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Evolution of the Correlation Between Body Mass Index (BMI) and Agility of Primary School Students in North-Eastern Romania

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Abstract: *Interacting with children's cognitive processes and mental health status, body mass index (BMI) could be analyzed in relation to motor performance. This study aims to analyse the relationship between BMI and agility of primary school students in the northeast of Romania. Hypothesis testing was done by analyzing data obtained from 3250 pupils (1605 girls and 1645 boys) aged 6 to 11 years old from the North-East of Romania. BMI was calculated based on height and weight, as well as agility through the 505 change of direction speed test. The sample was divided according to gender and age, and the differences and correlations were analysed. We assumed that our sample has a significant correlation of BMI with agility and that its strength increases with age, based on neural maturation. Children's results showed gender- and age-determined differences in anthropometric as well as motor skills. The development of Romanian girls and boys differs punctually at this stage, with the two genders having close BMI values at age 11. The time to complete the 505 test is close at age 6, with boys performing better by age 11. The correlation between BMI and agility has weak strength in the 6-11 years age group of Romanian students. It is significant in girls at 9 (r = 0.20) and 10 years (r = 0.15), and in boys from 7 (r = 0.20) to 10 years (r = 0.22). The data partially confirm our hypothesis, with the correlation existing in the 7-10 years age range, its strength having a fluctuating evolution. At 11 years the link between BMI and agility ceases to exist.*

Keywords: *cognitive development; executive functions; psychopathology; neuromotor performance; sport selection; physichal activity.*

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1. Introduction

Evaluation of 203,323 children in 36 countries in Northern, Eastern, Southern and Central Europe (nationally representative samples of children aged 6-9 years) showed that 28.7% of boys and 26.5% of girls were overweight (including obese) as defined by the World Health Organisation. Efforts to stop this decades-old situation are outdated, with unhealthy weight still a topical problem in the World Health Organization's European Region (Spinelli, et al., 2021). More than a third of children aged 5-10 in the North Central Province, Sri Lanka, have low BMI values, and 1/6 of these have anaemia (Naotunna, et al., 2017). In Germany, a negative tendency of BMI has been found between 2016 and 2021 in primary school children (Wessely, et al., 2022).

As in other countries, Romania faces difficulties in terms of the physical fitness of the population, with obesity being present at the youngest ages. A determining factor in this problem is a sedentary lifestyle (Pop, et al., 2021). Pop et al. (2021) aimed to estimate the prevalence of underweight, overweight, obesity, and severe obesity in children enrolled in urban schools in the northwestern part of Romania. Analyzing nutritional status (reference criteria: World Health Organization, International Obesity Task Force (IOTC) and Centers for Disease Control and Prevention (CDC)) of 21,650 children (48.19% boys) aged 7 to 18 years, they observed the highest prevalence of excess adipose tissue (including obesity) in children aged 10 years and the lowest in adolescents aged 18 years.

A factor with high relevance to population health status is BMI, which is often used to assess body composition in different types of samples (Naotunna, et al., 2017; Gomwe, et al., 2022; Matlosz, et al., 2022; Gomes, et al., 2015; Larsen, et al., 2017; Lee, et al., 2022; Mears, et al., 2020).

The increased likelihood of weight gain, and therefore increased BMI levels among children, is caused by factors such as environment, genetics, endocrine dysfunction, nutrition, and sleep (Kumar & Kelly, 2017). Strong associations were observed between the BMI of children assessed at ages 5-6 years and later when they were 8-9 years old ($p = < 0.005$). This score increased over the years among both girls ($p=<0.005$) and boys ($p=0.0047$) (Mears, et al., 2020). Great attention should be paid to monitoring BMI values and acted upon from an early age (5-6 years), as high BMI values predispose to maintaining a high level in later life (8-9 years) (Mears, et al., 2020).

Healthy maturation can start from early childhood through an orientation towards motivation, the pursuit of goals, self-control, and thinking in accordance with the given context and organization. Involvement in appropriate physical activities makes healthy development possible, preventing the appearance of pathologies that are difficult to treat (Raudeniece, et al., 2024).

Among the first executive components of the brain is working memory, which ensures the temporary storage of information in order to perform certain tasks. The structure responsible for this function is the prefrontal cortex. Academic success depends on optimizing working memory in childhood and adolescence. Obesity affects cognitive performance through its structural changes. (Christina, et al., 2021) A reduction in gray matter and activation of the prefrontal area was found in children with an increased BMI (Zhang, et al., 2023). There is a possibility that in children of normal weight, working memory is not directly affected by BMI, but rather by the genetic background associated with obesity (Takahashi, et al., 2021).

Physical exercise engages the executive functions of the brain, which will become a foundation of goal-achieving behavior. Sports activities that involve competition and the need to adapt to complex situations could represent an important factor in the development of cerebral executive functions, especially among boys. Every sport has a tactical substrate that makes the sports experience increase in relation to cognitive flexibility, as happens in tennis, for example (Ishihara, et al., 2018).

Relative to increasing age, Jang et al. (2018) find that children become more independent in decision-making, a behavior that appears in the transition from primary to secondary school, with BMI levels also increasing. Thus, they conclude that they engage less in team sports and spend more time in front of digital devices, implicitly paying less attention to rest, aspects that are correlated with high BMI values. Children who included more fruit and vegetables in their daily diet were involved in team sports and performed physical activities more times a day (Jang, et al., 2018).

In Denmark, 8-10-year-old children who are enrolled in a sports club, mostly playing sports games (with a ball), have a much better physical condition and body composition compared to children who are not enrolled in a sports club (Larsen, et al., 2017). Donnelly and Lambourne (2011) stated that physical activity sessions positively influenced performance in reading, math, and spelling.

