot maintain balance, falls sideways and must be held by the examiner.

Trunk rotation in a sitting position

The child is seated on the examination table, with arms resting on knees. The head is centered. The child is asked to reach for the toy which the examiner holds next to and slightly above his head. The child's left or the right hand is activated, depending on the position of the examiner. The child's head rotation must be at 180º. The procedure is repeated 3 times to one and 3 times to the other side.

The child turns his head and rotates shoulders towards the side of the object. The child's hips remain centred.

Scoring:

2 – trunk rotation while maintaining stable sitting position

1 – trunk rotation with hand support

0 – absence of turning towards the object or the rotation of the whole trunk (the pectoral and the pelvic girdle) with presence of the compensatory movements of the legs (knee extension, leg deviation to the contralateral side).

Evaluation of body posture and head posture in the standing position

The child is asked to stand still, with arms relaxed at the sides. In a normal body posture, arms should be slightly extended and adducted. Particular attention is paid to the width of the base of support, i.e. the space between the feet, which is a prerequisite to maintain good balance. At the age of 3, a child stands on a wider base of support, and at the age of 5 at a narrower base of support. The examiner observes the posture of head, body and extremities. Scoring:

2 – head centred, body symmetrical, arms relaxed

1 – body is not symmetrical, the child has a wider base of support

0 – moves and shows difficulties in maintaining balance in the standing position.

Position with the arms extended forward middle

The child is asked to stand for 20 seconds with feet together, head centered, arms extended forward middle, palms facing down and eyes closed. The examiner observes whether the child's arms move into lateral or vertical abduction from the median line.

Gentle movement of arms to one or the other side is often present in children under 6 years of age. Upward movement of arms appears when palms are facing down (pronation). Downward movement of arms appears when palms are facing upward (supination).

Scoring:

2 – no arm abduction, i.e. arms do not move away from the median line

1 – gentle movement of arms to the side or up and down

0 – distinct movement of arms to one side or up and down, one hand may be turned inwards (the thumb facing up).

Evaluation of forward and backward walk

The child is asked to take 5 steps forward and 5 steps back.

Scoring:

2 – maintains direction, does not turn sideways

1 – turns alternatively to one side and then the other

0 – turns to the same side (3 times and more).

Evaluation of toe walking

The child is asked to walk on toes, 10 steps forward, and then come back. Children older than 3 years of age are capable of toe walking.

Scoring:

2 – walks on toes well, the heel is constantly lifted

1 – walks on toes with interruptions (standing on the whole foot), the heel is lifted only for a moment

0 – cannot walk on toes.

Evaluation of heel walking

The child is asked to walk on heels, 10 steps forward and then come back. After the age of 3, the child is completely capable of walking on heels.

Scoring:

2 – walks on heels well, toes are constantly lifted

1 – walks on heels with interruptions, the toes are lifted only for a moment

0 – cannot walk on heels.

Jumping in place

The child is asked to jump in place, at least 10 times on each foot. At the age of 3, the child is capable of jumping on one foot several times, at the age of 4 they can jump 5–8 times, and at the age of 5, the expected number of jumps in place on one foot is 9–10 times.

Scoring:

2 – jumps in continuity 9–10 times

1 – jumps 3–8 times

0 – cannot jump at all or jumps only once or twice.

Children conducted each task in three attempts which were scored with 0 points – unsuccessful, 1 point – partially successful and 2 points – successful. The average score was calculated for all three attempts together thus creating the scale of 0–2 points for the achievement in each of 15 tasks. In certain tests, depending on their complexity and in accordance with the methodologically clearly defined standard procedure, the tasks were conducted in three attempts to the left and to the right, three times forwards and backwards, i.e. three times upwards and downwards. While processing the obtained data, average marks for the left and the right side were calculated first, then for the attempts upwards and downwards i.e. backwards and forwards, based on which the mark for the execution of the complete test was calculated.

In the tested sample, Neda Subota's test was used to evaluate speech and language development within the scale for evaluation of psychophysiological abilities of children aged 0–7 (an integral part of the battery of standardized tests of the IEPSP). All data are collected by the method of individual testing in conditions defined in the instructions within the guidelines for the implementation of the aforementioned tests. Depending on the achieved level of speech and language development of five-year-olds, the success in the test is marked in percentage in relation to 100%. The number of positively scored questions is calculated in relation to 100%, so the deviations for the given age can be clearly seen.

