ORIGINAL ARTICLE

Aquatic gymnastics program to improve kinesthetic manual praxis in children with Down syndrome

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Authors' Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection

Abstract

Background and Study Aim An alternative solution to improve the praxis function in children with Down syndrom is the application of modern therapeutic programs that take place in the aquatic environment. The article focuses on a study tracking the effects of a therapeutic program based on water gymnastics resources as an alternative technology to improve kinesthetic manual praxis in individuals with Down syndrome.

Material and Methods Thirty children with Down syndrome (aged between 9 and 11 years) participated in the experiment and were differentiated in equal numbers into two groups: experimental (undergoing an 11-month therapeutic water gymnastics course) and control (taught using traditional technologies). The research battery for tracking the dynamics in the kinesthetic organization of manual movements included three neuropsychological probes with six items each, performed separately by the fingers of both hands. The empirical data were processed according to generally accepted methods of mathematical statistics: a Shapiro-Wilk test for the assumption of normality, descriptive statistics for the dependent variables and an independent samples t- test to verify between-group differences. SPSS 16.0 statistical package was used for statistical analysis, with a level of significance $\alpha = 0.05$.

Results In the primary phase, the two groups were homogeneous in terms of the initial results of their performance in the area of fine motor movements. In the final phase, a statistically significant difference was identified between the experimental and control groups in the performance of all three probes: Reproduction of finger postures by the visual model ($t = 4.053$, $p<0.001$); Reproduction of finger postures by the kinesthetic model ($t = 2.973$, $p<0.01$); Transfer of finger postures by the kinesthetic model ($t = 2.866$, $p<0.05$). A significant improvement was registered in the experimental group's performance in all components of manual praxis ($\Delta= 15.70\%$; $\Delta= 12.58\%$; $\Delta= 10.39\%$).

Conclusions The positive dynamics in praxis function development within the studied domain serve as clear evidence. These changes in the realization of purposeful, pre-planned manual actions can be generated through a well-structured training and therapy program utilizing the benefits of water gymnastics as an intervention method. This is a sufficiently encouraging fact for children with Down syndrome, given the specific psychomotor profile determined by the genetic pathology.

Keywords: praxis function, alternative therapy, water space, Down syndrome

Introduction

Down syndrome is one of the most striking examples of a genetic pathology that determines the symptoms of permanent underdevelopment of the mental sphere. In the modern psychology of atypical development, the idea of the total (diffuse) characteristic of this type of development [1] is inspired. It predominantly affects the formation of the highest levels of all mental functions, in particular, praxis - the planning, execution and sequence of movements. The kinesthetic praxis, classified by Luria [2] as afferent, is a basic structural unit in the architectonics of praxis as a higher psychic function. Its emanation is the manual praxis, which is interpreted as the ability to perform the necessary set of movements (especially without visual control) based on kinesthetic analysis and synthesis [3]. Kinesthetic intelligence integrates the skills to measure, differentiate and reproduce the force, temporal and spatial parameters of movement. It plays a vital role in various types of activities in the performance of precise hand movements when fine control and management of adjustable parameters are required: decrease or increase the amplitude of the movement, a change in its pace, in the amount of force. Contemporary child development researchers are united around the position of the priceless effect of the hand function on speech development [4]. The subordination between the level of development of the speech function and the degree of formation of manual movements is determined by the anatomical proximity of the disposition of the motor and speech areas in the cerebral cortex, the mutual relationship between speech and motor formation in the conditions of typical [5] and atypical development [6].

In children with Down syndrome, there is a lack of precision in the execution of movements, an inability for motor planning and control and a deficiency

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in spatial representations and spatial-motor coordination [7, 8]. The degraded tactile sensitivity can lead to alterations in the kinesthetic component of movements [9, 10]. Most infants and toddlers go through the stages of early motor development more slowly and exhibit greater within-population variability than typically developing infants [11]. Specific movement disorders of the limbs, including difficulties with precise finger movements, have also been observed in 10-16-year-old children [12]. The abnormal motor patterns in individuals with Down syndrome may be of particular concern for academic functioning in school, performance in daily life, play, and other areas of professional life [13].

The awareness of the specific nature of the praxis function deficiency in Down syndrome concentrates the efforts of specialists from various fields on the search for effective therapeutic approaches [14, 15, 16]. Traditional intervention technologies follow procedures and steps that take place in the usual „dry“ environment and that assist to some degree in improving the overall functioning of the child with a chromosomal aberration. In contemporary practice, more and more attention is paid to different duration, intensity and technique therapeutic programs for people with motor, neurological and mental disorders whose physical activities are carried out in a water space [17, 18, 19, 20]: swimming, water spinning, surf yoga, aqua aerobics, aqua gymnastics.

