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MOTOR PROFICIENCY OF STUDENTS WITH COCHLEAR IMPLANTS

TIHOMIR VIDRANSKI, ZVONIMIR TOMAC, DARIA FARKAŠ
School of Education, University of Osijek, Croatia

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Abstract: *The purpose of this study was to examine the development of motor skills in hearing-impaired pupils with cochlear implants (CI). Sixteen pupils with CIs, aged 12.37 years (SD 4.42), who attended regular educational programs, and seventeen hearing pupils, aged 12.64 years (SD 3.69), participated in the study using the Bruininks - Oseretsky Test of Motor Proficiency. The results demonstrated that a very high percentage of pupils with CIs scored below the average range in all subtests. Even poorer results were between the observed groups found in the subtests assessing gross motor skills. The most significant differences were found in the subsets of upper limb coordination, bilateral coordination, and balance. It was noticed that hearing children performed significantly better than those with CIs.*

Key words: *Cochlear implant, hearing impairment, motor proficiency, Bruininks – Oseretsky test, regular educational system, pupils*

INTRODUCTION

According to the World Health Organization, hearing impairment is nowadays considered to be the third most common chronic medical condition. Hearing loss that develops during pregnancy or after birth occurs in 1 to 3 per 1000 newborn children. Therefore, it is more prevalent than many other congenital impairments (Sokol and Hyde, 2002). When comparing children with and without hearing loss, many researchers have found that hearing-impaired children (without a cochlear implant, or CI) have poorer motor skills, particularly in terms of balance disorders (Gheysen et al., 2008, Rine et al., 1996, De Sousa et al., 2012, Shaikh et al., 2013, Dummer et al. 2006, Siegel et al., 1991, Hartmann et al., 2011 and Wierzchowski ed., 2008). Quality motor development of gross and fine motor skills requires postural control and balance, which facilitate everyday movements (Rajendran, Roy & Jeevanantham, 2012). It is known that a well-developed hearing and vestibular apparatus are necessary for the stability of the body and the control of gravitational forces in motion. Similarly, the balance as a motor skill depends on the fully developed hearing and vestibular system. While exploring the level of motor abilities and skills of hearing-impaired children, researchers have found that in addition to the aforementioned balance, hearing-impaired children (without CIs) also score lower than hearing children in repetitive strength and flexibility (Winnick and Short, 1986), as well as in fine and gross motor skills (Shaikh & Sadhale, 2013). Furthermore, hearing-impaired children often score below the average range on reference standards (Siegel, Marchetti & Tecklin, 1991; Zwierzchowski, Gawlik & Grabar, 2008; Hartman, Houwen & Visscher, 2011). One of the most common clinical interventions for hearing impairments, which can also be used to improve motor development, is the cochlear implantation.

However, only a few studies have been conducted on samples of children with CI, and the results of these studies have been largely inconsistent (Gheysen et al., 2008, Cushing et al., 2008, Suarez et al. 2007, Shall, 2009, Horn et al., 2006). Out of all motor skills, these studies have focused solely on balance, leaving the relation between the other motor skills and having a CI unexamined. Therefore, hearing impairment presents not only a major communicational limitation, but also results in disadvantages in motor development.

As has already been mentioned, hearing impairment is considered to be the third most common chronic medical condition in the world. In Croatia, a total number of about 500 deaf persons have received cochlear implants since 1996. The Croatian educational system currently includes around 30 children with CIs.

The aim of this study was to determine the proficiency of motor skills of children with CIs who attend regular educational processes.

