Discobolul – *Physical Education, Sport and Kinetotherapy Journal*, Volume 63, Issue 4, 264-283

ASSESSMENT OF DYNAMIC BALANCE IN PEOPLE WITH DOWN SYNDROME

Valeria BĂLAN[1], Corina ȚIFREA[2], Raluca COSTACHE[3], Carmen GHERGHEL[4], Ana Maria MUJEA[1*]

[1] National University of Physical Education and Sports, Faculty of Physical Education and Sport, Bucharest, Romania
[2] National University of Physical Education and Sports, Sport Club, Bucharest, Romania
[3] National University of Physical Education and Sports, "Dr Alexandru Partheniu" Interdisciplinary Research Centre, Bucharest, Romania
[4] National University of Physical Education and Sports, Faculty of Kinetotherapy, Bucharest, Romania
*Corresponding author: mujeaanamaria@yahoo.com

https://doi.org/10.35189/dpeskj.2024.63.4.1

Abstract. *The ability to maintain a stable position of the body in motion and in different positions influences all motor actions. A low level of dynamic balance causes problems related to motor skills both in daily activities and for learning sport-specific motor skills. This paper aims to assess dynamic balance in people with Down syndrome before and after attending a specially designed education program applied during training lessons. Balance education was also achieved through the sport of bocce, which was played by the participants in this study. The research involved 14 athletes (aged 20.29 ± 2.74 years) with Down syndrome (IQ below 75) who participated in bocce training over three months. The assessment was performed using the OptoJump device for the 30-second march-in-place test during two stages. A number of anthropometric measurements were also used, namely: height (162.29 ± 10.57 cm), weight (69.08 ± 13.96 kg), body mass index (26.22 ± 4.94 kg/m2) and foot length (23.94 ± 5.17 cm). Between the two testing sessions, people with Down syndrome took part in bocce lessons during which they performed various specific exercises to educate their dynamic balance. In addition, the lessons included means for the development of bocce-specific skills, which involved the use of balance but also other psychomotor abilities. The results obtained for the recorded parameters helped maintain gains in psychomotor abilities. We believe that the implementation of a specially designed program associated with specific movement skills contributes to maintaining or educating dynamic balance in people with Down syndrome.*

Keywords: *dynamic balance; OptoJump; anthropometric measurements; interventional program, bocce.*

Received: *17 October 2024* / **Accepted:** *5 December 2024* / **Published:** *17 December 2024*

Introduction

People with Down syndrome (DS) are known to have a multitude of conditions associated with their clinical characteristics. Obviously, not all of these conditions are found in the same person. The various conditions are possible not to appear since birth but only later in life.

Balance is defined as the ability to maintain a stable position of the body in motion and in different positions, influencing all motor acts and actions (Tudor et al., 2015) performed to improve motor skills, achieve sports performance or reach a state of relaxation. A low level of balance causes problems related to the development of motor skills (Barral, 2015; Malak et al., 2015; Capio et al., 2017; Stins & Emck, 2018) that are needed both in daily activities and for learning specific motor skills.

Balance problems are due to low postural control (Galli et al., 2008; Maiano et al., 2018) or postural tone (Maiano et al., 2018) caused by weak muscle contractions (Malak et al., 2015) as a consequence of hypotonic muscles (Bequaj et al., 2018). At the same time, the poor balance of people with DS is due to low bone density, inappropriate cartilage development and the presence of mental retardation and dysfunctions in the areas of sensory information integration (Malak et al. 2013; Lim et al. 2018). Authors have demonstrated the importance of neuromuscular factors (including the integration of visual sensory, vestibular and somatosensory information) for good balance (Alves de Baptista et al. 2018) as well as the contribution of the proprioceptive sensory system to achieve it (Peterka, 2002).

Maintaining the upright position when standing with feet close together raises problems for many people diagnosed with DS. They cannot maintain the standing position with their feet close together due to inefficient balance or insufficient activation of agonist and antagonist muscles around their ankles. In order to maintain their position or avoid falling, these people develop a compensatory mechanism that consists in standing with legs apart, which gives them a wider base of support and more stability (Lauteslager, 2005).

People with DS also experience problems with maintaining balance during gait. Lack of balance is emphasized by the width of the step and the fear of going down the stairs or climbing stairs without holding on to a handrail or being supported by another person. It has been shown that gait problems are associated with developmental delays in motor behavior (Almuhtaseb et al., 2014).

Age also has an important influence on the balance of people with DS. Thus, some specialists (Oviedo et al., 2014) point out a decrease in balance indices with age, which is accompanied by a low or declining level of physical activity.

Balance education/re-education has positive effects on the gait of people with DS (Bandong et al., 2015). At the same time, it positively influences the way in which these people will change the directions of travel, giving them more safety and reducing the occurrence of injury, with a direct impact on the quality of movement (Malak et al., 2015). Educating or re-educating balance and maintaining body stability is even more necessary when people with DS use to play sports. Proper execution of the specific technique requires a lot of balance and stability training (Rowbotham, 2012). In people with DS, balance education/re-education is important not only for playing sports but also for performing out daily activities (Capio et al., 2017), self-care skills and some domestic activities that allow them to live normal lives with their relatives and friends.

In the process of education/re-education, one must take into account that mental disability is constant, which makes the process difficult, and progress is slow. Moreover, mental disability is associated with a movement impairment that is equal to mental disability (Teodorescu et al., 2007) or movement skills are much more impaired than mental ones.

Therefore, the study aims to assess dynamic balance in people with DS before and after attending a specially designed education program applied during training lessons. Balance intervention also included the sport of bocce played by the research participants during training lessons and was based on special education/re-education balance exercises. Bocce-specific motor skills are simple and can be easily learned by people with DS. Their execution involves a number of components of psychomotor abilities for which action must be constantly taken through intervention programs requiring the regular participation of people with DS. While performing the skills specific to the game of bocce, dynamic balance occurs from the moment the player takes possession of the ball until the moment of throwing it. In this context, we aimed to see how a specially designed exercise program could contribute to educating/re-educating dynamic balance in people with DS.

Methodology

The *aim* of the study is to assess dynamic balance in people diagnosed with DS and establish an intervention program able to improve the ability of these people to maintain their position during dynamic actions. The objective of the study is to develop dynamic balance in people with DS by implementing a full intervention program. This was achieved through an ascertaining ameliorative study using an experimental longitudinal design.

Hypotheses

H_1: The creation of an intervention program based on motor activities and regular participation in the proposed lessons would determine a significant improvement of dynamic balance in people with DS.

H_2: There are significant correlations between somatic indicators and the results for the 30-second march-in-place test.