Aqua gymnastics is a therapeutic method, the essence of which consists in performing physical exercises in a water environment under the guidance of a hydro therapist, with special equipment: belts, boards, cuffs, rubber dumbbells and swimming sticks. Researchers have defined water gymnastics as the safest and most effective way to treat and rehabilitate musculoskeletal disorders by combining suitable physical activity with the beneficial properties of water [21, 22]. From a biomechanical point of view, gymnastics includes a large variety of movements which can be used in a large range of connections and combinations [23]. Therapy through water gymnastics, due to the properties of the aquatic environment, allows: (a) Reduction of the load on the musculoskeletal system – the lifting force of the water compensates for the force of gravity, which generates pressure on the spine and joints; (b) Strengthening the muscular corset by using the „deep“ muscles of the body to maintain balance in the water; (c) Improving overall joint mobility and flexibility with minor muscular effort; (d) Strengthening the overall physical condition, which is manifested by the presence of healthier sleep and a good emotional status; (e) Improving the functional state of the basic neural processes – excitation and inhibition. All these aspects are in favor of water gymnastics as a promising strategy to improve kinesthetic differentiation of movements considering their high-quality performance.

In the course of researching literary sources and methodological developments on a national and global scale, we found a low amount of publications related to the use of water gymnastics programs for the development of manual praxis in children with Down syndrome. The presented situation motivates the need to conduct a study. *Its purpose was* to track the effects of a therapeutic program based on the resources of water gymnastics for the development of manual praxis in children with the characteristic profile of Down syndrome.

Materials and Methods

Participants

The experimental study involved thirty Bulgarian children with Down syndrome (Table 1). The age of the respondents ranged from 9 to 11 years, which allowed for conducting an adequate study through a battery of neuropsychological probes. All children are raised in families and attend the special education support centres in the city of Stara Zagora, Republic of Bulgaria.

Research Design and Procedure

An adapted version of an experimental methodology developed by Luria [24] was used to study kinesthetic manual praxis. The methodological complex included three neuropsychological probes:

- Reproduction of finger postures by the visual

Table 1. Background informaton of the partisipants

n=30			
Category	**Demographic characteristics**	**N**	**%**
Types of Down syndrome	Trisomy 21	26	86.87
	Mosaicism	4	13.13
Gender	Male	17	56.67
	Female	13	43.33
Age	9	8	26.66
	10	10	33.34
	11	12	40.00

model (RFPVM). The researcher consistently demonstrates a sequence of finger configurations and stimulates the child to produce them in the same way.

- Reproduction of finger postures by the kinesthetic model (RFPKM). The probe is performed in the absence of visual control by the child. The experimenter folds the child's fingers in certain positions, returns them to the starting position and instructs the child to reproduce them.
- Transfer of finger postures by the kinesthetic model (TFPKM). The experimenter folds the child's fingers in certain positions on one hand and asks him to make the same configuration on the other hand independently. The transfer of postures is performed first from the leading hand (for left-handed children from left to right) and then vice versa. The probe is performed without the presence of visual control.

The three probes included six items each, performed by both hands separately: the „goat" pose (stretching forward on the 2nd and 5th finger); the „scissors" pose (stretching forward on the 2nd and 3rd finger); the „wheel" pose (involving 1st finger in combination with each subsequent finger).

Fourth Grade Scale, which includes quantitative and qualitative indicators, was used:

0 – independent and correct performance of the task;

1 – performance of the task with a number of minor errors corrected by the child without the involvement of the experimenter;

2 – the realization of the sample is carried out after providing stimulus support;

3 – inability to complete the task.

The increase in quantitative indicators is inversely proportional to the correct execution of the probes. Tracking the dynamics of kinesthetic manual praxis development was carried out by fixing the obtained data before and after applying the therapeutic program.

Intervention

The preliminary procedure included preparing forms certifying the possibility of consent or refusal of participation in the study by the parents/guardian while respecting the requirement of the complete confidentiality of children's personal data. An 11-month structured program based on the resources of water gymnastics as a therapeutic physical activity was implemented on the children of the experimental group (Fig.1).

Before starting the therapeutic sessions, we made a study of the children's medical records in order to eliminate potential risk factors.

Statistical Analysis

The normal distribution of the variables was verified through the Shapiro-Wilk test. Descriptive statistics were used for the dependent variables. The Student's t-criterion determined the significance of the differences in the results. SPSS 16.0 statistical package was used for data processing. For all analyses, statistical significance was set to $\alpha = 0.05$.