Also, anamnestic data obtained from the children's parents in »face to face« interviews enabled collecting the data at the time when the children included in our research started talking. The data were recorded in months and after the basic processing, average values and standard deviations were calculated.

The data obtained at birth and at the age of 5 were recorded by a digital camera and subsequently scored and statistically and descriptively processed. Statistical data processing was conducted using the SPSS (Statistical Program for Social Sciences) package, version 20. Data processing included the following statistical measures and procedures: frequencies and percentage, the arithmetic mean and the standard deviation, the standard error of measurement and confidence intervals, significance of differences between arithmetic means, the Pearson's coefficient of linear correlation and the Cronbach`s alpha coefficient of reliability.

Results

At the Institute for Experimental Phonetics and Speech Pathology in Belgrade, the ability of balance and evaluation of speech and language development, were tested on the sample of 54 examinees, with an average age of 5.24 with the standard deviation of 0.14 years of age (5.0–5.4 years of age). Out of the total number of the tested children, 53.7% were male (29 examinees), and 46.3% female (25 examinees). In relation to the ideal proportion 0.50:0.50, our sample included two boys more, i.e. two girls less. The examinees were of the same gender and age. The group of reflexes related to maintaining balance was tested on the same sample of children, on the third day upon birth at the Institute of Gynecology and Obstetrics, *Clinical Centre of Serbia*. Examination of the degree of presence of the Moro reflex (MOR), the Head righting reflex (HRR), the Asymmetrical tonic neck reflex (ATNR), and the Vestibulo-ocular reflex (VOR) included three attempts, recording whether a reflex was present, incomplete or absent.

The data in Table 1 indicate that minimal (Min) presence of Moro reflex was recorded in 27 babies (i.e. 50%) with 1.00 point on the 0–2 points rating scale, whereas the absence of this reflex, i.e. the score of 0 points was not recorded in any of the newborns. Maximum (Max) presence of MOR (2 points) was also established in 50% of the newborns. The average value of the presence of Moro reflex (M) equaled 1.50 points, with the standard deviation (SD) of 0.50 points. The median value (Med) equaled 1.50 points, which also proves that the distribution of results shifted to the right – towards higher scores.

Head righting reflex was absent in 20.4% of the newborns with the score of 0 points. Incomplete Head righting reflex was recorded in 24% of the tested sample, and its maximum presence of 2 points was established in 55.6% of the newborns. The average value of the presence of Head righting reflex is 1.35 points, with the standard deviation of 0.80 points. The median value was 2.00 points, which also proves that the distribution of results shifted to the right – towards higher scores.

The absence of total Asymmetrical tonic neck reflex (ATNR to the right and ATNR to the left) i.e. the score of 0 points was not recorded. Incomplete Asymmetrical tonic neck reflex was recorded in 64.8% of the tested sample, and its maximum presence of 2 points was established in 35.2% of the newborns. The total average value of the presence of Asymmetrical tonic neck reflex equaled 1.35 points, with the standard deviation of 0.48 points. The median value was 1.00 points, which also proves that the distribution of results shifted to the right – towards higher scores.

TABLE 1
THE BASIC STATISTICS OF THE SENCE-BALANCE REFLEXES AND REFLEXES IN TOTAL TESTED ON THE 3RD DAY AFTER BIRTH

Statistics	Moro reflex	Head righting reflex	Asymmetrical tonic neck reflex	Vestibulo-ocular reflex	Reflexes in total
Min	1 (50.0%)	0 (20.4%)	1 (64.8%)	1 (61.1%)	2.42 (1.9%)
Max	2 (50.0%)	2 (55.6%)	2 (35.2%)	2 (38.9%)	8.00 (11.1%)
Med	1.50	2.00	1.00	1.00	6.04
$\overline{X}$	1.50	1.35	1.35	1.39	5.93
SD	0.50	0.80	0.48	0.49	1.46

Incomplete Vestibulo-ocular reflex was recorded in 61.1% of examinees, and its maximum presence of 2 points, was established in 38.9% of the newborns from the defined sample. The absence of total Vestibulo-ocular reflex (VOR right and VOR left) i.e. the score of 0 points was not recorded in any of the newborns. The total average value of the presence of Vestibulo-ocular reflex was 1.39 points, with the standard deviation of 0.49 points. The median value was 1.00 points which also proves that the distribution of results shifted to the right – towards higher scores.