Participants

The tests involved 14 participants with DS (Mean aged 20.29 ± 2.74 years), of which 7 males and 7 females, being thus evenly distributed by gender. According to the International Classification of Functioning, Disability and Health (ICF) (Organizația Mondială a Sănătății [World Health Organization], 2004), the research participants were included in the Category Code b117. Their IQ was below 75, as evidenced by their medical records found at the association whose members they were.

In addition to intellectual disabilities, participants also had other associated conditions, namely endocrine, cardiac and visual problems. One participant (a female) was diagnosed with scoliosis, and two others were known to be visually impaired (myopia) before the start of the study.

To protect the confidentiality of personal data, participants were coded from DS1 to DS14. Selection criteria for the research group were: participants' preference for the game of bocce, regular participation in training lessons, diagnosis of intellectual disability, and informed consent of parents for performing the proposed tests. Exclusion criteria were parents' disagreement for the participation in the study and absence from one or more lessons of the intervention program.

Measures

To establish the initial level of balance development, the OptoJump device was used. This is a mobile testing platform that can also be used to assess dynamic balance in both the gym and the testing lab. The OptoJump system was officially accredited in 2009 by the DNV GL Certification Body, according to the requirements of the standard for quality management systems - UNI EN ISO 9001: 2015 (MicroGate, 2016). The platform is used for biomechanical analysis to assess proprioception, coordination, etc. and provides various tests to those concerned. For this study, we chose the 30-second march-in-place test performed with eyes open and closed (Cork Institute of Technology, 2018), which is a preconfigured simple test that does not impose a great motor demand to participants. We opted for this test because walking is the basis of other locomotion skills – running, climbing stairs, etc. These skills require a higher level of balance education to be performed correctly. If people with DS show a deficit in dynamic balance, their body position during movement is affected, and maintaining it requires either a change in body position or additional support.

The 30-second march-in-place test allowed us to record the number of steps performed (from left to right), contact time and flight time. Based on these data, the software calculated a series of parameters (MicroGate, 2017) such as: L-R% contact time, indicating the percentage difference between the left (L) foot and the right (R) foot at ground contact; L-R% flight time, indicating the percentage difference between the left (L) foot and the right (R) foot when held in the air; the coefficient of variation (CV), indicating the degree of correlation between the results recorded for the left (L) foot and the right (R) foot in terms of both contact time and flight time. Some of these parameters are graphically represented. Figure 1 shows the graphical representation of contact time for athlete DS8 (as an example) in the final test performed with eyes open.

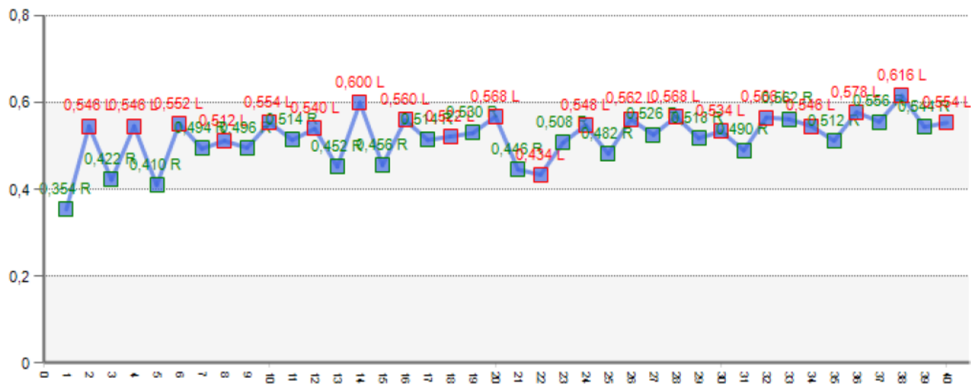

Figure 1. Contact time for athlete DS8 in the final test performed with eyes open

The OptoJump device also helped us determine the participant's ability to keep body mass in the same place (BFS Magazine, 2011) by measuring the alpha angle, which is formed by the longitudinal axis of the starting point with the line of the point where the tested athlete finished the step. Figure 2 shows an example of alpha angle recording with OptoJump. To note that the "+" sign indicates moving to the right of the starting point; this movement can occur facing forward to the right at 0-90 degrees and backwards to the right at 90-180 degrees. The "-" sign indicates moving to the left of the starting point; this movement can occur facing forward to the left at 0-90 degrees and backwards to the left at 90-180 degrees. The test also gave us information about both the forward-backward and middle-side movements in the two stages (MicroGate, 2020) and the area where the participant moved.

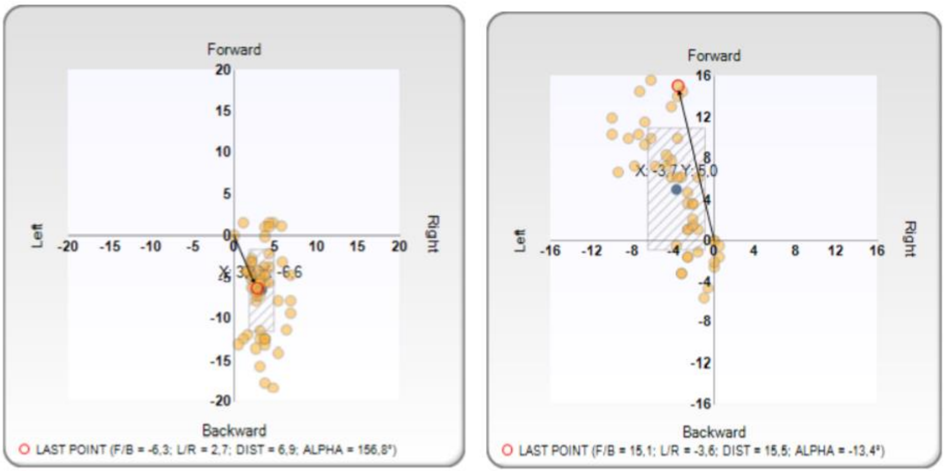

Figure 2. Alpha angle for two people with DS (DS8 and DS11) in the final test performed with eyes open (an example of recording provided by OptoJump)

To achieve good balance, the body needs to remain in the same position whether the test is performed with eyes open or closed.

To better interpret the data, athletes were also assessed from a morphological point of view in terms of height (cm) – measured using a stadiometer, weight (kg) – measured by a scale, foot length (cm) – measured with the Genuine Brannock device, and calculated body mass index (kg/m^2). To determine excess weight, a computer was used to calculate body mass index (BMI) based on participants' weight (kg), height (cm), gender and age. The nutritional status proposed by the World Health Organization (2024) was used to interpret BMI results as follows: below 18.5 - underweight; 18.5-24.9 - normal weight; 25.0-29.9 - pre-obesity; 30.0-34.9 - obesity class I; 35.0-39.9 - obesity class II; above 40 - obesity class III.

