BRAIN. Broad Research in Artificial Intelligence and Neuroscience
e-ISSN: 2067-3957 | p-ISSN: 2068-0473
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2024, Volume 15, Issue 4, pages: 154 -169.

Submitted: August 7th, 2024 | *Accepted for publication:* October 15th, 2024

Neural and Motor Differences in Acceleration and Running Speed of Children Aged 6 to 11 Years in the North-Eastern Part of Romania

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Abstract: *Acceleration and running speed develop in childhood based on biological growth. The research aims to compare, according to gender and age, the running times of 5, 10, and 15 m of children aged 6 to 11 years in the north-eastern area of Romania. Our proposed distance analysis is scarce in the literature and we want to enrich and update the existing data, especially for the north-eastern region of Romania. Our research included 3460 primary school students whom we grouped according to chronological age and gender. Using the TracTronix TF100, the 12 groups formed were measured for 5, 10, and 15 m running times during physical education classes. The first hypothesis states that boys will have higher acceleration and speed values. Second, we assume that growth from 6 to 11 years will improve acceleration and speed for both genders. The unpaired t-test and one-way ANOVA confirmed both hypotheses (p<0.05). Both criteria we tested influence acceleration and running speed. Boys achieved better times than girls in all three events, except for 5 m at 10 and 11. Advancing in age improves acceleration and speed, there is a stagnation from 10 to 11 years for both genders, as well as the 7-8 years threshold for boys. Our study reinforces the effect that gender and age have on children's acceleration and speed, and can be a benchmark for practitioners.*

Keywords: *cognitive development; running speed; attention; psychological metrics; primary school; neurocognitive growth.*

How to cite:. (2024). Trofin, P.F., Coteață, M.A., Honceriu, C., Ciobîcă, A.S., Mayroudis, I., Puni, R.A., Neural and Motor Differences in acceleration and running speed of children aged 6 to 11 years in the north-eastern part of Romania. *BRAIN. Broad Research in Artificial Intelligence and Neuroscience, 15*(4), 154-169. https://doi.org/10.70594/brain/15.4/12

1. Introduction

Movement is determined by the interaction between the central nervous system and the locomotor apparatus, which generates coordination, optimization, and motor learning (Čoh et al., 2010).

Motor and cognitive accumulations characterise childhood. Regarding the motor ones, it goes from reflex movements to sports ones, which appear between 7 and 14 years old. Motor training for children is recommended to increase their coordination, strength, endurance, and flexibility (Yapıcı et al., 2022). The former develops on a biological basis, and flexibility needs to be maintained throughout life (Utesch et al., 2018).

An advanced level of neuro-motor development during childhood and adolescence has been associated with higher levels of physical activity in adults (Holfelder & Schott, 2014). Thus, there is both a direct and indirect influence of neuro-motor capacity on levels of physical activity throughout life (Hulteen et al., 2018; Lloyd et al., 2014).

Brain maturation is analysed in two directions: functional and physiological. The first follows the efficiency of cognitive processes, and the second the characteristics of white and gray matter (Śmigasiewicz et al., 2021).

By the age of 7, approximately 95% of the adult nervous system is formed, and by 14 years they will reach their maximum volume. During life, the gray matter decreases and the white matter increases. The phenomenon is given by neural plasticity, which aims to permanently optimise the circuits needed for daily activity. At 10 years of age, boys reach their maximum volume of gray matter, followed by large accumulations in motor control between 10 and 12 years of age. This could be the age range where speed can be trained (Meyers R., 2016).

At the primary school level, children are at specific ages for the development of speed in most of its forms: running, reacting, decision-making, etc. All components of speed (ability to change direction quickly, acceleration, reaction speed, etc.) tend to develop during childhood as children grow and mature (Hammami et al., 2015; Vando et al., 2013; Vando et al., 2013)

Neuroplasticity is present in the child's development, involving mechanisms of cell construction and destruction, and the nervous system constantly seeking to contribute to the optimization of the body's functional processes (Hüppi, 2010).

The biological maturation of the white and gray matter determines the improvement of the speed and efficiency of neural processes. It increases the quality of information transfer, as well as the timing of cortical areas. These aspects give the neural network better performance. With the maturation of the last component of the brain, the prefrontal cortex, cognitive ability evolves in parallel. Getting older has been associated with an improvement in working memory, which allows the performance of tasks, including motor skills (Myatchin & Lagae, 2013). The child manages, through the biological complexity created at the level of the nervous system, to adapt to be able to store sociocognitive skills (Hüppi, 2010).

White matter matures during childhood and adolescence, the process extending into adulthood. This process improves the speed of axonal transmission of nerve impulses and the communication between the cortical networks created (Scantlebury et al., 2014). The structural changes of the nervous system are associated with the experiences lived and the learning that an individual has during adulthood (Hüppi, 2010).

Myelination and growth of axons can cause a decrease in latency. Reorganization of nervous matter may be accompanied by an improvement in reaction speed through neuromotor adaptation. The determination of the reaction time can be accompanied by a pre-innervation, which would lead to its reduction. Preinnervation could be activated by the previous experience of the analysed individual (Fietzek et al., 2000).