Great attention should be paid to monitoring BMI values and acted upon from an early age (5-6 years), as high BMI values predispose to maintaining a high level in later life (8-9 years) (Mears, et al., 2020).

Children with motor coordination difficulties are characterized by problems with behaviour, learning, reading, and speaking. One of the solutions that can solve these problems is physical exercise (Banjevic, et al., 2022; Christina, et al., 2021). Other means, very theoretically important, have also been tried, including the training of executive functions, but without much-proven success so far (Luis-Ruiz, et al., 2023).

Consistent physical activity and low BMI correlate with high mental well-being and quality of life (biological and psychological) (Eddolls, et al., 2018). Excessive use of technology (TV or PC) reduces well-being, requiring a different approach to physical activity depending on gender (Martínez-López, et al., 2015).

High body mass values in children primarily lead to motor difficulties, making it difficult to develop basic motor skills. At the same time, the qualitative decline continues towards the cognitive side. A negative relationship between overweight and intelligence, general cognitive ability, executive nervous function, memory, verbal skills, attention, and others has been shown. Carrying out some movements with weight is caused by the reduced cognitive processes and less by the anti-gravitational effort caused by the high mass. In preschoolers (5-6 years old), overweight affects only coarse movements, with the cognitive side and the fineness of movements being less affected (Banjevic, et al., 2022).

Between the ages of 6 and 16, children with obesity and overweight problems have impaired cognitive functions, and high BMI most affecting the 9 to 11-year group. The use of BMI and waist circumference as indicators of reduced brain integrity in children is indicated (Kaltenhauser, et al., 2023).

Obesity can cause dysfunctions of the respiratory tract during the child's sleep, an aspect reflected in the structural changes of the brain. Reduced cortical areas were found in the frontal (executive functions) and temporal (mental and sensory activities) areas. Increased BMI is associated with inhibition of the orbitofrontal cortex, affecting emotional processing and modulation. In the long term, excess weight causes gray matter to shrink (Cui, et al., 2023).

Practicing a physical activity independently requires motor skills that are formed in childhood, along with which self-esteem develops and helps to interact with peers (for example, in sports games) (Gu, et al., 2018). In the social groups that assimilate them, most often those at school, overweight children are subjected to acts of bullying and marginalization, an aspect that can cause the appearance of anxiety or depression. Low life satisfaction could result (Gómez-Paniagua, et al., 2024). Weight stigma can also play a role, which could affect the psychological behavior of the future adult (Guardabassi & Tomasetto, 2020).

Socio-economic background influences children in Vietnam, with obesity doubling for girls. Children aged 7-9 are overweight in urban areas, as are those living further away from school (Pham, et al., 2020). Children from disadvantaged backgrounds have lower BMI values compared to children from more developed backgrounds (Mears, et al., 2020). There are links between parental BMI and that of 6-9 year olds, with lower BMI at ages 10-14 or 15-17. The environment of upbringing influences children's BMI, with those living with parents having a higher value than those living elsewhere. A higher BMI is found for children who are in the care of their mother, similarly for those who share lunch or dinner with their parents. (Ma, et al., 2021) Increased BMI of parents, both mother and father, between ages 5-6 years and 8-9 years was associated with higher BMI of children, but the observed effect was small (Mears, et al., 2020). Time of digital device use was associated with BMI values of Iranian children under 5 years of age. Moreover, it was also shown to be influenced by children's sleep duration (Sourtiji, et al., 2019). Sleep correlated with BMI ($p = 0.008$) in children (9-11 years) in northern Italy (Rosi, et al., 2017).

Increased economic status leads to an increase in BMI among children from one historical stage to another (Gomes, et al., 2015). Socioeconomic status is related to neurocognitive performance, with increased BMI being related to poor living conditions (Dennis, et al., 2022; Wynne, et al., 2016). These negative effects of weight problems can be ameliorated by physical activities, reducing children's anxiety and depression symptoms (Romero-Pérez, et al., 2020).

Reducing BMI requires behavioral changes based on motivation and self-regulation. Unfortunately, in children with a high BMI, the two psycho-cognitive characteristics have a low level, hence the difficulty of a body remodeling process (Mason, et al., 2021). Feeding self-regulation in children has a closer relationship with body mass than behavioral self-regulation, the latter intervening in the processes of exiting the obesity zone (Francis, et al., 2022).

Agility is the ability to rapidly change running direction and position on a horizontal plane. Thus, it becomes a necessity for competitive athletes as the dynamics of sports games increase. There is an association with strength, speed, power, coordination, and decision capacity. Good neuronal functioning results in a shorter response time to a complex stimulus. We can consider agility as a necessary parameter to assess children to be involved in the sport selection process (Usher, 2019).

Indicators of motor capacity are decreasing with advancing time, as it happens with German primary school pupils who within 5 years have a decrease in agility and aerobic endurance capacity. In contrast, explosive leg strength was not affected (Wessely, et al., 2022).

Agility studies were conducted in dynamic sports (football, volleyball, basketball, handball) at ages exceeding 11 years (Jones, et al., 2021; Pleša, et al., 2022; Kosni, et al., 2022; Asimakidis, et al., 2022; Alemdaroğlu, 2012; Falces-Prieto, et al., 2022; Marco, et al., 2023; Fernandez-Fernandez, et al., 2020). These analyses the impact of agility on sports performance or the interconnections with other neuromotor capacity parameters.

The link between agility and BMI has been examined in other research, the age level being in adolescents or seniors (Yıldırım & Ozdemir, 2010).

Considering the correlation between body composition and agility, body fatness indicates a negative correlation among values recorded in a group of 164 children (107 boys, 57 girls) aged 10 years in Korea. Performance of the 505 agility test is influenced by age, Countermovement jump height, isometric hip adductor strength, and North Hamstring Strength (Jones, et al., 2021).