Procedure

The study was conducted over three months at the "Dr Alexandru Partheniu" Interdisciplinary Research Centre of the National University of Physical Education and Sport in Bucharest and was based on an ameliorative experiment. The tests were performed in the Testing Laboratory of the aforementioned Interdisciplinary Research Centre on a flat surface, at an optimal ambient temperature of 22°C and with artificial light. Each time, the investigated participants performed the test twice. First time, the test was performed with eyes open, which allowed participants to understand the testing protocol and use all balance control inputs. After a short break (2 minutes), the same test was performed with eyes closed to sensitize participants' balance testing in the absence of visual control.

Statistical analysis

To determine the relationship between height and the results obtained from motor tests, the Spearman correlation coefficient was used, given that not all conditions for using the Pearson correlation coefficient were met. Version 26 of IBM SPSS (Statistical Product and Service Solutions) software was used to statistically process the study data.

The Wilcoxon test was used to compare results obtained by the two paired samples. The degree of correlation (rho) between the targeted parameters was assessed by calculating the Spearman correlation coefficient. A p-value of the coefficient of statistical significance less than 0.05 ($p < 0.05$) was considered significant.

Intervention program – bocce lessons

Between the two testing sessions, people with DS participated in bocce training lessons. At the time of initial testing, they had a 10-month experience in the game of bocce. The designed exercise program was based on motor actions specific to this sport because the research participants expressed their option to play bocce in an organized setting. It is worth mentioning that the game of bocce involves simple, low-intensity aerobic exercise. The intervention program lasted three months during which people with DS attended 12 training lessons. They participated in a weekly 60-minute bocce lesson. Together with participants' parents, it was decided to conduct one lesson per week, given that the weekly intervention program for people with DS was extremely busy, including a number of therapies in which motor activities were complemented by artistic and occupational activities. Throughout the study, the rights of people with DS and the imposed moral and ethical principles were respected (Petre, 2022).

The methods used during the implementation of the intervention program were: the practical exercise method, in which people with DS performed the recommended means together with teachers and volunteers; the fragmented imitative method, in which the teacher or volunteer performed the motor action at the same time as the person with DS.

After warming up, athletes performed various specific means to educate their dynamic balance. These means were practiced in the first part of the lesson, knowing that balance education/re-education is done when participants are rested. The intervention program for balance education/re-education included 25 means that were divided into two categories:

- 15 means without objects. Some of these means involved different body segments that had to move or reduce their ground support to increase the difficulty of the means concerned;
- 10 exercises with objects (in our case, the bocce ball was the auxiliary object). The ball has a diameter of 107-110 mm and a weight of about 1 kg, which made it difficult for people with DS to perform the exercise due to the multiple demands on their bodies. However, the participants managed to execute the requested means.

The means were variously combined throughout the lessons so as to arouse the interest of people with DS, attract them and make them perform the proposed means. For each of the 12 lessons, 5 means for balance education/re-education were chosen to be practiced. The selection of means to be performed during a lesson took into account the transition from easy to difficult, from simple to complex and from known to unknown. The number of repetitions varied from lesson to lesson. The average number of balance repetitions per lesson performed by each person with DS was 17.83 ± 5.

Besides these means, the lessons also included exercises aimed at practicing bocce-specific skills that required balance, but also other components of coordination and conditional abilities.

Results

The study was based on anthropometric measurements and the testing performed with the OptoJump device. Somatic data were collected before the assessment with the OptoJump device, and the following results were obtained (the mean values are presented):

Height was 162.29 ± 10.57 cm.

Weight was 69.08 ± 13.96 kg.

Body Mass Index (BMI) – The mean BMI for the research participants was 26.22 (Figure 3). BMI values deviated from the mean by ± 4.94 kg/m^2. The minimum BMI value was 20.67, and the maximum value, 38.94 (Table 1).

Table 1. *Statistics - BMI (kg/m^2)*

N	Valid	14
	Missing	0
Mean		26.22
Mode		20.67[a]
Std. Deviation		4.94
Minimum		20.67
Maximum		38.94

a. Multiple modes exist; the smallest value is shown.

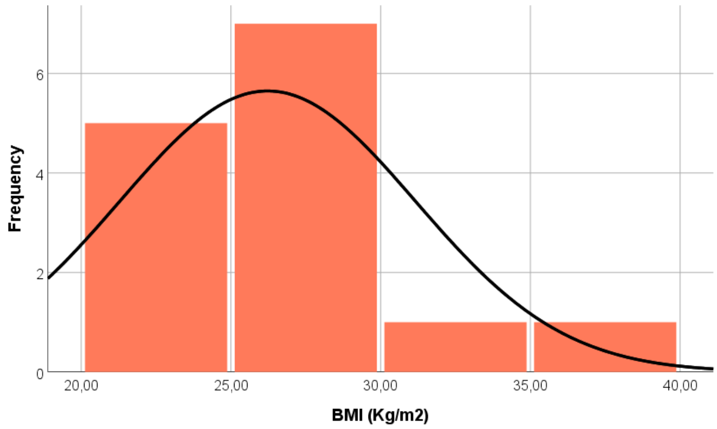

Figure 3. Relationship between BMI and its frequency

The nutritional status of people with DS indicated 5 participants with normal weight, but 7 were included in pre-obesity class, 1 in obesity class I, and 1 in obesity class II.

Foot length (cm)

The length of the foot had a mean value of 23.94 cm (Figure 4). Analyzing the distribution of values, it was found that they deviated from the mean by ± 5.17 cm. The minimum value was 13.97 cm, and the maximum value, 34.29 cm (Table 2).

Table 2. *Statistics - Foot length (cm)*

N	Valid	14
	Missing	0
Mean		23.94
Mode		22.86[a]
Std. Deviation		5.17
Minimum		13.97
Maximum		34.29

a. Multiple modes exist; the smallest value is shown.