Depending on the complexity of the physical effort, the area of the primary motor cortex is activated upwards, as shown by magnetic resonance recordings. The intensity of the nerve signal transmitted follows the intensity of the physical effort (Carson, 2006).

Reaction speed is an indicator of neural functionality. In children, evaluated in simple conditions, it registers an improvement between 6 and 12 years, and in complex conditions, it maintains its value between 6 and 11 years, then increases until 14-16 years. In this way, the involvement of memory in complex tasks can be highlighted (Myatchin & Lagae, 2013).

Reaction speed is measured in practice by timing the difference between the appearance of a stimulus and the voluntary response, usually manifested by a motor act. Its value was used to estimate information processing speed, with adults having better values due to the structural organization of the white matter. The response is influenced by the transfer of information through the inferior fronto-occipital bundle (Scantlebury et al., 2014).

The child's cognitive development is non-linear, being related to reaction speed. Response time consists of premotor and motor time. Increasing age leads to a reduction in premotor time, which has a high weight in children (Śmigasiewicz et al., 2021).

Motor performance can be classified according to the neural control mechanism. Simple movements of a segment can be considered less complex than those in which the perception and coordinated execution of contractions are required. Repetitive movements, such as running, could be in the middle zone. Departure includes the reaction speed by which the body can trigger the contractions necessary for acceleration (Fietzek et al., 2000).

Motor performance is determined by muscular endurance and the power that can be generated by voluntary contraction. Strength can be associated with thickened muscle fibers and endurance with a high oxidative capacity (Zwaard et al., 2018).

Speed is one of the motor qualities that is very difficult to develop, being dependent on the central nervous system that can influence muscle coordination. As the speed of a movement increases, nervous control decreases. Thus, at maximum speed, the nervous control of the movement is the least. Nerve signals depart from the cerebellum and spinal cord, and the intensity of the processes carried out does not allow the analysis of proprioceptive information and correction (Čoh et al., 2010).

Muscle coordination is based on synergistic actions. They are made with motoneurons and motor units, to create mechanisms through which the central nervous system can control and integrate them into a functional ensemble. The repeatability of physical training leads to automation of neural mechanisms and easier execution of movements in already-known conditions (Carson, 2006).

Movement speed is an important parameter that determines sports success in most disciplines. It has as factors: morpho-functional characteristics, available energy sources, age, gender, motor training, muscle coordination, biomechanical characteristics, etc. To perform at a high level, he needs the high speed of execution of movements, strength, and coordination (Čoh et al., 2010).

Running speed includes 3 components: acceleration, reaching maximum speed, and deceleration (Čoh et al., 2010).

Running speed is influenced by environmental, equipment, biomechanical, and psycho-physiological factors. Very well-coordinated actions of antagonistic and synergistic muscles can attract a good time to cover a predetermined distance. While running, each muscle must generate the maximum force possible, in the appropriate time frame and moment. Functional asymmetries appear whereby some joints flex, others extend and bilaterally the force is the same. Even though it seems like only the lower train is engaged in the effort, the upper train is very important in balancing the body throughout the effort. Thus, running speed acquires the characteristics of a complex physical effort (Majumdar & Robergs, 2011).

There is a positive influence of anthropometric measures, strength, and power on running speed (Meyers et al., 2017).

In children, the following were indicated as factors of running speed: muscle power, horizontal propulsive force, stride length, and ground contact time. The biological maturation of boys leads to an increase in the frequency and length of steps (Meyers et al., 2017).

The ability to run at high speed is given by muscle synergies that develop with age in children (Bach et al., 2021). Neuromuscular adaptations, noted as the main reason for improved sprinting performance, indicated physical training based on running speed exercises with a permanent effect on children still growing, as the neural system is not fully mature (Pettersen & Mathisen, 2012).

Reaction speed is of particular importance in running a sprint race. From the moment of the start signal, a series of triggering mechanisms of strong muscle contractions begin, which have the role of propelling the runner as strongly as possible. However, existing data do not significantly associate reaction speed with performance (Valamatos et al., 2022).

Muscle strength is a basic factor in developing high running speed. Its manifestation is conditioned by the percentage of muscle fibers that have been selected by the nervous system for contraction. At the same time, intra-muscular and inter-muscular coordination takes place. Professional sprinters have very good muscle coordination. The nervous system contributes to a sprinter's muscle contraction through muscle fiber activation and deactivation, impulse frequency, and fiber innervation timing. The type of muscle fiber is a determining factor for obtaining a good running speed. The white ones, which excite 4 times faster than the slow ones, are an asset for children entering the selection of a sport whose specifics require speed. Training makes fast-twitch fiber selectivity possible after a long period of training, so the best-trained athletes can manage white fibers. More than 60 lower limb muscles are involved during a sprint. To produce a maximum motor potential, a very good coordination of them is necessary. The movements performed require muscles that contract, but also some that relax to create the optimal conditions for biomechanical executions as close as possible to a kinematic model (Čoh et al., 2010; Van Praagh, 2000).

Of course, it's not just strength training that will improve running performance, but combining it with running speed as well (Majumdar & Robergs, 2011).

