

**ICPEK 2018**  
**International Congress of Physical Education, Sports and**  
**Kinetherapy. Education and Sports Science in the 21st**  
**Century, Edition dedicated to the 95<sup>th</sup> anniversary of UNEFS**

**EFFECTS OF SWIMMING ON PHYSICAL GROWTH IN**  
**ADOLESCENTS WITH DOWN SYNDROME**

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*Abstract*

The rate and extent of growth are influenced by many genetic and non-genetic factors such as: heredity, gender, genetic disorders and, respectively, nutrition, physical activity, disease, lifestyle, social, cultural and emotional environments etc. Children with Down syndrome, a genetic disorder, also grow and develop, but such processes take place more slowly and show a number of special peculiarities. Somatic growth can be emphasised by means of anthropometric assessment, on which our research relies. Our initiative assessed a number of selected parameters specific for auxological anthropometry, designed to evaluate the growth status of three adolescents with trisomy 21: two boys and one girl aged 12 years. The research was conducted for a period of one year, during which the three adolescents involved were subjected to a full intervention programme that also included sporting activity, namely swimming classes. The final test highlighted that our subjects' height has increased (especially the lower limb length) and their posture during current activity has improved. Moreover, somatic improvements occurred due to the aerobic effort specific for the conducted swimming classes, and these improvements were also reflected by functional parameters like thoracic mobility or chest expansion, which has developed. All those gains have potentiated the health condition of adolescents with Down syndrome and, through the high wellness level obtained, have positively influenced their daily life.

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**Keywords:** Down syndrome, adolescents, growth, anthropometric measurements, swimming..



## **1. Introduction**

Growth and development of the human body are processes that start since the conception and continue postpartum, throughout infancy, childhood, adolescence and early adulthood, when they stop.

Growth and development do not take place uniformly, the periods with slower rhythm being followed by periods with faster rhythm of growth. The rate and extent of growth are influenced by two groups of factors: genetic factors (they set the limits of grows – heredity, gender, genetic disorders including trisomy 21) and numerous non-genetic factors or environmental factors which modulate those limits (nutrition, physical activity, illness and disease, lifestyle, social, cultural and emotional factors etc. (Gallahue & Cleland-Donnelly, 1993; Cameron & Bogin, 2002).

## **2. Problem Statement**

Growth is a quantitative process of cell multiplication materialised by an increase in body weight, volume and dimension, referred to as “quantitative accumulation and augmentation” (Ionescu, 2013, p. 242). Development is a qualitative process of cell differentiation that implies functional changes and qualitative improvements highlighting the adaptation of body systems, their complex evolution and coordinated integration within a unitary whole (Ionescu, 2013).

Among non-genetic factors, a significant place is taken by physical exercise, which has a positive influence on the body growth and development. Systematically practiced, it is one of the key factors for both obtaining a harmonious physical development of the body and maintaining its good condition. Any motor action which is systematically practiced and appropriately dosed develops the musculoskeletal system by toning up the muscles, strengthening the joints, improving oxygenation, enabling thermo-genesis (Predescu & Popescu, 2011). At the same time, physical exercise engages other systems in the activity, having a direct influence on the full body growth and development.

The growth and development of children with Down syndrome take place at a specific rate and have a number of special peculiarities (Arnheim & Sinclair, 1995). Thus, children with Down syndrome grow much slowly and can be shorter than the other children (Marcason, 2016).

Early specialised intervention, consisting of a combination between different therapies and motor activity, has positive effects not only on the general health condition and functional skills of the child with Down syndrome, but also on his/her growth and development (Teodorescu, Bota, & Stănescu, 2007; Marcason, 2016; Boer & Moss, 2016).

## **3. Research Questions**

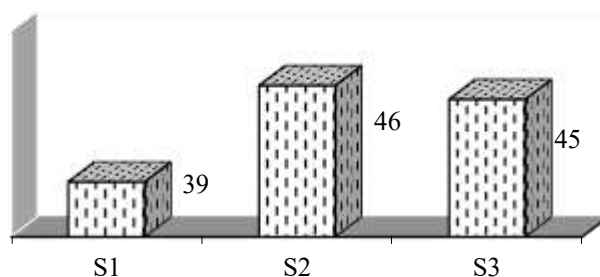
The systematic practice of swimming, as part of the intervention programme addressing Down syndrome teenagers, supports and stimulates their growth process so that they reach the maximum limits of growth imposed by their genetic background.

## **4. Purpose of the Study**

The study exploits the somatic growth data (anthropometric data) of three Down syndrome adolescents (one girl and two boys aged 12 years, Tanner stage III). The anthropometric evaluation of the subjects was conducted at the beginning of the research (initial testing) and 12 months later, at the end of

the research. During that period of time, the study subjects followed an intervention programme consisting of swimming classes practiced at a rate of 1 class per week.