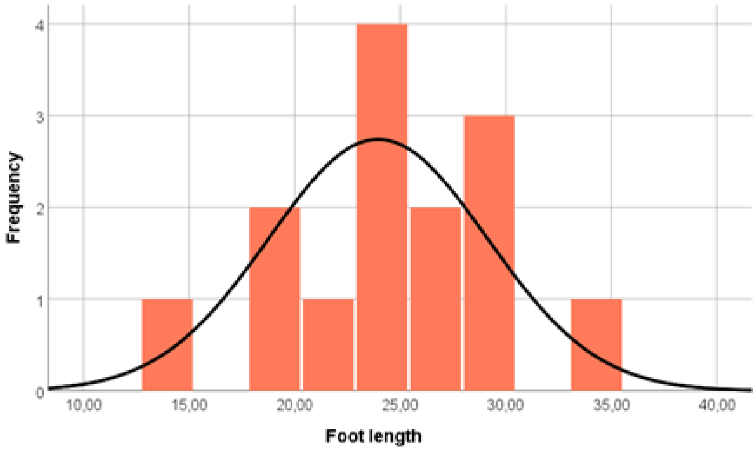

Figure 4. Relationship between foot length (cm) and its frequency

The results obtained from assessments performed with the OptoJump device (30-second march-in-place test) were tabulated and statistically interpreted. They are presented in a logical sequence to facilitate understanding.

Comparison between initial and final testing for the data obtained in each parameter (ground contact time, flight time and alpha angle) for each condition (eyes open and eyes closed)

Eyes-open test condition

Table 3 shows a comparison of mean values and standard deviations for ground contact times in the two testing sessions: m = 0.801 ± 0.098 in the initial test and m = 0.759 ± 0.105 in the final test.

To see if the ground contact time was significantly lower in the final test compared to the initial one, we applied the Wilcoxon test. According to the obtained results, the training program did not have a significant effect, as there were no significant differences between pre- and post-test values (z = -1.256, p = 0.209).

Table 4. *Wilcoxon test – Ground contact time (s)*

	Mean	N	Std. Deviation	Z	p
Initial test	.801	14	.098	-1.256	0.209
Final test	.759	14	.105		

By applying the same Wilcoxon test, we aimed to compare flight times in the initial and final testing. The mean flight time obtained in the initial test is 0.418 seconds and differs from the mean flight time obtained in the final test (m = 0.375 seconds). The results shown in Table 5 indicate that the training program had a significant effect in this regard, as there were significant time differences between pre- and post-program (z = -3.040, p = 0.002), with much lower flight times in the final test compared to the initial one. The effect size is 0.81, which highlights a strong effect of the training program on flight times.

Table 5. *Wilcoxon test – Flight time (s)*

	Mean	N	Std. Deviation	Z	p
Initial test	.418	14	.061	-3.040	0.002
Final test	.375	14	.047		

We also tracked the effect of applying the training program on the alpha angle. Since the significance threshold of 0.056 is very close to the accepted standard threshold of 0.05, we can consider that the program had a marginally significant effect on the alpha angle (z = -1.915, p = 0.056), as shown in Table 6. The effect size is moderate (r = 0.51).

Table 6. *Wilcoxon test – Alpha angle*

	Mean	N	Std. Deviation	Z	P
Initial test	36.986	14	81.388	-1.915	0.056
Final test	-24.686	14	89.677		

Eyes-closed test condition

We used the same Wilcoxon test to see if the ground contact time measured with eyes closed was significantly improved after applying the training program compared to the pre-test situation.

According to the obtained results (Table 7), the program did not have a significant effect on ground contact time, given that there were no significant differences between the times measured before and after applying the program (z = -0.282, p = 0.778).

Table 7. *Wilcoxon test – Contact time (s)*

	Mean	N	Std. Deviation	Z	p
Initial test	.812	14	.082	-0.282	0.778
Final test	.787	14	.082		

Regarding the impact of the program on the flight time measured with eyes closed, the results show a statistically significant difference (z = -2.858, p = 0.004) between the two testing sessions. The program led to a significant decrease in flight time compared to the initial situation. The effet size is r = 0.76, highlighting a strong effect of the program (Table 8).

Table 8. *Wilcoxon test – Flight time (s)*

	Mean	N	Std. Deviation	Z	p
Initial test	.623	14	.196	-2.858	0.004
Final test	.438	14	.108		

As for the impact of the program on the alpha angle measured with eyes closed, no statistically significant changes (z = -0.094, p = 0.925) were found in the final test compared to the initial one (Table 9).

Table 9. *Wilcoxon test – Alpha angle*

	Mean	N	Std. Deviation	Z	p
Initial test	-16.464	14	90.963	-0.094	0.925
Final test	-5.657	14	94.881		

Difference between the results obtained in the test performed with eyes open and eyes closed at the final assessment.

The mean values and standard deviations for ground contact times obtained with both eyes open and eyes closed are shown in Table 10. The difference between ground contact times measured in the two situations is not statistically significant (z = -0.644, p = 0.520).

Table 10. *Contact time – difference between test conditions*

Test condition	N	Mean	Std. Deviation	Z	p
Eyes open	14	.75943	.105092	-0.644	0.520
Eyes closed	14	.78714	.082380		

Statistical analysis indicates that there are significant differences between the flight times measured with eyes open and those measured with eyes closed (z = -2.416, p = 0.016), considering that flight times were longer when measured with eyes closed (Table 11). The effect size is moderate to strong (r = 0.64).

Table 11. *Flight time – difference between test conditions*

Test condition	N	Mean	Std. Deviation	Z	p
Eyes open	14	.37557	.047537	-2.416	0.016
Eyes closed	14	.43871	.108799		

By applying the Wilcoxon test, we aimed to compare the alpha angle measured with both eyes open and eyes closed (Table 12). The results do not indicate statistically significant differences (z = -1.195, p = 0.232).

Table 12. *Alpha angle – difference between test conditions*

Test condition	N	Mean	Std. Deviation	Z	p
Eyes open	14	-24.686	89.6775	-1.195	0.232
Eyes closed	14	-5.657	94.8819		

Correlation between somatic and motor test (final assessment)

Eyes open

The bivariate correlation analysis (Table 13) based on the Spearman correlation coefficient showed a lack of significant correlations between height and the results obtained from motor tests performed with eyes open.

Table 13. *Correlations – height (cm)*

		Contact time (s) - final test	Flight time (s) - final test	Alpha angle (degrees) - final test
Spearman's rho	r	-.304	.104	-.397
	p	.291	.723	.160
	N	14	14	14

The study continued with the analysis of the correlations between weight and the results obtained from motor tests performed with eyes open. Then, the other indicators such as BMI and foot length were included in the correlations with the results obtained from motor tests, but these correlations were not statistically significant, as can be seen in Tables 14-16.