Summing up the results of Moro reflex, Head righting reflex, Asymmetrical tonic neck reflex and Vestibulo-ocular reflex, the scale of 0–8 points was obtained, showing the presence of all four reflexes together in the newborns (reflexes in total). Minimal presence of reflexes in total was recorded in only 1.9% of examinees equaling 2.42 points on the 0–8 points rating scale, whereas the absence of all four reflexes, i.e. the score of 0 points was not recorded in any of the newborns. The maximum score of 8 points, which represents the maximum presence of reflexes in total, was established in 11.1% of the tested sample. The total average value of the presence of reflexes equaled 5.93 points with the standard deviation of 1.46 points. The median value of 6.04 was higher than the arithmetic mean, which also proves that the distribution of results shifted to the right – towards higher scores.

The application of the Pearson`s coefficient of linear correlation examined whether there was any significant correlation between the degree of the presence of reflexes in total, and the presence of reflexes separately (be it Moro reflex, Asymmetrical tonic neck reflex, Head righting reflex or Vestibulo-ocular reflex). Established values of correlation coefficient (0.40; 0.50; 0.67 and 0.41), are statistically significant on the level of p=0.01 (99%. reliability of conclusion). Therefore, in the newborns with more emphasized presence of some of the four reflexes, there is significantly higher presence of all reflexes collectively.

All three reflexes were present in the largest part of the tested sample, i.e. 44.4% of the newborns. The presence of two reflexes was determined in a significantly smaller number of the newborns (29.6%). The presence of only one reflex was recorded in 14.8% of the newborns, whereas in 11.1% of examinees all four reflexes collectively were fully present (maximum score of 8 points).

The results in Table 2 indicate that the five-year-olds from our testing sample, achieved the lowest average results in the test of the ability of standing on one foot (Standing on one foot), where the arithmetic mean equaled 1.50 points on average (with the standard deviation of 0.53 points). Only 1.9% of examinees, i.e. only one child, had the minimum score of 0 points. Maximal score of 2 points had 37.0% of the sample i.e. 20 out of 54 examinees. That was the only task in which the five-year-olds realized an average achievement which was not higher than 1.50 points, i.e. all other examined parameters of balance ability were more developed than the ability of maintaining balance while standing on one foot. The highest average achievement of 1.90 points was recorded in task 10 which evaluated body and head posture when standing (Evaluation of body posture and head posture in the standing position). None of 54 examinees scored below 1 point. Only in one case (1.9% of children) the score of 1 point designated a task completed with a partial success. The total of 14.9% of children scored 1.33 and 1.67 points, whereas 83.3% of examinees scored the maximum of 2 points.

Summing up the results in the aforementioned 15 tasks, the scale was created to evaluate the total balance ability, ranging from 0 to 30 points followed by a correla-

TABLE 2
BASIC RESULTS OF EVALUATION OF THE BALANCE ABILITY IN FIVE-YEAR-OLDS

Balance variable	Min	Max	$\overline{X}$	SD
Romberg's test	1.00 (14.8%)	2 (59.3%)	1.73	0.38
Evaluation of standing balance	1.00 (1.9%)	2 (57.4%)	1.78	0.31
Evaluation of walking in a straight line	0.67 (1.9%)	2 (77.8%)	1.88	0.28
Standing on one foot	0.00 (1.9%)	2 (37.0%)	1.50	0.53
Finger to finger test	0.00 (1.9%)	2 (68.5%)	1.84	0.34
Evaluation of the vestibulo-ocular reflex	0.67 (3.7%)	2 (61.1%)	1.83	0.33
Evaluation of body and head posture in the sitting position	0.67 (3.7%)	2 (53.7%)	1.68	0.41
Balance reaction in the sitting position	0.50 (1.9%)	2 (51.9%)	1.70	0.41
Trunk rotation in a sitting position	1.00 (7.4%)	2 (40.7%)	1.75	0.30
Evaluation of body posture and head posture in the standing position	1.00 (1.9%)	2 (83.3%)	1.90	0.24
Position with the arms extended forward middle	0.00 (1.9%)	2 (61.1%)	1.70	0.46
Evaluation of forward and backward walk	1.00 (1.9%)	2 (57.4%)	1.83	0.24
Evaluation of toe walking	0.00 (1.9%)	2 (61.1%)	1.68	0.46
Evaluation of heel walking	0.00 (1.9%)	2 (61.1%)	1.68	0.46
Jumping in place	0.00 (1.9%)	2 (50.0%)	1.67	0.49