It was assumed that physical skills that come into relation with cognitive ones need nervous control to be performed at a high level. Neurocognitive executive functions were divided into 3: inhibition, working memory, and cognitive flexibility. The first cancels the child's attention to other tasks than the one he is about to perform. The second retains only the information necessary to perform the motor action. The third makes it possible to adapt to different environmental conditions and demands. All three are found in the psycho-social needs of the child (Bruijn et al., 2023).

There are links between physical capabilities, neurocognitive abilities, and school performance, but the mechanism leading to these interdependencies is not yet being clarified. The area of neurocognitive skills includes attention, memory, and visual processing, important elements in sports practice, where they could contribute to taking information from the coach in order to improve motor performance (Bruijn et al., 2023).

Cardiovascular fitness has been found to correlate with neurocognitive abilities in children and adolescents. Throwing and catching the ball, running, jumping, and balance have been added (Bruijn et al., 2023).

Compared to the age range of 10-12 years, higher physical performance was observed among boys, compared to girls, in the testing of trunk muscle strength, lower limb explosive strength, 20 m running speed, and agility (Katić et al., 2012).

Continuous updating of the student speed assessment scale is necessary to be able to assess the evolution of the two parameters. Standardisation of measurement is very important so that data can be accurately reported to other statistical populations or even to one's results through longitudinal monitoring.

We wish to complement the literature with values of running times for distances from 5 to 15 m, as these are rarely used in existing research and are suitable for children under 11 years of age, in our opinion. These data could reflect the neuromuscular changes that children go through.

This research aims to compare, according to gender and age, the level of running speed over distances of 5, 10, and 15 m of children aged 6 to 11 years in the north-eastern area of Romania.

Thus, we aim to test whether gender influences running speed over 5, 10, and 15 m, and whether advancing age modifies running speed over these distances. The boundary between acceleration and speed is generally set at 10 m, we consider that the 5 m event appreciates acceleration and the 10 and 15 m event speed, given the anthropometric characteristics of children under 11 years old.

We assume that boys will have higher values of the times obtained by timing running the three distances for the age range 6-11 years. At the same time, our second hypothesis aims to confirm the impact of age-determined biological development in the 6-11 year age range on the increase in running speed for girls and boys.

2. Material and methods

2.1. Participants

The research subjects are 3460 students aged 6-11 years (6 years: 124 girls and 137 boys; 7 years: 290 girls and 331 boys; 8 years: 415 girls and 372 boys; 9 years: 340 girls and 359 boys; 10 years: 346 girls and 346 boys; 11 years: 185 girls and 215 boys).

The study was made possible through a research partnership between the University "Alexandru Ioan Cuza" of Iasi and the Iasi County School Inspectorate (no. 1804/04.02.2022), which allowed the research team access to 47 schools in Iasi County, Romania.

Teachers, students, and their legal representatives were informed about our action through documents specifying the aim, objectives, and working methodology: the information brochure, the agreement between the partner institutions, and the draft parental agreement to be completed and signed. The subjects' participation in the measurements was voluntary and conditional on the existence of a signed parental agreement.

The conduct of the research was approved by the Scientific Research Ethics Committee of the Faculty of Physical Education and Sport of Iasi (no. 23/28.02.2023).

2.2. Measures

The team of evaluators of the project was formed by members of the Sports Selection and Counselling Centre of the Faculty of Physical Education and Sport of "Alexandru Ioan Cuza" University of Iasi (Romania).

The evaluators were trained before the field tests started through simulations with control samples to optimise the application of the evaluation protocol. Each student in the sample was measured by the research team during the physical education classes they had in the school program. Teachers in the schools assisted with the measurements and had an organisational role, as they knew the students best.

The measurement was carried out in 2 stages:

1. Indoor–anthropometric characteristics: height (cm) and body mass (kg);
2. Outdoor – acceleration and running speed (5, 10 and 15 m - s).

2.2.1. Anthropometry

Height and body mass were measured in the students' classroom. For height, a horizontal surface was sought on which the student was placed sitting. The student was instructed to maintain as upright a position as possible, facing forward. A Handy electronic level was used, together with a Bosch Professional GLM80 rangefinder (Gerlingen-Schillerhöhe, Germany) placed on the subject's head. The reading of the height value was made when the level indicated an inclination below 0.5 degrees and the laser beam of the rangefinder was projected vertically on the ground. We chose this method of measurement because of the need to adapt to any measuring conditions. Two Omron BF511 analysers were used for body mass to optimise the waiting times.

2.2.2. Acceleration and running speed

Before each test, students were given precise instructions on how to run the test. The children warmed up under the guidance of the physical education and sports teacher for 10-15 minutes. During this time, distances of 5, 10, and 15 m from the start line were marked on a horizontal surface in the school sports ground using cones. Then, TracTronix TF100 (Lenexa, KS, USA) beam gates were placed at each lane line. At the end of the warm-up, students were picked up by the teacher for measurement of running speed. At the evaluator's signal, the tested student took off at will running down the marked lane trying to reach maximum speed as quickly as possible. The students were instructed to run the 20 m distance, marked by the finish line, to avoid deceleration until the last distance assessed (15 m).

Each child was given 2 repetitions for which the 3 results indicated by the timing system were scored. Between repetitions, there was a break of 3-5 minutes, sufficient for energy restoration.