Table 14. *Correlation – weight (kg)*

		Contact time (s) - final test	Flight time (s) - final test	Alpha angle (degrees) - final test
Spearman's rho	r	-.099	.144	-.299
	p	.737	.624	.299
	N	14	14	14

Table 15. *Correlations – BMI (kg/m2)*

		Contact time (s) - final test	Flight time (s) - final test	Alpha angle (degrees) - final test
Spearman's rho	r	.002	-.188	-.202
	p	.994	.520	.488
	N	14	14	14

Table 16. *Correlations – foot length (cm)*

		Contact time (s) - final test	Flight time (s) - final test	Alpha angle (degrees) - final test
Spearman's rho	r	-.095	-.509	.217
	p	.747	.063	.457
	N	14	14	14

Eyes closed

Regarding the relationship between height and the results obtained in motor tests performed with eyes closed, a statistically significant correlation was found only for height and flight time (r = -0.577, p = 0.031), as shown in Table 17 and Figure 5.

Table 17. *Correlations – height (cm)*

		Contact time (s) - final test	Flight time(s) - final test	Alpha angle (degrees) - final test
Spearman's rho	r	-.096	-.577*	.064
	p	.744	.031	.828
	N	14	14	14

*. The correlation is significant at a significance threshold of 0.05.

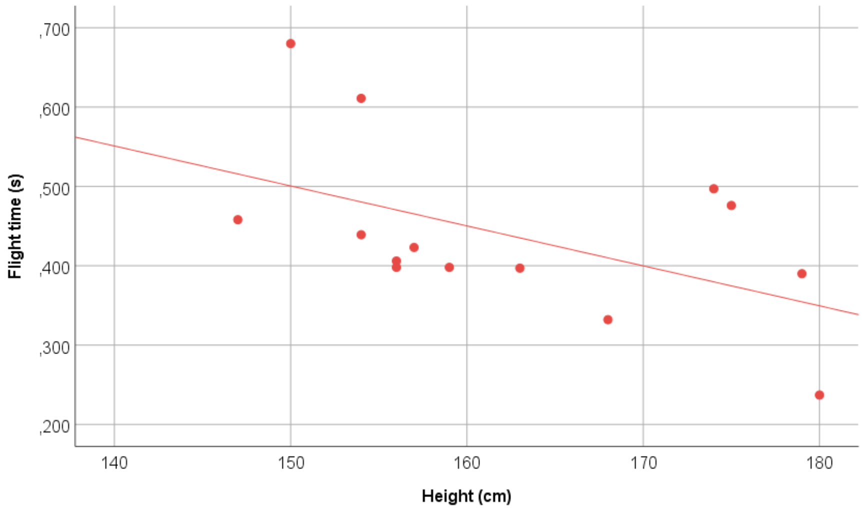

Figure 5. Correlation between height and flight time

We can say that the higher the participant's height, the shorter the flight time. The value of the Spearman's rho test is interpretable in itself, expressing the intensity of the association between variables (Table 10 and Figure 5). In the descriptive model (Hopkins, 2000) on the interpretation of values for correlation coefficients, a value of rho less than 0.3 shows a low correlation between variables, a value of rho between 0.3 and 0.5 shows a moderate correlation between variables, while values above 0.5 show strong correlations between variables. In our case, the analyzed correlation was of moderate to strong intensity.

Results from the analysis of the correlation between weight and motor tests performed with eyes closed showed a statistically insignificant relationship (Table 18).

Table 18. *Correlations – weight (kg)*

		Contact time (s) - final test	Flight time (s) - final test	Alpha angle degrees) - final test
Spearman's rho	r	-.060	-.189	.477
	p	.840	.517	.085
	N	14	14	14

Regarding the relationship between body mass index and the results obtained from motor tests performed with eyes closed (Table 19 and Figure 6), a statistically significant correlation was found only between BMI and alpha angle (r = 0.604, p = 0.022).

Table 19. *Correlations – BMI (kg/m2)*

		Contact time (s) - final test	Flight time (s) - final test	Alpha angle (degrees) - final test
Spearman's rho	r	-.201	.042	.604*
	p	.492	.887	.022
	N	14	14	14

*. The correlation is significant at a significance threshold of 0.05.

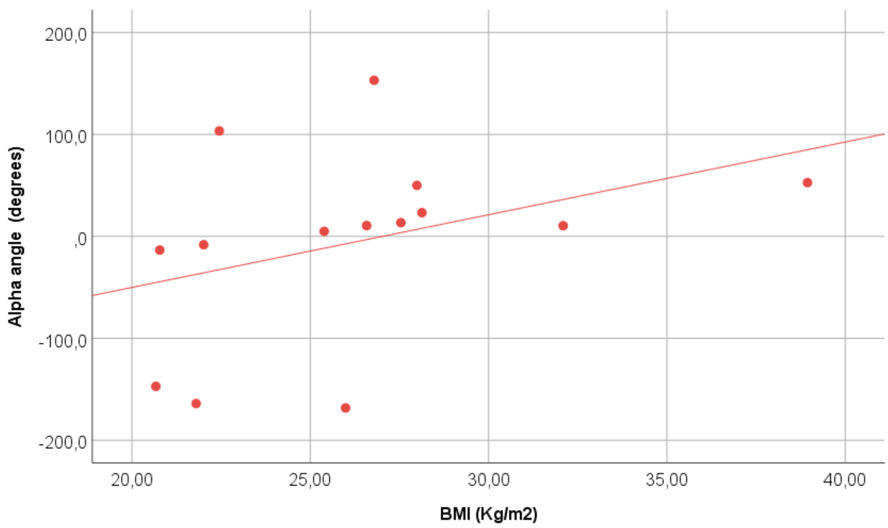

Figure 6. Correlation between BMI and alpha angle

Analyzing the correlations between foot length and the results from motor tests performed with eyes closed, no statistically significant correlations were found (Table 20).

Table 20. *Correlations - Foot length (cm)*

		Contact time (s) - final test	Flight time (s) - final test	Alpha angle (degrees) - final test
Spearman's rho	r	-.262	-.041	-.077
	p	.365	.890	.793
	N	14	14	14

Discussions and limits

The participants included in our research like motor activities, an aspect also found in other people with DS and confirmed by several studies (Boer & DeBeer, 2019; Kerstiens & Green, 2015). The selection of motor activities to be practiced by this category of individuals should take into account their preferences. Their associated medical conditions should also be considered for proper exercise dosage so that their health is not affected. The benefits of systematically practicing motor activities are reflected at the bio-psycho-social level, and their effects are seen in the long term.

People with DS actively participated in the various tests performed, especially if they were attracted to what they were doing. The proposed tests attracted our participants, which made it easier for us to assess their dynamic balance, knowing that walking involves successive imbalances and rebalances through which the body adapts to the support surface and the test environment.