Body composition is significantly correlated with strength and agility, two characteristics that require optimal neuromuscular control (Lee, et al., 2022). An increased level of body fat leading to an increased BMI can affect coordination and agility (Martins, et al., 2010). Yıldırım and Ozdemir (2010) argue that high BMI leads to decreased agility, strength, and flexibility and causes energy loss, which has a negative impact on physical performance.

Agility is a necessary human characteristic for everyday activities as well as motor activities. Formed in childhood through practice, it needs a good biological foundation. This can be given by the efficient functioning of the neuromuscular system or body composition, the quality of which is reflected in BMI.

The biomechanics of movement specific to agility argue that a low body mass is necessary for a high capacity to change direction and direction.

Existing information provides few benchmarks of agility among primary school children, even less in Romania.

Based on these considerations, we aim to examine the relationship between BMI and agility in children aged 6-11 years in Romanian education. The hypothesis of our study asserts the existence of a significant correlation between BMI and agility in girls and boys aged 6-11 years in the north-east of Romania, with its strength increasing with age. We base our assumption on the biological growth of children that may improve locomotor functioning.

2. Materials and Methods

Our research has a cross-sectional design. 3250 students were tested (1605 girls: 123 - 6 years, 267 - 7 years, 389 - 8 years, 320 - 9 years, 320 - 10 years, 166 - 11 years; and 1645 boys: 119 - 6 years, 308 - 7 years, 344 - 8 years, 332 - 9 years, 330 - 10 years, 187 - 11 years). The preparation of the research was done through the signature of a partnership between the University "Alexandru Ioan Cuza" of Iasi and the Iasi County School Inspectorate (no. 1804/04.02.2022). This document made possible the testing of subjects belonging to the 47 schools in Iasi County, Romania, which responded positively to our proposal. Our research was presented to all those involved (teachers, pupils, parents) through information documents. Each subject presented on the day of the test a parental consent signed by a legal representative and participated voluntarily, the only benefit was receiving the evaluated results. The above-mentioned partnership was accompanied by the approval of the Scientific Research Ethics Committee of the Faculty of Physical Education and Sport of Iasi (no. 23/28.02.2023), in the spirit of the Helsinki Declaration.

2.1. Measurements

Each student was measured by a team trained for this purpose, and the validity of the application of the measurement procedures for the required parameters was ensured. Members of the Centre for Selection and Sports Counselling of the Faculty of Physical Education and Sport of the University "Alexandru Ioan Cuza" of Iași (Romania) were trained by simulations with samples of students. In this way, the application of the working protocol was possible in each school where the field team of the research project went.

The measurements were carried out during the physical education classes that the children had in the school program. The teachers of the class assisted in the measurements and acted as support for the team of evaluators.

BMI and agility were measured in 2 environments:

1. indoor – anthropometric characteristics: height (cm) and body mass (kg), from which BMI (kg/m2) was generated;
2. outdoor – agility (505 test-s).

Anthropometry

Anthropometric characteristics were quantified in the students' classroom. Height was determined from sitting, with the student on a horizontal surface searched in the classroom with a level.

With an electronic Handy levelling device to which a Bosch Professional GLM80 (Gerlingen-Schillerhöhe, Germany) was attached, the height was measured in cm. Each subject was instructed to assume as upright a posture as possible. The height value was noted when indicating an inclination of less than 0.5 degrees of the level and the rangefinder beam was projected vertically on the ground. Body mass was measured in kg with an Omron BF511 body analyser.

Agility

After recording the height and body mass values in the classroom, the students went out to the sports base and performed the warm-up for the effort under the guidance of the teacher. The time allowed was 10-15 minutes, the time needed for the assessors to prepare the field. They prepared the surface for the 505 test. A running lane 2 m wide and 15 m long was marked on a horizontal area. A TracTronix TF100 gate (Lenexa, KS, USA) set to start-stop mode was placed 10 m from the start line.

After the warm-up was completed, students were picked up by one of the evaluators to explain the test procedure and communicate the order in which they would run. Each student sat at the start line awaiting the start acceptance of the evaluator at the timer. When this was received, the pupil could start at any time on a sprint to the 15 m line and return as quickly as possible to the start, with the indicated 5 m round trip time recorded. Test 505 was administered twice to each student, at minimum 3-minute intervals, with the best result being taken into account.

In order to secure the results obtained, these were audio recorded on the tablet where they were scored, as well as audio-video recorded with 2 Sony Handycam HDR-CX240E cameras. The cameras filmed the subject from the back and side. All results were verified by the research team by listening to the audio recordings and scoring errors were eliminated.

2.2. Statistical analysis

Synthesis of data sets was done with mean and standard deviation. Our pooled sample being a large one generated outliers that were eliminated by the ROUT method (Q=1). Gender and age data differences were assessed with unpaired t-tests and one-way ANOVA, and the normality of the data distribution was checked with the Kolmogorov-Smirnov test (Bilon, 2023).

A correlation was assessed by Pearson's r coefficient, its values giving the following correlation strengths: weak - <0.29; moderate - 0.30-0.49; strong - 0.50-0.69; very strong - 0.70-0.89; almost perfect - >0.90 (Hopkins, et al., 2009).

Subjects were grouped according to gender and age (6-11 years), with years being those completed at the time of measurement. A significance threshold of 0.05 was set in the settings of GraphPad Prism 9.3.0 software (GraphPad Software Inc.) to validate the applied tests.