The proposed intervention programme is based on the aerobic effort specific for swimming. Such a programme was carefully monitored and took into consideration the clinical peculiarities and related diseases of the three subjects involved. Their participation in the swimming classes of the intervention programme was not constant. It was conditioned by multiple other variables, among which we mention: children's IQ and mental age, season illnesses, number of individual swimming classes conducted with each child, other sporting and/or social activities involving the subjects at their school or association, other unexpected situations occurred during the research etc. However, during the year when the intervention programme was implemented, each adolescent participated in minimum 39 swimming classes (Figure 01).



**Figure 01.** Number of swimming classes attended by each Down syndrome adolescent within the intervention programme

To note that the parents of Down syndrome children were informed about the scientific research we wanted to carry out. They gave their consent for the participation of children in the evaluation tests, as well as in the swimming classes in the intervention programme. We also received their consent for interpreting and processing the data and disseminating the research results. We also mention that the research took into consideration the provisions of WMA Declaration of Helsinki (2013) on the ethical principles for studies conducted on human subjects.

## 5. Research Methods

The anthropometric measurements carried out involved several parameters, because the aim was to obtain a detailed overview of the somatic growth evolution in Down syndrome adolescents following the practice of aerobic exercise. The reference literature studied provides many anthropometric data related to the nutritional status of Down syndrome children (Bull, 2011; Marcason, 2016; Aguero, Llorente, Cabello, Rodriguez, & Casajus, 2017). But the above-mentioned literature provides little information related to other auxological anthropometric parameters for children with trisomy 21.

Therefore, our research aims to bring to the attention of experts data/issues about Down syndrome adolescents and to warn on the need of having a centralised database containing all such data concerning the Down syndrome population.

The somatic growth assessment is conducted by means of an anthropometric examination that provides objective data on the body size, shape and proportions, the nutrition status and body composition (Ionescu, 2013). Cordun (2009) specifies that such an examination includes physical anthropometric measurements (somatometry or somatic anthropometry) and functional anthropometric measurements (physiometry).

Somatometry evaluates the longitudinal, transverse, sagittal and circumferential dimensions of the body. Cordun (2009) adds to the body weight, skinfolds and body composition, which aim at the somatic mass dimensions.

To assess the somatic growth of the three Down syndrome adolescents included in the research, we used:

### **5.1. Longitudinal dimensions:**

- Standing height – it is the distance between the vertex and the base; it is measured by using the stadiometer, in the standard orthostatic position, with the head in the Frankfurt plane parallel to the support surface and perpendicular to the vertical rod of the stadiometer; it is expressed in centimetres;
- Sitting height – it is the distance between the vertex and the buttock support plane; it is measured by using the stadiometer, in the sitting-in-a-chair position (40 cm), with the head in the Frankfurt plane parallel to the support surface; it is expressed in centimetres;
- Subischial leg length: it is calculated as the difference between standing height and sitting height.

### **5.2. Transverse dimensions:**

- Arm span – it is measured between the middle fingers of both hands, the subject being in the sitting position with upper limbs in 90° abduction to shoulders, extended elbows and palms in an intermediate position (Cordun, 2009), using a tape (marked in mm) leaning on a wall; it is expressed in centimetres.

### **5.3. Circular dimensions:**

- Chest circumference in the resting position – it is measured by passing the tape (marked in mm) under the armpits and frontally at the xyphiale level for boys and at the mesosternal level (the 4<sup>th</sup> sternocostal joint) for girls. The subject was in a relaxed orthostatic position, with the arms in slight abduction, such a dimension being measured during the post-normal expiration apnea. The dimension is measured by using the tape (marked in mm) and is expressed in centimetres (Cordun, 2009; ISAK, 2001);
- Chest circumference during inspiration – it is measured in the same position of the subject, after a maximum inspiration, by using the tape (marked in mm), and is expressed in centimetres;
- Chest circumference during expiration – it is measured in the same position of the subject, after a deep expiration, by using the tape (marked in mm), and is expressed in centimetres.

#### 5.4. Other proportionality indexes:

- The sitting height ratio:  $(\text{sitting height}/\text{standing height}) \times 100$ ; the relative subischial leg length:  $\text{standing height} - \text{sitting height}/\text{standing height} \times 100$ ; the arm span index: arm span to height ratio.