METHODS

Sample

The study involved a total of 33 participants, aged 6-18 years, from one Croatian region. The participants were divided into two groups. The first group included 16 participants (10 females and 6 males) with CIs. The average age of the first group was 12.37 years (SD 4.42). The males belonging to the first group were slightly older than the females (the average age of the females was 12.10 years, as compared to the average age of the males, which was 12.83 years). The second group included 17 participants without hearing loss, whose average age was 12.64 years, SD 3.69 years (7 males with an average age of 13.37 and 10 females with an average age of 12.00). To be included in either of the two groups, the participants had to (a) be enrolled in regular elementary schools or secondary schools, (b) attend regular sport classes within their schools, and (c) have no additional medical, psychological, neurological, or motor impairment apart from hearing impairment. All subjects with CIs included in this study had unilaterally embedded CIs. From the total 16 respondents with CIs, 6 received their CIs at the age of two years, 8 received their CIs when aged three years, and two respondents when aged six and seven years, respectively. None of the respondents had any medical history of hearing impairment in their families. The causes of hearing loss were genetic in 13 respondents, meningitis-related in 2 respondents, and the result of birth complications in one respondent. Four of the respondents were included in additional 60-minute physical activity besides their regular PE class three times a week, two patients twice a week, and 10 of the respondents had no additional physical activities.

Participants in the second group, which consisted of children without hearing impairment, were selected in such a way that each participant with CI was paired with a participant of the same age and gender without hearing impairment from the same school. Out of a total of 17 subjects without hearing loss, five subjects were included in additional 60-minute physical activity three times a week, two subjects twice a week, and 10 subjects had no additional physical activities.

Ethical approval was granted for this study. The participants' parents were familiarized with the aims of the study and signed a consent form which allowed their children to participate in this research.

Table 1

	Cohlear implant		**Hearing**			
	N	**Years**	**N**	**Years**	χ^2	**p**
Boys	6	12,83	7	13,37	6,94	0,32
Girls	10	12,10	10	12,00	11,00	0,27

Instruments

The Bruininks-Oseretsky Test of Motor Proficiency, 2nd Edition ($BOT_{TM}2$) was used for this study. $BOT_{TM}2$ is an individually administered test that is used to measure a wide array of motor skills in individuals aged 4 to 21. It provides researchers with a reliable and efficient measure of fine and gross motor control skills. Since its publication in 1987, it has been the most widely used standardized measure of motor proficiency (Crowe, 1989, Ulrich, 1985). Many clinical research studies use $BOT_{TM, \text{ which is}}$ usually chosen as the standard for the criterion-validation of other motor ability instruments (Flegel & Kolobe 2002, Tan, Parker & Larkin 2001). A growing number of studies have also used $BOT_{TM \text{ to}}$ explore the nature and degree of motor-skill deficits in individuals with motor disorders (Faught, Hay, Flouris, Cairney & Hawes, 2002, Smits-Engelsman, Niemeijer & Van Galen, 2001). $BOT_{TM}2$ consists from 53 sections, which are divided into eight subsets for assessing fine and gross motor skills (Bruininks & Bruininks 2005).

Data collection

The data was collected during 2014. Each participant was studied individually throughout one physical education class in the school's sports hall. Participants with CIs carried out all the tasks while their Cis were turned on. The measuring was conducted by two experienced physical education teachers in such a way that one teacher carried out the measurement while the other one assisted in the preparation of the tasks and recorded the results.

Data analysis

The obtained raw results were transformed for each participant into point scores by using the statistical software BOT-2 ASSIST version 1.0. These scores were further used to classify participants into five descriptive categories (well below average, below average, average, above average, well above average). Based on the results, the percentages of the total number of participants were calculated in individual descriptive categories of each subset of the measuring instrument, and the chi-square test was used to determine the differences in frequencies between the participants with and without hearing impairment. The Kolmogorov - Smirnov test (KS) was used to determine the normality of distribution. The t-test for independent samples was used to determine the difference between the pupils with CIs and hearing pupils, and the Mann-Whitney U-test was used after the raw scores were converted to point scores in those variables that did not have a normal distribution. All analyses were performed at a significance level of p=0.05.

RESULTS

The difference analysis indicates no statistically significant difference between hearing subjects and subjects with CIs in their anthropometric characteristics in both boys and girls. The research results show that participants with CIs mostly achieved average scores in all subtests as well as in the total score, but they did not achieve well–above-average scores in any of the subtests. A very small number of the participants achieved above-average results (Table 1). A very high percentage of the participants achieved below average results on all subtests, and well-below-average results were reached mainly on the subtests for the assessment of gross motor skills in relation to fine motor skills. However, the most striking aspect is that, on the subtests for upper limb coordination, bilateral coordination, and balance, many participants with CIs achieved below-average and well-below-average results. The results show that 40% of the participants achieved below-average and well-below-average scores on the upper limb coordination and bilateral coordination tests, and 53% of the participants achieved below-average and well-below-average results on the balance test. This is the only subtest in which the number of below-average results is larger than the number of average and above-average results combined. Unlike the participants with CIs, the hearing participants did not achieve below-average results on any subtest and are more frequently found in the above-average and well-above-average categories, which was especially noticeable in the subsets of fine motor precision, fine motor integration, running speed agility, strength, as well as in total motor composite.

