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NON-VERBAL INTELLIGENCE NONVERBAL AND MOTOR FITNESS LEVEL IN CHILDREN AGED 7-14 YEARS

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Abstract

Introduction. The issue related the importance of mental processes (including non-verbal intelligence) in the determination of physical fitness and its structure is not new. It has been solved in different ways, but most often, the basis for interpretation of results was the issue of statistical significance of linear correlation between indicators of intelligence and motor components of physical fitness. In our own study, we also applied the statistical to solve the undertaken research problem. In developing the concept of research, we based it on the S-O-R teleological neobehaviourism model by E.S. Tolman and dynamic psychology introduced by R.S. Woodworth. In such an approach, we assessed the indirect affect of non-verbal intelligence (O) on - physical fitness and its components (R) being the reverse side of a certain level of physical activity (S), shaped under the influence of mental processes, which in our study included non-verbal intelligence.

Hipotheses: 1. The high level of statistically significant coefficients of linear correlation between physical fitness and non-verbal intelligence can be confirmed by the phenomenon of people having higher intelligence, greater motivation to stay healthy, the dimension of which can be motor components recognized under the American concept of health (H-R-F). 2. Biological factors of the organism [O], included in the eclectic model of dynamic psychology by S.R. Woodworth: S-O-R, such as age, sex and status of residence (a large or small city, a village) should not affect the differentiation of the pace of mental and motor development in children, nor the strength of correlations between the level of non-verbal intelligence and physical fitness.

Basic procedures. Observations included children of both sexes aged 7-14 from three Malopolska cities: Krakow (big city), Slawkow (small town), Barcice (village). Basic somatic features (body height and mass) were measured by methods used in somatometry. To measure speed and strength abilities, we used the Denisiuk test. Non-verbal intelligence was evaluated using the J. C. Raven test. The collected material was elaborated using two methods: descriptive statistics (calculated mean and standard deviations that were needed to characterize the kinetics and dynamics of development of somatic, motor and mental indicators) and mathematical statistics (determined the strength of the relationship between intelligence and non-verbal indicators of somatic and motor development).

Results. Comparative analysis of the kinetics and dynamics of physical, motor and mental development helped to confirm the hypothesis assuming that social gradients become equalized in the development of children from different residence backgrounds:

village, small town, big city. After eliminating the issue of spurious correlations and basing the correlation analysis on materials guaranteeing penetration into the material nature of developmental phenomena, it was found that, in most of the analyzed cases, the relationships were insignificant or small, and were statistically insignificant. On this basis, we did not undertake verification of the consecutive hypotheses that assumed the influence of intermediary variables (age, gender, living environment) on the relationship between intelligence and non-verbal indicators of biological development, including motor fitness components. Therefore, our findings do not allow a positive answer to the question: is a smarter child more physically fit? From the pedagogical point of view, the negative result of our own research forces us to reflect on the existing situation and the reasons for not using the potential of students in achieving the directional objectives of physical education.

Conclusions. 1. Despite the still noticeable repercussions of social stratification existing in the past, the results of our study obtained using anthropological methods document the existence of a positive trend of change in the biological and psychological development of children in Malopolska, which consists of equalizing the distances between the development of the children from rural and urban areas. 2. Approaching the issue of using statistical methods to study the phenomena of development should be done with caution. Pure mathematical analysis can lead to erroneous conclusions, as in the example of the spurious-correlation found in the present study. 3. The disclosed very poor strength of correlations between intellectual potential and physical fitness of children from Malopolska encourages to take measures to change the unfavorable situation by creating conditions and facilitating teaching in schools allowing effective exploitation of the intellectual potential of students to shape pro-health attitudes during physical education classes.

