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IMPROVING GENERAL COGNITIVE ABILITIES AND COGNITIVE ABILITIES SPECIFIC TO MOTOR ACTIVITIES THROUGH THE INFLUENCE OF BALANCE AND LATERALITY IN PREADOLESCENT STUDENTS

DOCTORAL THESIS SUMMARY

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INTRODUCTION

Preadolescence represents an essential stage in individual development, characterized by significant transformations at the cognitive and neuromotor levels. During this period, executive functions involved in attention, working memory, and inhibitory control are consolidated, alongside the progressive maturation of postural control mechanisms and lateral organization. The scientific literature highlights that cognitive development cannot be analyzed independently of sensorimotor integration processes, as these are supported by shared neural networks involved both in movement regulation and information processing.

Numerous studies have investigated the relationship between balance and cognitive performance, as well as between laterality and functional organization, suggesting the existence of interdependencies between neuromotor demands and executive processes. However, most studies address these dimensions separately, either from a motor or a cognitive perspective. The systematic integration of balance and laterality exercises into a unified protocol, explicitly oriented toward optimizing cognitive abilities in preadolescence, remains insufficiently explored in the current literature.

In this context, the present research aimed to clarify how the interaction between balance parameters, lateral organization, and cognitive performance manifests in preadolescence, and to what extent these relationships can be leveraged through structured neuromotor interventions. The research approach was structured in two successive stages: first, the identification of existing associations between these components, followed by the experimental testing of an integrated intervention protocol designed to simultaneously stimulate balance and laterality, with the aim of evaluating its impact on the development of cognitive abilities.

The present thesis is organized into two main parts. The first part is theoretical in nature and analyzes the conceptual foundations of cognitive development, neuromotor organization, balance, and laterality in preadolescence, highlighting both the relationships described in the scientific literature and the existing gaps.

The second part is dedicated to the original contributions and includes two research stages. In the first stage, a preliminary study was conducted, aimed at investigating the associations between balance parameters and cognitive performance, in order to support the development of the subsequent intervention.

In the second stage, based on the results obtained in the preliminary study, the main study was designed and implemented, within which an intervention program based on balance and laterality exercises was applied. The inclusion of the laterality component aimed to integrate a functional dimension relevant to cognitive processes, in accordance with the theoretical framework. The study focused on evaluating the effectiveness of the program on cognitive abilities.

Keywords: cognitive abilities, balance, functional laterality, motor intervention, preadolescent.

PART I – CURRENT PERSPECTIVES IN THE SCIENTIFIC LITERATURE

THEORETICAL CONCLUSIONS

The analysis of the literature highlights that preadolescence represents a developmental stage characterized by interdependent neurobiological, neuromotor, and cognitive processes. Motor control processes and higher cognitive functions evolve in an integrated manner, supported by shared mechanisms of neural organization and sensorimotor integration.

Postural balance and laterality emerge as indicators of neuromotor maturation, being involved not only in motor control but also in cognitive processes such as attention, planning, and executive control. The literature suggests that motor activities with increased demands for coordination, adaptation, and control can stimulate cognitive development.

Although there is evidence regarding the effects of balance and laterality exercises on cognitive functions, most studies analyze these components separately, with limited research integrating them within a unified framework. In this context, the need for integrated approaches becomes evident, aiming to investigate the combined impact of balance and laterality exercises on cognitive functioning in preadolescence.

PART II – ORIGINAL CONTRIBUTIONS

CHAPTER 5. PRELIMINARY STUDY ON THE INTERACTION BETWEEN BODY COMPOSITION, BALANCE, AND GENERAL COGNITIVE ABILITIES AND COGNITIVE ABILITIES SPECIFIC TO MOTOR ACTIVITIES IN PREADOLESCENTS

