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The Effects of Integrated Proprioception Development Strategies in Increasing the Psycho-Neuro-Motor Level of Children

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Abstract: *This research aims to evaluate the improvement of proprioception capacity in 24 male subjects, aged 10 years, by applying an intervention strategy and proposing a specific competence within the physical education school program for the 4th grade in Romania. An experimental group (EG, n=12) underwent an ameliorative intervention for 14 weeks, having two lessons per week, while a control group (CG, n=12) followed the usual football training program at the club sport. Both EG and CG subjects were evaluated, under similar conditions, using four tests: Body Sway, Flamingo, March in place – MIP and Circle, using scientific equipment OptoJump Next and GYko Microgate. The statistical analysis compared the results of the two groups, using the Kolmogorov Smirnov test to verify the normality of the distributions, and to verify the significance of the statistical differences, the Independent T-test and the Mann Whitney U-test were used. The results revealed statistically significant differences in three of the four applied tests, confirming the general efficiency of the experimental program. These findings support the possibility of optimizing the contents of the school physical education program to support the development of proprioception and body awareness in primary school children. The use of high-tech equipment, such as GyKo Microgate and OptoJump Next, can provide standardized data on neural processing of sensory information, thus contributing to a more accurate and efficient approach to school physical education.*

Keywords: *awareness; didactic strategy; proprioception; psycho-neuro-motor; school curriculum.*

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Introduction

Learning and performing motor behaviors are essential elements in the daily activities of people, regardless of their age (Song, 2019; Szabo et al., 2021). To enhance motor skills, the integration of exercise programs aimed at stimulating proprioceptors into the physical education routines of students (Camenidis et al., 2024) and even in sports training (Lee & Joo, 2024; Zackarakis et al., 2024; Souglis et al., 2023; Kızılay & Cengiz, 2023; Marotta et al., 2023; Rapotan et al., 2023) in various sports, is currently being widely utilized worldwide.

The proprioceptive internal environment represents the domain where information from the visual analyzer is processed, juxtaposing personal perceptions with the sensations experienced during task-related exercises. An essential aspect of an individual's awareness of this internal environment is that, when working with eyes closed, there is a heightened attentiveness to the quality and completion of exercise tasks.

Motor behavior is governed by perception, "particularly when visual perception complements it" (Gibson, 2015, 213), a phenomenon that encompasses proprioception as a fundamental sensory function of the body, crucial for understanding body position and movement in space (Valdes et al., 2023; Zhang & Zhang, 2023). It has been underscored that proprioceptive perception plays "a pivotal role in optimizing motor skills" (Tezel et al., 2024; Winter et al., 2022). This assertion aligns with the findings of Nadin (1986), who suggested in his study that perception, or "sensory data analysis" (Nadin, 2003), involves comprehensive information, while emission, as a consequence of information processing in the brain, is focused, structured, and indispensable. In Nadin's research (2003), the author acknowledges Rosen as one of the pioneers in this field, noting in the preface of his 1985 book that "biological behavior, from molecular to cellular to physiological and behavioral, is based on internal and external models of prediction to control their motor behavior" (Rosen, 1985).

In this context, Wolpert defines "an internal model that represents the causal relationship between actions and their consequences" as a forward model, as it anticipates future behavioral inputs based on motor outputs (Wolpert, 2013, 747). A forward model elucidates how the motor system's state will evolve in response to a motor command. Additionally, Wolpert asserts that "the nervous system possesses multiple internal control mechanisms that utilize prediction and sensory feedback across various domains" (Wolpert, 2013, 758-759). Regarding the elucidation of neural internal models, Camenidis et al. (2020) have shown that proprioceptors stimulation induces conscious neuromuscular activity, regulating both postural elements and the efficacy of task-related outcomes.

This underscores the importance of assessing subject's attentiveness during exercise independently of visual influences from external factors. To address this concern, Camenidis & Geantă (2022) have shown the benefits of proprioceptive effects following an exercise regimen conducted with eyes closed which has been evaluated through "The Wheel of Awareness" questionnaire scale that offered insights into children's awareness levels.

Our research was grounded in Rusalov's temperament theory, which proposes "a delineation of traits associated with physical, communicative, and mental dimensions of behavior, advocating for the advantages of tailored activities" (Rusalov, 2018). Rusalov (2018) identified four distinct temperament traits: ergonicity, referring to an individual's capacity to sustain prolonged or intense activities, quantified by factors such as duration of engagement and instances of abandoning attempts to solve insoluble problems; plasticity; rhythm; and affectivity.

Motor learning exhibits greater efficiency when 100 trials are divided into 5 sets of 20 rather than practiced in a single set. This phenomenon resonates with behaviors observed in both "humans and other animals" (Moon et al., 2023), as well as in insects (Gebehart & Büschges, 2024). It has been noted that learning is more effective when "trials are distributed over time than when long practice sessions are used" (Raibert, 1977, 42).

In the context of comprehending proprioception stimulation and its effects on human motor behavior, one of the brain's most notable properties is "the adaptability of its circuits to changes in the environment – the ability to learn from experience and store acquired knowledge as memories" (Kalaska & Rizzolatti, 2013, 858-862). Consequently, as an individual repeats a motor action, their motor performance tends to improve.

From a medical standpoint, "poor posture can lead to intervertebral disc degeneration and herniation" (Corniola et al., 2014), which may result in "compression of a nerve root" (Selkirk & Ruff, 2016, Chapter 53, pp. 1027-1033), a condition often associated "with obesity, significantly impacting long-term health" (Mocanu et al., 2023). Given that motor recovery is a multifaceted process, "rehabilitation programs aim to enhance spinal mobility, bolster lower limb muscle strength, and improve walking ability" (Sardaru et al., 2023).

Postural analysis is a frequently employed method for evaluating the stability and balance of individuals while standing stationary and maintaining eye level gaze. In our study, we devised reference axes within the body schema to facilitate research on balance and coordination. To this end, we developed test protocols and implemented them, as depicted in Figure 1.

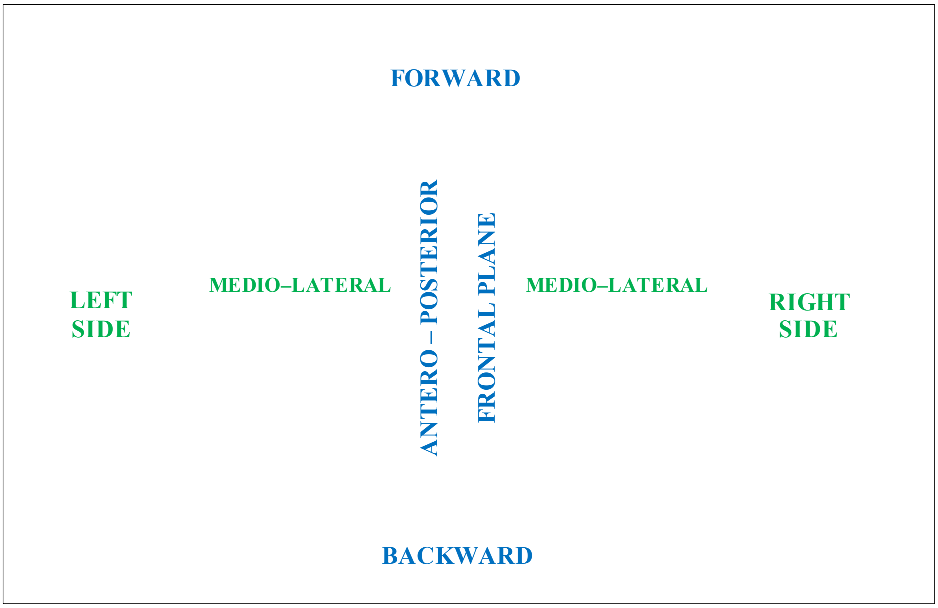


Figure. 1. References axis design

A comparative study by Voichyshyn et al. (2022) implementing a physical rehabilitation program revealed that 15-17-year-old subjects residing in mountainous regions exhibit a lower prevalence of postural disorders in the sagittal plane compared to their counterparts residing in plains areas. This finding underscores the potential neurophysiological and neuro-medical implications for improving patient anamnesis and integrating post-correction data into subsequent medical interventions.