INTRODUCTION

Since the times of Antiquity, the view on different systems of upbringing children and youth is expressed that physical fitness, being a function of physical exercises, can be a determinant in the development of intellectual abilities. Proof of this may be the position of physical education theorists referring to the idea of Athenian kalokagathia and the phrase "Satire" by the Roman poet - Juvenal (wrongly attributed to Thales): "*orandum est ut sit mens sana in corporesano*"[1]. Long sought has been evidence to support such a hypothesis based on the relationships between the various tests of physical fitness and indicators of intelligence. A strong correlation between the above mentioned variables was discovered in the first decades of the twentieth century by Pieter Joseph, a famous psychologist, philosopher, educator, science-expert and lecturer at many Polish universities, including the CIWF (Central Institute of Physical Education) in Warsaw. In the first period of his scientific work, he proved the existence of a positive, statistically significant relationship between the level of intellectual development and environmental derivation [1,2]. In the next cycle of research, he took up the issue of the relationship between IQ and the level of movement abilities, which in the modern concept of human motor skills are classified as a component of physical fitness [3]. The results published in the journal "*Wychowanie Fizyczne"* (Physical Education) [4,5] indicate that J. Pieter discovered very strong relationships between the constructed test of motor abilities and intellectual FITNESS of CIWF candidates. This was indicative of *"the existence of compatibility between the goodness of the brain and the goodness of talent in the muscles"* [4:194-199]. Although, based on modern psychological knowledge one should refer to such extreme views with large distance [6,7], it is difficult not to emphasize the fact that after many decades of suggestions, the Polish psychologist and Physical Education educator (also!) are confirmed by some of today's American studies on the relationship between activity and physical fitness, and the level of intelligence or cognitive ability [8-15]. Therefore, it is still an open question to be solved by educators: is a more intelligent child fitter and whether the level of physical fitness can be an indicator of a child's non-verbal intelligence?

When seeking for the answer to the problem formulated as such, for now, we may refer to very interesting experiments, but performed (unfortunately!) on animals [16-17]. Improved hippocampal performance was documented by an increase in proteins called growth factors [18]. It turned out that as a result of the applied training, there was an increase in neurotrophic factor (BDNF) and also in the insulin-like growth factor (IGF-1) as well as vascular endothelial growth factor (VEGF) stemming from the brain. These proteins may promote cell proliferation and growth [19] (i.e., in this case, growth factors) as well as the development and functioning of neurons [20-21] (that is why they are referred to as neurotrophic factors).

The Brain-derived Neurotrophic Factor (BDNF), functionally and structurally related to the family of growth factors, is primarily concentrated in the hippocampus and cerebral cortex [22-24]. It is decisive of the functioning of neurons, growth and synaptic plasticity. Re-

[1] Decymus Junius Juvenalis (67–138) Translated from Latin. Eng. Juvenal (10.356-64): *"You should pray for a healthy mind in a healthy body"*. Juvenal (1992) The Satires, Trans. Niall Rudd, Oxford: Oxford University Press.

search has shown that with age, a process of systematic reduction occurs in the brain, which causes dysfunction of the hippocampus and the same disorder primarily in the short-term memory [25]. The conducted meta-analyzes showed that some studies found a halt in this process after the implementation of aerobic activities for a long period of time [26, 27]. It was suggested that this could be due to the effect of improving the plasticity of the hippocampus caused by increased levels of BDNF. The effect of these changes was improvement in memory [28-34].

As it is known, an important determinant of cognitive ability is intelligence. Therefore, it may seem that improvement in physical function, which is a result of physical activity, would improve human cognitive abilities (and intelligence, too) through better functioning of the hippocampus as a result of the BDNF growth factor [35-36].

Another protein included in the group of growth factors is - as already mentioned – the VEGF (Vascular Endothelial Growth Factor). It is believed that it is responsible for angiogenesis and increased vascular permeability. Research has shown that VEGF promotes the formation and development of blood vessels which is associated with cognitive improvement in hypoxic conditions [37-39]. The effects of training carried out among animals showed an increase in the interaction of VEGF and IGF-1, especially in processes of neurogenesis and angiogenesis [40-43].

The Insulin-like Growth Factor 1 (IGF-1) is assigned an important role in improving cognitive processes [44-46]. It is primarily known for its function in energy metabolism and homeostasis. It is also considered to be a key growth factor that modulates: synaptic plasticity, synaptic density, neurotransmission and the process of neurogenesis in adults [47, 48]. It also takes part in the reconstruction and remodeling of blood vessels [49]. With age, there is an observed decline in its level, parallel to adverse changes in vessel density and blood flow in the brain [50]. Studies in animals have shown that during exercise, protection of the brain against damage is done by stimulating the uptake of circulating IGF-I [30]. Its increase is also the induction of BDNF in the hippocampus. It is believed that the effect of such mediation should be considered as a major causative factor in the effect of exercise on learning and memory [30, 31].