RESEARCH PREMISES

During late childhood and preadolescence, cognitive functioning and motor control are in an active process of maturation, being influenced not only by neurofunctional mechanisms but also by biological and functional factors that can modulate their efficiency (Borato et al., 2025; Costa e Silva et al., 2022). The scientific literature suggests that both postural balance and body composition may be involved in individual variations in cognitive performance, reflecting complex interactions between neuromotor and cognitive development. In this context, studies indicate that postural balance is not a strictly motor process, but is closely linked to cognitive functioning, being associated with executive processes such as attention, inhibition, and working memory during late childhood and preadolescence (Rigoli et al., 2012; Oberer et al., 2017). At the same time, the literature shows that studies conducted on children, adolescents, and young adults highlight negative associations between higher levels of body adiposity and performance in cognitive tasks, suggesting that excess body weight may be associated with reduced efficiency of cognitive control processes (Fabea et al., 2024; Lv et al., 2025; Tafuri et al., 2025). Overall, these findings support the need for an integrated analysis of postural balance and body composition in relation to cognitive functioning, particularly during preadolescence, when neuromotor and cognitive processes undergo a stage of reorganization and active maturation.

AIM, VARIABLES, AND RESEARCH HYPOTHESES

Aim of the Study

The aim of this preliminary study was to identify the levels of body composition parameters, balance, and cognitive abilities according to age and gender, and to examine whether certain parameters of body composition and balance are correlated with cognitive abilities in children aged 10–13 years.

Research Variables

- **Independent Variables**
  - Gender (M/F);
  - Age (years).

- **Dependent Variables**
  - Cognitive Abilities:
    - Response time in the attention test (s);
    - Number of correct responses in the attention test (score);
    - Number of incorrect responses in the attention test (score);
    - Response time in the visual memory test (s);
    - Number of correct responses in the visual memory test (score);
    - Number of incorrect responses in the visual memory test (score);
    - Response time in the working memory test (s);
    - Number of correct responses in the working memory test (score);
    - Number of incorrect responses in the working memory test (score);
    - Intelligence quotient (IQ score).
  - Body Composition Parameters:
    - Body weight (kg);
    - Body mass index (BMI) (kg/m^2);
    - Body fat mass (kg);
    - Body fat percentage (%);
    - Skeletal muscle mass (kg);
    - Skeletal muscle mass percentage (%).
  - Balance Parameters:
    - Area of the ellipse encompassing the center of pressure (cm^2);
    - Maximum and minimum force applied on the left/right plantar surface (kgf);
    - Dynamic balance (score).

Research Hypotheses

MAIN HYPOTHESIS 1: It is hypothesized that participants' age will determine differences in body composition parameters, static and dynamic balance, and cognitive abilities in preadolescent students.

Secondary Hypothesis 1.1.: Differences are expected between the two age groups (10–11 years and 12–13 years) in terms of body composition parameters.

Secondary Hypothesis 1.2.: Static and dynamic balance parameters are expected to differ between the age groups (10–11 years and 12–13 years).

Secondary Hypothesis 1.3.: The level of general cognitive abilities and motor activity-specific cognitive abilities is expected to vary between the age groups (10–11 years and 12–13 years).

MAIN HYPOTHESIS 2: It is hypothesized that gender differences exist in body composition parameters, static and dynamic balance, and cognitive abilities in preadolescents.

Secondary Hypothesis 2.1.: Body composition parameters are expected to differ according to participants' gender.

Secondary Hypothesis 2.2.: Static and dynamic balance parameters are expected to differ according to gender.

Secondary Hypothesis 2.3.: Differences are expected according to gender in both general cognitive abilities and motor activity-specific cognitive abilities.

MAIN HYPOTHESIS 3: It is hypothesized that associations exist between body composition parameters, static and dynamic balance, and cognitive abilities in preadolescents.

Secondary Hypothesis 3.1.: Associations are expected between body composition parameters and both general cognitive abilities and motor activity-specific cognitive abilities.

Secondary Hypothesis 3.2.: Associations are expected between static and dynamic balance parameters and both general cognitive abilities and motor activity-specific cognitive abilities.

