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The Effectiveness of Therapeutic Physical Exercises in Improving Balance and Coordination in Children with Down Syndrome

Cristina Elena POPA[1], Tatiana DOBRESCU[2]

Abstract: This paper presents a study conducted on a group of 13 subjects, with the clinical diagnosis of Down syndrome, between 6 and 14 years old. The research was conducted between October 2015 and May 2016, at the research base of the "Vasile Alecsandri" University of Bacau, and at the sensory-motor integration laboratory. The assessment was made with the "Gross motor function measure" (GMFM) test. The specific objectives were to: increase the muscle strength and endurance; educate and rebuild the body image and scheme, the laterality, the spatial-temporal orientation and organization; increase the stability, balance, control, and coordination. The physical therapy programs comprised: various possibilities of starting motor acts and actions, the continuation of motions that are already known, the use of alternate motions, global and segmental, the improvement of stability, balance and perceptive-motor coordination, over the course of the strategy. Following the physical therapy intervention over the course of approximately 1 year and a half on the Down syndrome subjects, I noticed that the psycho-motor deficiencies recorded initially have obviously diminished. The analysis of the results offered us concrete data with a reduced margin of error, because the assessment consisted of simple, known actions that were implemented in children in the first stages of the basic motor skills education. The initial testing emphasized the level of functional development, during static and dynamic activities, the values being between 47.05% - 59.52%, while in the final testing the maximum values were between 99.04% -100%.

Keywords: Down syndrome, deficiencies, body scheme, stability, motor skills.

1. Introduction

In the first years of their lives, many of the children with Down syndrome face various medical problems. The most important ones are determined by visceral malformations, especially cardiac and digestive.

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Respiratory infections are frequent (because of a nonspecific immunodeficiency), and the risk of leukemia is 15-20 times higher than in the general population. For this reason, the mortality in their first 5 years of their lives is (was!) higher; in 1960, only half of the children with Down syndrome survived beyond this age.

This disorder was chosen because in the last decades its incidence has grown among the population, drawing the attention of scientists from various fields on its causes, forms of manifestation, and ways of treating the children diagnosed with this syndrome.

2. Problem Statement

Over the las 30 years, in the developed countries, the survival rate has significantly improved (through the surgical treatment of the congenital cardiomyopathies, antibiotics, reduction of institutionalization, and social integration), and the life expectancy in the Down syndrome patients is about 55 years [1], [15], [16]. Trisomy 21 determines a severe mental retardation and language disorders. Children with Down syndrome have a high risk of brain reduction [13], specifically regions such as the hippocampus and the cerebellum [14]. There is also an atrophy of the corpus callosum [9]. The IQ of the persons affected by this syndrome varies between 20 and 85. After the age of 30-35, there is a decrease in the cognitive functions, the patients presenting also sensory disorders, especially auditory and visual [4]. 40% of the children who have Down syndrome present congenital malformations of the heart that can be light or severe, the most frequent being the atrioventricular septal defect and the ventricular septal defect [8].

A study conducted by Pitteti et al. (2013) showed the following about the young people with Down syndrome: a) they have a low capacity for cardiovascular and muscular exercises; b) they manifest a higher prevalence for overweightness and obesity; c) most of them do not perform the recommended aerobic exercise; d) their physical activity drops from childhood to adolescence.

Cowie (1970) proved the persistence of certain primitive reflexes, as well as of multiple disorders and abnormal responses due to generalized muscle hypotonia, which could also influence the children's motor development. The ligament hyperlaxity in the coxal-femoral joints in the sitting position was observed by Lydic and Steele (1979) after examining 104 children through a questionnaire filled by their parents. MacNeill and Mezzomo (1985) have shown that balance disorders are caused by the unequal force between the agonist and antagonist muscles around the ankle

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joints. Haley (1987) has analyzed the children's postural control in concordance with their chronological age and neuro-motor development, and the results show that the intervention focused on facilitating the postural reactions improves the psycho-motor development of children with Down syndrome. The effects of jumping-focused programs on the improvement of balance during walking in children were proven by González-Agüero et al. (2012). Gupta et al. (2011) have proven that an exercise program adapted to the age particularities and symptoms improve muscle strength and balance in children with Down syndrome. The authors have reached the conclusion that an individualized exercise program leads to an increase in muscle strength and an improvement of balance in children with Down syndrome.