Results

When interpreting the results of the study, the successful performance of the tests in both groups before and after the application of the therapeutic program in water gymnastics was taken into account. In addition, the qualitative features of the mistakes made were analyzed, and the achievements of the children who were being worked with using traditional methods were compared to those who passed the therapeutic course.

First of all, it should be noted that the results of the Shapiro-Wilk test were not significant ($p > .05$) for both control and experimental groups, which means that the assumption of normality in both groups was met.

The data obtained from the first probe (RFPVM) formed the following picture (Table 2).

At the beginning of the experiment, the children demonstrated identical results, which showed no statistically significant difference between the experimental and control groups in the studied component ($p>0.05$). The examination and evaluation of the achievements of the children of the experimental group after passing the water gymnastics course showed a statistically significant improvement of 15.70%. At the same time, a minimal change was noted in the control group, which did not have statistical significance ($\Delta=3.76$). A comparison of the statistically valid data in both groups regarding the ability to produce finger postures according to a visual pattern showed a significant difference between them at the final stage of the study ($t_{emp} > t_T$, $p<0.001$).

The results of the children in both groups at the beginning of the experiment were similar in terms of their ability to reproduce finger postures according to a kinesthetic model (Table 3), where there was also no statistically significant change ($p>0.05$).

The therapeutic nature of the program was evident in the experimental group, which showed a statistically significant improvement of 12.58%. In contrast, the quantitative indicators of the control group were characterized by a low level of positive change in motor behavior that had no statistically significant effect ($\Delta=6.43\%$). The comparative approach to the results in the two groups in the final phase of the experiment revealed a statistically significant difference in this domain as well ($t_{emp} > t_T$, $p<0.01$).

The tendency for the approximately identical results of the two groups at the beginning of the study was also maintained when applying the third probe ($p>0.05$). However, performance on

Duration of the therapeutic program: 11 months, twice a week

Specialist conducting the therapy sessions: An aquatics instructor

Place and the conditions for emplementing therapeutic program: Indoor swimming pool, depth 1.10 m, t 28°C

Devices and tools: Inflatable swimming rings, rubber dumbbells for water gymnastics, swimming sticks for water gymnastics, oblong rubber equipment, light balls of different sizes

8-10 min — ***Warming-up exercises on land***

- Walking (*on toes, on heels, on the inside and outside of the foot, with high knees with different positions of the hands - to the side, above, with a clap behind the back*) and running (*regular running, high knee running , skipping running*)
- General development exercises for: arms, shoulder girdle, torso, lower limbs, with general impact (*squats, jumps*)

23-25 min — ***Water exercises for upper and lower limbs***

- For the hands and fingers (*sample exercises: figure-of-eight movements with the wrists - with fingers together and spread and at different speeds; movements with the whole hand with and without contraction in the elbow joint - along a straight and curved trajectory, etc.*)
- For the legs (*sample exercises: balancing, kicking, cycling, etc.*)

3-5 min — ***Relaxing exercises in water environment***

- Walking in different directions (*forward, backward, sideways*)
- Jumping into the water (*performed from the edge of the pool*)
- Mobile games (sample games: *Carousel, The Four Elements, Where's the Ball*)

Figure 1. Therapeutic water gymnastics program applied in the study

Table 2. Results of the RFPVM probe

Groups	Period of the experiment	Mean	Std. Deviation	Std. Error Mean (Final of experiment)	t	p
Control	Start	9.83	0.31	0.26	4.053	<0.001
	Finish	9.46	0.86			
Experimental	Start	9.93	0.61	0.07		
	Finish	8.37	0.25			

Table 3. Results of the RFPKM probe

Groups	Period	Mean	Std. Deviation	Std. Error Mean (Final of experiment)	t	p
Control	Start	10.27	0.55	0.18	2.973	<0.01
	Finish	9.61	0.55			
Experimental	Start	10.33	0.49	0.06		
	Finish	9.03	0.19			

Table 4. Results of the TFPKM probe

Groups	Period	Mean	Std. Deviation	Std. Error Mean	t	p
				Final of experiment		
Control	Start	9.24	0.42	0.13	2.866	<0.05
	Finish	8.90	0.35			
Experimental	Start	9.33	0.28	0.13		
	Finish	8.36	0.35			

the probe was different after the children from the experimental group participated in the 11-month water gymnastics course (Table 4).