The data were noted on tablets that had the result sheets, these had two levels of backup: audio recording made by the tablet and audio-video recording with 2 Sony Handycam HDR-CX240E cameras, positioned sideways and behind the children. Based on the audio recordings from the tablets, all results were checked for scoring errors.

2.3. Statistical analysis

Subjects' results were expressed as mean and standard deviation. Outliers were removed from the initial database using the ROUT method (Q=1). Gender differences were assessed with the unpaired t-test, and the effect size was estimated with Cohen's d-value (0.2 – small, 0.5 – medium, and 0.8 – large) (Fagerland, 2012; Cahusac & Mansour, 2022; Poncet et al., 2016; Iacobucci et al., 2023). The measure of differences between age groups for each sample was calculated with the one-way ANOVA test, and particular differences were identified by Tukey's multiple comparisons test. The Kolmogorov–Smirnov test verified the normality of the distribution of the data (Bilon, 2023). The groups analysed were made up of girls and boys, from 6 to 11 years old, aged at the time of the field tests. The significance threshold was set at 0.05. Data analysis was performed using GraphPad Prism 9.3.0 (GraphPad Software Inc.).

3. Results

Statistical analysis of the data aimed to synthesise information related to anthropometric parameters, and differences in running times by gender, and age. The central trend parameters used were mean and standard deviation.

Table 1 - Anthropometric characteristics and un-paired t-test results for gender difference

Group	Height (cm, M ± SD)	Weight (kg, M ± SD)	BMI (kg/m2, M ± SD)
G_6	121.5 ± 5.5	24.09 ± 4.72**	15.97 ± 2
B_6	121.1 ± 5.72	22.72 ± 3.1	15.59 ± 1.69
G_7	125.2 ± 6.14	25.63 ± 4.75	16.35 ± 2.21
B_7	126.1 ± 6.17	26.53 ± 5.1*	16.55 ± 2.11
G_8	131.4 ± 6.59	29.96 ± 6.36	17.2 ± 2.57
B_8	132.1 ± 6.42	30.95 ± 7.44*	17.57 ± 3.06
G_9	137 ± 6.94	33.93 ± 8.4	17.74 ± 3.03**
B_9	137.3 ± 6.61	35.08 ± 9.02	18.48 ± 3.67
G_10	143.9 ± 7.36**	38.71 ± 9.4	18.22 ± 3.06
B_10	142.2 ± 6.56	37.67 ± 8.53	18.52 ± 3.23
G_11	148.4 ± 7.74	42.13 ± 11.24	18.99 ± 4.01
B_11	147 ± 7.8	41.75 ± 10.66	19.04 ± 3.66

*Note: Expressed as Mean ± Standard Deviation; G_6 (to 11) – girls of 6 (to 11 years); B_6 (to 11) – boys of 6 (to 11 years); * / ** / *** / **** – significantly different with p<0.05, p<0.01, p<0.001, respectively p<0.0001.*

Table 1 shows the anthropometric characteristics of the subjects. Gender differences exist in isolation for the three measured parameters. Height is different at age 10 (t=3.13 (689), p=0.002, d=-0.24), with girls being taller. They are also heavier at age 6 (t=2.75 (250), p=0.006, d=-0.34), with boys increasing in body mass at age 7 (t=2.23 (599), p=0.026, d=0.18) and 8 years (t=2.00 (771), p=0.045, d=0.14), respectively. At 9 years, boys have a higher BMI than girls (t=2.87 (687), p=0.004, d=0.22), with the other ages approaching the values.

Differences in acceleration and running speed according to gender are shown by the t-test results for each test. Up to the age of 10 years, the difference in running time over 5, 10, and 15 m between girls and boys is significant ($p<0.05$), with advancing age reducing the difference for the 5 m distance (Figure 1). Cohen's d indicates a medium effect of gender from 6 to 9 years, becoming small for 10 and 11 years.