The results of the Mann Whitney U-test regarding further analysis of the differences between the two groups of participants (Table 4) demonstrate that the differences are significant in all total scores of each subtest and that hearing participants achieve significantly better results than participants with CIs. Table 5 shows the only statistically significant difference in the results of individual tests

Table 2. *Descriptive parameters and differences in anthropometric characteristics and body mass index between subjects with CI and their hearing peers*

		Mean	SD	Median	U	Z	p
Body height	BCi	162.00	26.74	170.50	13.50	0.64	0.52
	BH	160.50	11.26	165.10			
Body weight	BCi	54.56	18.90	33.40	16.50	-0.16	0.87
	BH	56.05	8.27	56.75			
BMI	BCi	19.80	1.95	19.55	12.00	-0.88	0.37
	BH	20.10	4.86	21.15			
Body height	GCi	148.80	20.78	154.50	41.00	-0.28	0.77
	GH	154.58	13.08	155.60			
Body weight	GCi	48.18	21.08	44.60	42.00	0.20	0.83
	GH	44.97	10.08	49.30			
BMI	GCi	20.46	4.32	21.50	36.50	0.65	0.51
	GH	19.25	3.22	18.30			

BCi- boys with cochlear implant; BH - Hearing boys; GCi - Girls with cohlear implant; GH – hearing girls

Table 3. *Frequencies of children with and without hearing impairment in individual descriptive categories*

	WELL BELOW AVERAGE		BELOW AVERAGE		AVERAGE		ABOVE AVERAGE		WELL ABOVE AVERAGE	
	CI	H	CI	H	CI	H	CI	H	CI	H
FINE MOTOR PRECISION	0 0.00 %	0 0.00 %	4 26.66 %	0 0.00 %	10 66.66 %	8 47.06 %	1 6.66 %	9 52.94 %	0 0.00 %	0 0.00 %
FINE MOTOR INTEGRATION	0 0.00 %	0 0.00 %	3 20.00 %	0 0.00 %	10 66.66 %	7 41.18 %	2 13.33 %	10 58.82 %	0 0.00 %	0 0.00 %
MANUAL DEXTERITY	0 0.00 %	0 0.00 %	4 26.66 %	1 5.82 %	9 60.00 %	13 76.47 %	2 13.33 %	2 11.65 %	0 0.00 %	1 5.82 %
UPPER LIMB COORDINATION	1 6.66 %	0 0.00 %	5 33.33 %	0 0.00 %	8 53.33 %	10 58.82 %	1 6.66 %	7 41.18 %	0 0.00%	0 0.00 %
BILATERAL CORDINATION	2 13.33 %	0 0.00 %	4 26.66 %	0 0.00 %	8 53.33 %	15 88.23 %	1 6.66 %	2 11.65 %	0 0.00 %	0 0.00 %
BALANCE	4 26.66 %	0 0.00 %	4 26.66 %	2 11.65 %	7 46.66 %	11 64.70 %	0 0.00 %	4 23.53 %	0 0.00 %	0 0.00 %
RUNNING SPEED AGILITY	0 0.00 %	0 0.00 %	3 20 %	0 0.00 %	10 66.66 %	5 29.41 %	2 13.33 %	10 58.82 %	0 0.00 %	2 11.65 %
STRENGHT	0 0.00 %	0 0.00 %	2 13.33 %	0 0.00 %	8 53.33 %	4 23.53 %	5 33.33 %	10 58.82 %	0 0.00 %	3 17.65 %
TOTAL MOTOR COMPOSITE	1 6.66 %	0 0.00 %	3 20 %	0 0.00 %	10 66.66 %	4 23.53 %	1 6.66 %	7 41.18 %	0 0.00 %	6 35.30 %