PARTIAL CONCLUSIONS

Overall, the preliminary study indicates that the relationships between balance parameters and cognitive performance in preadolescence are not uniform, but vary according to age and gender, in the context of ongoing neuromotor and biological maturation. The 10–13 age range represents a transitional stage, during which postural control evolves from forms dependent on executive processes toward more automated and efficient forms.

The differences observed between groups suggest that, with increasing age, balance tasks require relatively fewer cognitive resources, while gender-related particularities reflect distinct developmental trajectories, without indicating the superiority of one gender over the other.

The correlational analysis revealed that the most relevant associations with cognitive performance were found in balance parameters and applied force, whereas body composition showed weak relationships with limited interpretative value. Although most correlations were of low to moderate magnitude, they support the existence of functional interactions between postural control, force, and executive processes.

Linear regression analyses confirmed that static balance and applied force contribute to explaining the variance in cognitive performance, including intelligence scores, in both genders, with certain age- and gender-specific particularities. However, these parameters do not act as exclusive predictors, but rather as partial contributors within a multifactorial system.

In conclusion, the hypotheses of the preliminary study were partially confirmed, and the results support the relevance of balance and force in the motor–cognition relationship, justifying further investigation through an experimental approach in the main study.

CHAPTER 6. MAIN STUDY ON THE INFLUENCE OF BALANCE AND LATERALITY ON COGNITIVE ABILITIES IN PREADOLESCENTS

RESEARCH PREMISES

The results of the preliminary study highlighted the existence of significant relationships, predominantly of low to moderate magnitude, between postural balance parameters, lower-limb applied force, and cognitive performance, particularly in relation to working memory, visual memory, and general intelligence. Although unevenly distributed, these associations suggest the existence of a functional link between postural control and higher cognitive processes. Regarding body composition, the identified relationships were weak and inconsistent, which supports its consideration as a secondary variable within the main study. At the same time, the literature indicates that laterality reflects the functional organization of the central nervous system and is associated with cognitive processes such as attention and executive functions, while bilateral coordination exercises may contribute to the optimization of cognitive performance (Tomas & Volkow, 2024; Chang et al., 2022; Wu et al., 2022). In this context, the integration of balance and laterality exercises into an intervention program is supported both by the results of the preliminary study and by findings from the scientific literature, outlining the premise that this approach may facilitate the simultaneous stimulation of motor and cognitive processes.

AIM, VARIABLES, AND RESEARCH HYPOTHESES

Aim of the Study

The aim of this study is to examine the effects of an intervention program based on balance and laterality exercises on general cognitive abilities and cognitive abilities specific to motor activities in preadolescents.

Research Variables

- **Independent Variables**
  - Intervention program;
  - Gender (M/F);
  - Age (years).
- **Dependent Variables**
  - *Cognitive Abilities*:
    - Response time in the attention test (s);
    - Number of correct responses in the attention test (score);
    - Response time in the visual memory test (s);
    - Number of correct responses in the visual memory test (score);
    - Response time in the working memory test (s);
    - Number of correct responses in the working memory test (score);
    - Intelligence quotient (IQ score).
  - *Balance Parameters*:

- Area of the ellipse enclosing the center of pressure points (cm^2);
- Intrapodal asymmetry index (medial–lateral).

➢ *Laterality*:

- Upper limb dominance;
- Ocular dominance;
- Lower limb dominance;
- Overall laterality.

➢ *Body Composition Parameters*:

- Body weight (kg);
- BMI (kg/m^2);
- Body fat (kg);
- Body fat percentage (%);
- Skeletal muscle mass (kg);
- Skeletal muscle mass percentage (%).

Ipotezele cercetării

MAIN HYPOTHESIS 1: It is hypothesized that the application of an intervention protocol based on balance and laterality exercises will be associated with improvements in both general cognitive abilities and motor activity-specific cognitive abilities in preadolescents.

Secondary Hypothesis 1.1.: It is hypothesized that the effects of the intervention protocol on both general cognitive abilities and motor activity-specific cognitive abilities will not differ between age groups (10–11 years vs. 12–13 years).