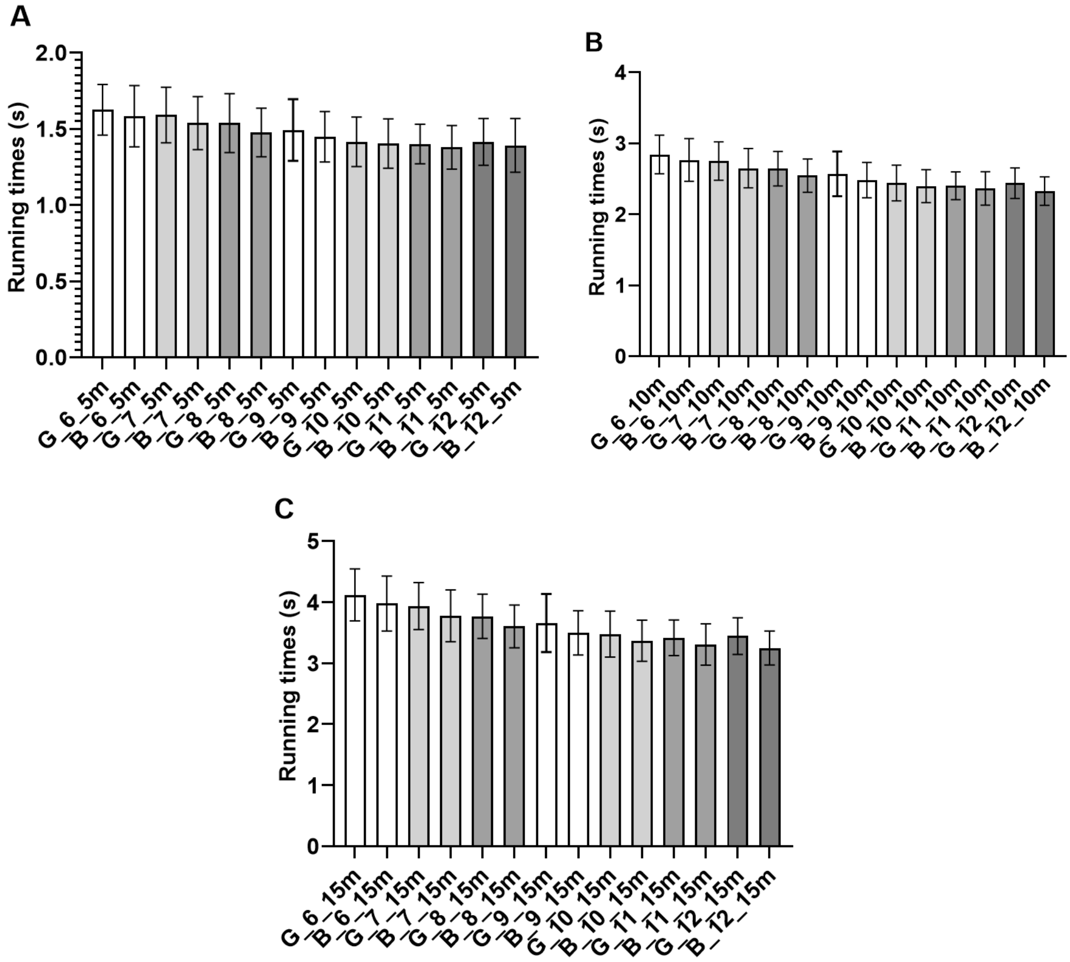

Figure 1. Gender differences of running times, according to unpaired t-test for 5 m (A), 10 m (B), and 15 m (C) (G – girls; B - Boys)

Age affects the change in running times over the three distances analysed. Comparison of girls' results with One-Way Anova demonstrates the age-driven difference for 5 m ($F_{(5,\ 1585)}=72.45$, $p<0.0001$), 10 m ($F_{(5,\ 1580)}=110.1$, $p<0.0001$) and 15 m ($F_{(5,\ 1568)}=107.9$, $p<0.0001$) running times (Table 2).

Table 2. Age differences in girls running times, according to the One-Way ANOVA test

Group	5 m (s, M ± SD)	10 m (s, M ± SD)	15 m (s, M ± SD)
G_6	1.63 ± 0.17	2.83 ± 0.26	4.12 ± 0.43
G_7	1.58 ± 0.14	2.74 ± 0.23	3.94 ± 0.38
G_8	1.53 ± 0.15	2.63 ± 0.22	3.76 ± 0.35
G_9	1.48 ± 0.15	2.54 ± 0.22	3.63 ± 0.34
G_10	1.41 ± 0.15	2.43 ± 0.23	3.47 ± 0.35

G_11	1.4 ± 0.13	2.4 ± 0.2	3.42 ± 0.29
F / p	$F_{(5, 1585)}$ = 72.45 / p<0.0001	$F_{(5, 1580)}$ = 110.1 / p<0.0001	$F_{(5, 1568)}$ = 107.9 / p<0.0001

*Note: Expressed as Mean ± Standard Deviation; G_6 (to 11) – girls of 6 (to 11 years); * / ** / *** / **** – significantly different with p<0.05, p<0.01, p<0.001, respectively p<0.0001.*

Running times of boys, like those of girls, indicate an influence of growth on anaerobic potential. Thus, for 5 m ($F_{(5, 1647)}$=51.17, p<0.0001), 10 m ($F_{(5, 1644)}$=88.29, p<0.0001), and 15 m ($F_{(5, 1614)}$=106.6, p<0.0001) a development of the results is observed, with boys managing to cover the distances in shorter and shorter times (Table 3).

Table 3. Age differences in boys running times, according to the One-Way ANOVA test

Group	5 m (s, M ± SD)	10 m (s, M ± SD)	15 m (s, M ± SD)
B_6	1.56±0.14	2.73 ± 0.23	3.94 ± 0.37
B_7	1.53 ± 0.16	2.63 ± 0.25	3.73 ± 0.35
B_8	1.47 ± 0.14	2.53 ± 0.21	3.59 ± 0.32
B_9	1.44 ± 0.14	2.46 ± 0.21	3.48 ± 0.3
B_10	1.4 ± 0.15	2.39 ± 0.22	3.36 ± 0.32
B_11	1.38 ± 0.14	2.34 ± 0.19	3.28 ± 0.26
F / p	$F_{(5, 1647)}$=51.17 / p<0.0001	$F_{(5, 1644)}$=88.29 / p<0.0001	$F_{(5, 1614)}$=106.6 / p<0.0001

*Note: Expressed as Mean ± Standard Deviation; B_6 (to 11) – boys of 6 (to 11 years); * / ** / *** / **** – significantly different with p<0.05, p<0.01, p<0.001, respectively p<0.0001.*

One-Way ANOVA analysis confirms the intervention of age change in increasing the acceleration and running speed of girls as well as boys. Our interest is in the particular differences that exist between the running times of children aged 6 to 11 years. The gender difference is demonstrated, so we continued the analysis for girls and boys to identify the magnitude of the difference due to chronological age.