CI – Cochlear implant; H – hearing

Table 4. *Differences among children with and without hearing impairment in the subtests of the measuring instrument*

	Mean CI	Median	Quartile Range	Mean H	Median	Quartile Range	Rank Sum CI	Rank Sum H	U	Z	p	ES
TOTAL SCORE FMP	33.87	36.50	13.00	39.82	40.00	1.00	173.50	387.5	37.5	-3.53	0.000*	0.27
TOTAL SCORE FMI	36.75	29.00	12.50	39.41	40.00	1.00	206.00	355.0	70.0	-2.35	0.018*	0.20
TOTAL SCORE MD	28.06	38.50	4.00	33.70	35.00	4.00	212.00	349.0	76.0	-2.14	0.032*	0.18
TOTAL SCORE BC	19.06	21.00	10.50	23.41	24.00	0.00	197.00	364.0	61.0	-2.68	0.007*	0.26
TOTAL SCORE B	26.31	30.50	15.00	33.70	33.00	1.00	204.00	357.0	68.0	-2.43	0.015*	0.26
TOTAL SCORE RSA	33.93	35.50	13.50	43.52	44.00	3.00	176.50	384.5	40.5	-3.42	0.001*	0.36
TOTAL SCORE ULC	28.62	31.50	16.00	36.88	38.00	2.00	189.00	372.0	53.0	-2.97	0.003*	0.28
TOTAL SCORE S	26.68	26.00	7.00	34.70	35.00	5.00	179.00	382.0	43.0	-3.33	0.001*	0.36

*p= 0,05; CI – Cochlear Implant; H – Hearing ; Mean – Mean; SD; Standard Deviation; Median- Median; FMP- Fine Motor Precision; FMI – Fine Motor Integration; MD – Manual Dexterity; BC- Bilateral Coordination; B – Balance; RSA – Running Speed And Agility; ULC – Upper - Limb Coordination; S- Strength; ES – effect size

between participants with CIs and hearing participants, which makes it obvious that these differences are significant in 30 out of 55 particles of the $BOT_{TM}2$. In all particles where the difference was noticed, hearing participants also achieved significantly better results.

DISCUSSION

As has already been mentioned, numerous studies have confirmed that hearing-impaired children (without CIs) have poorer fine and gross motor skills (Shaikh & Sadhale, 2013), repetitive strength

Table 5. *Differences in motor skills of the measuring instrument between children with and without hearing impairment*

	Mean CI	Median CI	Quartile Range CI	Mean H	Median H	Quartile Range H	Rank Sum CI	Rank Sum H	U	Z	p-value	ES
FMP 2	2.38	2.00	1.00	2.94	3.00	0.00	195.00	366.00	59.00	-2.76	0.006*	0.30
FMP 6	5.19	12.00	7.50	6.77	12.00	0.00	211.50	349.50	75.50	-2.16	0.031*	0.14
FMI 8	5.00	5.00	1.00	5.82	6.00	0.00	215.00	346.00	79.00	-2.04	0.042*	0.07
MD 1	5.94	35.50	22.00	7.59	42.00	16.00	210.50	350.50	74.50	-2.20	0.028*	0.10
MD 3	5.25	7.50	2.00	6.35	8.00	1.00	216.50	344.50	80.50	-1.98	0.048*	0.09
BC 4	1.19	6.00	2.00	2.77	5.00	0.00	198.50	362.50	62.50	-2.63	0.009*	0.28
B 6	1.94	4.77	5.40	3.29	10.00	1.50	192.00	369.00	56.00	-2.86	0.004*	0.23
B 8	2.81	10.00	6.85	4.00	10.00	0.00	212.50	348.50	76.50	-2.13	0.034*	0.22
RSA 1	6.81	8.70	2.14	8.53	7.37	0.88	191.50	369.50	55.50	-2.88	0.004*	0.24
RSA 2	7.88	38.50	10.00	9.12	45.00	10.00	204.00	357.00	68.00	-2.43	0.015*	0.13
RSA 3	7.31	36.00	7.00	8.65	40.00	7.00	206.50	354.50	70.50	-2.34	0.019*	0.22
RSA 4	5.13	20.50	20.00	8.71	42.00	5.00	166.00	395.00	30.00	-3.80	0.000*	0.42
RSA 5	6.63	32.50	20.50	8.53	35.00	5.00	202.00	359.00	66.00	-2.50	0.012*	0.28
ULC 4	2.94	4.50	4.00	4.59	5.00	0.00	214.50	346.50	78.50	-2.05	0.040*	0.16
ULC 5	5.06	10.00	6.50	6.65	10.00	0.00	215.00	346.00	79.00	-2.04	0.042*	0.15
ULC 6	4.50	7.50	7.00	6.82	10.00	0.00	202.50	358.50	66.50	-2.49	0.013*	0.28
ULC 7	2.50	3.00	3.00	3.94	4.00	1.00	207.00	354.00	71.00	-2.32	0.020*	0.16
S 1	6.56	18.00	13.50	9.00	161.00	36.00	189.50	371.50	53.50	-2.95	0.003*	0.19
S 2	5.06	112.50	67.50	6.53	26.00	13.00	209.00	352.00	73.00	-2.25	0.024*	0.16
S 3	6.13	24.00	12.50	7.53	30.00	9.00	203.00	358.00	67.00	-2.47	0.014*	0.27
S 4	4.75	45.83	26.15	5.77	60.00	0.00	203.00	358.00	67.00	-2.47	0.014*	0.30
S 5	4.06	35.15	43.61	5.53	60.00	0.00	209.50	351.50	73.50	-2.23	0.026*	0.25