3. Results

Anthropometric data of our subjects show differences between girls and boys (*Table 1*). Starting at the age of 6 years (121.3 ± 5.46 cm), girls increase in height up to 11 years (148 ± 7.57 cm), surpassing boys (146.8 ± 7.78 cm). At age 6, height is significantly close between the two genders, with boys outpacing girls at age 7 (p = 0.03). At age 10, girls become taller (143.9 ± 7.44 cm, p = 0.002). Body mass is higher in girls at age 6 (24.09 ± 4.72 kg), and at age 7 becomes lower than that of boys (26.49 ± 5.12 kg). From age 8 onwards, girls and boys maintain similar body mass values, which increase from one year to the next.

BMI increases for each gender with age. The only noticeable difference between girls and boys is seen at age 9 when boys increase to 18.46 ± 3.61 kg/m2, which is higher than girls (17.73 ± 3.03 kg/m2, p = 0.006).

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

Group	Height (cm) M ± SD	t(df) / p / d	Weight (kg) M ± SD	t(df) / p / d	BMI (kg/m^2) M ± SD	t(df) / p / d
G_6	121.3 ± 5.46	0.07 (229) / 0.94 / 0.02	24.09 ± 4.72*	2.43 (232) / 0.016 / -0.32	15.97 ± 2	1.55 (226) / 0.12 / -0.21
B_6	121.4 ± 5.85		22.8 ± 3.21		15.58 ± 1.7	
G_7	125 ± 6.08	2.11 (571) / 0.03 / 0.18	25.47 ± 4.5	2.46 (552) / 0.014 / 0.21	16.34 ± 2.15	1.14 (551) / 0.25 / 0.09
B_7	126.1 ± 6.2*		26.49 ± 5.12*		16.54 ± 2.15	
G_8	131.5 ± 6.66	1.14 (725) / 0.25 / 0.08	30.1 ± 6.42	1.55 (714) / 0.12 / 0.12	17.25 ± 2.58	1.45 (710) / 0.15 / 0.11
B_8	132 ± 6.4		30.91 ± 7.48		17.56 ± 3.1	
G_9	136.9 ± 6.96	0.41 (647) / 0.68 / 0.04	33.9 ± 8.41	1.77 (643) / 0.08 / 0.14	17.73 ± 3.03	2.74 (637) / 0.006 / 0.22
B_9	137.2 ± 6.55		35.12 ± 9.09		18.46 ± 3.61*	
G_10	143.9 ± 7.44**	3.04 (641) / 0.002 / -0.24	38.73 ± 9.57	1.49 (643) / 0.14 / -0.12	18.2 ± 3.02	1.29 (611) / 0.2 / 0.10
B_10	142.2 ± 6.5		37.67 ± 8.53		18.53 ± 3.27	
G_11	148 ± 7.57	1.39 (351) / 0.17 / -0.16	41.93 ± 11.39	0.41 (347) / 0.68 / -0.04	19.02 ± 4.1	0.10 (347) / 0.92 / 0.01
B_11	146.8 ± 7.78		41.45 ± 10.38		19.06 ± 3.7	

*Expresed as Mean ± Standard Deviation; G_6 (to 12) – girls of 6 (to 12 years); B_6 (to 12) – boys of 6 (to 12 years); * – p < 0.05; ** – p < 0.01; *** – p < 0.001; **** – p < 0.0001*

Agility assessed with the 505 test differs by gender as well as age (*Table 2*). The results of the t-test indicate significantly better values of the times obtained by boys compared to girls.

Table 2. Gender and age differences of 505 test results, according to t-test and One-Way ANOVA test

Age (years)	Girls – 505 (s)	Boys – 505 (s)	t(df) / p / d
6	3.75 ± 0.45	3.79 ± 0.46	0.54 (231) / 0.59 / 0.07
7	3.69 ± 0.4	3.6 ± 0.5*	2.18 (570) / 0.03 / -0.18
8	3.57 ± 0.4	3.46 ± 0.43***	3.60 (731) / 0.0003 / -0.26
9	3.41 ± 0.35	3.32 ± 0.36**	3.29 (650) / 0.001 / -0.26
10	3.33 ± 0.35	3.26 ± 0.37**	2.68 (647) / 0.007 / -0.21
11	3.29 ± 0.35	3.17 ± 0.34**	3.30 (351) / 0.001 / -0.35
F / p	F (5, 1570) = 2.90 / p<0.0001	F (5, 1613) = 9.40 / p<0.0001	
Tukey's multiple comparisons test	6-8***, 6-9****, 6-10****, 6-11****, 7-8**, 7-9****, 7-10****, 7-11****, 8-9****, 8-10****, 8-11****, 9-11*	6-7***, 6-8****, 6-9****, 6-10****, 6-11****, 7-8***, 7-9****, 7-10****, 7-11****, 8-9****, 8-10****, 8-11****, 9-11**	

*Expresed as Mean ± Standard Deviation; G_6 (to 11) – girls of 6 (to 11 years); B_6 (to 11) – boys of 6 (to 12 years); * – p < 0.05; ** – p < 0.01; *** – p < 0.001; **** – p < 0.0001*

The exception is age 6 (p = 0.59), when boys complete the test structure in 3.79 ± 0.46 s and girls in 3.75 ± 0.45 s. The age progression leads to an improvement in girls' time (F (5, 1570) = 2.90, p<0.0001) up to age 11 (3.29 ± 0.35 s), a phenomenon also found in boys (3.17 ± 0.34 s). The evolution of the data shows a greater increase in agility in boys (F (5, 1613) = 9.40, p<0.0001) from 7 (3.6 ± 0.5 s) to 11 years (3.17 ± 0.34 s).

The application of Tukey's multiple comparisons tests revealed different changes in agility between genders. Both genders stagnated with agility between the ages of 9 and 10 years, and 10 and 11 years, respectively.