The optimization of psychomotor skills is intricately linked to the accumulation of knowledge facilitated by motor actions, which enable "exploration of the environment and acquisition of pertinent information essential for cognitive development" (Romero-Naranjo & Andreu-Cabrera, 2023). Early and multifaceted stimulation during natural stages of human evolution is posited to enhance both motor and cognitive development (Romero-Naranjo et al., 2022).

Additionally, a study investigating the relationship between IQ and spatial orientation skills in 9-year-old children proposed that IQ serves as a predictor for spatial orientation proficiency. The findings indicate a positive correlation between these variables, suggesting that "spatial orientation skills can be enhanced through activities such as chess, thereby positively influencing academic performance" (Stegariu et al., 2023).

With the growing emphasis on investigating cerebral activity through procedures that stimulate various aspects such as the cortex, perception, movement programming, motor control, or decision-making during motor actions, the term "neuromotricity" has been coined (Romero-Naranjo et al., 2023a). Neuromotricity thus encompasses a methodology of motor education and re-education, focusing on stimulating cognitive functions through interventions targeted at the executive functions of the brain (Andreu-Cabrera & Romero-Naranjo, 2021).

Hence, understanding aspects related to the psycho-neuro-motor level or "the principles of motor coordination in relation to the cognitive and executive functions of the brain becomes crucial" (Romeo-Naranjo & Andreu-Cabrera, 2023), particularly when engaging in instructional educational processes with students. In the context of a neuropedagogical approach, it becomes imperative to cultivate the communication competence of future educators, as it serves as a foundational element in professionalizing pedagogical activities, contributing to "the comprehensive development of object-subject and subject-subject interactions within the educational process" (Kernas et al., 2024).

To enhance proprioception, we posit that the relationship between the type of information, reaction time for workload awareness, and motor behavior plays a significant role. The attention factor (see Figure 2) is instrumental in selectively focusing on sensory information, "thereby heightening awareness of specific elements" (Carter et al., 2019).

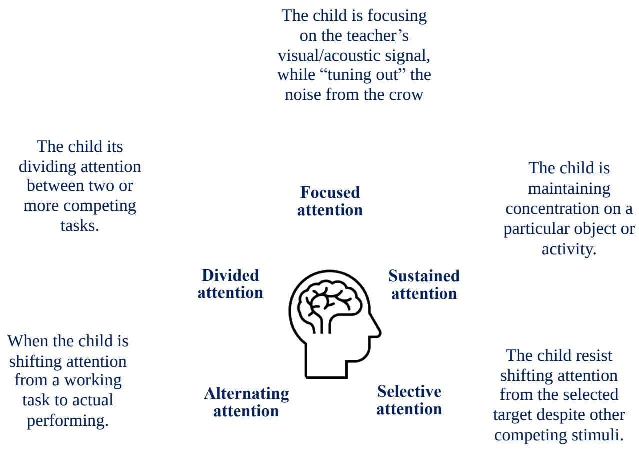


Figure 2. Type of attention

Additionally, in motor control learning, the complexity of the task and the conscious attention that the child devotes to efficiently accomplishing the tasks could be taken into consideration. Bowers et al. (2020, 48-49) regards learning as one of the primary factors of plasticity in the central nervous system, as information is transferred from our short-term (working) memory to long-term memory stores, which become better stabilized and more resistant to disruptions through the development of practice and motor experience.

The planning and initiation of complex motor actions necessary to gain an advantage over an opponent "can be processed by the brain before realizing that the action will begin" (Carter et al., 2019). Therefore, familiarization with the body language of opponents also allows us to make well-informed unconscious predictions about when we will block the opponent's action if we pay conscious attention to the motor actions we intend to initiate, as the relationship between brain processing time and motor behavior plays an important role in performing motor actions (Figure 3).

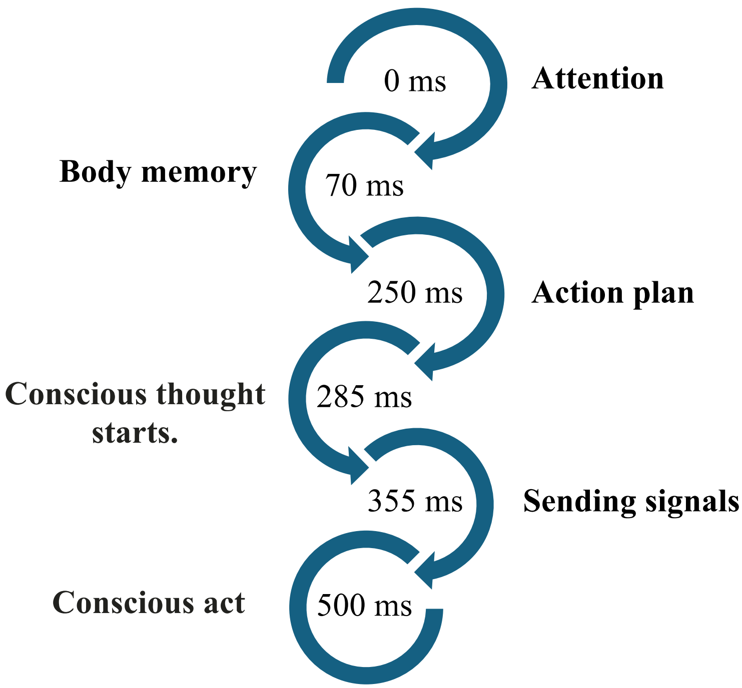


Figure. 3. The relationship between time and motor behavior

The research hypotheses include:

- **H.1.** Using an exercise program to develop eye muscle/eye motricity and body schema at the age of 9-10 years leads to improved proprioception.
- **H.2.** Using an exercise program to develop coordination and balance at 9–10 years of age increases proprioception.

Purpose of the research

The research aimed to stimulate proprioception by establishing a specific competence in this direction and operationalizing it based on specific learning units.

Material and methods

Subjects

The research was conducted at two different locations between September 2022 and March 2023. The first location was at the "Ferdinand I" Elementary School, and the second location was at the Lions Football Sports Club, both in Bucharest. The research subjects were 24 children aged 10 years. An equal number of 12 subjects participated in the experimental group (EG, n=12) and the control group (CG, n=12). They were informed about the characteristics of the cross-sectional research and provided a written consent document signed by a parent.

Methods

In order to achieve the aim of the research we used the following methods described below:

The documentation method. We began the design of the didactic approach with a review of the literature and analysis of official documents, namely the current physical education curriculum for the fourth grade.

The pedagogical experiment method. In order to verify the hypotheses of the research and in accordance with its purpose, we initiated, organized and carried out a classical pedagogical experiment with an experimental group and a control group. The subjects were enrolled in the fourth grade in the primary cycle of the public school system, playing competitive football.

The measurement and assessment method employed in the study involved the following procedures: In the experimental group (EG), an ameliorative intervention (Tables 1-3 and Figure 4) was implemented over a duration of 14 weeks. This intervention was operationalized through the didactic strategy (Mihăilescu, 2008) utilized within the framework of the two weekly sessions of school physical education, spanning from November 2022 to February 2023. Conversely, the control group (CG) adhered to standard football training sessions as outlined in the planning set by the team coach, ensuring no influence from the experimental group. The evaluation encompassed two task assignments: conducting exercises with eyes open (OD) and conducting exercises with eyes closed (OI). Initial testing was conducted between the 3rd and 21st of October 2022, with the final testing occurring from the 27th of February to the 10th of March 2023, under similar conditions for both groups. The equipment utilized for these assessments included the GyKo Microgate inertial sensor and OptoJump Next equipment, both recognized as high-tech tools for analyzing perceptual-motor coordination. This system, equipped with advanced sensors and software, precisely captured and evaluated various aspects of human movement. Specifically, it assessed "the synchronization between sensory perception and motor responses, thereby providing crucial insights" (Roşu et al., 2024).