Other experiments showed that physical exercise performed for 10 minutes produces an increase in GH, which may persist for up to 120 minutes following the exercise [52]. For athletes, stress is also important, which synergistically with exercise, causes a physiological increase in the concentration of GH. This phenomenon has been documented, among others, by studies conducted among Italian gold medalists from the Olympic Games in Sydney, who were falsely accused of doping GH based on a single blood test [53]. It should be noted, however, that - so far - these are just hypotheses - partly confirmed in contributing studies conducted on people in old age. Studies in people who are physically active are rare. It has been done on the example of an increase in the concentration of MGF mRNA in young people performing knee extensor exercises consisting of 10 sets of 6 repeats representing an intensity of 80% of the maximum single repetition [55].

However, in the last decades of the twentieth century, there has been a shift towards the undesirable impact of IGF-1 on physical performance in the case of physically fit persons [54]. Knowledge on the endo-para-acutocrinic properties of the GF growth factor, and especially the condition of the muscles producing it has been used in sport. It is known that the Insulin-like Growth Factor 1, apart from increasing the synthesis of proteins and chondromucoprotein, also stimulates repair processes, increases glycolysis, reduces lipolysis, stimulates the immune system, enhances growth and inhibits apoptosis [55].

Currently, the GH (Growth Hormone), and the Insulin-like Growth Factor 1 (IGF-1), next to erythropoietin and insulin, are the most commonly used polypeptide doping agents by athletes, including animals participating in racing [54, 55]. Although the substances have been banned for many years and are on the list of the World Anti-Doping Agency [56], the athletes knowing the analytical and lipolytic effect of the growth hormone which help to effectively increase muscle mass and thus their FITNESS and reduce fat mass, or its anabolic properties cause the expression of Insulin-like Growth Factor 1 (IGF-1) – they do not hesitate to use them together or separately to achieve better post-training effects [57, 58].

Belief in the success of training was initially based on the effects of the research carried out on animals. These studies showed that genetic manipulation based on increasing IGF-1 myocytes, led to a 15-percent increase in weight and 14-percent increase in muscle-strength without changes in IGF-1 levels in the blood plasma [59]. The use of exogenous IGF-1 in combination with physical training resulted in an increase in the number of nuclei in muscle cells and an increase in the volume of muscle fibers [60, 61].

To date, only one study [62] noted the effect of physical training on the volatility of variation in the level of the following factor belonging to the group of proteins that are secreted by certain types of cells stimulating other cells to divide or differentiate, which is the Platelet-derived Growth Factor, PDGF. It plays an important role in angiogenesis. It is a dimer. In the above mentioned study, one of its five isoforms - PDGF-C was considered, which is constructed of two "C" chains [63]. It is mainly produced by vascular cells and is secreted as a homodimer. It has been found to be particularly expressed in the brain and spinal cord [64, 65].

From the above overview of literature, it can be stated that the researchers' attention was, however, directed towards the possibility of increasing the performance of athletes by administrating the above mentioned compounds in a synthesized form. This resulted in a spontaneous shift of the line of research onto the tracks of illegal activities in competitive sports, which is the use of gene doping.

It should be clearly stressed that the evidence to support the hypothesis assuming the ability to achieve the benefits of physical exercise for the functioning of the brain, were primarily collected from studies in animal models. As is clear from a review of literature [66-68], the experiments conducted on humans in old age did not unequivocally confirm the relationships discovered in the training of animals [69]. Most often, they focused on the impact of jogging or walking (aerobic exercise) on the mental performance of healthy elderly people. Results from a recent study conducted at a high scientific level - indicate that systematic, several-month-long or single training experiments used in the above 60 age group, based on the use of jogging and walking, had no significant effect on the serum concentrations of BDNF, IGF-I or VEGF. It was similar to the levels found in the control groups [34,62,70].

Only one study indicated favorable post-exercise changes in the volume of the hippocampus, which translated to significant improvement in spatial memory [34]. In other publications, one may find suggestions for opportunities to improve executive functions in active elderly people (over 70) due to the increase in BDNF [71]. There are also reports showing weak susceptibility of the hippocampus to the effects of physical exercise in older people, especially on blood perfusion and the related process of improving short-term memory under the influence of jogging performed for 3 months [72]. So far, only two studies have shown the weak positive effects of aerobic exercise on BDNF levels in young healthy, physically active individuals [73, 74].