In addition, girls have close results between 6 and 7 years. For all other age comparisons, for each gender, the differences are significant, indicating biological development.

The relationships between BMI and agility were plotted in Figures 1-6, according to age and gender.

Each of these is addressed to age, starting at 6 years (Figure 1), an age at which the two parameters are not interdependent in girls (p = 0.66) or boys (p = 0.57). At 7 years (Figure 2), girls continue with the lack of significance of the link between BMI and agility, boys exceed the threshold (r = 0.20, p = 0.0005). The same happens at 8 years (Figure 3), with the strength of the correlation registering an increase. At this age, boys show the strongest relationship between BMI and agility (r = 0.26). Age 9 years brings significant correlations for both genders (Figure 4), with girls showing the best correlation value (r = 0.20).

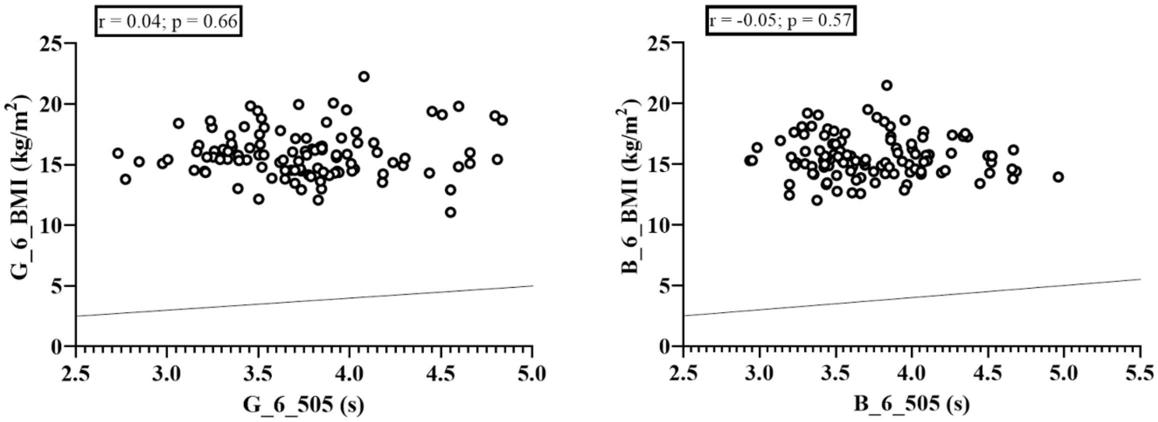

Figure 1. Correlation between BMI and agility of 6-year-old girls and boys

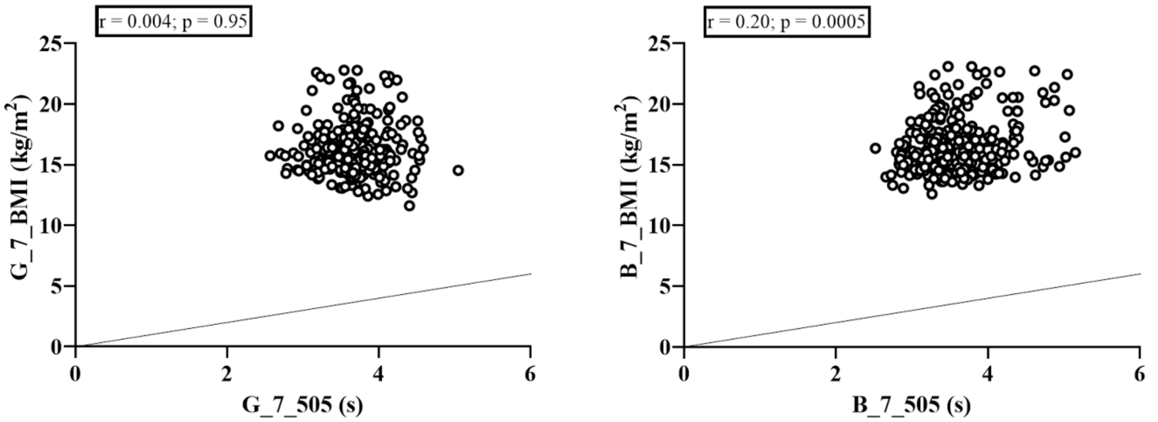

Figure 2. Correlation between BMI and agility of 7-year-old girls and boys

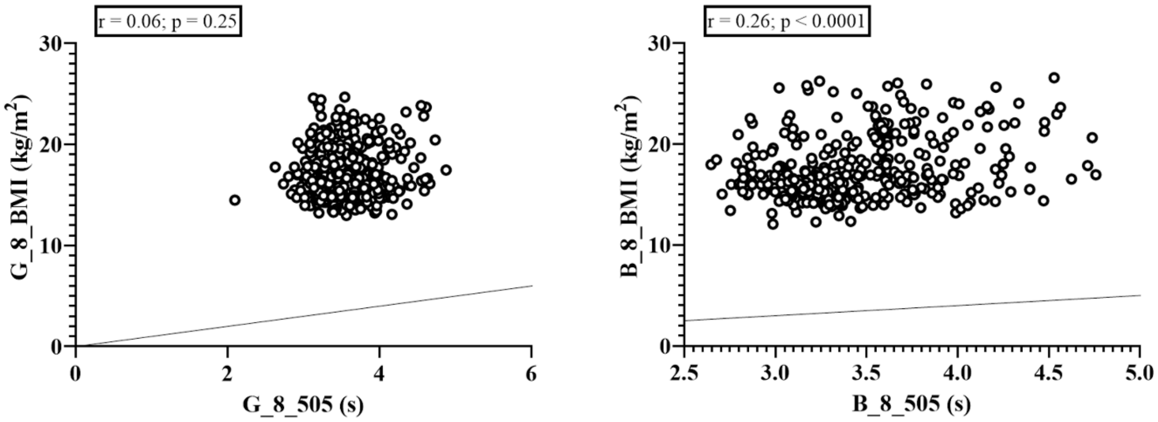

Figure 3. Correlation between BMI and agility of 8-year-old girls and boys

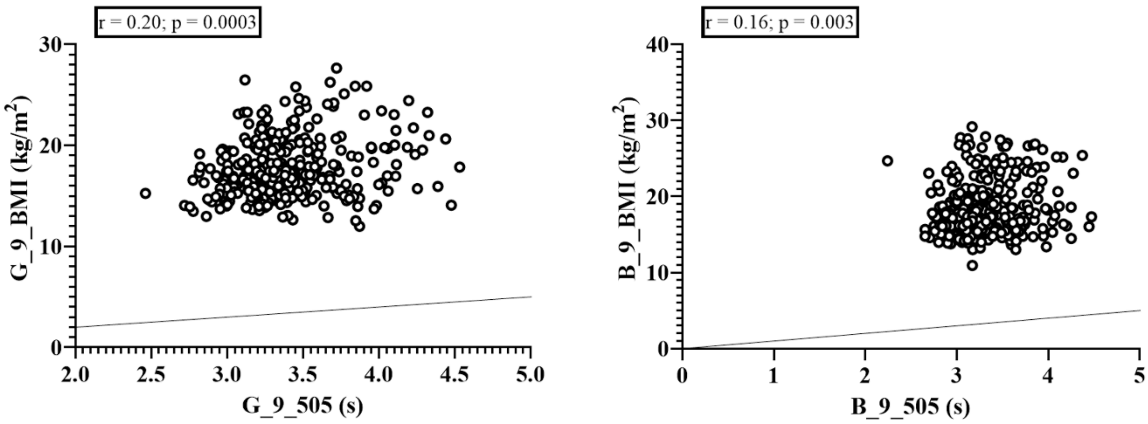

Figure 4. Correlation between BMI and agility of 9-year-old girls and boys

The link is still weak at age 10 years (Figure 5), decreasing for girls (r = 0.15, p = 0.007) and increasing in boys (r = 0.22, p = 0.0001).

Moving to 11 years (Figure 6) marks a weak, insignificant, and close correlation between girls (r = 0.12, p = 0.11) and boys (0.10, p = 0.15).