The statistical-mathematical method employed aimed at comparing the results of the two research groups. Firstly, the normality of distributions was assessed using the Kolmogorov-Smirnov test to determine the appropriate test for comparing between groups. Subsequently, based on the results, either the independent samples t-test or the Mann-Whitney U test was utilized. The independent samples t-test was employed whenever both distributions were found to be normal. Conversely, the Mann-Whitney U test was applied when one or both distributions were found to be non-normal.

Table 1. Program No. 1 of stretching exercises.

Exercise no. 1: P.I.: Standing with feet shoulder-width apart, back straight: T1: bending the head towards the right shoulder. T2: the right hand is placed on the left ear. It is maintained for 15 s. T3: bending the head towards the left shoulder. T4: the left hand is placed on the right ear. Hold for 15 s. T5: return to the initial/start position (P.I.)	**Exercise no. 2:** P.I.: Standing with feet shoulder-width apart, back straight: T1: flexion of the head, chin in the chest T2: the right hand is placed on the back of the head. It is maintained for 15 s. T3: head extension T4: the left hand is placed under the chin. Hold for 15 s. T5: return to the initial/start position (P.I.)
Exercise no. 3: P.I.: Standing with feet shoulder-width apart, back straight: T1: raising the right arm forward. T2: bringing the right arm to the left side. T3: the left hand is placed on the right elbow. It is maintained for 15 s. T4: raising the left arm forward. T5: bringing the left arm to the right side. T6: the right hand is placed on the left elbow. Hold for 15 s. T7: return to the initial/start position (P.I.)	**Exercise no. 4:** P.I.: Standing with feet shoulder-width apart, back straight: T1: raising the right arm up. T2: flexion of the forearm back past the right ear T3: right hand touches right shoulder blade T4: the left hand is placed on the right elbow and pressed backwards. Hold for 15 s. T5: raising the left arm up. T6: flexion of the forearm back past the left ear T7: left hand touches left shoulder blade. T8: the right hand is placed on the left elbow and presses backwards. Hold for 15 s. T9: return to the initial/start position (P.I.)
Exercise no. 5: P.I.: Standing with feet shoulder-width apart, torso straight, hands behind the back of the head: T1: bending the trunk to the right. Hold for 15 s. T2: return to P.I. T3: bending the trunk to the left side. Hold for 15 s. T4: return to the initial/start position (P.I.)	**Exercise no. 6:** P.I.: Sitting with the lower limbs straight, do not bend the knees: T1: leg flexion T2: trunk bending, hands grasp toes. Hold for 15 s. T3: return to P.I. T4: leg extension T5: trunk flexion, hands grasp toes. Hold for 15 s. T6: return to the initial/start position (P.I.)
Exercise no. 7: P.I.: From lying face down: T1: lower limbs outstretched. T2: the hands are placed on the ground next to the shoulders. T3: trunk and upper limb extension. Hold for 15 s. T4: return to the initial/start position (P.I.)	**Exercise no. 8:** P.I.: From lying on the back with the lower limbs extended: T1: bringing the right knee to the chest, the hands are placed on the knees. Hold for 15 s. T2: return to P.I. T3: bringing the left knee to the chest, the hands are placed on the knees. Hold for 15 s. T4: return to P.I. T5: bringing both knees to the chest, hands are placed on the knees. Hold for 15s. T6: return to the initial/start position (P.I.)

Legend: P.I. = initial/start position; T1-9 = task times

Table 2. Program No. 2 of exercises for coordination and balance

Exercise no. 1:	**Exercise no. 2:**
P.I.: Standing inside a hexagon: T1: Jump forward on both feet outside the hexagon. T2: return by jumping inside it. T3: jump forward diagonally to the right, on both feet outside the hexagon. T4: return by jumping inside it. T5: Jump back diagonally to the right, on both feet outside the hexagon. T6: return by jumping inside it. T7: backward jump on both feet outside the hexagon T8: return by jumping inside it. T9: Jump back diagonally to the left, on both feet outside the hexagon. T10: return by jumping inside it. T11: Jump forward obliquely to the left, on both feet outside the hexagon. T12: return by jumping inside it.	P.I.: Standing inside a hexagon: T1: Jump forward on the right leg outside the hexagon. T2: return by jumping inside it. T3: jump forward obliquely to the right, on the right foot outside the hexagon. T4: return by jumping inside it. T5: jump back obliquely to the right, on the right foot outside the hexagon. T6: return by jumping inside it. T7: backward jump on the right leg outside the hexagon T8: return by jumping inside it. T9: Jump back obliquely to the left, on the right foot outside the hexagon. T10: return by jumping inside it. T11: Jump forward obliquely to the left, on the right foot outside the hexagon. T12: return by jumping inside it.
Exercise no. 3:	**Exercise no. 4:**
P.I.: Standing inside a hexagon: T1: Leap forward on the left leg outside the hexagon T2: return by jumping inside it. T3: jump forward diagonally to the right, on the left leg outside the hexagon. T4: return by jumping inside it. T5: backward jump diagonally to the right, on the left leg outside the hexagon T6: return by jumping inside it. T7: backward jump, on the left leg outside the hexagon T8: return by jumping inside it. T9: Jump back obliquely to the left, on the left leg outside the hexagon. T10: return by jumping inside it. T11: Jump forward obliquely to the left, on the left leg outside the hexagon. T12: return by jumping inside it.	P.I.: Standing inside a hexagon: T1: jump in the frontal plane and landing on both feet apart. T2: return by jumping inside it. T3: Jump in the sagittal plane, oblique to the right with a lunge landing on the right leg, the left leg is extended back outside the hexagon. T4: return by jumping inside it. T5: Sagittal jump, oblique to the left landing in a lunge on the left leg, the right leg is extended back to the outside of the hexagon. T6: return by jumping inside it.
Exercise no. 5:	**Exercise no. 6:**
P.I.: Standing inside a hexagon: T1: rising the arms through the side to the level of the shoulders, the trunk will remain facing the frontal plane. T2: with the tip of the right foot, touch all 6 corners of the hexagon in a clockwise direction. T3: each touch in T2 is held for 10 s T4: return to P.I. and hold 10 s at each touch in T2	P.I.: Standing inside a hexagon: T1: vertical free jumps T2: at the buzzer, land on the right foot T3: hold 10 s T4: vertical free jumps T5: at the buzzer, land on the left foot T6: hold 10 s
Exercise no. 7:	**Exercise no. 8:**
Practicing the combination of exercises 1+3+5	Practicing the combination of exercises 2+4+6

Legend: P.I. = initial/start position; T1-12 = task times

Table 3. Program No. 3 of exercises for the development of eye motility and body orientation