In most psychological and neurophysiological studies, there is no conclusive evidence of the positive effect of physical exercise on the improvement of cognitive function and functional capacity of the brain. This can be confirmed by meta-analysis of research achievements in this field performed in terms of methodology, taking into account works from the years 1966-2009 [75]. None of the expected positive effects have been shown in the already mentioned recent, multi-faceted experiments carried out among international teams at the German Center for Neurodegenerative Diseases research center in Magdeburg, the results of which were not announced until 2016 [62]. Most of these studies support the previous observations relating to no grounds for assigning a unique role to increased physical activity in the improvement of growth factors, which improve the brain functions. Several months of training in the elderly has significantly contributed to raising their physical condition to a higher level. In the experimental and control group, there were no identified changes in the strength of the relationship between blood levels: BDNF, VEGF, PDGF or IGF-I and indices of cognitive ability. For several cases performing the speed training run in the experimental group, the negative impact of training effects on hippocampal plasticity was noticed. It is suggested that the slight, positive changes in the brain may be a consequence of the improvement of nerve function, regardless of angiogenesis, neurogenesis or synaptogenesis.

It follows that hopes for an explicit explanation of the effects of increased physical activity on improving the FITNESS of the functioning of the human brain - appear to be still premature at this stage of research [76, 77]. It should also be added that so far, there are no reports on the impact of physical activity on the expression of these growth factors and their significance in the improvement of intellectual function in children and adolescents. Although the effects of changes in the functioning of the brain under the influence of the use of physical exercise have not yet been clearly defined, some researchers suggest the hypothesis that regular physical activity can result in greater benefits for the functioning of the central nervous system in children and adolescents than in adults [78]. Such hope is seen in the very interesting results of research regarding the effects of physical activity on the cerebral cortex using electromyography and measures of the response-time gauges [78, 79]. In them, it was proven that the more physically efficient children had greater activity of the cerebral cortex, especially in the areas responsible for cognitive function, than their peers with lower levels of motor ability. Such positive changes were not noted in similar observations of older people [80].

As previously stated, the search for the relationship between the level of activity and physical fitness of children and adolescents and the widely recognized intellectual and functional potential of the human brain, which underlies intellectual processes including intelligence, was only carried out using classic psychological and pedagogical methods. In many meta-analysis, based on the results of research carried out in the world at the turn of the century, it is difficult to find a clear statement that the level of motor skills caused by increased physical activity has a positive effect on cognitive abilities [8,12]. For example, in large US population-based studies conducted in the early twenty-first century, there was no one-way, positive impact of physical activity and fitness on some of the cognitive functions in children during their progressive ontogenetic development [8,9,13,15]. According to normal statistical distribution, there was rarely a negative or positive impact on their intellectual development. Most commonly perceived in Amercian psychological and pedagogical studies was the lack of association between increased physical activity and a higher level of physical fitness and efficiency. A similar conclusion also resulted from the study among Polish children of both sexes, presenting different levels of physical fitness [81]. Comparability of the Polish results of studies with those conducted abroad undoubtedly hinders the use of different methods for measuring physical activity and fitness, as well as testing cognitive abilities [9].

In the American research, as if on the margins of research on the determinants of cognitive development, the issue of the relation of physical activity with the intelligence of children was undertaken. In a small number of subjects, high correlation coefficients between non-verbal IQ and the level of fitness and physical activity were usually perceived [82]. Similar results were obtained in the Polish observations of children aged 8-14 years conducted in the previous century. S. Strzyzewski [83] showed a high correlation between the level of motor skills evaluated using the Denisiuk test and the Ozierecki motor ability test, and non-verbal IQ as measured by the Raven test. Such relationships were more often present in girls than boys. The subsequent observations carried out in different regions of Poland indicated similar correlations between the level of physical fitness and intelligence potential, most often also measured using J.C. Raven's test [84-87]. These relationships were not confirmed by the results of continuous observation of children aged 4-15 years, which were performed in the second half of the 20th century in three different populations of Malopolska (village, small town, big city), [88] nor by their repetition 35 years later in the same towns [89, 90]. Only further environmental diversification of intelligence level and its variability over time (the Flynn/Lynn phenomenon) was documented in these studies, which occurred more strongly in children from small towns. However, in other studies conducted in the 21st century, a strong correlation was found between non-verbal intelligence and coordination abilities. The same strength of the relationship did not occur when fitness abilities were considered in the correlation. This observation draws attention to similar functional (biological) grounds of mental processes and coordination, which is EFFICIENCY of the central nervous system. Assuming the hypothesis that both coordination skills and non-verbal intelligence are susceptible to the effects of the same environmental factors is suggested. Adopting the above mentioned assumption, it can be believed that the level of FITNESS coordination measured by testing motor skills, may be the litmus test in the development of a child's intelligence. Such relations were indicated in the results of studies on the relationship between non-verbal intelligence and the level of development of selected somatic and psychomotor skills in a small group of 11-12 year old boys and girls in Wroclaw [86]. In a sense, the earlier mentioned results of students in J. Pieter's study were in this way confirmed [1-5].