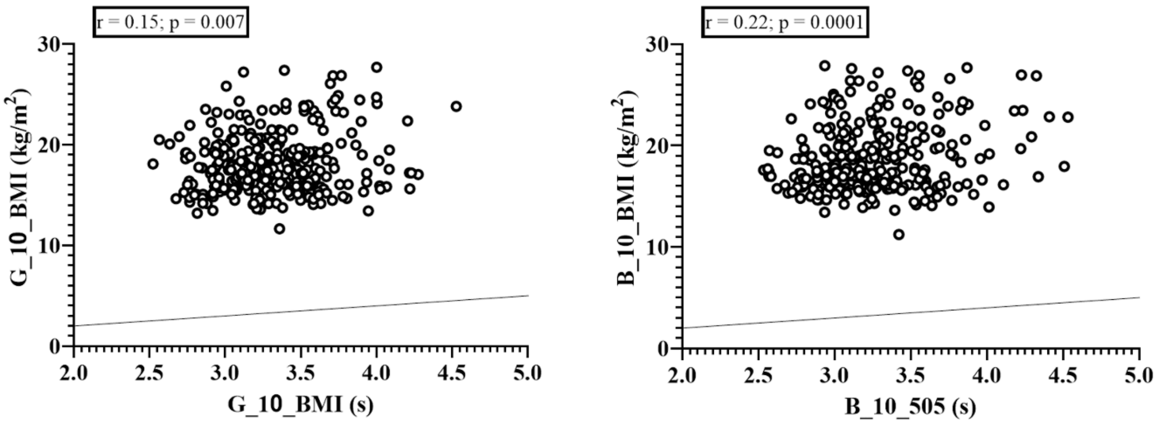

Figure 5. Correlation between BMI and agility of 10-year-old girls and boys

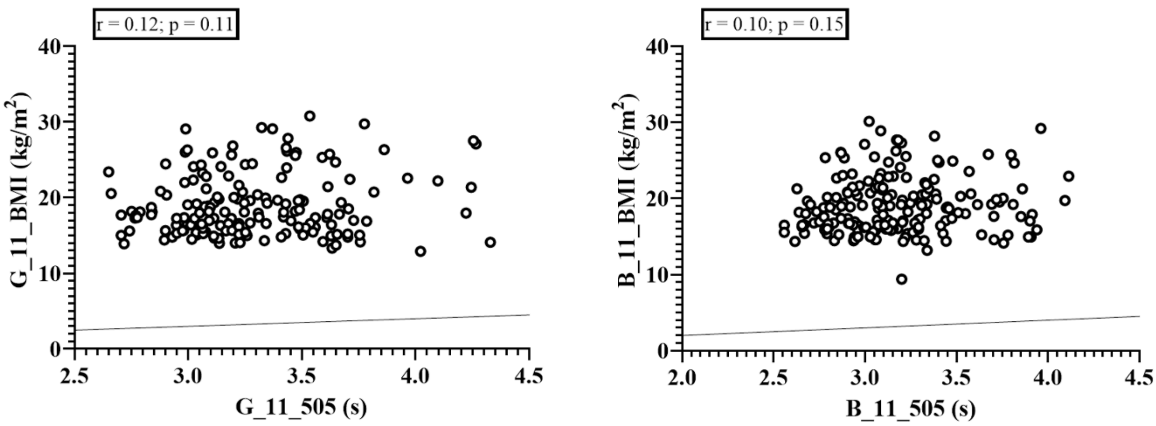

Figure 6. Correlation between BMI and agility of 11-year-old girls and boys

4. Discussion

Our study aimed to analyze the links between BMI and agility of Romanian primary school students, whose development takes place in the North-East of Romania. We started from the correlations that exist between agility and BMI, two indicators of health status, the first linked to coordination capacity, and the second to health status. (Naotunna, et al., 2017; Zhao, D, Zhang, & Y, 2015; Mears, et al., 2020; Matlosz, et al., 2022; Gomwe, et al., 2022; Lee, et al., 2022; Pham, et al., 2020; Greeff, et al., 2016; Ma, et al., 2021). We focused on the interconnection that could exist between the two parameters in children from 6 to 11 years old whose biological maturation is in progress. From this, we deduced that children from this category present correlations between body composition and the ability to change running direction, which become stronger with age.

The results of our sample showed an anthropometric difference between girls and boys. Girls' height increases from age 6 to 11, at which age boys will be shorter. In contrast, boys are as tall as girls at age 6 and will overtake them at age 7. In terms of body mass, gender differences are also shown at ages 6 and 7, becoming similar after age 8.

The closeness of height and BMI in 6- and 7-year-olds was also observed in southern Poland (Merkiel & Chalcarz, 2011), with the values for girls (16.0 ± 1.8 kg/m2) and boys (16.4 ± 1.9 kg/m2) being similar to our results. In research by Annan et al. (2020) in a group of 422 Ghanaian children (8-13 years), girls have higher BMI than boys, they are taller and heavier than boys.

BMI increases with age and has a single gender difference at age 9 when boys reach higher values. It has been correlated with various factors that might influence it. Ma et al. (2021) tested the relationships that are established between the BMI of 1973 Chinese children and that of their parents, with ages 6-9 years ($r = 0.30$-0.35) showing greater strength than those in the 10-17 years range ($r = 0.15$-0.24)

Monitoring of 580 children in the northern part of Portugal (9-11 years) showed a lack of a link between BMI and sedentariness or sleep duration. Instead, exposure to digital media in the bedroom leads to higher BMI values (Gomes, et al., 2015). Chinese children aged 6-11 years have the same lack of significance of the link, and it becomes stronger in middle school students (Chen, et al., 2023).

The effect of time spent in physical education classes is a major determinant of BMI development among 10-11-year-olds (Pallan, et al., 2014). A study of 376 children in the north of the Netherlands (grades 2 and 3), divided into 2 samples, tested the impact of physical activity in other classes versus dedicated time. The effect was beneficial for the BMI of 3rd graders, but insignificant for 10 × 5 m shuttle run, 20 m endurance shuttle run, standing broad jump, sit-ups in 30 s, and handgrip strength. (Greeff, et al., 2016)