Secondary Hypothesis 1.2.: It is hypothesized that the effects of the intervention protocol on both general cognitive abilities and motor activity-specific cognitive abilities will not differ according to gender.

MAIN HYPOTHESIS 2: It is hypothesized that the implementation of an intervention protocol based on balance and laterality exercises will be associated with improvements in balance parameters, laterality, and body composition in preadolescents.

Secondary Hypothesis 2.1.: It is hypothesized that the effects of the intervention protocol on balance parameters, laterality, and body composition will not differ between age groups.

Secondary Hypothesis 2.2.: It is hypothesized that the effects of the intervention protocol on balance parameters, laterality, and body composition will not differ according to gender.

MAIN HYPOTHESIS 3: It is hypothesized that significant associations exist between balance parameters, laterality, body composition, and both general cognitive abilities and motor activity-specific cognitive abilities in preadolescents.

Secondary Hypothesis 3.1.: It is hypothesized that the strength of the associations between balance parameters, laterality, body composition, and cognitive abilities varies according to age.

Secondary Hypothesis 3.2.: It is hypothesized that the associations between balance parameters, laterality, body composition, and cognitive abilities differ according to gender.

Participants

The study included 224 students (aged 10–13 years), recruited from two secondary schools in Iași, Romania. Participants were assigned to an experimental group (n = 117) and a control group (n = 107), and were further categorized into two age groups: 10–11 years and 12–13 years.

Intervention Program

The experimental group followed an intervention protocol based on balance and laterality exercises, implemented over a period of 12 weeks (2 sessions per week). The program was progressively structured, with increasing task complexity, including exercises performed on unstable surfaces, with eyes closed, and combined tasks. The control group followed the regular physical education program.

RESULTS AND DISCUSSION

The analysis of the results from the main study aimed to evaluate the effectiveness of the intervention protocol on general cognitive abilities and motor activity–specific cognitive abilities, as well as to examine the influence of age and gender variables on the observed changes.

Table 6.1 Effects of the intervention protocol on cognitive abilities in the 10–11-year-old group

Cognitive ability assessed	**Statistical results**	**Experimental group 10-11 years**	**Control group 10-11 years**
	Number of subjects	69	63
Response time in the attention test	Adjusted post-test mean	**,771**	1,080
	Difference	**-0,309**	
	p-value	**0,001**	
	Effect size (ηp²)	**0,097**	
Correct responses in the attention test	Adjusted post-test mean	**13,45**	12,93
	Difference	**0,52**	
	p-value	**0,004**	
	Effect size (ηp²)	**0,061**	
Response time in the visual memory test	Adjusted post-test mean	0,399	0,467
	Difference	-0,068	
	p-value	0.171	
	Effect size (ηp²)	0,014	
Correct responses in the visual memory test	Adjusted post-test mean	**14,568**	14,108
	Difference	**0,460**	
	p-value	**0,014**	
	Effect size (ηp²)	**0,046**	
Response time in the working memory test	Adjusted post-test mean	1,153	1.287
	Difference	-0,134	
	p-value	0,104	
	Effect size (ηp²)	0,020	
Correct responses in the working memory test	Adjusted post-test mean	**12,86**	12,17
	Difference	**0,695**	
	p-value	**0,001**	
	Effect size (ηp²)	**0,128**	

IQ	Adjusted post-test mean	**111,28**	108,11
	Difference	**3,17**	
	p-value	**0,002**	
	Effect size (ηp²)	**0,074**	

Table 6.2 Effects of the intervention protocol on cognitive abilities in the 12–13-year-old group