*p= 0,05; CI – Cochlear Implant; H – Hearing ; Mean – Mean; SD; Standard Deviation; Median- Median; FMP2 –Fine Motor Precision Filling In Shape; FMP 6- Fine Motor Precision Folding Paper; FMI 8 – Fine Motor Integration Copying Overlapping Pencils; MD1 – Manual Dexterity Making Dots In Circles; MD 3 – Manual Dexterity Placing Pegs Into Pegboard; BC 4 – Bilateral Coordination Jumping In Place – Opposite Sides; B 6 –Balance Standing On One Leg One A Line – Eyes Closed; B 8 Balance Standing Heel To Toe On Balance Beam; RSA 1 – Running Speed And Agility Shuttle Run; RSA 2- Running Speed And Agility Stepping Sideways Over A Balance Beam ; RSA 3 Running Speed And Agility; RSA 4 Running Speed And Agility One Legged Side Hop; RSA 5 Running Speed And Agility Two Legged Side Hop; ULC 4- Upper Limb Coordination Catching A Tossed Ball One Hand; ULC 5- Upper Limb Coordination Dribbling A Ball One Hand; ULC 6- Upper Limb Coordination Dribbling A Ball Alternating Hand; ULC 7- Upper Limb Coordination Throwing A Ball At Target; S 1 – Strength Standing Long Jump; S 2- Strength Push Ups; S 3 – Strength Sit Ups; S 4 – Strength Wall Sit; S 5 – Strength V- Up ; ES – effect size

and flexibility (Winnick & Short, 1986), and especially evident difference in balance (Gheysen et al., 2008, Rine et al., 1996, De Sousa et al., 2012, Shaikh et al., 2013, Dummer et al. 2006, Siegel et al., 1991, Hartman et al., 2011, Zwierzchowski and ed., 2008). However, studies conducted on children with CIs are scarce. The majority of studies has only evaluated the balance, and contradictions in results are prominent (Jernice et al., 2011, Gheysen et al., 2008, Cushing et al. 2008, Suarez et al., 2007, Shall, 2009, Horn et al., 2006).