The results obtained are put in a table and compared to each other, as well as to data from the Centres for Disease Control and Prevention (CDC) – *2000 CDC Growth Charts for the United States* (2002), *CDC Growth Charts for Children with Down Syndrome* (2015), the *Anthropometric Reference Data for Children and Adults* (Fryar, Gu, & Ogden, 2012) and other international research (Cole, Freeman, & Preece, 1995; Fredriks et al., 2005) conducted on Down syndrome children of the same age as our subjects. We also took into consideration the international anthropometric standards (ISAK, 2001).

Tests concerning the somatic growth of the subjects (Table 01) were conducted at the “Gral” Clinic of UNEFS by specialised medical personnel (a medical doctor and a physical therapist).

**Table 01.** Subjects involved in the research

	Gender	Age	
		Initial Test	Final Test
S1	Male	12 years and 11 months	13 years and 11 months
S2	Female	12 years and 11 months	13 years and 11 months
S3	Male	12 years and 10 months	13 years and 10 months

The data obtained after our longitudinal experiment were compared with the data of challenged and non-challenged teenagers, which were presented in national and international studies. They were presented as tables and discussed. All our research was based on the documentation method, which was obtained from both the international and national literature.

## 6. Findings

### 6.1. Longitudinal dimensions:

- Standing height (cm)

The height of subjects increased by 8 cm in the case of S1, 3 cm in the case of S2 and 8.5 cm in the case of S3, the arithmetic mean being 6.5 cm. Comparing these values with the *2000 Growth Charts for Children with Down Syndrome in the United States* (CDC, 2015) (Table 02), it can be seen that the initial and final heights of investigated subjects are above the average height for Down syndrome adolescents of similar age and gender (the height values ranging between 50 and 75%).

**Table 02.** Height-for-age percentiles – *Growth Charts for Children with Down Syndrome* (CDC, 2015)

	Gender	Age	
		Initial Test	Final Test
S1	Male	< 75%	75%
S2	Female	75%	>75%
S3	Male	50%	<75%

**Table 03.** Height-for-age percentiles compared to the general population growth standards (CDC, 2002)

	Gender	Age	
		Initial Test	Final Test
S1	Male	11.2%	12.9%
S2	Female	3.5%	2.3%
S3	Male	9.2%	12.1%

Compared to the general population, the height of our subjects is lower, being below the average height of children of similar age and gender (50%): boys have the initial height and the final height between 9.2 and 12.9%, falling within normal range of the general population (Table 03).

In the case of female subject, there is a difference compared to normal height, the final height being below 3% (namely 2.3%), which indicates a short stature compared to the general population. This study confirms the shorter stature of Down syndrome adolescents compared to the stature of the general population. The growth rate is slower in girls and can be explained by the occurrence of menarche at the age of 13, as well as by the presence of co-morbidities (surged congenital heart malformation).

- Sitting height (cm)

For the sitting height, the growth is 2.5 cm in the case of S1, 1 cm for S2 and 2.5 cm for S3, the arithmetic mean of these values being 2 cm. The sitting height of subjects, compared to growth maps for Dutch children within the general population, as shown in the study achieved by Fredriks et al. (2005) and expressed in the form of standard deviations (SD), ranges between 0 and -2SD, meaning below the general average, but within normal limits for the relevant age and gender considered by the authors.

**Table 04.** Sitting height ratio and relative subischial leg length (%)

	Gender	Age			
		Initial Test		Final Test	
S1	Male	51	50	48	50
S2	Female	52	51	47	48
S3	Male	54	52	45	47

- Subischial leg length (cm)

The comparison between the values calculated for the subischial leg length and the *Growth Charts for Children with Down Syndrome* mentioned above (Fredriks et al., 2005) indicated the following: S1 showed, at the initial test, -2SD, while at the final test, -1 SD, S2 showed in both tests the value of -2 SD, and the subischial leg length for S3 was -2.5SD at the initial test and increased to -2SD at the final test.

Most values, except for the final test applied to S1 (77 cm), range at the minimum level or below it for the subischial leg length of the general population of the same age and gender, which shows the typical differences related to the body proportions of Down syndrome children.

Although their lower limbs are proportionally shorter than those of the general population, the increase in body height for our subjects is mainly due to the subischial leg length growth (subischial leg length has increased by 5.5 cm in the case of S1, 2 cm in the case of S2 and 6 cm in the case of S3), and not to the sitting height growth (2.5 cm in the case of S1, 1 cm in the case of S2 and 2.5 cm in the case of S3), which is in accordance with the pubertal period of the investigated adolescents. This is more clearly

revealed by computing the sitting height ratio [(sitting height/standing height) × 100], respectively the relative subischial leg length (subischial leg length/standing height x 100), which highlights a decrease in the first ratio and an increase in the second ratio between the two evaluations (Table 04).