The results of our athletes were also influenced by the focus of their interest at the time of testing, in the sense that some of them focused on the testing device or the events of the day (the tests were done in the afternoon, between 4 and 5 p.m.) rather than the test and motor task they had to achieve. These findings confirmed those of other studies (Malak et al., 2013; Asonitou et al., 2018) on the ability of people with DS to focus attention.

Participants with DS should attend intervention programs (Asonitou et al., 2018) aimed at maintaining or educating their balance. The intervention should start as early as possible (Mikolajczyk & Jankowicz-Szymanska, 2016), should be systematic and address several levels of motor ability (Bandong et al., 2015) but also several development areas.

In the literature, there are very few studies related to the use of OptoJump equipment for balance assessment. Thus, Slomka et al. (2018) assessed the unilateral dynamic balance of some non-impaired top athletes, and the study carried out by Elliott and Smith (2024) acknowledged the role of OptoJump equipment in re-educating the dynamic balance of some elite athletes during the application of recovery programs for leg injuries. Given that the above authors tested unilateral balance, the testing protocol used single-leg jumps. Similar to our approach, the results obtained by the previously mentioned studies indicated improvements in dynamic balance, but they cannot be taken as a benchmark for our study because we used a different testing protocol and impaired athletes.

OptoJump equipment was used to assess dynamic balance and was also applied to 8.5-year-old children (Palomo-Nieto et al., 2015) who were divided into typical development and low motor coordination groups. Unlike the test applied by us, their dynamic balance was assessed while walking along a 10-m distance in four testing situations, with the gradual limitation of their visual control. The obtained results showed significant differences between children with and without motor problems. What is important for our study is that persons with low motor coordination maintained the standing position on both feet for a longer time, which showed balance problems, these persons spending more time on two feet to regain balance.

Processing the results of the *30-second march-in-place test with eyes open - contact time* (initial assessment) for participants with DS highlighted an average of 0.801 seconds. At the final assessment, their average was 0.759 seconds. Thus, a decrease could be observed compared to the initial assessment, indicating an improvement in balance. Regarding the results obtained in the *30-second march-in-place test with eyes closed - contact time* (initial assessment), the average was 0.812 seconds, and at the final assessment, 0.787 seconds. Thus, a difference was noticed compared to the initial test, which indicated an improvement in balance, as in the previous case.

These data reinforce the idea that people with DS can improve various fitness components. However, specialists need to pay attention to the fluctuations in their way of achieving gains: there are periods when gains are quickly achieved, as in the case of valid people (Mureşan &

Coman, 2011), but sometimes they alternate with periods of stagnation or even obvious regression.

In the *30-second march-in-place with eyes open - flight time*, the average obtained by participants with DS at the initial assessment was 0.418 seconds. At the final assessment, the average was 0.375 seconds. A difference was found between the two testing sessions, which showed an improvement in balance. In the *30-second march-in-place test with eyes closed - flight time*, the average obtained by participants with DS at the initial assessment was 0.623 seconds, and at the final assessment, it was 0.438 seconds. Therefore, an improvement in balance was observed.

As regards athletes' results for contact time, small differences can be noted. Thus, an improvement (reduced time) was observed in contact time and flight time, which led to an increase in the number of steps taken. Even if the statistical interpretation of the results showed both significant and insignificant differences for the assessed parameters, it was important for our participants to improve their results from one test to another. This highlighted the role of exercise in the intervention program for people with DS and their adaptation to the proposed movements. These results are also confirmed by several studies, some of them demonstrating the role of balance education (Tsimaras & Fotiadou, 2004; Ansari et al., 2021), others talking about insignificant differences obtained in the tests performed (Martinez-Lemos et al., 2019; Carter & Horvat, 2016). Important is that dynamic balance can be developed through an appropriate intervention program (Mikolajczyk & Jankowicz-Szymanska, 2016) adapted to the characteristics of individuals with DS. This program needs to be applied for a long time to reach statistically significant differences. It is essential for this category of people to exercise in order to maintain or improve the progress achieved, knowing that motor activity has beneficial effects on the whole body (Bondar et al., 2020; Pastula et al., 2012).

The results recorded for the alpha angle showed instability in keeping the body in the same place (Table 21). A good level of dynamic balance is based on a stable point, which could not be found in the research participants.

Table 21. *Alpha angle values (expressed in degrees)*

Athletes	Eyes open (Degrees)		Eyes closed (Degrees)	
	Initial test	Final test	Initial test	Final test
DS1	26.6	-172.6	166.5	13.4
DS2	-3.0	-8.8	-93.9	-168.3
DS3	170.8	156.8	37.6	-8.2
DS4	17.2	10.2	-16.0	23.3
DS5	173.7	-168.4	-158.5	10.4
DS6	171.9	-1.4	-2.0	103.4
DS7	-3.6	14.1	10.9	10.6
DS8	-116.6	-13.7	-145.5	153.1
DS9	22.8	-1.4	27.0	4.9
DS10	23.0	10.8	26.7	52.7
DS11	23.4	-171.3	26.6	-164.0
DS12	10.7	-3.6	-13.8	-13.4
DS13	4.8	13.9	-147.5	-147.1
DS14	-3.9	-10.2	51.4	50.0

As regards the distribution according to the right or left deviation calculated using the alpha angle, it was found that 10 athletes with DS showed deviation to the right and 4 showed deviation to the left in the initial test performed with eyes open. At the final assessment, 5 athletes with DS showed deviation to the right and 9 athletes showed deviation to the left.

At the initial assessment performed with eyes closed, 7 athletes with DS showed deviation to the right and 7 athletes showed deviation to the left. At the final assessment, 9 athletes showed deviation to the right and 5 showed deviation to the left.

We emphasize, however, that athlete DS2 had all deviations to the left, while athlete DS10 had all deviations to the right. Athletes DS4, DS7 and DS12 had the smallest oscillations from the starting point. But the values differ a lot from one test to another and from one test condition to another.

Regarding the alpha angle, a lateral movement (to the right or left) or a movement in the frontal plane (forward-backwards) was noticed in all participants, which indicated great difficulty for them to maintain the starting point from the beginning to the end of the 30-second test. At the same time, the results obtained for the alpha angle indicated a deviation from the straight line, which is commonly encountered during gait in people with DS. The inability to maintain the body at the starting point indicated low muscle control for our participants. Low level of muscle control is a specific characteristic of people with DS. For this reason, they need be constantly stimulated through motor activities adapted to their individual features in order to maintain or improve this level. Any small improvement has a positive effect on the walking parameters of people with DS.

Based on the available data, we can say that the implementation of a specially designed program associated with specific movement skills contributes to maintaining or educating dynamic balance in people with DS.