3. Research Questions/Aims of the research

Aim of the research. This type of disorder - the Down syndrome - was chosen to see how much the physical therapy means can improve the treatment of its sequelae.

Thus, the *hypothesis* of this study was that, presumably, through an intervention using physical therapy means (exercise), one can contribute to the improvement of psycho-motor components of Down syndrome patients, and an individualization of the treatment - capitalizing on a series of processes that are specific to that age, such as the playful component, harmonious physical development, the child's need for assertion, etc., will lead to faster beneficial results and to a positive integration of the children in their social environment.

4. Research Methods

This study has used the following research methods: the analysis method, through the study of the professional literature; the observation method; the inquiry method; the case study method; the experiment method; the evaluation and exploration method; the recording, analysis, and graphical representation and tabulation method; the statistical-mathematical method.

The research was conducted between October 2015 and May 2016, at the research base of the "Vasile Alecsandri" University of Bacau, at the Sensory-motor Integration Laboratory, and at the Bacau "Down Syndrome Association". For the experimental part (the physical therapy intervention), the subjects were children with Down syndrome from Bacau county. The number of Down syndrome cases during the studied period was important (81), and because the psycho-motor problems of DS patients are multiple, the authors of this paper believed that this disorder would be a good

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candidate for physical therapy, with favorable long term results. This experiment was conducted on a group of 13 subjects (7 males and 6 females), with the clinical diagnosis of Down syndrome, between 6 and 14 years old, while the selection criteria were as follows: a common clinical diagnosis, a lack of other associated disorders (heart, kidney, etc.), a lack of recent surgeries, a mild psycho-motor retardation, close age, good physical shape. The choice to study a single group of subjects was due to the low incidence of this disorder, but also to the fact that its physical and psychological manifestations are different for each individual with DS, thus the progress of the group of subjects and the individual progress would not have had an objective comparison. Throughout the research a series of tests were conducted to obtain relevant data regarding the level of development of the subject (physically and mentally), and to assess the functional levels, initial and final:

The anamnesis, even if it does not offer a diagnosis, it can guide the therapist in gathering the right data regarding the history, the development, the evolution and the dynamics of the disease.The anamnesis was done through structured or semi-structured interviews, taking into account the particularities of each subject. The data was collected from the closest and most involved people in the child's environment (parents, teacher, psychologist).

Knowledge of the family situation is essential and it allowed the collection of data from the physical, social, and personal environment about how the subjects are, involving family members in relation to the subjects, their attitude and relationships.

The Gross motor function measure (GMFM) is a clinical instrument conceived to evaluate the changes in the gross motor functions, in children. It contains 88 items (exercises) and is divided into 5 criteria: "lying position", "sitting position", "all-fours and kneeling position", "standing position", "walking, running, jumping". This test can be used for children up to 16 years old diagnosed with different disorders, containing objective and complex questions. The scale is graded from 0 to 3, as follows: 0 - the subject cannot outline the gesture; 1 - the subject outlines the gesture; 2 - the subject performs the gesture partially; 3 - the subject performs the gesture. Without other indications, "outline" is defined as performing less than 10% of the gesture. "Performs partially" is defined as a performance, from 10% up to less than 100% of the gesture. The scale must give general indications. However, most items have specific indications for each grading, that is why it is mandatory for the researchers to use the markings for each item.

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The physical therapy rehabilitation goals are general and specific, and were set in agreement with the psycho-motor components (body scheme, laterality, balance, perceptive-motor coordination, ideomotor skills, ability and quickness of movements, general dynamic segmental coordination).

The general goals of this paper were to: maintain an optimal health; favor the growth processes and achieving a harmonious physical development; educate the basic and specific motor skills; correctly form a complex system of motor skills; form the ability to systematically practice the physical exercises.