Still unexplained is the issue of the weak relationship between intelligence and the level of fitness abilities - traditionally understood as the group of motor fitness abilities related to: strength, spped and endurance. Their biological basis is the energy produced in the muscle metabolism. To date, there is a lack of evidence regarding the existence of a direct relationship between the psychological and energy processes occuring the a human's muscles. Based on the Basic behaviouristic model: stimulus (S) – response (R), seeking for the relationship between intelligence and motor potential can be considered as unjustified.

It appears that the role of psychological factors (including intelligence) in the determination of fitness level (the above-mentioned complex of condition motor abilities) can be explained on the basis of the neobehaviouristic model: S-O-R. Within its framework, the effectiveness of performing the task (R) in the measuring experiment (S) should be connected with function of the "mediator" - "O" as it was defined by Edward Chase Tolman [92] in the concept of teleological neobehaviourism or Robert Session Woodworth [93] in eclectic dynamic psychology. A place for intelligence can be found in the wide, dynamic structure of the mediating factor in testing motor skills (according to Robert Woodworth Session "O" factors are the "body" [93-95]). It should be an important condition in creating motor potential in a dynamic manner, through the quality and quantity of the used motor stimuli. It is not unreasonable to assume that a person with a high intelligence level, especially at a young age, needs to have strong motivation to systematically take up various forms of movement in order to achieve a high level of motor abilities. In the modern American concept of Health Related Fitness, the motor component is after all an important measure of health. It would be expected that smarter children should also be more susceptible to the impact of school education, aimed at shaping attitudes of lifelong care for their own body, including physical fitness, regarded as an indicator of positive health. In turn, the lack of association between intelligence and physical fitness can attest to the non-utilization of conditions conducive to the directional objectives of physical education in children and youth.

From the theoretical premises and our own experience, some distance should be shown in the calculations of the statistical coefficient of linear correlation. It is known that in assessing the relevance and strength of correlations in auxological research, the following should be considered: the period of ontogenesis, sex, number of subjects and environmental considerations taken into account in the correlation of dependent and independent variables.

Based on the results of a review of literature and considering the assumed theses, in our study, we attempted to determine the strength and significance of the correlation between the level of non-verbal intelligence and fitness of children aged 7-14 years, with regard to their place of residence.

Therefore, the study aim is:

1. Understanding the kinetics and dynamics of the development of non-verbal intelligence and the physical condition of selected motor skills in children aged 7-14 from three Malopolska areas: a village, a small town and a big city.
2. Demonstrating the strength of the relationship between the level of development of non-verbal intelligence and the conditioning aspect of physical fitness in the progressive course of biological development in children from Malopolska, aged 7-14.
3. Assessment of the role of selected biological (age, gender) and environmental (village, small town, big city) factors in the differentiation of the pace of development and the strength of correlations between the level of somatic and motor development in children aged 7-14 years.

Research issues

In order to carry out such objectives, solving the following research problems was attempted:

1. To what extent do the pace of somatic, motor and mental development and the strength of relationships between the level of development of non-verbal of intelligence and the indicator of physical fitness and its components (fitness abilities) reveal itself in the course of ontogenetic development in children aged 7-14 years from Malopolska?
2. What is the role of biological determinants (age and gender) in shaping the pace of physical and mental development and the strength of relationships between indicators of mental and motor development in children aged 7-14?
3. Can the place of residence (village, small town, big city) be a modifier of physical and mental development in children during their progressive period of ontogenetic development and the strength of correlations between the level of mental and motor development of children aged 7-14 years?