Tukey's multiple comparisons test compared running times for each of the three proposed distances.

Tables 4 and 5 show the significance of the differences between the data series of each age for girls and boys respectively. Due to the exclusion of outliers, the number of results of each age group varies from distance to distance.

The increase for girls brings an increase in acceleration and running speed (p<0.05), the exception being the increase from 10 to 11 years for running the three test distances (Table 4).

Table 4. Adjusted p-value of Tukey's multiple comparisons test results for running time on girls sample

	Distance	N	G_6	G_7	G_8	G_9	G_10
G_6	5 m	114					
	10 m	113					
	15 m	109					
G_7	5 m	268	0.044*				
	10 m	269	0.0015**				
	15 m	259	<0.0001****				
G_8	5 m	390	<0.0001****	0.0002***			
	10 m	387	<0.0001****	<0.0001****			
	15 m	386	<0.0001****	<0.0001****			
G_9	5 m	329	<0.0001****	<0.0001****	0.0003***		
	10 m	327	<0.0001****	<0.0001****	<0.0001****		
	15 m	329	<0.0001****	<0.0001****	<0.0001****		
G_10	5 m	322	<0.0001****	<0.0001****	<0.0001****	<0.0001****	
	10 m	322	<0.0001****	<0.0001****	<0.0001****	<0.0001****	
	15 m	323	<0.0001****	<0.0001****	<0.0001****	<0.0001****	
G_11	5 m	168	<0.0001****	<0.0001****	<0.0001****	<0.0001****	0.981
	10 m	168	<0.0001****	<0.0001****	<0.0001****	<0.0001****	0.718
	15 m	168	<0.0001****	<0.0001****	<0.0001****	<0.0001****	0.601

*Note: G_6 (to 11) – girls of 6 (to 11 years); * / ** / *** / **** – significantly different with p<0.05, p<0.01, p<0.001, respectively p<0.0001.*

For boys, acceleration and running speed show the same changes as for girls, with little difference in the comparison between ages 6 and 7 years in acceleration (Table 5).

Table 5. Adjusted p-value of Tukey's multiple comparisons test results for 5 m running time on boys' sample

	Distance	N	B_6	B_7	B_8	B_9	B_10
B_6	5 m	119					
	10 m	119					
	15 m	110					
B_7	5 m	307	0.405				
	10 m	306	0.0005***				
	15 m	287	<0.0001****				
B_8	5 m	356	<0.0001****	<0.0001****			
	10 m	356	<0.0001****	<0.0001****			
	15 m	354	<0.0001****	<0.0001****			
B_9	5 m	345	<0.0001****	<0.0001****	0.04*		
	10 m	346	<0.0001****	<0.0001****	0.0005***		
	15 m	347	<0.0001****	<0.0001****	<0.0001****		
B_10	5 m	328	<0.0001****	<0.0001****	<0.0001****	0.012*	
	10 m	329	<0.0001****	<0.0001****	<0.0001****	0.0004***	
	15 m	327	<0.0001****	<0.0001****	<0.0001****	<0.0001****	
B_11	5 m	198	<0.0001****	<0.0001****	<0.0001****	<0.0001****	0.491
	10 m	194	<0.0001****	<0.0001****	<0.0001****	<0.0001****	0.099
	15 m	195	<0.0001****	<0.0001****	<0.0001****	<0.0001****	0.051

*Note: B_6 (to 11) – boys of 6 (to 11 years); * / ** / *** / **** – significantly different with p<0.05, p<0.01, p<0.001, respectively p<0.0001.*

4. Discussion

Our study is based on the concern for important motor quality in children. Speed in its forms of manifestation reflects a well-functioning locomotor system as well as the nervous control that the child exerts over muscles. The motor intensity developed by the child depends on the strength of the nervous system (Polevoy G., 2021; Polevoy G., 2018). Intensely reviewed in the literature, running speed is easy to measure, assess, and monitor. Its level can be linked to the health status and exercise capacity of a human individual.

Differences in 5-15 m running speed by gender

A comparison of girls and boys for the times obtained in running each distance at speed revealed the expected differences (Figure 1). Boys have a better time running each interval (5, 10, and 15 m) than girls, except for 5 m at 10 and 11 years. Thus, girls catch up with boys in acceleration as they get older, which is supported by the change in the central tendency of the data series. The narrowing of the 5 m time difference may be due to the biological change in the female body. The explanation of these differences could be related to the body composition of boys who, compared to girls, at prepubertal age have higher values of appendicular skeletal muscle mass and the ratio between muscle mass and fat (muscle-to-fat ratio), as well as a reduced percentage of body fat (Brener et al., 2021). They exceeded the height of boys at 10 years (G_10=143.9±7.36 cm vs. B_10=142.2±6.56 cm, $p=0.002$) and kept their weight on the same trend (Table 1). Regarding 10 and 15 m running, the difference is maintained throughout the age range of 6-11 years. The first hypothesis is confirmed (Brener et al., 2021).