Physical therapy strategies

The motor development in children who have Down syndrome has a different profile than that of a child without disabilities in the sense that not only it happens later, but the age category at which a specific motor level is reached, is higher. Thus, almost every child who has Down syndrome is hypotonic, which also influences their motor development.

The physical therapy programs comprised:

- Various ways of triggering motor acts and actions;
- Maintaining the postures and positions and performing active movements during it;
- Continuing the already known movements;
- Using alternating global and segmental movements, proprioceptive neuromuscular facilitation, therapeutic physical exercises during applicative tracks;
- Improving the stability, the balance, and the perceptive-motor coordination throughout the program, going from static to dynamic balance;
- Being more aware of the body scheme, laterality, and temporal-spatial orientation;
- Improving the skills during the daily life activities.

The voluntary movements and the consolidated skills will be completed every day with the applicative ones, together with the simple games, during the physical therapy programs.

Next, the generalized physical therapy program is presented, which was applied to all subjects with Down syndrome over the course of the research, taking into account the treatment goals and the psycho-motor skills components that are deficient in these children. The exercises were particularized and individualized, according to the symptoms of the disorder. Thus, the experimental design was conceived according to the functional diagnosis following the assessments.

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Physical exercises for improving the laterality

In order to separate the activities attributed to the dominant hemisphere or to the minor one, a battery of tests was applied, for the upper limb (e.g.: to ring a bell, to open and close the zipper, to divide some cards, etc.) and the lower limb (to kick a ball using the preferred leg/foot), because without testing, the laterality education process cannot start. The experiment was focused also on the movement performance speed, the signal reaction time, and the precision of the movements. When the notions of right and left were properly internalized, the experiment moved on to their exemplification during certain exercises, simple at first then gradually more complex, the children being asked to verbalize their actions. The means used to develop the laterality consisted in physical exercises for the arms and legs, first separately, then by making the subjects use alternatively and simultaneously their limbs in various simple and complex motor acts.

Physical exercises for improving the static and dynamic balance

In the children with muscle deficiencies, balance disorders are manifested by maintaining a position with a large support base in the case of the static balance, or slower, heavier, rigid walk, in the case of the dynamic one, because the body is positioned on a mobile surface, a situation in which the body and its segments must perform extra motions, and maintaining the balance is difficult, because the center of gravity is often in the situation of exiting the support polygon. The improvement of balance was done progressively, starting with static exercises and a large support base in all-fours, kneeling, standing positions, gradually reducing the support surface, furthering the center of gravity of the body or of its segments from the support base, heightening the support level during the positions and during walking, in relation to the ground, changing the usual movement procedure, modifying the speed and rhythm, going over obstacles or transporting weights, decreasing the sensory control, etc. In order to enlarge their understanding of the actions, the children were asked to verbalize every movement, particularly the ones related to how they maintain their bodies in a correct position, the way in which they perform steps, how they transport objects, etc.

Physical exercises for improving the coordination

Coordination is gained over time, through a large number of repetitions, and its development leads to precise movements and muscle effort economy.

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To reach this goal, the study observed the formation and the development of polyvalent and polymorph gestures, of the basic motions in the upper and lower limbs, independently and in relation to the body, and the finalization of complex actions. For this, physical exercises were applied, which were previously demonstrated and performed based on verbal command, such as: maneuvering objects of various size and weight, with gradual and progressive speed and strength, the voluntary or on command modification of the direction, range, tempo and rhythm of movements, etc. For a progressive increase in intensity, automated movement schemes were used, to create new movement schemes, imposed by the children's psycho-motor progress. The physical exercises used to improve coordination were applied as applicative tracks when the activity was performed in groups, first at a low, then medium, then high difficulty, according to the internalization of the applicative tracks. These applicative tracks were performed as relay competitions with balanced groups, with great movement speed and optimal distance between the performers, and as chases, the obstacles being positioned in a closed loop (triangle, square, rhomboid, etc.).

5. Findings

Because the physical therapy treatment was applied both individually and on the whole group of subjects, a series of aspects were considered, related to the history of each patient, the most important information from their medical charts being selected for this research.