Hypotheses

1. Assuming that children with a higher level of intelligence can achieve a high level of motivation to perform exercise during the period of progressive biological development and thus, improve the motor components of physical fitness considered as indicators of positive health, it can be considered that there will be a strong correlation between the results of motor skill and non-verbal intelligence tests. in a randomly selected group.
2. Biological factors considered as "mediating variables" in the study of correlations between intelligence and components of physical fitness, such as gender and age of the children, should not significantly differentiate the pace of mental and motor development and the strength of correlations between the dependent and independent variable.
3. Due to equalization of living standards of Polish families in the system transition period and the unification of the physical education system in Polish schools, it can be assumed that factors such as: living in a big or a small town and rural areas do not affect the diversity of the correlation relationship strengths between indicators of somatic and motor development and non-verbal intelligence of children aged 7-14.

II. RESEARCH MATERIAL AND METHODS

1. Number of participants

The study was conducted in the years 2005-2010 in three different metropolitan areas of Malopolska: a big city - Krakow, a small town – Slawkow, a village - Barcice[2]. We classified the results of complete observations of measurements regarding the level of the somatic, motor and mental development of children representing both sexes from the above mentioned towns. The total number of the studied children aged 7-14 years amounted to 1039, including 526 girls and 526 boys attending primary schools in Slawkow and Barcice, and 6 randomly selected primary and secondary schools of

[2] According to the approach of dynamic psychology by Robert Session Woodworth, developed on the basis of functionalism, the word motivation should be understood etymologically, as a compound of the words: ***motive and action***, and according to the Latin root-word, *moveo, movere* can be assigned the following meaning: *to propel, push, move, carry*. Therefore, it should be assumed that motivation is a propeller of an action or an "unspecified energy" in the biological category, triggered by an organism to ensure an action is directed towards an aim [93-95].

Table 1. The number of children taken into account in the development of observation, conducted in three towns of Malopolska in the years 2008-2010, according to gender

Age/Sex	7	8	9	10	11	12	13	14	Total
Boys	54	49	65	73	73	43	86	70	513
Girls	55	47	72	66	58	50	87	91	526
Total	109	96	137	139	141	93	173	161	1039

three districts in Krakow. Table 1 contains the detailed distribution of the number of children studied according to year of birth.

As it can be concluded from analysis of the data in the table, the number of younger children in the age group 7-10 years was 240 boys and 241 girls, and in the older group of 11-14 years: 286 girls and 272 boys.

2. Methods and scope of research

We conducted observations of the somatic, motor and mental development of children aged 7-14 years from three different Malopolska towns in terms of size.

3. Tools and techniques

Somatic features

- Body height was measured with an anthropometer in the Frankfurt plane.
- Body mass was calculated using "the Tanita" type scale.

Motor FITNESS

- Motor skills
  a) The ability to develop dynamic strength determined in the test by throwing a medicine ball from above the head. Ball weight: 1kg – age 7-10 years, 2 kg – age 11-14 years [96].
  b) The ability to develop explosive strength of the lower limbs examined with the use of the long jump test from starting position – no run up, both feet on the ground [92].

c) Speed abilities were determined based on the results of the running test – standing start. The distance was: 30 m - age 7-10 years, 60 m – age 11-14 years [96].

Non-verbal intelligence test

The level of non-verbal intelligence was quantitatively assessed taking into account the results of the Raven's Progressive Matrices Test, which is the most commonly used test in psychological practice around the world [97]. We used two versions of the test due to the ontogenetic development age of the subjects:

a) Raven's Progressive Matrices Test in TMK colour version, three series of tasks A, Ab, B for the youngest children aged 7-10 [98].
b) Raven's Progressive Matrices Test in black and white version. Standard. Series A, B , C, D, E, during which children aged 11-14 years were tested [99].

4. Statistical methods

1. After checking the normality of distribution of the measurements concerning selected somatic features and motor skills using the Kolmogorov-Smirnov test, we calculated the arithmetic mean values ($\overline{x}$) and standard deviation (SD), taking into account age, gender, place of residence of the subjects: big city, small town, village.
2. From the total number of correctly solved tasks in the four series of the J.C. Raven test in color version and in five series in the black and white version, arithmetic means were calculated separately for sex, age, the total of subjects and divided according to their place of residence: big city, small town, village.
3. On the other hand, the difference between the measurements of motor skills and the indicator of correct answers in the J. C. Raven test for each subject and the value of the arithmetic average for all subjects, were regulated to standard deviation of the studied group. On this basis, points on the T scale were calculated using the formula:

$$T = \frac{x^*_i - \overline{x}}{\overline{s}} \times 10 + 50,$$

where: T = point value on the T scale; x = arithmetic mean for the population; s - standard deviation from the arithmetic mean of individual measurements; x_i = sum of the points from the Raven test or motor test ; *– If the result is expressed in units of time, the order of the expressions contained in the numerator ($x - x_i$) was changed.