No	Exercise	Photo
1	P.I.: Sitting cross-legged, hands on knees, head not moving: T1: eyes open look up for 12 s. T2: eyes open look down for 12 s	
2	P.I.: Sitting cross-legged, hands on knees, head not moving: T1: eyes look to the right side, for 12 s. T2: eyes look to the left side, for 12 s.	
3	P.I.: Sitting cross-legged, hands on knees, head not moving: T1: the eyes look obliquely up to the right side, hold for 12 s. T2: the eyes look obliquely up to the left side, hold for 12 s.	
4	P.I.: Sitting cross-legged, hands on knees, head not moving: T1: roll eyes from right to left side for 12 s. T2: roll eyes from left to right side for 12 s.	
5	P.I.: Sitting cross-legged, hands on knees, head still: T1: close eyes tightly for 15 s. T2: open eyes suddenly for 10 s	
6	P.I.: Sitting with legs crossed, hands on knees, head not moving: T1: Open your eyes as wide as possible for 15 s. T2: Return to normal view	
7	P.I.: Standing with legs apart with arms by the body: T1: The right hand is placed on the right eye. T2: Rising the left arm through the side at the level of the left shoulder, the left eye looks to the left, hold for 12 s. T3: Rising the left arm up, the left eye looks up, hold for 12 s. T4: Left arm comes down in front and goes to the right, left eye looks to the right side, hold 12 s. T5: Rising the left arm down on the left side, the left eye looks down, hold for 12 s. T6: Both upper limbs relax	
8	P.I.: Standing with legs apart with arms by the body: T1: The left hand is placed on the left eye. T2: Rising the right arm through the side at the level of the right shoulder, the right eye looks to the right side, hold for 12 s T3: Rising the right arm up, the right eye looks up, hold for 12 s. T4: Right arm comes down in front and goes to the left, right eye looks to the left side, hold for 12 s. T5: Rising the right arm down on the right side, the right eye looks down, hold for 12 s. T6: Both upper limbs relax	

Legend: P.I. = initial/start position; T1-6 = task times

Through the ameliorative intervention above (tables 1-3), we aimed to achieve, by the experiment group (EG), the following operational skills:

- to educate his visual analyzer by being aware of the movement of the eyeballs in different spatio-temporal directions.
- to be able to be aware of their own body schema.
- to be able to understand what they feel and how they feel during practice with eyes open and eyes closed.
- be able to synchronize the movement of their body segments.

- be able to consciously maintain different positions of static and dynamic balance.
- to be able to perform acts and motor actions, aware of the positioning of the body in the spatio-temporal dimension of practice.

Test protocols

The protocol of the "Body Sway" test to assess balance, consisted of two static (Sway) work tasks. The position of the students was: sitting on the ground with the upper limbs next to the body. Participants wore a corset in the shoulder blade area, on which the GyKo Microgate inertial sensor was attached with magnetic clips. The recording time was 30 s for each work task. At the end of the protocol, we obtained a report that provided comparison results between the eyes open (BOD) and eyes closed (BOI) exercise.

By applying the "Flamingo" test from the Eurofit test battery for a dedicated time of 60s, we assessed the maintenance of balance and coordination on the analysis of proprioception quality in the study participants. During the testing, students wore sports shoes. The test was performed with eyes open (OD), and eyes closed (OI).

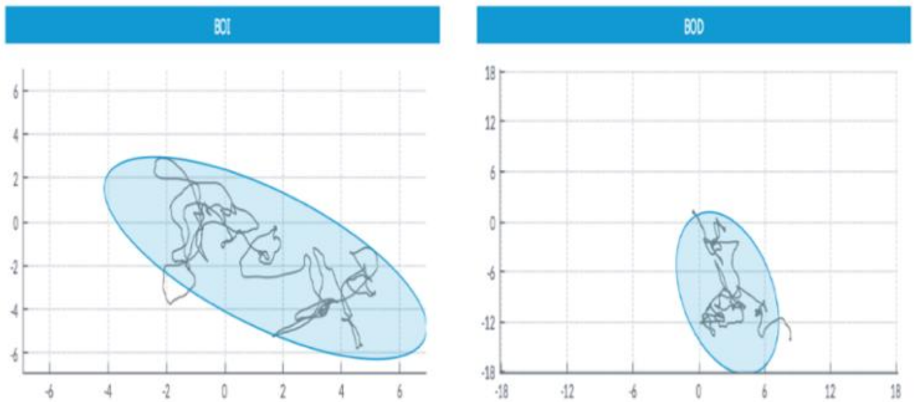
The dedicated "March in place - MIP" test protocol of the OptoJump Next equipment consisted of two tasks (OD and OI) in which students walked in place for 30 s. The test was defined with a starting point within the OptoJump bar area, and the right foot as the starting leg. Each subject started the test by lifting the right foot first.

In the "Circle" test subjects in both groups performed 2 sets of 4 simultaneous jumps on two legs. Inside the OptoJump Next bars we drew a 60 cm diameter circle on the ground. We drew four lines from paper tape, which formed four quadrants. The first jump was forward/forward/front plane, then clockwise. The recording time was 15 s. The initial starting position of the exercise was sitting in the center of the circle, with legs close together, knees slightly bent, arms bent at the side of the body. After each jump, one returned to the inside of the circle. Participants were not allowed to rotate their body when jumping and maintained a frontal orientation facing the teacher for each jump performed. They were instructed by the teacher on the correct technique for executing the jumps. A settling-in period was given to the participants and consisted of a rehearsal of the exercise before the test began.

Results

Our research was conducted as a cross-sectional experiment for all 4 tests applied to subjects included in both EG (experimental group) and CG (control group). All tests were performed with eyes open, and eyes closed by the subjects.

The "Body Sway" test. Prior to the start of the test, we measured for each subject the height from the ground to the center of the sensor, which we fed into the GyKo Microgate software, so that it generated a real-time ellipse of the vertical projection on the ground of the inertial sensor. The image provided by the dedicated report represents the viewing area of the subjects' center of gravity, which gave us clues about the quality of proprioception (figure 4).



Legend: BOD = Body Sway Test performed with eyes open; BOI = Body Sway Test performed with eyes closed.

Figure. 4. OD and OI results for the "Body Sway" test (S3)

The Gyko Microgate inertial sensor has allowed us to obtain the most popular indices of the projection of the body's center of gravity quickly and easily on the ground. The graph obtained is an ellipse whose size represents how much the torso moves in the Antero-Posterior (AP), frontal plane and Medio-Lateral (ML), sagittal plane directions. The more the trunk moves, the larger the area of the ellipse, which means a lack of motor control. Based on the X-plot, we highlight an ellipse initiated/formed based on the vertical projection on the ground of the inertial sensor, showing the movement of the subject to the right and left in the sagittal plane.

In the eyes-closed task (BOI), the subject shifted his center of gravity both to the right and to the left. There is also a marked backward tilt of the body compared to the forward tilt. On the other hand, on the Body Sway test with eyes open (BOD), the subject even though he controlled his balance, his torso was maintained backwards and to the right. The X-axis shows the sagittal body sway of the subjects to the right (after the plus zero) and to the left (after the minus zero). The Y-axis represents the body movement of the subjects, in the frontal plane, forward (above the plus zero) and backward (below the minus zero).

Based on the high values obtained in the Body Sway test with eyes closed (BOI) compared to the Body Sway test with eyes open (BOD), we can draw a first conclusion that it is necessary to apply a methodology aimed at stimulating the proprioceptors in order to improve the quality of the student's proprioception (Tables 4-8).

Table 4. Testing the normality of distributions and choosing the statistical comparison test – cross-sectional experiment – at the beginning of the experiment – BODY SWAY test

Measurements	Statistic Kolmogorov-Smirnov	df	Sig. *Kolg-Smirn.*	Interpretation p	Finding/ status of distributions	Appropriate statistical test
C_TI_OD_ML_MD	.216	12	.129	p>0.05	normal	Independent
E_TI_OD_ML_MD	.189	12	.200	p>0.05	normal	Sample t
C_TI_OI_ML_MD	.133	12	.200	p>0.05	normal	Independent
E_TI_OI_ML_MD	.172	12	.200	p>0.05	normal	Sample t
C_TI_OD_AP_MD	.178	12	.200	p>0.05	normal	Independent
E_TI_OD_AP_MD	.211	12	.146	p>0.05	normal	Sample t
C_TI_OI_AP_MD	.238	12	.059	p>0.05	normal	Independent
E_TI_OI_AP_MD	.177	12	.200	p>0.05	normal	Sample t

Note: C = control group; E = experimental group; TI = initial testing; OD = eyes open; OI = eyes closed; ML_MD = mean sagittal plane distance; AP_MD = mean frontal plane distance.