Evolution of running speed on 5 - 15 m according to age

Our interest also focused on changes in running speed according to chronological age. Table 2 supports the second hypothesis in the girls' group, the largest difference being in the 10 m running test ($F_{(5,\ 1580)}=110.1$, $p<0.0001$). The same are the results of the boys (Table 4), instead the largest difference being given by the 15 m test ($F_{(5,\ 1614)}=106.6$, $p<0.0001$). With these results, the second hypothesis is confirmed, according to which the increase from 6 to 11 years brings an improvement in the speed of girls and boys.

The results of Tukey's multiple comparisons test can fill in the overall picture of age-related changes. Except for the comparison between 10 and 11 years old, girls' running speed increased from one year to the next ($p<0.05$). The age of 11 years no longer brings progress compared to 10 years for 5 m (G_10=1.41±0.15 s vs. G_11=1.4±0.13 s, $p=0.981$), 10 m (G_10=2.43±0.23 s vs. G_11=2.4±0.2 s, $p=0.718$) and 15 m (G_10=3.47±0.35 s vs. G_11=3.42±0.29 s, $p=0.601$) (Table 2 and Table 4).

Boys fall on the same age-dependent changes, with moreover a closeness of values for 5 m between 6 and 7 years (B_6=1.56±0.14 s vs. B_7=1.53±0.16 s, $p=0.405$) (Table 5). This shows the biological stagnation that is holding back the support needed for acceleration. The transition from 10 to 11 brings a stagnation of the times obtained for 5 m (G_10=1.41±0.15 s vs. B_11=1.38±0.14 s, $p=0.491$), 10 m (B_10=2.39±0.22 s vs. B_11=2.34±0.19 s, $p=0.099$) and 15 m (B_10=3.36±0.32 s vs. B_11=3.28±0.26 s, $p=0.051$) (Table 3 and Table 5). This maintenance of running speed could be due to delayed skeletal maturation in boys during this time frame (Duckham et al., 2021). Furthermore, at 10 years of age girls in our sample are taller than boys (Table 1) based on a growth plot. In this way, the biomechanics of running can be modified, with longer segments becoming important levers for an efficient effort. The factors that determine the maintenance of speed between 10 and 11 years in children from the north-east of Romania can be researched through the concentrated analysis of this category.

Comparison of our results with existing

The north-eastern area of Romania is characterised by a low socioeconomic status, especially in the rural area, which faces an aging population (Horea-Serban & Fîrţală, 2022). Most of the children measured by us are from rural areas located in hilly areas. This fact can modify the morphological characteristics that could positively influence physical performance, including speed. Reporting to other children from existing studies is complicated by the methodological approach of the research.

Hammani et al. (2015) used two of our proposed distances in their research to measure the running speed of a group of 84 students aged 14±1 years. They ran 5 m (1.28±0.08 s), 10 m (2.18±0.12 s), 20 m (3.42±0.28 s) and 30 m (5.30±0.35 s).

Ceylan et al. (2014) tested 945 children's (7-12 years) 30 m speed differences. Gender differences are in agreement with our results, with boys' times being better than girls'. Comparison between age groups identified the same stagnation in running speed from age 10 onwards in boys, with girls having close values between ages 9 and 10 as well as 11-12. In running speed, an important role is played by coordination, which increases with age.

Other specialists followed the trend in the physical performance of first graders over 10 years (2006-2015), assessing 441 to 552 children (6.76±0.56 years) each year. The results of the 5001 students (50.8% boys) recorded in the 20 m distance running speed test were better from one generation to the next, this being noticeable in both genders (Spengler et al., 2017).

Another group of 15548 children (7840 girls and 7708 boys) aged 9-12 years (grades 4-6) were studied in order to determine health status and to establish baseline values for physical ability levels. This was quantified by measuring lower body explosive strength, agility, aerobic capacity, and 30 m running speed. An increase in physical performance was noted with age (Aimar et al., 2023).

(Manna et al., 2014) tested the 30 m running speed of a sample of 50 pre-pubertal children (11.0±0.8 years), their result was 6.6±0.3 s. At the same time, two other groups (pubertal and post-pubertal) were evaluated, each of which obtained better times. The results were reasoned based on biological growth.

Considering gender and stage of maturity in a group of 113 children (9-12 years), differences were observed between girls (n=68) and boys (n=45) in 20 and 30 m running speed, with boys performing better than girls ($p \leq 0.05$) (Meylan et al., 2014).

The effect of relative age on running speed was also tested by Wattie et al. (2014) on a group of 1218 German children (9.72±0.45 years, 142±0.07 cm, 36±7.50 kg). They were divided into 2 groups of 9 and 10 years. The running distance used was 20 m and they checked whether the month of birth influences speed, the result was positive. Boys born in July-September (4.03±0.31 s) and October-December (4.04±0.28 s) performed better than those born in April-June (4.15±0.33 s). However, the girls' speed was without differences.