Cognitive ability assessed	Statistical results	Experimental group 12-13 years	Control group 12-13 years
	Number of subjects	48	44
Response time in the attention test	Adjusted post-test mean	**0,696**	0,835
	Difference	**-0,139**	
	p-value	**0,030**	
	Effect size (ηp²)	**0,052**	
Correct responses in the attention test	Adjusted post-test mean	**13,71**	13,25
	Difference	**0,47**	
	p-value	**0,017**	
	Effect size (ηp²)	**0,063**	
Response time in the visual memory test	Adjusted post-test mean	0,355	0,444
	Difference	-0,089	
	p-value	0,168	
	Effect size (ηp²)	0,021	
Correct responses in the visual memory test	Adjusted post-test mean	**14,99**	14,42
	Difference	**0,56**	
	p-value	**0,003**	
	Effect size (ηp²)	**0,096**	
Response time in the working memory test	Adjusted post-test mean	1,055	1,152
	Difference	-0,097	
	p-value	0,250	
	Effect size (ηp²)	0,015	
Correct responses in the working memory test	Adjusted post-test mean	**13,02**	12,57
	Difference	**0,46**	
	p-value	**0,040**	
	Effect size (ηp²)	**0,047**	

IQ	Adjusted post-test mean	101,96	100,95
	Difference	1,02	
	p-value	0,197	
	Effect size (ηp²)	0,019	

Table 6.3 Effects of the intervention protocol on balance parameters in the 10–11-year-old group

Parameter assessed	**Statistical results**	**Experimental group 10-11 years**	**Control group 10-11 years**
	Number of subjects	69	63
A_RFeo_F (cm^2)	Adjusted post-test mean	**78,423**	159,569
	Difference	**81,146**	
	p-value	**0,017**	
	Effect size (ηp²)	**0,043**	
A_LFeo_F (cm^2)	Adjusted post-test mean	**70,204**	119,221
	Difference	**49,017**	
	p-value	**0,001**	
	Effect size (ηp²)	**0,141**	
A_RFec_F (cm^2)	Adjusted post-test mean	**371,732**	544,976
	Difference	**173,244**	
	p-value	**0,001**	
	Effect size (ηp²)	**0,107**	
A_LFec_F (cm^2)	Adjusted post-test mean	**437,014**	597,778
	Difference	**160,764**	
	p-value	**0,021**	
	Effect size (ηp²)	**0,041**	

Legend: A – Area of the ellipse enclosing the center of pressure points; RFeo – Right Foot, eyes open; LFeo – Left Foot, eyes open; RFec – Right Foot, eyes closed; LFec – Left Foot, eyes closed; F – Final testing.

Table 6.5. Effects of the intervention protocol on laterality in the 10–11-year-old group

Type of laterality	**Statistical tests**	**Experimental group 10-11 years**			**Control group 10-11 years**		
		Regression	No change	Improvement	Regression	No change	Improvement
Upper limb	Crosstabulation N (%)	17 24,6%	29 **42%**	23 **33,3%**	5 **7,9%**	43 68,3%	15 23,8%
	Chi square	$\chi^2(2)$=**10,701** p=**0,005**					
	Cramer's V	**0,285**					
Eye	Crosstabulation N (%)	17 24,6%	35 **50,7%**	17 **24,6%**	5 **7,9%**	45 71,4%	13 20,6%
	Chi square	$\chi^2(2)$=**8,073** p=**0,018**					
	Cramer's V	**0,247**					
Lower limb	Crosstabulation N (%)	17 24,6%	38 **55,1%**	14 **20,3%**	5 **7,9%**	51 81%	7 11,1%
	Chi square	$\chi^2(2)$=**10,527** p=**0,005**					
	Cramer's V	**0,282**					
Overall	Crosstabulation N (%)	15 21,7%	40 58%	14 20,3%	6 9,5%	45 71,4%	12 19%
	Chi square	$\chi^2(2)$=4,041 p=0,123					
	Cramer's V	0,175					

Table 6.6 Effects of the intervention protocol on balance parameters in the 12–13-year-old group