tion analysis between the achievements on the scale on the whole and in each of the 15 tasks separately. The results of this analysis are given in Table 3. All values of the Pearson's coefficients of linear correlation had a positive sign and are statistically significant on the level of p=0.01, with 99% reliability of conclusion.

TABLE 3
CORRELATIONS BETWEEN THE TASKS AND THE SCALE FOR EVALUATION OF THE GENERAL BALANCE ABILITY

Balance variable	The scale as a whole (general balance ability)
Romberg's test	r=0.51
Evaluation of standing balance	r=0.62
Evaluation of walking in a straight line	r=0.66
Standing on one foot	r=0.66
Finger to finger test	r=0.72
Evaluation of the vestibulo-ocular reflex	r=0.62
Evaluation of body and head posture in the sitting position	r=0.40
Balance reaction in the sitting position	r=0.63
Trunk rotation in a sitting position	r=0.41
Evaluation of body posture and head posture in the standing position	r=0.49
Position with the arms extended forward middle	r=0.83
Evaluation of forward and backward walk	r=0.67
Evaluation of toe walking	r=0.79
Evaluation of heel walking	r=0.79
Jumping in place	r=0.86

The results indicated that five-year-old children from our research who achieved better results in some of the tasks, also had significantly higher results on the scale for evaluation of the total development of the balance ability. This represented the statistical basis to create the scale based on all 15 tasks. If the obtained correlations between certain tasks and the scale on the whole had a negative sign, or correlations with the positive sign were not statistically different, it was necessary to omit the results of the scale for evaluation of the balance ability on the whole, based only on the tasks which meet the mentioned criteria. However, the obtained average value of the correlation between the scale on the whole and 15 tasks it included equalled 0.64, which indicates a high level of positive correlation with 99% reliability. At the same time, the reliability of the scale was checked by the Cronbach's alpha coefficient and the determined value (α=0,90) indicated a very high inner consistency of the scale for evaluation of the general balance ability in children at the age of 5.

Minimal achievement of 11.67 points on the 0–30 points rating scale was recorded in only one examinee i.e. in 1.9% of children. This means that nobody scored 0–11 points, i.e. none of the five-year-olds from our research had undeveloped ability of maintaining balance up to that extent. The maximum of 30 points was realized by 7.4% of examinees, the theoretical arithmetic means equaled 15, whereas the value of the arithmetic means was 26.16 points, with the standard deviation of 3.73 points. The largest part of the tested five-year-olds (64.8%) achieved results which were above the average, whereas 35.2% of examinees achieved the score below the average.

It was established that there is a statistically significant correlation between the presence of all four reflexes collectively at birth (Moro reflex + Head righting reflex + Asymmetrical tonic neck reflex + Vestibulo-ocular reflex) and the development of the balance ability at the age of 5 (r=0,50; p=0,01). It can be concluded with 99% reliability that the children who had higher number of reflexes (Moro reflex, Head righting reflex, Asymmetrical tonic neck reflex and Vestibulo-ocular reflex together) present immediately after birth, had a more developed ability of maintaining balance at the age of 5, whereas the children with the lower number of reflexes present after birth had a less developed balance ability at the age of 5.

The total of 9.3% of the children started talking when they turned 11 months of age, whereas 1.9% of the children started talking at the age of 26 months, which was recorded as the latest onset of speech. The average age at which the children from our research started talking equaled 12.89 months with the standard deviation of 2.28 months. The total of 64.8% of children began to talk until the age of 12.89 months. At the age of 13–18 months, 33.3% of children began to talk, whereas only 1 child or 1.9% of the sample began to talk at the age of 26 months.