Table 5. Testing the similarity of the groups at the beginning of the experiment normal distributions (verification by Independent Sample t) – BODY SWAY test

Measurements test t	N	Mean	Std. Deviation	t	df	Sig. (2 tailed)	p
C_TI_OD_ML_MD	12	.88	.52	.403	22	.691	p>0.05
E_TI_OD_ML_MD	12	.80	.40				
C_TI_OI_ML_MD	12	.90	.41	1.167	22	.256	p>0.05
E_TI_OI_ML_MD	12	.72	.37				
C_TI_OD_AP_MD	12	.93	.44	-1.344	22	.193	p>0.05
E_TI_OD_AP_MD	12	1.21	.59				
C_TI_OI_AP_MD	12	.99	.39	.113	22	.911	p>0.05
E_TI_OI_AP_MD	12	.97	.44				

Note: C = control group; E = experimental group; TI = initial testing; OD = eyes open; OI = eyes closed; ML_MD = mean sagittal plane distance; AP_MD = mean frontal plane distance.

Following the comparisons between the two groups in the initial phase of the experiment using the Independent T-test and based on the significance threshold obtained, which is less than .05, we can state that there are no statistically significant differences for all four variables compared in the Body Sway test. In this case, the conditions for further starting the experiment with two research groups (control and experimental) are confirmed. Thus, we can state that the performances evaluated in the initial phase for all subjects involved in the research show similar values.

Table 6. Testing the normality of distributions and choosing the statistical comparison test – cross-sectional experiment – at the end of the experiment – BODY SWAY test

Measurements	Statistic Kolmogorov-Smirnov	df	Sig. *Kolg-Smirn.*	Interpretation p	Finding/ status of distributions	Appropriate statistical test
C_TF_OD_ML_MD	.161	12	.200	p>0.05	normal	Independent
E_TF_OD_ML_MD	.117	12	.200	p>0.05	normal	Sample t
C_TF_OI_ML_MD	.147	12	.200	p>0.05	normal	Independent
E_TF_OI_ML_MD	.236	12	.064	p>0.05	normal	Sample t
C_TF_OD_AP_MD	.135	12	.200	p>0.05	normal	Independent
E_TF_OD_AP_MD	.214	12	.136	p>0.05	normal	Sample t
C_TF_OI_AP_MD	.095	12	.200	p>0.05	normal	Mann Whitney
E_TF_OI_AP_MD	.248	12	.040	p<0.05	abnormal	U

Note: C = control group; E = experimental group; TF = final testing; OD = eyes open; OI = eyes closed; ML_MD = mean sagittal plane distance; AP_MD = mean frontal plane distance.

Table 7. Testing groups at the end of the experiment normal distributions (verification by Independent Sample t) – BODY SWAY test

Measurements test t	N	Mean	Std. Deviation	t	df	Sig. (2 tailed)	p
C_TF_OD_ML_MD	12	1.33	.44	1.952	22	.064	p>0.05
E_TF_OD_ML_MD	12	1.03	.31				
C_TF_OI_ML_MD	12	1.84	.35	13.300	22	.000	p<0.05
E_TF_OI_ML_MD	12	.35	.18				
C_TF_OD_AP_MD	12	1.39	.34	.231	22	.819	p>0.05
E_TF_OD_AP_MD	12	1.33	.78				

Note: C = control group; E = experimental group; TF = final testing; OD = eyes open; OI = eyes closed; ML_MD = mean sagittal plane distance; AP_MD = mean frontal plane distance.

Table 8. Calculation of differences between groups at the end of the experiment – abnormal distributions – (check by Mann Whitney U test) – BODY SWAY test

Measurements Test U	N	Mean rank	sum of rank	U	Asymp Sig. (2 tailed)	p
C_TF_OI_AP_MD	12	18.50	222.00	.000	.000	p<0.05
E_TF_OI_AP_MD	12	6.50	78.00			

Note: C = control group; E = experimental group; TF = final testing; OD = eyes open; OI = eyes closed; AP_MD = mean frontal plane distance.

The Body Sway test from the final testing (tables 6-8) can only be used for the "eyes closed" variant where differences between the two groups can be highlighted ($p<0.05$), even if the work tasks were highlighted with different tests.

The "Flamingo" test

In tables 9-11, both the comparisons performed with the Independent Sample t-test and the Mann Whitney U-test show that the differences between research groups in the Flamingo Test at the start of the experiment are not statistically significant ($p>0.05$ in all 4 comparisons) validating the starting conditions of the experiment with two research groups (control and experimental). Thus, the initial performance and/or abilities of the research subjects are at the start of the experiment relatively similar.

Table 9. Testing the normality of distributions and choosing the statistical comparison test – cross-sectional experiment – at the beginning of the experiment – Flamingo test

Measurements	Statistic Kolmogorov-Smirnov	df	Sig. *Kolg-Smirn.*	Interpretation p	Finding/ status of distributions	Appropriate statistical test
C_TI_OD_ML_MD	.176	12	.200*	p>0.05	normal	Independent
E_TI_OD_ML_MD	.153	12	.200*	p>0.05	normal	Sample t
C_TI_OI_ML_MD	.135	12	.200*	p>0.05	normal	Independent
E_TI_OI_ML_MD	.158	12	.200*	p>0.05	normal	Sample t
C_TI_OD_AP_MD	.248	12	.041	p<0.05	abnormal	Mann Whitney
E_TI_OD_AP_MD	.217	12	.122	p<0.05	abnormal	U
C_TI_OI_AP_MD	.196	12	.200*	p>0.05	normal	Mann Whitney
E_TI_OI_AP_MD	.246	12	.044	p<0.05	abnormal	U

Note: C = control group; E = experimental group; TI = initial testing; OD = eyes open; OI = eyes closed; ML_MD = mean sagittal plane distance; AP_MD = mean frontal plane distance.

Table 10. Testing the similarity of the groups at the beginning of the experiment normal distributions – Flamingo test

Measurements test t	N	Mean	Std. Deviation	t	df	Sig. (2 tailed)	p
C_TI_OD_ML_MD	12	4.45	2.43	-1.628	22	.118	p>0.05
E_TI_OD_ML_MD	12	6.20	2.83				
C_TI_OI_ML_MD	12	11.55	4.53	.059	22	.954	
E_TI_OI_ML_MD	12	11.43	5.46				

Note: C = control group; E = experimental group; TI = initial testing; OD = eyes open; OI = eyes closed; ML_MD = mean sagittal plane distance.

Table 11. Testing the similarity of groups at the start of the experiment at abnormal distributions – Flamingo test

Measurements Test U	N	Mean rank	sum of rank	U	Asymp Sig. (2 tailed)	p
C_TI_OD_AP_MD	12	10.67	128	50	.204	p>0.05
E_TI_OD_AP_MD	12	14.33	172			
C_TI_OI_AP_MD	12	11.08	133	55	.326	p>0.05
E_TI_OI_AP_MD	12	13.92	167			

Note: C = control group; E = experimental group; TI = initial testing; OD = eyes open; OI = eyes closed; AP_MD = mean frontal plane distance.

As can be seen in tables 12 and 13, for the first three measurements the differences between the groups are statistically significant (p<0.05), while for the fourth measurement in Table 13, the differences are not statistically significant.

Therefore, the evaluation of subjects with the Flamingo Test generally validates the effectiveness of the experimental program, with most of the experimental group results at the end of the experiment (3 out of 4 measurements) being statistically significantly different from those of the control group.