Eight months of physical activity (daily 10-minute sessions based on TAKE 10! programme) decreased the BMI of girls aged 6 to 12 years (-0.47 kg/m2) compared with girls who did not follow the program (0.66 kg/m2) (Liu, et al., 2007). Improvements in body composition values were observed following a 16-week programme of physical activity, with 3 sessions of 60 minutes per week, by 101 children classified into 4 groups according to weight: normal weight (n=19), overweight (n=15), obese (n=35), severely obese (n=32). Significant differences were found, predominantly in the severely obese group, between BMI ($p<0.05$), body fat ($p<0.05$), and muscle mass ($p<0.001$) values recorded before and after the programme (Lee, et al., 2022).

Progression in BMI with increasing age may be influenced by following a physical activity programme carried out according to specialist recommendations. 212 pupils (110 boys and 102 girls) who followed a modified structure of physical education classes for 2 years (different duration, intensity, and frequency) improved their daily physical activity level ($p<0.01$), compared to another group of 216 pupils (113 boys and 103 girls) who followed the structure itself. The BMI values of the first group were reduced in both boys and girls ($p<0.001$) compared to the control group. Children were measured before and after 2 years, at baseline being aged 8-9 years and at end line 10-11 years (Sacchetti, et al., 2013).

The 505 test is a simple test for children to apply and perform. At age 6 the gender differences are insignificant, and by age 11 boys have better times than girls.

Biological maturation leads to an increase in the agility performance of girls and boys, with boys performing better. The transition from 9 to 10 as well as 10 to 11 years brings stagnation in the agility of both genders. In girls, the 6-7 years threshold is added.

BMI can have a strong effect on the motor performance of primary school students (Greier, et al., 2017). Coordination has a beneficial effect on the neuromotor activities a child can perform. Increasing children aged 6-11 years brings a reduction in coordination (Giuriato, et al., 2019). Those with high BMI associated with overweight have limited motor coordination (Lopes, et al., 2012).

The agility of 121 children aged 6-7 years (southern Poland), measured with a 4 × 5-m shuttle run while carrying a 150-g building block, was rated as insufficient (64.1% of girls, 45.6% of boys), sufficient (29.6.1% of girls, 26.3% of boys), good (4.7% of girls, 26.3% of boys) or very good (1.6% of girls, 1.8% of boys). The difference between girls and boys was significant ($p = 0.009$). Agility correlated with BMI only in girls ($r = -0.27$, $p = 0.03$), with very low tie strength in boys ($r = - 0.06$). Medicine-ball throw correlated significantly with BMI for both genders, but not standing broad jump and 20 m run (Merkiel & Chalcarz, 2011).