The correlation analysis was used to examine the correlation between the presence of sense balance reflexes in total at birth and the age at which the children from the tested sample began to talk (Table 4). The obtained value of the Pearson`s coefficient of linear correlation is significant on the level of p=0.01 and indicates that there is a negative correlation (r=–0.47) between the total presence of the four tested reflexes immediately after birth (Moro reflex + Head righting reflex + Asymmetrical tonic neck reflex + Vestibulo-ocular reflex) and the age at which children start talking. Therefore, it can be concluded with 99% reliability that children with higher number of reflexes developed at birth started talking at a younger age (less months of age), whereas children with smaller number of reflexes related to the ability of maintaining balance at birth, started talking later, i.e. at more months of age.

There was a statistically significant correlation between the onset of speech and the ability to maintain balance in the five-year-olds. The established correlation coef-

TABLE 4
CORRELATIONS BETWEEN THE ONSET OF SPEECH AND BALANCE ABILITY AT BIRTH AND AT THE AGE OF 5

	Onset of speech	p
Sense of balance at birth	r=–0.47	0.01
Balance ability at the age of 5	r=–0.69	0.01

ficient (r=–0.69) is significant on the level of 0.01. It can be concluded with 99% reliability that children with better ability to maintain balance at the age of 5 (higher scores on the scale for evaluation of balance ability) started talking earlier, whereas the children who started talking later had insufficiently developed ability to maintain balance when they reached 5 years of age.

The evaluation of speech and language development of children at the age of 5 was conducted by means of the standardized scale from the IEPSP battery of tests. The results on the scale are expressed as a success rate. In order to avoid potential confusion between the percentage of examinees and the success rate on the mentioned scale, the results are expressed in points so that each success rate percent corresponds to an identical score (i.e. the number of points) on the 0–100 points rating scale (0% success corresponding to the 0 points score, and 100% success corresponding to the 100 points score). On the scale for evaluation of speech and language development, minimal achieved result equaled 35.29 points and was present in only one child, i.e. in 1.9% of the tested sample. None of the five-year-olds from our research had a score below 35.29 points, i.e. there were no children with such a low degree of speech and language development. Maximum achievement (100 points) was registered in 22.2% of children (i.e. in 12 out of 54 examinees). Average achievement equaled 83.22 points on the 0–100 points rating scale, with the standard deviation of 16.22 points. The total of 40.7% of five-year-olds achieved results lower than the average value (35.29–76,47 points), whereas in 59.3% of examinees of that age there was an above average degree of speech and language development. All this proves that the distribution of speech and language development shifted to the right, i.e. towards higher scores.

There was a very high positive correlation (r=0.87) between the degree of speech and language development and the degree of balance development (Table 5, Scale on the whole). It can be concluded with 99% reliability that the children with better balance skill also had a higher degree of speech and language development and vice versa.

On the speech and language evaluation scale, girls aged 5 had 85.41 points on average (with the standard deviation of 1.82 points), whereas boys of the same age had 81.34 points on average (with the standard deviation of 17.37 points). The difference of 4.07 points, on the 0–100 points rating scale, is not statistically significant, which is confirmed by the t-test value of 0.92. It can be concluded that five-year-old boys and girls from our research had the same degree of speech and language development.

On the scale for the evaluation of maintaining balance, in 15 tasks on the whole, girls aged 5 had 26.23 points on average with the standard deviation of 3.89 points), and the boys of the same age had 26.09 points on average (with the standard deviation of 3.65 points). On the 0–30 points rating scale, the average difference of 0.14 points is negligible and is not statistically significant, which is confirmed by t-test values of 0.14. The results of this analysis are given in Table 6. It can be concluded that five-year-old boys and girls from our research had an equal ability in maintaining balance.