4. From the total points of T-Scores in three measurements of motor skills, we calculated indicators of overall motor physical fitness for each participant [3] and then, we calculated the arithmetic mean according to sex, age group of the total sample, taking into account the place of residence: village, small own, big city.
5. In the distinguished age and gender groups, divided according to place of residence and for the total sample, we calculated Pearson's simple correlation coefficients (RXY) on the point values between non-

verbal intelligence and measurements of individual motor skills and the overall indicator of physical fitness.

Two tests were used to verify the statistical significance of Pearson's simple correlation coefficients:

- In the first case, the following hypotheses were traditionally formulated [100]:

$$H_0 \div \rho = 0 \text{ and } H_1 \div \rho \neq 0,$$

where ρ is the true value of the correlation coefficient in the population.

To verify the hypothesis regarding the lack of linear relationship between the two characteristics of the population, we used the most popular test in statistics, based on the formula:

$$t = \frac{r\sqrt{n-2}}{\sqrt{1-r^2}}$$

- In the second case, we considered a more rigorous test, proposed by statisticians [101]. The formal record of the test is presented as follows:

$$H_{0\div} \mid \rho \mid = \rho_0, H_1 \div \mid \rho \mid > \rho_0$$

where p is the real value of the correlation coefficient of the population, p_0- r_{xy}= 0.70

Due to the fact that the alternative hypothesis can also be left-sided, but the nature of the test justifies using only the right-sided test, verification of the null hypothesis was done using the following formula:

$$Z = \frac{1}{2}(Z - zo)\sqrt{n} - 3$$

$$Z = \frac{1}{2}\, ln\left(\frac{1+r}{1-r}\right) zo = \frac{1}{2} ln\left(\frac{1+po}{1-p0}\right)$$

where:

Assumption: the T-statistic for samples larger than 10, normal distribution N (0.1) and ρ_0 = 0.7, which in turn, in the regression model totals a determination coefficient of about 50%.

III. RESULTS

1. The dynamics of non-verbal intelligence development compared with the pace of physical and motor development of children aged 7-14 years

In tables 2-3, we present the arithmetic mean of the measurement results: Raven Test [RAV], basic somatic characteristics (height [HEI] and mass [MASS]), motor skills (speed abilities [30-m R], the ability to develop dynamic strength of the upper limbs [BALL], explosive strength of the lower limbs [LONG], point indicator of overall physical fitness [FIT]. Determining their values as a function of the subjects' age: 7-14 years, we conducted assessment regarding the dynamics of development related to psychological and biological features and physical components. Based on the well-understood biological regularities of ontogenetic development, it was decided to pay attention to the development of the relationship between the growth rate of non-verbal intelligence compared to motor development in the period of progressive biological development in boys and girls living in three different towns of Malopolska (village, small town, big city).

<u>*Girls*</u>

According to the data presented in the Table. 2, despite the cross-sectional nature of the study regarding the collected material, it is possible to determine the typical processes of physical development of the studied girls. Analyzing the dynamics of somatic development, we may come to the conclusion that the process of intensive biological maturation occurred very early in the studied girls.

It can be assumed that, on average, in the study group, the puberty spurt in body height occurred between the age of 11 and 12 (Table 2). However, its strength was clearly environmentally differentiated. Apparently, it was revealed in girls living in a small town (d=11.14 cm) and less in the big city (8.25 cm) and rural areas (6.99 cm). It should be added that the period of accelerated growth could probably occur as early as between 10-11 years of age. This was evidenced by the large increase in body height at this time for the girls from Barcice (d=6.22 cm) and Krakow (d=5.86 cm), with a very low growth rate during this period in the girls from Slawkow (d=2.88 cm). Comparing the characterized phenomenon in the somatic development to the pace of motor and mental development, a strong resemblance of the development lines can be found, but only at certain periods of ontogeny.