Table 12. Testing the normality of distributions and choosing the statistical comparison test – cross-sectional experiment – at the end of the experiment – Flamingo test

Measurements	Statistic Kolmogorov-Smirnov	df	Sig. *Kolg-Smirn.*	Interpretation p	Finding/ status of distributions	Appropriate statistical test
C_TF_OD_ML_MD	.137	12	.200*	p>0.05	normal	Independent Sample t
E_TF_OD_ML_MD	.117	12	.200*	p>0.05	normal	
C_TF_OI_ML_MD	.240	12	.056	p>0.05	normal	
E_TF_OI_ML_MD	.153	12	.200*	p>0.05	normal	
C_TF_OD_AP_MD	.151	12	.200*	p>0.05	normal	
E_TF_OD_AP_MD	.172	12	.200*	p>0.05	normal	
C_TF_OI_AP_MD	.196	12	.200*	p>0.05	normal	
E_TF_OI_AP_MD	.153	12	.200*	p>0.05	normal	

Note: C = control group; E = experimental group; TF = final testing; OD = eyes open; OI = eyes closed; ML_MD = mean sagittal plane distance; AP_MD = mean frontal plane distance.

Table 13. Calculation of differences between groups at the end of the experiment – normal distributions – Flamingo test

Measurements test t	N	Mean	Std. Deviation	t	df	Sig. (2 tailed)	p
C_TF_OD_ML_MD	12	3.25	1.20	-3.408	22	.003	p<0.05
E_TF_OD_ML_MD	12	5.28	1.67				
C_TF_OI_ML_MD	12	4.14	1.62	2.122	22	.045	p<0.05
E_TF_OI_ML_MD	12	3.07	.64				
C_TF_OD_AP_MD	12	2.67	1.22	-2.686	22	.014	p<0.05
E_TF_OD_AP_MD	12	4.17	1.52				
C_TF_OI_AP_MD	12	3.00	1.40	.563	22	0.579	p>0.05
E_TF_OI_AP_MD	12	2.71	1.13				

Note: C = control group; E = experimental group; TF = final testing; OD = eyes open; OI = eyes closed; ML_MD = mean sagittal plane distance; AP_MD = mean frontal plane distance.

The "Circle" test

In tables 14 and 15, the comparisons made with the Independent Sample t-test show that the differences between the research groups in the Circle test at the start of the experiment are not statistically significant (p>0.05, in 5 out of 6 comparisons relatively validating the starting conditions of the experiment with two research groups (control and experimental. Thus, the initial performance and/or abilities of the research subjects are at the start of the experiment relatively similar.

Table 14. Testing the normality of distributions and choosing the statistical comparison test – cross-sectional experiment – at the beginning of the experiment – Circle test

Measurements	Statistic Kolmogorov-Smirnov	df	Sig. *Kolg-Smirn.*	Interpretation p	Finding/ status of distributions	Appropriate statistical test
C_TI_OD_X	.233	12	.071	p>0.05	normal	Independent
E_TI_OD_X	.201	12	.197	p>0.05	normal	Sample t
C_TI_OI_X	.217	12	.123	p>0.05	normal	Independent
E_TI_OI_X	.154	12	.200	p>0.05	normal	Sample t
C_TI_OD_Y	.100	12	.200	p>0.05	normal	Independent
E_TI_OD_Y	.154	12	.200	p>0.05	normal	Sample t
C_TI_OI_Y	.139	12	.200	p>0.05	normal	Independent
E_TI_OI_Y	.125	12	.200	p>0.05	normal	Sample t
C_TI_OD_DIST	.150	12	.200	p>0.05	normal	Independent
E_TI_OD_DIST	.128	12	.200	p>0.05	normal	Sample t
C_TI_OI_DIST	.146	12	.200	p>0.05	normal	Independent
E_TI_OI_DIST	.222	12	.104	p>0.05	normal	Sample t

Note: C = control group; E = experiment group; TI = initial testing; OD = eyes open; OI = eyes closed; X = x-axis; Y = y-axis; DIST = total jump distance.

Table 15. Testing the similarity of the groups at the beginning of the experiment normal distributions (verification by Independent Sample t) – Circle test

Measurements test t	N	Mean	Std. Deviation	t	df	Sig. (2 tailed)	p
C_TI_OD_X	12	1.51	6.04	-.052	22	.959	p>0.05
E_TI_OD_X	12	1.62	3.41				
C_TI_OI_X	12	1.26	7.56	-.176	22	.862	p>0.05
E_TI_OI_X	12	1.82	8.03				
C_TI_OD_Y	12	-4.01	8.79	-.091	22	.928	p>0.05
E_TI_OD_Y	12	-3.72	6.22				
C_TI_OI_Y	12	4.23	10.96	.015	22	.988	p>0.05
E_TI_OI_Y	12	4.16	11.00				
C_TI_OD_DIST	12	10.47	3.76	2.262	22	.034	p<0.05
E_TI_OD_DIST	12	6.68	4.43				
C_TI_OI_DIST	12	11.94	6.57	-.222	22	.826	p>0.05
E_TI_OI_DIST	12	12.51	6.11				

Note: C = control group; E = experiment group; TI = initial testing; OD = eyes open; OI = eyes closed; X = x-axis; Y = y-axis; DIST = total jump distance.

In table 15 above, the negative values obtained mean that the jumps were inside/outside the circle but not correct in the 4 dedicated quadrants, which means no motor control. The positive values obtained mean that the jumps were inside/outside the circle in the 4 dedicated quadrants, indicating the presence of motor control, and the quality of proprioception as well.

In the final testing, as can be seen in tables 16 and 17 below, *the Circle test is effective for testing proprioception*, is very good for measuring jump distances (DIST) for both the eyes-open (OD_DIST, $p<0.05$) and eyes-closed (OI_DIST, $p<0.05$) workload. Therefore, this test is suggestive in demonstrating, in different ways, the superiority of the effectiveness of experimental exercise programs.

Table 16. Testing the normality of distributions and choosing the statistical comparison test – cross-sectional experiment – at the end of the experiment – Circle test

Measurements	Statistic Kolmogorov-Smirnov	df	Sig. *Kolg-Smirn.*	Interpretation p	Finding/ status of distributions	Appropriate statistical test
C_TF_OD_X	.145	12	.200	p>0.05	normal	Independent
E_TF_OD_X	.178	12	.200	p>0.05	normal	Sample t
C_TF_OI_X	.245	12	.045	p>0.05	normal	Independent
E_TF_OI_X	.142	12	.200	p>0.05	normal	Sample t
C_TF_OI_X	.245	12	.045	p>0.05	normal	Independent
E_TF_OD_Y	.158	12	.200	p>0.05	normal	Sample t
C_TF_OI_Y	.214	12	.136	p>0.05	normal	Independent
E_TF_OI_Y	.169	12	.200	p>0.05	normal	Sample t
C_TF_OD_DIST	.163	12	.200	p>0.05	normal	Independent
E_TF_OD_DIST	.108	12	.200	p>0.05	normal	Sample t
C_TF_OI_DIST	.248	12	.039	p>0.05	normal	Independent
E_TF_OI_DIST	.137	12	.200	p>0.05	normal	Sample t

Note: C = control group; E = experiment group; TF = final testing; OD = eyes open; OI = eyes closed; X = x-axis; Y = y-axis; DIST = total jump distance.

Table 17. Calculation of differences between groups at the end of the experiment – normal distributions – CIRCLE test

Measurements test t	N	Mean	Std. Deviation	t	df	Sig. (2 tailed)	p
C_TF_OD_X	12	-3.43	6.74	-1.831	22	.081	p>0.05
E_TF_OD_X	12	.18	1.15				
C_TF_OI_X	12	-9.80	17.21	-2.007	22	.057	p>0.05
E_TF_OI_X	12	.19	.97				
C_TF_OI_X	12	3.61	9.60	1.168	22	.255	p>0.05
E_TF_OD_Y	12	.32	1.82				
C_TF_OI_Y	12	5.39	18.39	.972	22	.342	p>0.05
E_TF_OI_Y	12	.22	.94				
C_TF_OD_DIST	12	11.31	5.03	6.387	22	.000	p<0.05
E_TF_OD_DIST	12	1.86	.99				
C_TF_OI_DIST	12	23.62	12.74	6.114	22	.000	p<0.05
E_TF_OI_DIST	12	1.09	.79				

Note: C = control group; E = experiment group; TF = final testing; OD = eyes open; OI = eyes closed; X = x-axis; Y = y-axis; DIST = total jump distance.