Descriptive statistical indicators for the Gross motor function measure (GMFM) test:

Table 1. The values for the Gross motor function measure (GMFM)

Initials	A. Lying and rolling (%)		B. Sitting (%)		C. All-fours and kneeling (%)		D. Standing (%)		E. Walking, running, jumping (%)		Total (%)	
	I.T.	F.T.	*I.T.*	F.T.	I.T.	F.T.	I.T.	F.T.	I.T.	F.T.	I.T.	F.T.
C.M.	35.29	100	30	96.66	33.3	97.61	28.20	92.30	34.72	91.66	36,262	95,646
C.A.	45.01	96.07	50	100	42.85	100	46.15	100	40.27	100	44,856	99,214
B.D.	33.33	94.11	30	95	47.61	95.23	46.15	97.43	45.83	90.27	40,584	94,408
N.A	47.05	100	31.66	100	57.14	100	51.28	100	51.38	97.22	47,702	99,444
M.I.	43.13	100	36.66	100	47.61	97.61	48.71	100	55.55	97.22	46,332	98,966
D.A.	33.33	88.23	31.66	95	47.61	88.09	38.46	92.30	38.88	87.5	37,988	90,224
F.I	39.21	98.03	40	100	52.38	95.23	56.41	100	50	100	47.6	98,652
O.I.	39.21	100	41.66	100	59.52	100	48.71	100	47.22	97.22	47,264	99,444
G.A.	27.45	84.31	25	86.66	19.04	90.47	23.07	87.17	25	91.66	23,912	88,054
B.A.	45.09	98.03	33.33	100	59.52	100	46.15	94.87	52	95.83	47,218	97,746
D.I.	41.17	94.11	36.66	98.33	57.14	100	51.28	100	41.66	94.44	45,582	97,376
B.D.	39.21	94.11	31.66	95	52.38	92.85	46.15	92.30	47.22	93.05	43,324	93,462
R.A.	43.13	100	*38.33*	100	59.52	95.23	51.28	100	51.38	97.22	48,728	98.49

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Table 1 shows that the "*total score*" results for the 5 criteria (lying and rolling; sitting; all-fours and kneeling; standing, walking, running, jumping) were initially between 23.912% and 48.728% out of a maximum of 100%, and finally between 88.054% and 99.444%, which indicates a considerable progress of the subjects from a motor point of view.

Table 2 presents the statistical indices describing the Gross motor function measure test results for the group of subjects. Thus, one can see that in the case of the various items of the GMFM, during the initial testing, the subjects recorded values between 19.04% and 27.45% (out of 100%), and during the final testing, the minimal values were between 84.31% and 88.09%. In regards to the maximum values recorded, during the initial testing they were between 47.05% and 59.52%, and during the final testing, between 99.44% and 100%. *The average values* during the initial testing were between 35.12% and 48.89%, and during the final testing, between 94.86% and 97.43%. Also, one can see that the variability *coefficient values* are initially between 14.43% and 24.16%, and finally, between 3.86% and 5.18%. Both in the case of the initial and of the final tests, the variability coefficients indicate that the groups have a high homogeneity, during *the initial GMFM tests* and a moderate homogeneity during the final tests.

Table 2. Values of certain statistical indices following the physical therapy intervention

	N	Minimum	Maximum	Arithmetical mean	Standard deviation	Variability coefficient (%)
Lying and rolling position - initial	13	27.45	47.05	39.3546	5.67741	14.43
Lying and rolling position-final	13	84.31	100.00	95.9231	4.96584	5.18
Sitting position - initial	13	25.00	50.00	35.1246	6.43564	18.32
Sitting position - final	13	86.66	100.00	97.4346	3.88742	3.99
All-fours and kneeling position-initial	13	19.04	59.52	48.8938	11.81434	24.16
All-fours and kneeling position-final	13	88.09	100.00	96.3323	3.96441	4.12
Standing position-initial	13	23.07	56.41	44.7692	9.51563	21.25
Standing position-final	13	87.17	100.00	96.6438	4.36818	4.52
Walking, Running, Jumping - initial	13	25.00	55.55	44.7008	8.42988	18.86
Walking, Running, Jumping - final	13	87.50	100.00	94.8685	3.82130	4.03
Total score - initial	13	23.91	48.73	42.8732	6.91539	16.13
Total score - final	13	88.05	99.44	96.2405	3.71792	3.86

Comparison between the average values recorded during the initial and final assessments by the group of subjects participating in the Gross motor function measure test.