Age-determined anthropometric and neuromotor changes create the foundation for the links that exist between BMI and agility. The correlation between the two parameters analysed is significant in girls aged 9 and 10 and in boys in the 7 to 10 age groups. All correlations are weak ($r < 0.29$), with girls having the best correlation at age 9 ($r = 0.20$) and boys at age 8 ($r = 0.26$). The evolution of correlation strength shows an increase up to age 9 for girls, followed by a regression up to age 11. In boys, the link between BMI and agility reaches a maximum level at 8 years, following the same path as for girls. These results partially confirm our hypothesis, with the correlation of the two variables being significant only at a few age levels, and its increase in strength being present only for the 6-9 years interval for girls and 6-8 years for boys.

BMI correlated significantly in South African children aged 9-14 years (11.04 ± 1.50 years, 519 girls and 351 boys) with Push-ups ($r = -0.124$, $p < 0.01$), Sit-ups ($r = -0.122$, $p < 0.01$), Sit and reach ($r = 0.132$, $p < 0.01$) and VO2Max ($r = -0.179$, $p < 0.01$). Girls had a higher BMI than boys. These links support our results through the interaction of BMI with measures of strength, flexibility, and aerobic capacity, with Pearson's r-index having low power, this being better in the girls' group (Gomwe, et al., 2022).

Children in the study by Annan et al. (2020) obtained a significant correlation only between BMI and handgrip strength, the other indicators (forward jump, sit-ups, flexibility, and 50 m run) being unrelated to body composition. The only run-based test showed a negative non-significant correlation ($r = -0.05$, $p = 0.29$) with BMI.

Children aged 5-14 years in Greece (Doloma, et al., 2020) also had significant correlations of BMI with the Körperkoordinationstest test für Kinder score during 3 years of follow-up ($r = -0.42$ to -0.38, $p < 0.05$).

A similar correlation was found by Martins et al. (2010) by monitoring a 6-10 year sample. Girls showed a negative correlation ($r = -0.21$, $p < 0.001$), as did boys ($r = -0.16$, $p < 0.006$).

Bulgarian students (7-11 years) perform worse in handgrip strength, standing long jump, 4x10 m shuttle run, and VO2max, if they fall into the overweight or obese categories defined by BMI assessment (Bonova, et al., 2019). BMI has been shown to have a negative effect on children's 20 m running speed (6-11 years, central England) (Bryant, et al., 2014). Also, BMI has been shown to have a negative effect on children's 20 m running speed (6-11 years, central England) (Bryant, et al., 2014).

In Usher's (2019) paper, subjects (11-18 years, Australia) showed a significant correlation between Illinois agility test scores and BMI ($r = 0.223$, $p = 0.05$), vertical jump ($r = 0.31$, $p < 0.0001$), broad jump ($r = 0.253$, $p = 0.002$), sit up ($r = 0.11$, $p = 0.05$), 40 m sprint ($r = 0.40$, $p < 0.0001$), and 12-minute run ($r = 0.15$, $p = 0.02$), respectively. The strength of the correlation with BMI is similar to that found by us.

The results of our research complete the picture of the links established between BMI and neuromotor skills of Romanian students aged 6 to 11 years in the North-East of Romania. Of interest was the correlation between the body composition indicator and agility assessed by the 505 test.

5. Practical Applications

The age range of 6-11 years is less debated in studies with neuromotor applications, the interest being in the process of sport selection.

We have chosen to understand the links that are established between BMI and agility of primary school students because this is the moment when a part of Romanian students can enter the primary sport selection process to practice an activity that can develop their physical and cognitive skills. This is a complex process by which coaches can assess the quality of a child whose potential can be developed later.

The way in which a neuromotor or anthropometric characteristic evolves can explain why at certain stages children change and their performance is modified.

We aimed to argue with the link between BMI and agility the necessity of an optimal body structure for good health as well as for the possibility of practicing sports activities.

The correlations found in our sample are in agreement with other studies focusing on the same age level and link BMI with other physical characteristics. In addition, our study is focused on the connection that is established between BMI and agility determined with the 505 test. This link, to our knowledge, has not been examined before, especially in children.

With our data, we can create scales to assess the time obtained in the 505 test with which coaches in the north-eastern area of Romania can assess children with motor potential. Of course, the range of applicability can be extended.

Our research was limited by: logistics, time, responsiveness, and weather conditions. The logistics involved increasing the funds available to cover all equipment-related expenses, as well as preparing field teams to work strictly according to established protocol. The time required to measure a considerable number of children is large, which limits the geographical area covered. We encountered a lack of responsiveness from some schools based on the supposed reason for transferring high-performing children to sports-specific units. The sports bases at most of the schools where we measured children were outdoors and possible changes in weather conditions (e.g. rain) would have made it very difficult to measure agility. Overcoming these limitations, the desire and passion of each specialist bring solutions to overcome any obstacle.

6. Conclusions

Anthropometrically, girls and boys differ in height and body mass. At 6 years of age, the two categories are close in height, and by 11 years of age, the girls are taller. In the same age range, girls are heavier at first. From the age of 8, Romanian girls and boys will have similar weights.

Except at age 9, where boys have it higher, BMI is similar for the two genders between 6 and 11.

The results of the 505 test show gender and age differences. At age 6, girls and boys have close values, and by age 11 boys perform better on the agility test. Age causes an improvement in results among both genders, with the magnitude of the increase being greater for boys.

During the age range analysed, there is a stagnation of agility at 9-10 and 10-11 years old, and girls have an insignificant difference when moving from 6 to 7 years old.

In general, the correlation between BMI and agility of children in the north-east of Romania is with a weak strength in the 6-11 years age group. For girls, the link is significant only at ages 9 and 10, while for boys it is significant from ages 7 to 10. At 11 years the link between BMI and agility ceases to exist for both genders. Our analysis supports the results of other studies with the same thematic orientation, the possibilities of study are very broad in this direction, especially among the target population of sport selection.

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