The "March in place – MIP" test

In the final testing, as can be seen from tables 18-20 below, in all assessments the differences between groups are statistically insignificant (p>0.05). We can conclude that the "March in place-MIP" test measurement *does not validate* the effectiveness of the experimental program, as all differences between the results of the experimental group and the control group at the end of the experiment are statistically insignificant (p>0.05).

Table 18. Testing the normality of distributions and choosing the statistical comparison test – cross-sectional experiment – at the end of the experiment – March in place – MIP test

Measurements	Statistic Kolmogorov-Smirnov	df	Sig. *Kolg-Smirn.*	Interpretation p	Finding/ status of distributions	Appropriate statistical test
C_TF_OD_FB	.256	12	.029	p<0.05	abnormal	Mann Whitney
E_TF_OD_FB	.156	12	.200	p<0.05	normal	U
C_TF_OI_FB	.231	12	.076	p>0.05	normal	Independent
E_TF_OI_FB	.154	12	.200	p>0.05	normal	Sample t
C_TF_OD_LR	.196	12	.200	p>0.05	normal	Independent
E_TF_OD_LR	.203	12	.183	p>0.05	normal	Sample t
C_TF_OI_LR	.132	12	.200	p>0.05	normal	Independent
E_TF_OI_LR	.180	12	.200	p>0.05	normal	Sample t
C_TF_OD_DIST	.172	12	.200	p>0.05	normal	Mann Whitney
E_TF_OD_DIST	.263	12	.021	p<0.05	abnormal	U
C_TF_OI_DIST	.171	12	.200	p>0.05	normal	Mann Whitney
E_TF_OI_DIST	.326	12	.001	p<0.05	abnormal	U
C_TF_OD_ALPHA	.118	12	.200	p>0.05	normal	Independent
E_TF_OD_ALPHA	.185	12	.200	p>0.05	normal	Sample t
C_TF_OI_ALPHA	.199	12	.200	p>0.05	normal	Mann Whitney
E_TF_OI_ALPHA	.247	12	.042	p<0.05	abnormal	U

Note: C = control group; E = experimental group; TF = final test; OD = eyes open; OI = eyes closed; FB = forward-backward (frontal plane displacement); LR = left-right (sagittal plane displacement); DIST = total body displacement distance between the start and end zone of the test; ALPHA = the angle formed between the start and end position when the body moved during the test.

Table 19. Calculation of differences between groups at the end of the experiment – normal distributions – March in place – MIP test

Measurements test t	N	Mean	Std. Deviation	t	df	Sig. (2 tailed)	p
C_TF_OI_FB	12	8.45	14.64	.294	22	.772	p>0.05
E_TF_OI_FB	12	4.73	41.44				
C_TF_OD_LR	12	1.69	7.39	1.303	22	.206	p>0.05
E_TF_OD_LR	12	-1.47	3.99				
C_TF_OI_LR	12	-1.16	10.46	.416	22	.681	p>0.05
E_TF_OI_LR	12	-2.91	10.14				
C_TF_OD_ALPHA	12	4.60	102.42	1.006	22	.325	p>0.05
E_TF_OD_ALPHA	12	-36.59	98.09				

Note: C = control group; E = experimental group; TF = final test; OD = eyes open; OI = eyes closed; FB = forward-backward (frontal plane displacement); LR = left-right (sagittal plane displacement); ALPHA = the angle formed between initial and final position when the body moved during the test.

Table 20. Calculation of differences between groups at the end of the experiment – abnormal distributions – March in place – MIP test (verification by Mann Whitney U test)

Measurements Test U	N	Mean rank	sum of rank	U	Asymp Sig. (2 tailed)	p
C_TF_OD_FB	12	11.42	137.00	59.000	.452	p>0.05
E_TF_OD_FB	12	13.58	163.00			
C_TF_OD_DIST	12	11.75	141.00	63.000	.603	p>0.05
E_TF_OD_DIST	12	13.25	159.00			
C_TF_OI_DIST	12	10.79	129.50	51.500	.236	p>0.05
E_TF_OI_DIST	12	14.21	170.50			
C_TF_OI_ALPHA	12	12.79	153.50	68.500	.840	p>0.05
E_TF_OI_ALPHA	12	12.21	146.50			

Note: C = control group; E = experimental group; TF = final test; OD = eyes open; OI = eyes closed; FB = forward-backward (frontal plane displacement); DIST = total body displacement distance between the start and end zone of the test; ALPHA = the angle formed between the start and end position when the body moved during the test.

Discussion

The aim of this study was to implement a 3M didactic strategy (methods, materials, means) to evaluate the proprioceptive internal environment of children, as attention, balance, and coordination factors are key components of the psycho-neuro-motor strategy concerning their motor development. This strategy proposed by us represents an innovative approach in the methodology of physical education, which can be implemented in physical education lessons. In the research conducted by Tudorache & Mihăilescu (2020), they have demonstrated how "the correctness and efficiency of the learning-teaching process result from the changes in the behavior of the designed activity". The authors of this research have concluded that the psychosocial approaches included in fostering prosocial behavior in each student have led to safety and self-confidence in their own psychomotor perspective, as well as correctness regarding the quality of children's potential and the correction of educational failures "among young students" (Stepanchenko et al., 2021), and "the creation of additional conditions for their school and social integration" (Stănescu & Tomescu, 2020). It is known that the transmission of vocal information from teachers to students is "an important factor in optimizing proprioception" (Camenidis et al., 2024) as they have shown, as the applied ameliorative intervention significantly impacts motor development, thereby potentially demonstrating improvements in proprioception quality.

During this age period of the subjects, the morpho-functional growth and development of children are "faster and generally more uniform than in previous stages" (Ionescu, 1994), and the initial educational effects will be highlighted in psycho-neuro-motor functions. Sîmbotin's study (2020) indicates that "to follow the development of personality, it is necessary to analyze multiple interactive variables [...] from the ontic triad, matter-energy-information, which at the human level is reflected in: knowledge (developed in our case as an image structure), energy (which is a source of imaginary activation originating from the relationship with the external or internal side as a way to trigger behaviors), and verification tools [of performance indicators - ed.] (which are the material support of all manifestations)" (Sîmbotin, 2020).

Therefore, the subjects engaged with a novel method of motor development, specifically exercising with eyes closed, where they were educated to visualize their motor actions to observe "why meditation would be useful for the contemporary human mind in search of inner balance" (Cucu & Lența, 2022).

Another study indicates that improving coordination capacity is an important qualitative aspect of motor actions, ensuring the greatest efficiency in the physical development process because physical exercises have beneficial effects on "psychological properties of students such as memory, thinking, attention, speed and accuracy of reactions, logic, perception of one's own motor skills, and sense of external space" (Bashtovenko et al., 2021).

Our interest, as well as that of other specialists, lies in improving body posture, movements, gestures, and all motor-related manifestations that can be more correct from the perspective of the harmonious development of children, as opposed to individuals who are already dependent on the internet, video games, or television, and who "have developed at least one virtual addiction that has affected their health, family life, self-image, behavior, will, and psychological immunity" (Dăscălescu, 2022).