What follows is an analysis of the average values recorded during the initial and final tests, at a group level, for each challenge.

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For the GMFM – the lying and rolling position: the average indicates a progress of 56.57% (fig. 1). The progress represents the fact that, following the physical therapy intervention, the subjects can perform correctly certain actions (3 on the performance scale = a correct performance) in the prone or supine position, such as: *in prone position, with one forearm supporting the body weight, the subject fully stretches his opposite arm forwards*; *in prone position, the subject rolls into supine position; in prone position, the subject pivots on his abdomen 90^0* to his left or right, using his extremities.

Table 3. Comparison between the averages of the paired samples. Student's T test

		Arithmetic al mean %	N	Standard deviation	Standard deviation for the average
1	Lying and rolling position - initial	39.3546	13	5.67741	1.57463
	Lying and rolling position-final	95.9231	13	4.96584	1.37728
2	Sitting position - initial	35.1246	13	6.43564	1.78493
	Sitting position - final	97.4346	13	3.88742	1.07818
3	All-fours and kneeling position-initial	48.8938	13	11.81434	3.27671
	All-fours and kneeling position-final	96.3323	13	3.96441	1.09953
4	Standing position-initial	44.7692	13	9.51563	2.63916
	Standing position-final	96.6438	13	4.36818	1.21151
5	Walking, Running, Jumping - initial	44.7008	13	8.42988	2.33803
	Walking, Running, Jumping - final	94.8685	13	3.82130	1.05984
6	Total score - initial	42.8732	13	6.91539	1.91798
	Total score - final	96.2405	13	3.71792	1.03116

The absolute value of t = 52.298 is grater than the variable t = 2.18 from Fischer's table for df = 12 degrees of freedom, and a confidence threshold of 0.05 or 95%. This value of t, as well as the $p < 0.05$, indicates the fact that the differences are statistically highly significant.

The initial value for the *GMFM – sitting position* is of 35.12%, which means that most subjects were at value 1 or 2 on the performance scale (1=the subject sketches the gesture; 2=the subject partially performs the gesture), and the final one is of 97.43% of 100%, indicating a progress of 62.61 (fig. 2).

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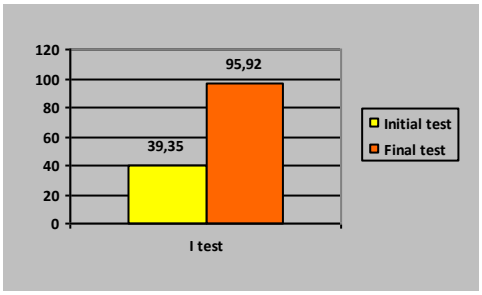


Figure 1. Average values recorded during the tests for the "lying and rolling" position

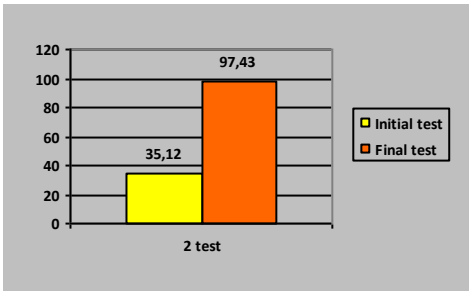


Figure 2.Average values recorded during the tests for the "sitting" position

Some of the actions that the children could perform easily during the final testing were: sitting on a rug, the arm used as support, maintaining this position for 5 seconds; sitting on a mattress, the subject touches an object held by the therapist in front of him: the child leans forward a bit to touch the object, after which he goes back without support; sitting on a bench, maintaining the position without support on his arms, his legs being free for 10 seconds, etc. The absolute value of t = 48.397 is grater than the variable t = 2.18 from Fischer's table for df = 12 degrees of freedom, and a confidence threshold of 0.05 or 95%.