We identified a statistically significant positive performance – a limited error rate manifested it in this component of the manual praxis (Δ=10.39%). The low score in the control group should be noted in contrast – it showed a minor improvement of 3.68% in the studied component after applying traditional strategies for its development. Statistical analysis of the results when examining the most complex pattern of motor behavior at the end of the study revealed another significant difference between the participants in the two groups ($t_{emp} > t_T$, $p<0.05$).

Discussion

The main aim of the study was to look into the therapeutic effect of a developed water gymnastics program on the kinesthetic organization of the manual movements in children with Down syndrome aged 9-11 years.

When performing the RFPVM probe, the children who completed the therapeutic course in water gymnastics demonstrated significantly higher achievements than those trained by traditional methods. Wrong finger choices were minimized. The range of the time intervals for producing the desired manual pose has been significantly narrowed. Movement disorder symptoms were reduced. Previously observed synkinesis, localized in the area of the hands and face, gradually limited their occurrence. Distinct difficulties in visual-motor coordination also became regressive, which is in correlation with earlier research reporting successful motor performance of children with Down syndrome [12]. In the control group, we recorded isolated successful attempts to reproduce postures by a visual model using the leading (usually left) hand. Obviously, these motor patterns of behavior are related to the features of interaction between the two hemispheres in children with Down syndrome, which are the subject of active research [25, 26, 27].

Compared to the first probe, the results obtained from the RFPKM probe showed weaker performances in both groups. However, the children trained in experimental conditions had a higher success rate than their peers in the control group, verified by the formed statistically significant difference. The difficulties found in the implementation of the probe, reflected in the lower scores in this study, are in line with the results of research that applies both to children with Down syndrome and children with other types of disorders [28]. The same authors found clear failures in the considered domain, even in children with typical development. However, the obtained data in no way diminishes the greater progress achieved in the experimental group, in which the children realized positive responses manifested by finger differentiation to represent the required postures without the presence of visual support. The typical inertia of movements was not observed, suggesting an easily achievable switch to the new posture.

Statistically significant differences between the two groups of children with Down syndrome were also identified regarding the TFPKM probe. In the initial stage of the research, the transfer of manual configurations by kinesthetic pattern was possible only in single cases. Almost all children were unable to quickly find the desired set of movements required for the corresponding hand configuration. Movements were diffuse in nature (e.g., fingers 3 or 4 were shown in parallel with fingers 2 and 5). We also recorded manifestations of echopraxia. An explanation for the specific kinesthetic behavior of the examined children could be sought in its conditioning by the existing deficits in tactile and proprioceptive sensitivity. A similar interpretation is found in the scientific works of some researchers, according to which the difficulties in the tactile system are related to the lack of integrity in the sphere of perception and the intermodal interactions with disorders of the muscle tone [29]. After applying the structured intervention scheme, a positive dynamic was reported in the experimental group when presenting the third probe. Probably, in an indirect way, opportunities are created to improve the interhemispheric regulation of motor reactions with a view to acquiring new bimanual skills and their successful use in the absence of visual control. The performance of this probe was also characterized by lower results, in general, but the positive trend exhibited at the end of the experiment is a sufficiently encouraging fact for the application of a non-traditional therapeutic model, providing conditions for improving the potential of higher mental functions, in particular, kinesthetic manual praxis.

A conclusion related to a significant improvement of kinesthetic manual praxis in the children of the experimental group can be formulated considering the results obtained from the three probes. Proof of the positive dynamics are the demonstrated results of the t-test of Student, which exceed the limit values. The strongest positive effect of the therapeutic program in water gymnastics was evident in the development of the manual expression skill by the visual model. The children encountered difficulties in the implementation of the other two probes in which visual control was excluded. However, compared to baseline values, a significant positive change was found.

Conclusions

The undertaken research was focused on identifying the effects of the applied water therapeutic program on the development of kinesthetic manual praxis in children with Down syndrome aged 9-11 years. It showed that the type of intervention models, different from the conventional ones, occupy a proper place in optimizing the motor behaviour of these children. The results showed that despite the imperfections in the vertical (subcortical) organization of the brain – an essential detail of the clinical picture of the syndrome, the structuring of a relevant training and therapy program can generate positive changes in the realization of purposeful, pre-planned manual actions. We should note that the conducted research, besides providing answers, also raises many questions, which requires concentrating the efforts of the specialists (specialists in Physical education and sport, specialists in Special education, neurophysiologists, etc.) on further research in this direction. Furthermore, the results of the conducted experiment could be extrapolated to the research corpus for the implementation of other intervention schemes for the development of praxis function in children from this heterogeneous population, such as Down syndrome.

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Conflict of interest

The authors state no conflict of interest.

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