Veligekas et al. (2012) examined the links between the standing long jump and running speeds over 10 and 30 m. The study group ranged in age from 9 to 12 years (66 girls and 59 boys). A lack of progress in 10 m running speed was demonstrated for children aged 10 (girls=2.27±0.1 s, boys=2.25±0.2 s) and 11 years respectively (girls=2.21±0.1 s, boys=2.21±0.1 s).

Papaiakovou et al. (2009) measured the running speed of 360 children aged 7 to 18 years. According to gender, boys ran better over the 10 m distance, with speed increasing more after 16 years. Age made significant differences for intervals of at least 2 years, with girls having a faster increase in speed. In our case, the differences were given by each year.

According to growth velocity, girls record a better time over the 50 m distance at ages 11 and 16 if maturation occurred earlier. In contrast, boys between the ages of 8 and 11 do not show the same tendency. In the 12-16 age group, boys who mature early cover the 50 m distance in a shorter time (Sokołowski & Chrzanowska, 2012).

Optimising acceleration and running speed

There is research aimed at improving running speed by following specific programmes. Applying them in practice can benefit children, especially at the right age for speed development. (Kotzamanidis, 2006) followed the development of running speed in a group of children (n=15, 11.1±0.5 years) who had completed 20 training sessions based on plyometric exercises for 10 weeks, and a control group (n=15, 10.9±0.7 years) who had followed the actual physical education programme. The first group was found to improve their running speed over 20 and 30 m. On 10 m, the changes were insignificant (initial=2.24±0.10 s vs. final 2.19±0.08 s). The same point on the improvement of running speed at 20 m is supported by (Pettersen and Mathisen, 2012). They studied the effects of a 6-week (1 hour per week) program of play-based running speed exercise activities on the 10 and 20 m running performance of two groups (experimental-14 children, 11.5±0.3 years; control-11 children, 11.4±0.3 years) of local-level soccer players. Running time over the 10 m distance decreased significantly from 2.29±0.12 s to 2.24± 0.11 s.

Bushati S. and Bushati M. (2021) assessed the running speed of a group of 100 students (50 girls, 50 boys) aged 6-10 years before and after the implementation of a 10-week program of playful physical activities included in physical education classes. Between the experimental group (the one that followed the activity programme) and the control group (which followed the actual structure of the class), given the results of the 25 m speed test carried out after the 10 weeks, an improvement in times of 0.07 s was observed for boys in 1st grade, 0.19 s for boys in 2nd grade and 0.13 s for boys in 3rd grade in the first group compared to the second group. The same evolution was also seen among girls in the experimental group, class I decreased their times by 0.13 seconds, class II by 0.15 seconds, and class III by 0.09 seconds, compared to the control group. Analysing the results of the initial test there were no differences between the two groups, differences were observed between the times of each class in both the initial and final tests. The boys and girls of the third grade recorded the best times, followed by the students of the second grade. The fastest times over the 25m distance were clocked in 1st grade.

These accumulations indicate the range of 6 – 10 years as suitable for optimising running speed.

Running speed measurement is a parameter often used in sports selection and needs to remain in any child's test battery to check their biological potential for sport. At the same time, speed monitoring can provide the teacher or coach with valuable information about the child's current state and development of the neuronal system.

Limitations of the research that we have identified are weather conditions (most schools had uncovered sports facilities during the measurements), project logistics (human and material), and the reluctance of some schools to get involved (the impression that children are measured to be transferred to sports institutions).

5. Conclusion

Our study demonstrates the existence of changes in the acceleration and running speed of children in the North-Eastern area of Romania aged between 6 and 11 years, depending on gender and stage of neurocognitive development. In relation to running speed, the level of neural functioning is important.

Running results measured on 5, 10, and 15 m distances differentiate girls from boys. As expected, boys performed better at every distance covered, except 5 m at 10 and 11 years. This phenomenon may be due to the biological development of girls who are taller than boys at 10 years and keep their weight below boys. The first hypothesis of the research is confirmed. It would be of interest to further investigate this gender difference by qualitative analysis of growth based on body composition.

Girls' growth between 6 and 10 years leads to an improvement in running speed over distances between 5 and 15 m, the difference between 10 and 11 years being insignificant. The same effect of growth exists in boys, with the addition of maintenance of speed for the 6-7 year age range. The changes observed confirm the last hypothesis.

The transition from 10 to 11 years of age is marked by stagnation in running speed over 5-15 m. In this way, it can be recommended to insist on the optimisation of running speed in the 6-10 years interval against the background of the progress observed.

This paper may be of use to physical education teachers and coaches in the north-eastern part of Romania in managing the developmental programme of children.

Applicability is given by the usefulness of the mean and standard deviation of each measured group in making grids for assessing children whose characteristics are similar. Further studies may lead to further investigation of this topic over a wider area, as well as monitoring running speed in older samples.

Aknowledgement

This work was supported by a grant by Alexandru Ioan Cuza University of Iași, within the Research Grants program, Grant UAIC no. 09/2021, "The biomotor profile of primary school students in Iași County and their potential for sports performance" (GI-UAIC-2021-09).

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