For the GMFM – the all-fours and kneeling position: the average indicates a progress of 47.44% (fig. 3). The progress consists in the fact that in the all-fours and kneeling position the subject can perform the actions easily (values 2 and 3 on the performance scale), because through the application of the physical therapy methods, procedures and techniques specifically to increase stability, the subjects' proprioception and controlled mobility have significantly improved, the children managing during the final testing to maintain the all-fours position with 3 or 2 support points, to climb down some stairs in all-fours, to lift themselves from kneeling to bent knee position, etc. The absolute value of t = 16.093 is grater than the variable t = 2.18 from Fischer's table for df = 12 degrees of freedom, and a confidence threshold of 0.05 or 95%. This value of t, as well as the $p < 0.05$, indicates the fact that the differences are statistically highly significant.

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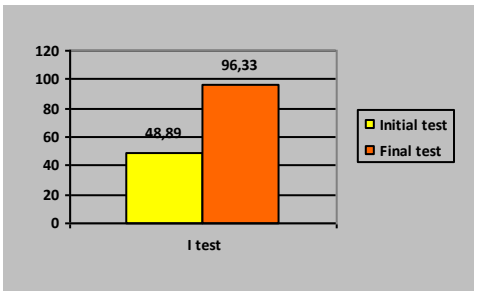


Figure 3. Average values recorded during the tests for the "all-fours and kneeling" position

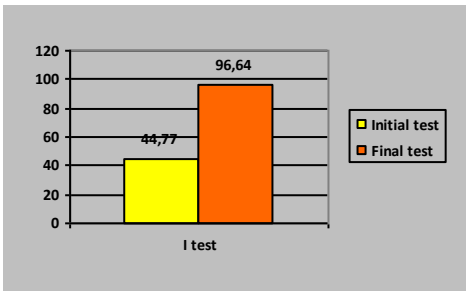


Figure 4. Average values recorded during the tests for the"standing" position

GMFM – standing position: records an average progress of 51.87% (fig 4). The standing position offers a smaller support base, thus the actions in this position were performed more difficultly, a higher number of sessions being dedicated to them, especially for balance and coordination. During the final testing, the value of 96.64% signifies the fact that the recorded results were positive, demonstrated by the correct performance of the exercises (value 3 on the performance scale): *in kneeling position, the subject passes to standing position, going through bent knee position, without using his arms; in standing position, the subject lets himself down in the sitting position, without using his arms, etc.*

The absolute value of t = 30.579 is greater than the variable t = 2.18 from Fischer's table for df = 12 degrees of freedom, and a confidence threshold of 0.05 or 95%. This value of t, as well as the p ‹ 0.05, indicates the fact that the differences are statistically highly significant.

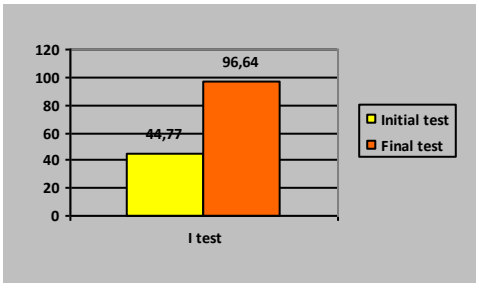


Figure 5. The average values recorded for walking, running, jumping

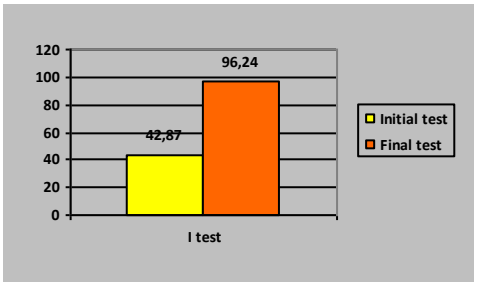


Figure 6. Total score for the results for the paired samples Student's t-test

For the *GMFM – walking, running, jumping,* the average indicates a progress of 50.10%. (fig. 5). Walking, running, and jumping are part of the