Other studies (Tan, 2024; Logan et al., 2024) emphasize neurocognitive integrity, which is defined by its importance both in terms of the child's optimal transition to adolescence and later to adult life, as well as in their "psycho-social integration" (Lupu et al., 2024). Afanasieva et al. (2022) study also highlighted the importance of awareness and motivation for self-development as landmarks for the psychological health of athletes, which can guide us in more effective communication with students so that they can provide conscious feedback throughout the educational process. Therefore, professional activity always requires from the teacher "the ability to build strategies, tactics, and techniques of discipline-discipline interactions, to organize joint activities with students to achieve educational goals" (Kernas et al., 2024).

Through our research, we aimed to highlight the interest of specialists in preventing various forms of deficits in the fluent, physical, and normally physiological development of children, who may grow up to be adolescents and adults without posture and locomotion deficiencies. Through the applied ameliorative intervention, we aimed to develop in participants of the experimental group (EG) skills related to "conscious learning" (Colibaba, 2007) and to improve their psycho-neuro-motor behavior through programs of exercises aimed at developing body schema, balance, and coordination. Thus, by the end of these interventions, participants were expected to acquire both general and specific competencies in physical education.

We believe that the ameliorative intervention also involves the development of proprioceptive capacity (stimulation of proprioceptors), which improves awareness, both conscious and unconscious, of body position and movement in space. This contributes to enhancing the designation of the psychomotor domain (C.G.2) and the expression of "psychomotor behavior" (Colibaba, 2007) with the phrase psycho-neuro-motor [n.a.] [1], as "efficient behavior also implies better performance and vice versa" (Colibaba, 2007). It is known that exercise analysis focuses on body mechanics, physiological responses to it, and energetic metabolism, aiming "to improve physical activity, quality of life throughout life, prevent illnesses and injuries, and create a habit of engaging in physical activities" (Ha et al., 2024).

The Romanian physical education curriculum for the fourth grade defines the 2nd General Competence (G.C.2) as *"Integrating specific acquired skills into actions to optimize health, physical growth and development and motor skills"*. And the specific competence 2.5 (C.S.2.5) for which the improvement intervention was carried out is *"Manifestation of appropriate indices of combined motor skills"*.

In this context, we propose to optimize the curriculum by adding an additional specific competence - C.S.8, which we have named: *Enhancing proprioceptive ability in motor acts and actions to increase student's awareness and increase their efficiency* (figure 5).

[1] [n.a.] = author's note: I will use hereafter the term psycho-neuro-motricity instead of psycho-motricity and/or neuro-motricity in order to emphasize the integrative nature of motor-related processes (cf. Hillerin, 2021).

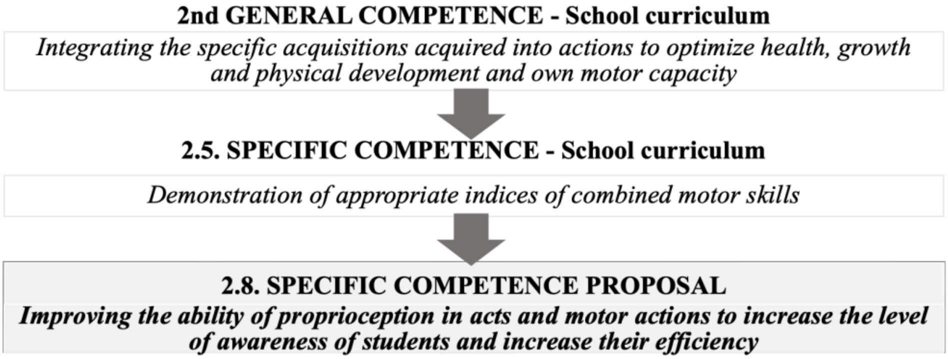


Figure. 5. Specific competence proposal for physical education curriculum

The exercise programmes for stimulating proprioceptors and therefore the coordination capacity, had the visual analyzer as a common denominator because the exercises were carried out by the students with both eyes open and closed. This proposed new strategy, implemented within the two school modules, during 14 weeks, 28 lesson plans, took into account the general and specific competence for which the intervention was carried out, as well as the new specific competence additionally proposed.

The proposed contents for proprioception specific competence are as follows:

- ❖ elements of organization of motor activities: development of cognitive processes through games and exercises for the awareness of the body scheme, the spirit of observation, the relation of the student's position to the spatial-temporal dimensions of the sport hall and the static and dynamic balance in the performance of learning tasks.
- ❖ elements of harmonious physical development: exercises to improve eye motor skills so that information from the visual analyzer improves perception of external features and the body's internal environment during motor acts and actions.
- ❖ motor skills: exercises to stimulate proprioceptors.

Therefore, studies (Camenidis et al., 2024; Iorga et al., 2024; Geantă & Hillerin, 2023; Geantă et al., 2022) have shown that physical exercise, regardless of the methods used, if based on programming and continuity, can generate beneficial cognitive effects that also depend on the variety of exteroceptive, proprioceptive, and interoceptive information. By acting with other innovative means to improve children's motor skills, proprioception, and the sensorimotor system contribute integrally to the growth and development of an individual, being beneficial for “balancing motor function and sensory experiences” (Valdes et al., 2023).

By employing tests such as “Body Sway”, “Flamingo”, “March in Place – MIP”, and “Circle” to both groups, we were able to assess and demonstrate the quality of proprioception. The results indicate that subjects in the experimental group (EG), compared to the control group (CG), succeeded in associating body schema with the four exercise quadrants, and that the ameliorative intervention programs represent innovative methods in evaluating the balance and coordination essential for the motor development of children.

Conclusions

The process of movement control is determined by the existence of internal models, ideomotor representations, so that the human body can evaluate the differences between planned movements and the concrete results achieved.

Through our study, we were able to demonstrate that the level of proprioception (in 3 out of 4 applied tests) can be optimized/developed by the experimental exercise programs used, evaluated with the following test possibilities:

- √ If we want to test proprioception through an action with closed eyes, the Body Sway test is also very good (Table 8, $p<0.05$).
- √ The Flamingo test is a very good test for all proprioception testing situations (Table 13, $p<0.05$). In experimental research, we found that the Flamingo test is suitable in proprioception testing, which is what the literature says. We have proven that it works and have strengthened the already existing positive arguments.
- √ If we want to test proprioception in a dynamic action, such as measuring jump distances, the Circle test is very good both for eyes open (Table 17, OD_DIST, $p<0.05$) and eyes closed (Table 17, OI_DIST, $p<0.05$). Therefore, this test is suggestive in demonstrating, in different ways, the superiority of the effectiveness of the experimental exercise programs.

The March in place – MIP test does not tell us anything from a statistical point of view (see table 20, $p>0.05$), so the test is irrelevant for testing some differences. Thus, we do not recommend this test for the evaluation of proprioception because proprioception is disturbed in both eyes-open and eyes-closed testing.

We consider it imperative for schools to have a physical education research laboratory equipped with digital equipment (currently absent from both public and private schools in Romania, existing only in specialized cabinets and other sports research organizations), providing measurement and research facilities readily accessible to physical education teachers. This would enable students to learn to distinguish between object and action, as well as to correct motor behavior deficiencies in real time. The differentiation between schools, sports clubs, and sports research organizations may limit a child's motor performance because real-time measurement of movement perception relative to an object may not always be clear as a sensorimotor representation, as response times "sometimes extend beyond the time of the operation itself" (Nadin, 1988).

Therefore, ameliorative intervention through optimized content focused on proprioception in formal physical education and sports lessons contributes to increasing awareness in improving proprioception quality, including balance, coordination, body schema, muscle elasticity, and joint mobility. Testing with specific digital equipment such as GyKo Microgate and OptoJump Next can be included in the assessment of children's motor skills, as they provide standardized data regarding the neuronal processing of sensory information in children. Therefore, real-time motor correction of incorrectly acquired or innate actions can be achieved.

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Authors contributions

All authors contributed equally to this work.

Conflicts of interest - If the authors have any conflicts of interest to declare.

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