Although our approach reached its goal, there were some limitations:

- education/re-education was possible, but progress was limited;
- the time period needed for people with DS to improve their dynamic balance was longer than for people without disabilities;
- the program was implemented in a relatively small number of lessons due to the multitude of professional, artistic or occupational activities in which people with DS were involved;
- the number of participants did not allow us to draw significant conclusions but allows for multiplication;
- the study results could not be generalized due to the low number of participants with DS;
- application of the tests and the intervention program was difficult to achieve due to the comprehension and memorization capabilities of people with DS. In most cases, a teacher or volunteer had to perform the ordered technical skill in front of people with DS. This execution allowed our participants to imitate the technical skill or to remember what they had to do.

Conclusions

The easy-to-use OptoJump equipment enabled us to assess the dynamic balance of people with mild DS without subjecting them to the additional stress of older generation testing devices (noise, unstable surfaces, exercise setting limited by artificially lit walls, etc.). At the same time, the use of this equipment to make assessments decreases the possibility of falls or getting injured for people with limitations in gait biomechanics.

The data obtained from the two testing sessions provide those interested indicators that could be used as starting points in future research and benchmarks for designing dynamic education/re-education programs for people with DS. Also, the study allows applying the 30-second march-in-place test to assess the dynamic balance of other categories of people with disabilities, elderly people or people with various health problems that cannot be assessed with modern equipment (IT) that requires successive balancing and re-balancing on various unstable support surfaces.

The results obtained were not remarkable but helped maintain gains in psychomotor abilities. The fact that people with DS performed motor activities and exercised the means in a correct sequence enabled them to educate/re-educate their balance. The combination of means for balance education/re-education with sport-specific movement skills involving balance contributed to maintaining gains in psychomotor abilities.

Acknowledgments: The authors would like to thank all participants involved in this study.

Funding: This research was funded by Erasmus + Sport Project: „Sport together, active forever” grant number 590526–EPP–1–2017–1–RO–SPO–SSCP, project co-financed by the European Union, project completed in 31 December 2019. The content of the paper reflects only the author's view and that Agency and the Commission are not responsible for any use that may be made of the information it contains.

Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Research Ethics Committee of UNEFS Bucharest (protocol code 4352).

Informed Consent Statement: Written informed consent was obtained from parents taking care of people with DS to test, analyze, process and interpret their data and also to publish this paper.

Data Availability Statement: Data can be made available upon request to the contact author.

Conflicts of Interest: The authors declare no conflicts of interest.

References

Almuhtaseb, S., Oppewal, A., & Hilgenkamp, T. I. M. (2014). Gait characteristics in individuals with intellectual disabilities: A literature review. *Research and Developmental Disabilities, 35*(11), 2858-2883. https://doi.org/10.1016/j.ridd.2014.07.017

Alves de Baptista, C. R. de J., Nascimento-Elias, A., Lemos, T. W., Garcia, B., Calori, P. D., & Mattiello- Sverzut, A. C. (2018). Characterizing postural oscillation in children and adolescents with hereditary sensorimotor neuropathy. *PLoS ONE, 13*(10): e0204949. https://doi.org/10.1371/journal.pone.0204949

Ansari, S., Hosseinkhanzadeh, A. A., AdibSaber, F., Shojaei, M., & Daneshfar, A. (2021). The effects of aquatic versus kata techniques training on static and dynamic balance in children with autism spectrum disorder. *Journal of Autism and Developmental Disorders, 51*(9), 3180-3186. https://doi.org/10.1007/s10803-020-04785-w

Asonitou, K., Mpampoulis, T., Irakleous-Paleologou, H., & Koutsouki, D. (2018). Effects of an adapted physical activity program on physical fitness of adults with intellectual disabilities. *Advances in Physical Education, 8*(3), 321-336. https://doi.org/10.4236/ape.2018.83028

Bandong, A. N. J., Madriaga, G. O., & Gorgon, E. J. R. (2015). Reliability and validity of the Four Square Step Test in children with cerebral palsy and Down syndrome. *Research and Developmental Disabilities*, *47*, 39-47. https://doi.org/10.1016/j.ridd.2015.08.012

Barral, J. (2015). Activitățile fizice adaptate și dizabilitățile intelectuale [Adapted physical activities and intellectual disabilities]. In Special Olympics Romania (Ed.), *Activitățile fizice adaptate ca instrument de incluziune socială* [Adapted physical activities as a social inclusion tool] (pp. 121-146). Discobolul.

Bequaj, S., Tërshnjaku, E. E. T., Qorolli, M., & Zivkovic, V. (2018). Contribution of physical and motor characteristics to functional performance in children and adolescents with Down syndrome: A preliminary study. *Medical Science Monitor Basic Research, 24*, 159-167. https://doi.org/10.12659/msmbr.910448

BFS Magazine (2011). A closer look at the OptoJump: The latest in a great testing and diagnostic tool. *Bigger Faster Stronger*, 26-29. http://office.biggerfasterstronger.com/uploads2/11_SepOct_26.pdf

Boer, P. H., & DeBeer, Z. (2019). The effect of aquatic exercises on the physical and functional fitness of adults with Down syndrome: A non-randomised controlled trial. *Journal of Intellectual Disability Research, 63*(12), 1453-1463. https://doi.org/10.1111/jir.12687

Bondar, R. Z., di Fronso, S., Bortoli, L., Robazza, C., Metsios, G. S., & Bertollo, M. (2020). The effects of physical activity or sport-based interventions on psychological factors in adults with intellectual disabilities: A systematic review. *Journal of Intellectual Disability Research, 64*(2), 69-92. https://doi.org/10.1111/jir.12699

Capio, M. C., Mak, T. C. T., Tse, M. A., & Masters, R. S. W. (2017). Fundamental movement skills and balance of children with Down syndrome. *Journal of Intellectual Disability Research, 62*(3), 225-236. https://doi.org/10.1111/jir.12458

Carter, K., & Horvat, M. (2016). Effect of Taekwondo training on lower body strength and balance in young adults with Down syndrome. *Journal of Policy and Practice in Intellectual Disabilities, 13*(2), 165-172. http://dx.doi.org/10.1111/jppi.12164

Cork Institute of Technology. (2018). *OptoJump presentation and demonstration: 11 January 2018*. https://www.redbackbiotek.com/wp-content/uploads/2017/02/CIT-OptoJump-Presentation_EN.pdf

Elliott, D., & Smith, X. (2024). Unilateral dynamic balance assessment: The test-retest reliability of the OptoJump Next Drift Protocol. *Journal of Bodywork & Movement Therapies*, *37*, 328-331. https://doi.org/10.1016/j.jbmt.2023.11.054

Galli, M., Rigoldi, C., Mainardi, L., Tenore, N., Onorati, P., & Albertini, G. (2008). Postural control in patients with Down syndrome. *Disability and Rehabilitation*, *30*(17), 1274-1278. https://doi.org/10.1080/09638280701610353

Hopkins, W. G. (2000). Measures of reliability in sports medicine and science. *Sports Medicine*, *30*(1), 1-15. https://doi.org/10.2165/00007256-200030010-00001

Kerstiens, R. L., & Green, M. (2015). Exercise in individuals with Down syndrome: A brief review. *International Journal of Exercise Science*, *8*(2), 192-201. http://dx.doi.org/10.70252/DCTG6034

Lauteslager, P. E. M. (2005). *Copiii cu sindromul Down: Dezvoltare motorie și intervenție* [Children with Down syndrome: Motor development and intervention]. Editura de Sud.