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basic motor skills, and their education has represented an important goal of the physical therapy program, because the correct performance of these skills ensures lower energy consumption. Some of the actions during which these skills have been performed and perfected were: *in standing position, the subject walks 10 steps forward on a 2 cm straight line; in standing position, the subject jumps 30 cm high using both of his legs; in standing position, the subject jumps using only one leg inside a 60 cm circle; he jumps using both of his legs on a 15 cm high step, etc.* The absolute value of t = 25.164 is greater than the variable t = 2.18 from Fischer's table for df = 12 degrees of freedom, and a confidence threshold of 0.05 or 95%. This value of t, as well as the p ‹ 0.05, indicates the fact that the differences are statistically highly significant. *T*he absolute value of t = 47.289 is greater than the variable t = 2.18 from Fischer's table for df = 12 degrees of freedom, and a confidence threshold of 0.05 or 95%. This value of t, as well as the p ‹ 0.05, indicates the fact that the differences are statistically highly significant.

6. Discussions

Mahoney et al. (2001) have studied the effects of an early physical therapy intervention on a group of 50 children: 27 of them were diagnosed with DS, and 23 with cerebral palsy. The motor deficiencies were assessed using the Gross Motor Function Classification System for Cerebral Palsy, after 1 year. The comparative results between the initial and final tests have indicated significant changes regarding the motor development in relation to the age and quality of movements over the course of the intervention. Nevertheless, the authors believe the results to be subjective, considering to be impossible to establish exactly whether the physical therapy intervention had truly improved some of the symptoms of those disorders. Wu et al. (2010) have assessed the range of motion in the coxal-femoral, knee, and ankle joints on a group of 26 subjects with DS, implementing afterwards a complex program with various physical activities for one year. The observations have shown that the experimental group subjects have developed a better joint stability and muscle strength, thus improving their global postural control during walking. Ulrich et al. (2001, 2008) have proven that the systematic practice of walking for 5 days per week, for several weeks, under parent supervision, helps improve the postural control during walking, thus reducing the substitution uncoordinated movements of children with DS. These results were confirmed also by Smith et al. (2007) on an experimental group of 8 children, observing that the systematic walking on a 75% capacity over 12 minutes, with approximately 800 steps,

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contributes to the improvement of uncoordinated movements by improving the joint stability. Also, Angulo-Barroso et al. (2008), and Wu et al. (2007) have investigated the effects of long term mechanical walking on the development of certain motor skills, in children with DS. The intervention was conducted on a group of 30 subjects, aged between 10 days and 1.9 months, over 1 year, at the patients' homes. The examined parameters were the following: performance speed, stride rate, average step length and height. The results have emphasized that stride walking helps to reduce asymmetries in the lower limbs caused by coxal-femoral joint rotation, and to facilitate the development of the basic motor skill, walking.

7. Conclusions

After applying the physical therapy treatment over the course of approximately 1 year and a half, it was noticed that the psycho-motor deficiencies recorded initially have considerably diminished. The analysis of the *"Gross motor function measure"*(GMFM) test results offered us concrete data with a reduced margin of error, the assessment consisting of simple, known actions that were implemented in children in the first stages of the basic motor skills education. The initial testing emphasized the level of functional development, during both static and dynamic activities, the values being between 47.05% and 59.52% (out of 100%), while in the final testing, the maximum values were between 99.04 % and 100%.

If initially the subjects had muscle hypotonia, after the application of the physical therapy program focused on increasing muscle strength, stability and controlled abilities, the deficient psycho-motor components have improved, thus they succeeded in performing dynamic exercises, such as walking, running, and jumping. At the same time with an increase in the muscle strength, there was an improvement in the coordination and controlled abilities, the children being able to perform various daily activities more easily and more precise.

Acknowledgement

The team that carried out the present study declares on their own responsibility that the subjects participating in the research and their parents were informed of the voluntary nature of participation in the research, understood the information received and requested for research. They understood that withdrawal from the research can be done at any time, without any adverse consequences on the participant or legal representative. Research has observed the ethical standards of research, we mention that the

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legal representatives of the research participants have given their informed consent for the participation of their children to this research.

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