TABLE 5
CORRELATİONS BETWEEN SPEECH AND LANGUAGE DEVELOPMENT OF FIVE-YEAR-OLDS AND ABILITY OF MAINTAINING BALANCE

Balance variable	Speech-language development
Romberg's test	r=0.36
Evaluation of standing balance	r=0.48
Evaluation of walking in a straight line	r=0.50
Standing on one foot	r=0.53
Finger to finger test	r=0.58
Evaluation of the vestibulo-ocular reflex	r=0.49
Evaluation of body and head posture in the sitting position	r=0.32
Balance reaction in the sitting position	r=0.61
Trunk rotation in a sitting position	r=0.43
Evaluation of body posture and head posture in the standing position	r=0.43
Position with the arms extended forward middle	r=0.75
Evaluation of forward and backward walk	r=0.61
Evaluation of toe walking	r=0.73
Evaluation of heel walking	r=0.73
Jumping in place	r=0.83
Scale on the whole	r=0.87

Discussion

The available literature offers very little data on diagnostics and general physiology of the vestibular function and its central pathways in newborns[24]. In order to set standards for the function of the vestibular sense in the first days after birth and determine its part in the overall balance ability of a newborn, examinees in this research were only healthy, full-term babies born from normal pregnancies[25]. Our methodological design was based on the findings in the literature that there are several reflexes which can be tested to indicate if the vestibular sense is already realizing its function. These are: the Vestibulo-ocular reflex, the Moro reflex, the Asymmetrical tonic neck reflex and the Righting reflex[26]. The majority of authors argue that they are vestibular reflexes and that they are caused by the stimulation of otolith labyrinth[27–29]. At the same time, we differentiated the tests that do not include the proprioceptive system and those that do. Thus, in order to test »Moro reflex« we chose the so-called head drop method, which implies activation of the vestibular nerve and otoliths rather than tactile and proprioceptive receptors[30,31]. Looking at the responses of all the tested reflexes taken together, we evaluated the regularity of the function of the vestibular sense and central vestibular pathways in newborns.

A relatively low rate of newborns with all four reflexes present at birth in our tested sample indicates that the

TABLE 6
COMPARISON OF MAINTAINING BALANCE ABILITIES IN BOYS AND GIRLS AT THE AGE OF 5

Balance variable	Boys		Girls		t-test
	$\overline{X}$	SD	$\overline{X}$	SD	
Romberg's test	1.75	0.37	1.71	0.39	0.39
Evaluation of standing balance	1.79	0.30	1.77	0.33	0.17
Evaluation of walking in a straight line	1.90	0.28	1.85	0.29	0.55
Standing on one foot	1.39	0.58	1.63	0.45	1.70
Finger to finger test	1.87	0.25	1.81	0.42	0.72
Evaluation of the vestibulo-ocular reflex	1.87	0.26	1.78	0.40	0.97
Evaluation of body and head posture in the sitting position	1.61	0.44	1.77	0.36	1.48
Balance reaction in the sitting position	1.69	0.40	1.71	0.43	0.15
Trunk rotation in a sitting position	1.73	0.34	1.77	0.26	0.44
Evaluation of body posture and head posture in the standing position	1.91	0.25	1.89	0.23	0.22
Position with the arms extended forward middle	1.72	0.41	1.68	0.51	0.35
Evaluation of forward and backward walk	1.80	0.28	1.86	0.20	0.92
Evaluation of toe walking	1.71	0.41	1.65	0.52	0.47
Evaluation of heel walking	1.71	0.41	1.65	0.52	0.47
Jumping in place	1.64	0.46	1.69	0.53	0.37
Scale on the whole	26.09	3.65	26.23	3.89	0.14

function of the vestibular sense and its central pathways during the first days after birth is not completely mature. This is in complete compliance with the findings in literature that the child is born with the developed vestibular sense, whereas maturation of vestibular reflexes and pathways continues after birth, relatively quickly in the first months of life[32].

The role of the vestibular function in establishing balance in hearing impaired children has been extensively researched[33,34]. In contrast, there are very few available papers dealing with the longitudinal monitoring of balance maturation during childhood. One of such researches was conducted by Cumberworth and associates on the sample of 60 healthy children aged 5–17[35]. Their results confirm that the vestibular function increases and balance skills improve with an age. The results of our study are compatible with this, indicating significant correlation of the certain level of maturity of the vestibular sense and balance at birth with the ability of balance and speech in early childhood ($p<0.01$), thus creating an opportunity for timely diagnostics and the application of an early stimulatory treatment in children at the earliest age. The results of the balance ability evaluation of children at the preschool age, achieved by Lam and associates indicated that girls are significantly more successful in maintaining balance compared to boys of the same age[36]. Contrary to these, the results of our search showed the absence of any significance between the genders regarding the balance ability of five-year-olds.