Lim, Y. H., Lee, H. C., Falkmer, T., Allison, G. T., Tan, T. L., Lee, W. L., & Morris, S. L. (2018). Effect of optic flow on postural control in children and adults with autism spectrum disorder. *Neuroscience*, *393*, 138-149. https://doi.org/10.1016/j.neuroscience.2018.09.047

Maiano, C., Hue, O., Tracey, D., Lepage, G., Morin, A. J. S., & Moullec, G. (2018). Static postural control among school-aged youth with Down syndrome: A systematic review. *Gait Posture*, *62*, 426-433. https://doi.org/10.1016/j.gaitpost.2018.03.027

Malak, R., Kostiukow, A., Krawczyk-Wasielewska, A., Mojs, E., & Samborski, W. (2015). Delays in motor development in children with Down syndrome. *Medical Science Monitor*, *21*, 1904-1910. https://doi.org/10.12659/msm.893377

Malak, R., Kotwicka, M., Krawczyk-Wasielewska, A., Mojs, E., & Samborskil, W. (2013). Motor skills, cognitive development and balance functions of children with Down syndrome. *Annals of Agricultural and Environmental Medicine*, *20*(4), 803-806.

Martinez-Lemos, R. I., Ayan-Perez, C., & Bouzas-Rico, S. (2019). Test-retest reliability of the Wii Balance Board for assessing standing balance in young people with intellectual disability. *International Journal of Developmental Disabilities*, *65*(4), 231-238. https://doi.org/10.1080/20473869.2017.1403065

MicroGate. (2017). *Dynamic balance control*. https://medical.microgate.it/en/solutions/dynamic-balance-control

MicroGate. (2020). *OptoJump Next: User manual*. https://training.microgate.it/sites/default/files/manuali/optojump/Manual-EN.pdf

MicroGate. (2016). *Quality*. https://www.microgate.it/en/quality

Mikolajczyk, E., & Jankowicz-Szymanska, J. (2016). Does extending the dual-task functional exercises workout improve postural balance in individuals with ID? *Research and Developmental Disabilities*, *38*, 84-91. https://doi.org/10.1016/j.ridd.2014.12.008

Mureşan, D. M., & Coman, M. F. (2011). *O şansă dată copilului cu sindrom Down* [A chance given to the child with Down syndrome]. Emma Books.

Organizația Mondială a Sănătății. (2004). *Clasificarea internațională a funcționării, dizabilității și sănătății* [International Classification of Functioning, Disability and Health]. MarLink.

Oviedo, G. R., Guerra-Balic, M., Baynard, T., & Javierre, C. (2014). Effects of aerobic, resistance and balance training in adults with intellectual disabilities. *Research and Developmental Disabilities*, *35*(11), 2624-2634. https://doi.org/10.1016/j.ridd.2014.06.025

Palomo-Nieto, M., Psotta, R., Adrian, A., Abdollahipour, R., & Valtr, L. (2015). The effects of various visual conditions on the gait cycle in children with different level of motor coordination – A pilot study. *RECYDE. Revista Internacional de Ciencias del Deporte*, *42*(11), 387-399. http://dx.doi.org/10.5232/ricyde2015.04207

Pastula, R. M., Stopka, C. B., Delisle, A. T., & Hass, C. J. (2012). effect of moderate-intensity exercise training on the cognitive function of young adults with intellectual disabilities. *Journal of Strength and Conditioning Research*, *26*(12), 3441-3448. https://doi.org/10.1519/jsc.0b013e318270fc83

Peterka, R. J. (2002). Sensorimotor integration in human postural control. *Journal of Neurophysiology*, *88*(3), 1097-1118. https://doi.org/10.1152/jn.2002.88.3.1097

Petre, R. L. (2022). *Etică, integritate și deontologie în domeniul științei sportului și educației fizice* [Ethics, integrity and deontology in sport and physical education science]. Discobolul.

Rowbotham, B. (2012). Balance of power. How the OptoJump is transforming athletic and physical fitness. *Bigger Faster Stronger*, 28-30. http://office.biggerfasterstronger.com/OLC/PDF-OLC/Balance-Articles/BalanceofPower.pdf

Slomka, K. J., Pawlowski, M., Michalska, J., Kamieniarz, A., Brachman, A., & Juras, G. (2018). Effects of 8-week complex balance training in young alpine skiers: A pilot study. *BioMed Research International*, *2018*(1): 6804534. https://doi.org/10.1155/2018/6804534

Stins, J. F., & Emck, C. (2018). Balance performance in autism: A brief overview. *Frontiers in Psychology*, *9*: 901. https://doi.org/10.3389/fpsyg.2018.00901

Teodorescu, S., Bota, A., & Stănescu, M. (2007). *Educaţie fizică şi sport adaptat pentru persoanele cu deficienţe senzoriale, mintale şi defavorizate social* [Adapted physical education and sport for sensory and mental impairments and socially disadvantaged people]. Semne.

Tsimaras, V. K., & Fotiadou, E. G. (2004). Effect of training on the muscle strength and dynamic balance ability of adults with Down syndrome. *Journal of Strength and Conditioning Research*, *18*(2), 343-347. https://doi.org/10.1519/r-12832.1

Tudor, V., Olescu, C., Vărzaru, C., & Mujea, A. M. (2015). Contribution for developing static and dynamic balance at 3rd grade students. In M. Stănescu, & M. Păunescu (Eds.), *International Proceedings Division of the International Congress of Physical Education, Sports and Kinetotherapy* (pp. 299-302). Medimond.

World Health Organization. (2024). *Body mass index - BMI*. https://who-sandbox.squiz.cloud/en/health-topics/disease-prevention/nutrition/a-healthy-lifestyle/body-mass-index-bmi