This study has established that participants with CIs achieve significantly poorer results than participants without hearing impairment in all tests of fine and gross motor skills. Participants without hearing impairment are significantly more dominant in the total score of all subtests than participants with CIs. A high percentage of participants with hearing impairment have achieved below-average and well-below-average results in balance, and the resulting differences between participants with CIs and without impairment were also obtained in previous studies (Gheysen, 2008, Cushing, 2008, Jarnice, 2011), i.e. balance disorders in patients with CIs were established by several researchers (Gheysen, 2008, Cushing, 2008, Jarnice, 2011), and thereby confirm the findings of this study. On a sample of participants aged 4-12 years, using the Movement Assessment Battery for Children (M - ABC), the One-Leg Standing Test, and the Körperkoordinationstest für Kinder (KTK - Test), Gheysen (2008) found that participants with hearing impairment and CIs scored significantly poorer than participants without hearing impairment in all tests of both dynamic and static balance. The same results were obtained by Cushing (2008) using the BOT2 battery of tests, as well as by Jernice (2011) and Suarez (2007) using the Force Plate platform. A high percentage of participants who scored below-average and well-below-average results on other subtests, except for balance, indicates poorer other motor skills in participants with CIs, which was confirmed by analyzing the differences when compared to the hearing participants. Unlike the participants with CIs, the hearing participants did not achieve below-average results on any subtest, and are more frequently found in the above and well above categories, which was especially noticeable in subsets of fine motor precision, fine motor integration, running speed agility, strength and also in the total motor composite. Shall (2010) and Gheysen (2008), using the M-ABC battery of tests, also found that participants with CIs showed a tendency for poorer results on tests of manual dexterity and ball skills, although the differences in these studies were not statistically significant. No additional research of other motor abilities and skills amongst the participants with CI has been conducted. A high percentage of the participants with CIs, who achieved below-average and well-below-average results and the determined differences in comparison to hearing participants point to less developed motor skills in the participants with CIs, and it is therefore recommended that customized programs be created for PE classes. An adjusted program for children with CIs, who are integrated in the regular program of physical education, will enable them to develop their motor skills with a special emphasis on balance. For future studies of this type, it would be desirable to have a larger sample.

CONCLUSION

The purpose of this study was to determine the level of motor abilities and skills of children with cochlear implants who attend regular Croatian schools. The results demonstrated negative deviation in the results achieved by children with CIs when compared to the reference values of the Bruinkins - Oseretsky Test in certain motor skills, especially on the subtests of balance and manual dexterity, as well as significant differences when compared to the hearing pupils on all subtests.

These discrepancies suggest the necessity of modifications in Croatian PE classes using custom-designed methods and adequate kinesiology operators who would encourage quality development of degraded motor abilities and skills.

According to some studies, there are indications that factors such as damage cause, age at implantation of CI, along with other physiological, sociological, and economic factors, can affect the level of motor skills development in subjects with CIs. However, due to the small sample size, the inclusion of these factors was not a subject of this study, which can be considered a shortcoming. The purpose of this study was to determine the structure of differences, and not their causes. Future studies on larger samples and with a greater number of variables could provide us with methodologically sound insight on the connections between having a CI and the level of development of motor skills.

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MOTORIČKE VJEŠTINE UČENIKA S KOHLEARNIM IMPLANTATOM

Sažetak: *Cilj ovog istraživanja bio je utvrditi razvoj motoričkih vještina kod učenika s kohlearnim implantatom. U istraživanju je sudjelovalo šesnaestero djece s ugrađenim kohlearnim implantatom u dobi od 12.37 godina (SD 4.42), polaznika redovitog odgojno – obrazovnog sustava te 17-ero djece bez oštećenja sluha, u dobi od 12.64 godina (SD 3.69). Za procjenu razvijenosti motoričkih vještina korišten je Bruininks - Oseretsky test. Rezultati pokazuju da veliki postotak djece s kohlearnim implantatom postiže ispodprosječne rezultate u svim subtestovima, te da najslabije rezultate postižu u subtestovima grubih motoričkih vještina. Najznačnije statistički značajne razlike među promatranim skupinama utvrđene su u subtestovima za procjenu kordinacije gornjih ekstremiteta, bilateralne koordinacije i ravnoteže. Na osnovu dobivenih rezultata može se zaključiti da djeca bez oštećenja sluha postižu statistički značajno bolje rezultate u testovima za procjenu motoričkih vještina od djece s kohlearnim implantatom.*

Ključne riječi: *Kohlearni implantat, oštećenje sluha, motoričke vještine, Bruininks – Oseretsky test, redoviti odgojno obrazovni sustav, djeca*