Despite the increasing frequency of disorders connected with the vestibular system and balance in children, the vestibular function in children is still insufficiently controlled. The reason for this are the existing techniques which are most commonly used to examine the vestibular apparatus in children: the Caloric test, the Rotational test and the Vestibular Evoked Myogenic Potentials (VEMP). These are techniques actually designed to examine balance disorders in adults, which have been adapted for children. In any case, many authors argue that the application of these techniques on children of a younger age is not safe. Namely, the Caloric test can cause vertigo and vomiting[37], the Rotational chair test cannot examine the chronic unilateral vestibular hypofunction, it also causes vertigo and vomiting, and lastly, this apparatus is too expensive and only few clinics have one[38]. The VEMP is a diagnostic procedure used in differential diagnostics of the vertigo in adults. It helps to determine whether only the sacculus is damaged, or the lower vestibular nerve as well. This method is relatively easy to perform, but it can only be an additional method to evaluate status of the vestibular apparatus and central vestibular pathways[39]. Due to the aforementioned, parents unwillingly accept to subject their children to such type of testing, except in cases when it is strongly indicated by diagnostics. The need to find easily applicable, non-invasive and economically acceptable tests to examine the vestibular function in children are more than justified.

In conclusion, the children who had higher number of reflexes immediately after birth, have a better ability to maintain balance and a higher degree of speech and language development at the age of 5, whereas the children with the lower number of reflexes present after birth, had a less developed balance and speech and language ability at the age of 5. The importance of this research lies in new knowledge in the domain of maturation of vestubular function immediately after birth, given that this segment of physiology of a newborn has not so far been processed in such a way, as well as in the recognition of function of the vestibular sense as another parameter of a child's maturation. The ability of balance can be influenced by targeted motor exercises, and this study confirmed which children need such exercising.

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KORELACIJA IZMEĐU SPOSOBNOSTI ODRŽAVANJA RAVNOTEŽE I GOVORNO-JEZIČNOG RAZVOJA DJECE

SAŽETAK

Longitudinalno istraživanje provedeno je s ciljem da se utvrdi da li je stupanj uspješnosti izvođenja refleksa vezanih za održavanje ravnoteže od rođenja u korelaciji sa stupnjem uspješnosti održavanja ravnoteže u ranom djetinjstvu, kao i da se ispita povezanost određenog nivoa govorno-jezičnog razvoja sa sposobnošću održavanja ravnoteže kod rođenja i na uzrastu od 5 godina. Osnovna grupa ispitanika obuhvatila je 54 djeteta oba spola, uzrasta od 5,0 do 5,4 godina, kod kojih je obavljena procjena ravnoteže i govorno-jezičnog statusa na osnovu standardizirane baterije testova, dok je grupa refleksa koji su vezani za funkciju vestibularnog aparata, klinički ispitana 3. dana po rođenju u istom uzorku djece. Dobiveni rezultati, kod rođenja i na uzrastu od 5 godina, dokumentirani su uz pomoć digitalne kamere, potom bodovani, statistički i deskriptivno obrađeni. Rezultati istraživanja su ukazali na postojanje statistički značajne povezanosti, kako u pogledu postignutog nivoa ravnoteže novorođenčadi i petogodišnjaka, tako i između ovladanih vještina ravnoteže i određenog nivoa govorno-jezičnog razvoja kod djece na uzrastu od 5 godina ($p<0,01$). Značaj istraživanja se ogleda u novim saznanjima u domeni sazrijevanja i funkcije aparata za ravnotežu odmah nakon rođenja, budući da ovaj segment fiziologije novorođenčeta do sada nije obrađen na takav način, kao i u prepoznavanju funkcije vestibularnog aparata kao još jednog parametra maturacije djeteta. Na sposobnost ravnoteže se može utjecati ciljanim motoričkim vježbama, a ovo istraživanje je pokazalo kojoj djeci je takvo vježbanje potrebno.