### 6.2. Transverse dimensions:

- Arm span (cm)

Of the study subjects, only S1 experienced an arm span growth of 5 cm between the initial test and the final test. The other two subjects did not experience any progress in this measurement.

Based on the data collected for the arm span and height, we also computed the arm span index by using the formula: arm span/height.

- Arm span index (cm)

Based on the above-mentioned data, a decrease in the arm span index is noticed, which reflects the disproportion between limbs in Down syndrome, where the upper limbs are proportionally shorter.

### 6.3. Circular dimensions:

- Chest circumference in the resting position (cm)

A growth in chest circumference was observed. So, the chest circumference in the resting position for S1 increased by 3 cm, for S2, by 2 cm, and for S3, by 5 cm, the average being 3.33 cm.

- Chest circumference during maximum inspiration (cm)

An obvious improvement is noticed for the values recorded by measuring the chest circumference during inspiration. At the final test, S1 showed an increase of 5.5 cm in chest circumference, S2, of 5 cm, and S3, of 6 cm, the average being 5.5 cm. Our opinion is that such improvements may also be due to the breathing exercises specific for swimming.

- Chest circumference during maximum expiration (cm)

Also in the case of chest circumference during maximum expiration, the values obtained show increases. But the most significant values are recorded for chest expansion (difference between chest circumference during maximum inspiration and chest circumference during maximum expiration).

The data in Table 05 show that S2 and S3 have improved their thoracic mobility or chest expansion by 3 cm and 4 cm, respectively. S1 recorded a good value at the initial test, the improvement being smaller.

**Table 05.** Thoracic mobility or chest expansion

	Gender	Age	
		Initial Test	Final Test
S1	Male	4.5 cm	5 cm
S2	Female	2 cm	5 cm
S3	Male	4 cm	8 cm

We remind that S1 is the only subject speaking correctly, out of the three subjects of the study. S2 spoke, but expressed her thoughts with difficulty, and S3 did not verbalise. Practicing swimming-typical breathing exercises (breathing gymnastics) contributed not only to developing thoracic mobility, but also speaking, breathing and sleep quality.

## 7. Conclusion

Following the research, we have reached the following conclusions:

- Supporting and stimulating the growth and development processes in Down syndrome adolescents involve early implementation of individualised intervention programmes. The effect of such an initiative lasts long. Programmes must be constantly applied, and the child's progress must be permanently monitored. Based on such evaluations, the future approach directions can be established;
- The systematic practice of aerobic exercise by the children involved in the research emphasised its beneficial influence on the bio-psycho-socio-motor level;
- During the research, Down syndrome adolescents experienced an increase in their anthropometric parameters. They grew in height (especially due to lower-limb length growth), gained better posture in their current activities and developed their rib cage and chest expansion. Moreover, Down syndrome children have a special phenotypic expression that is also reflected by a disproportion between the limb length and the body height (Haveman, 2007), which is also noticed in our subjects;
- Although it is not possible to determine the extent to which swimming has contributed to the achievement of the maximum potential imposed by the genetic factor, it has been found that the statural growth recorded during the research maintains our subjects above the average height for Down syndrome adolescents of similar age and gender;
- Preparation of national growth charts for Down syndrome children is required, because monitoring the anthropometric parameters of the somatic growth is important in auxological and diagnosis terms, enabling the identification of the existence or first appearance of co-morbidities typical for the chromosomal abnormality;
- The study results highlighted the positive effects of aerobic exercise not only on the anthropometric parameters, but also on the functional parameters (which is also confirmed by the studies of Boer & Moss, 2016). This aspect is also reflected by the results at the regular mandatory medical examinations (electrocardiography) undergone by these adolescents and also by functional parameters like thoracic mobility or chest expansion, which has increased;
- The other activities within the intervention programme (handmade therapy, art therapy etc.) do not have an influence on the research results, because they do not involve aerobic effort. Also, during our research, Down syndrome children did not practice any other sports discipline, which might have influenced their growth results;
- Gains obtained at the somatic growth level will be observed over time. They will strengthen the health condition of these adolescents, but will also influence their daily lives through the improved wellness level.

## Acknowledgments

The paper is achieved and published under the aegis of the National University of Physical Education and Sports of Bucharest, as a partner of the programme co-funded by the European Social Fund within the Operational Sectorial Programme for Human Resources Development 2007-2013 through the



project Pluri- and interdisciplinarity in doctoral and post-doctoral programmes Project Code: POSDRU/159/1.5/S/141086, its main beneficiary being the Research Institute for Quality of Life, Romanian Academy.

#### Authors' contributions

All authors contributed equally to this study and should be considered as main authors.

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