Parameter assessed	Statistical results	Experimental group 12-13 years	Control group 12-13 years
	Number of subjects	48	44
A_RFeo_F (cm^2)	Adjusted post-test mean	**62,832**	111,683
	Difference	**48,851**	
	p-value	**0,038**	
	Effect size (ηp²)	**0,047**	
A_LFeo_F (cm^2)	Adjusted post-test mean	82,631	98,266
	Difference	15,635	
	p-value	0,695	
	Effect size (ηp²)	0,002	
A_RFec_F (cm^2)	Adjusted post-test mean	472,796	667,268
	Difference	194,472	
	p-value	0,125	
	Effect size (ηp²)	0,026	
A_LFec_F (cm^2)	Adjusted post-test mean	**393,285**	692,394
	Difference	**299,109**	
	p-value	**0,026**	
	Effect size (ηp²)	**0,055**	

Legend: A – Area of the ellipse enclosing the center of pressure points; RFeo – Right Foot, eyes open; LFeo – Left Foot, eyes open; RFec – Right Foot, eyes closed; LFec – Left Foot, eyes closed; F – Final testing.

Table 6.12. Correlations observed within the statistical analysis using Pearson/Spearman correlation tests according to gender

Group	Correlation	RT_VM_I	RT_WM_I	RT_WM_F	CR_A_I
Girls (10–11 years)	**AI_MF_RFec_I**		r =0,407 p=0,006		
	AI_mF_RFeo_F			r =0,456 p=0,005	
	AI_mF_RFec_F			r =0,456 p=0,005	
Boys (12–13	**L_UL_Progress**		r =0,535		

years)			p=0,001		
Girls (12–13 years)	**AI_MF_RFec_I**	r =-0,422 p=0,007			
	AI_mF_LFec_I				r =-0,421 p=0,007

Legendă: AI – Asymmetry Index; MF – Maximum Force; mF – Mean Force; RFeo – Right Foot, eyes open; RFec - Right Foot, eyes closed; LFec - Left Foot, eyes closed; L – Laterality; UL – Upper Limb; RT – Response Time; CR – Correct Responses; VM – Visual Memory; WM – Working Memory; A – Attention test; I – Initial testing; F – Final testing; r – correlation coefficient; p – significance level.

PARTIAL CONCLUSIONS

The results indicate that the intervention led to improvements in cognitive performance, more pronounced in children aged 10–11 years, where increases were observed both in response speed and accuracy, as well as in IQ scores. In the 12–13 age group, the effects were smaller, mainly reflected in attention and response accuracy. Although differences in progression between groups were observed, the analysis did not reveal significant influences of age and gender on the recorded changes.

From a neuromotor perspective, the intervention had more evident effects on static balance, especially in children aged 10–11 years, while changes in laterality and intrapodal asymmetry were limited. The effects were similar between girls and boys, and body composition did not show significant changes.

The analysis of the relationships between neuromotor parameters and cognitive performance highlighted weak and non-uniform associations. Overall, the intervention contributed to the improvement of cognitive performance, supported by functional adaptations at the neuromotor level.

FINAL CONCLUSIONS

The results of the research confirm that interventions based on balance and laterality exercises can contribute to the improvement of cognitive performance in preadolescents, particularly in terms of processing speed and efficiency. The effects were more evident in children aged 10–11 years, suggesting greater sensitivity to neuromotor stimulation in the earlier stages of development.

From a neuromotor perspective, the intervention led to improvements in static balance, while changes in laterality and intrapodal asymmetry were limited and non-uniform, without a global reorganization of these parameters. No significant influences of age or gender on the effectiveness of the intervention were identified.

The relationships between neuromotor parameters and cognitive performance were weak, suggesting an integrative dynamic specific to the developmental stage, rather than direct cause–effect relationships.

The original contribution of the thesis lies in the development and implementation of an integrated protocol based on balance and laterality exercises, highlighting its potential to support cognitive development in preadolescence. From an applied perspective, the results support the integration of these exercises into educational and sports activities.

DISSEMINATION OF RESULTS

Mihuț, B.G., & Cojocariu, A.(2025). Review of the relationship between the level of cognitive abilities and that of physical development in preadolescents, *Sport and Society*, 25(1), 335–344. https://doi.org/10.36836/22-24/11/2024

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