Therefore, our study confirms the partially assumed harmony of the biological (including motor) and mental maturation noted in some studies. It is worth noting that during the puberty spurt, in girls from from various towns, there was a large differences in the pace of development of non-verbal intelligence. With its increase in the whole group d = 11.28 pts, the following ranges of development pace were noted: d = 15.11 pts - in girls from Krakow; d = 11.86 pts - from Barcice; d = 8.05 pts - from Slawkow. The scale of the dynamics of mental development in the period of intense biological changes may be indicated by the fact that the range of variation in the indicator of non-verbal intelligence up until the pubertal spurt (age 7-11 years) was at the lower level and in average values amounted to: in Barcice d = 10.9 pts; Slawkow d = 8.58 pts and in Krakow d = 7.81 pts.

Table 2. Arithmetic means of measurements regarding somatic features, physical fitness indicators of the level of non-verbal intelligence in the studied girls aged 7-14 years, division with and without regard to place of residence

Age/ Measurement		7	8	9	10	11	12	13	14
Barcice									
RAV	pts	21.76	24.77	26.78	32.14	31.85	43.71	42.56	44.79
HEI	cm	125.41	128.74	135.21	140.96	147.18	154.17	159.05	162.25
MASS	kg	27.89	27.18	31.28	35.12	39.74	46.61	49.72	54.69
LONG	cm	93.35	112.62	119.67	125.36	133.85	137.36	143.93	144.75
30-m RUN	s	7.25	6.57	6.47	6.38	5.95	5.66	5.39	5.24
BALL	cm	310.29	299.23	382.96	386.43	495.38	395.00	483.70	502.50
FITNESS	pts	38.38	43.35	46.81	47.95	53.68	52.76	56.99	58.21
Sławkow									
RAV	pts	22.80	24.25	28.38	29.22	31.35	39.40	44.35	41.96
HEI	cm	122.08	126.43	134.16	139.46	142.34	153.48	156.69	159.38
MASS	kg	25.48	26.88	31.19	33.90	37.69	42.77	46.68	51.72
LONG	cm	99.75	105.75	113.52	113.43	118.41	156.90	143.45	147.08
30-m RUN	s	7.19	6.83	6.74	6.62	6.25	5.70	5.77	5.76
BALL	cm	251.55	312.50	362.86	406.09	508.24	490.00	485.50	514.17
FITNESS	pts	37.89	41.75	44.35	46.01	50.84	57.38	55.34	56.55
Krakow									
RAV	pts	24.33	25.29	28.25	32.55	32.14	47.25	44.20	45.56
HEI	cm	123.76	128.19	137.23	141.49	147.35	155.60	158.41	161.61
MASS	kg	24.62	27.11	32.99	33.95	39.38	42.41	48.70	53.23
LONG	cm	85.56	97.29	98.67	115.52	120.18	132.44	144.15	142.77
30-m RUN	s	7.34	6.97	6.82	6.35	6.27	5.70	5.71	5.83
BALL	cm	264.17	345.36	405.00	478.45	548.21	445.63	529.50	560.70
FITNESS	pts	35.84	40.99	43.33	49.27	51.98	53.29	56.84	56.95
Total									
RAV	pts	22.98	24.70	27.74	31.30	31.84	43.12	43.72	44.41
HEI	cm	123.66	127.59	135.58	140.67	145.84	154.35	158.21	161.19
MASS	kg	25.94	27.03	31.82	34.18	38.96	43.73	48.55	53.22
LONG	cm	93.13	105.13	110.88	116.88	122.72	143.60	143.92	144.43
30-m RUN	s	7.26	6.80	6.67	6.45	6.19	5.69	5.62	5.66
BALL	cm	273.84	318.62	384.44	433.71	524.66	449.20	505.17	533.08
FITNESS	pts	37.37	41.97	44.93	47.86	52.03	54.78	56.54	57.18

Explanation of abbreviations: Raven Test - RAV; height – HEI; mass – MASS; speed abilities - 30-m RUN; the ability to develop dynamic strength of the upper limbs –BALL; explosive strength of the lower limbs – LONG; point indicator of overall physical fitness – FITNESS

Against this background, motor development was rated less favorably. During the body height pubertal spurt (age 11-12 years), a downward trend in the abilities of strength was revealed, measured by the medicine ball throw test. In the whole group of respondents (total), a regression was noted at the level of: d = -75.48 cm, along with the large diversity of children living in three regions; Krakow: d = -102.58 cm; Barcice: d = -100.38 cm and Slawkow: d = -18.24 cm. There was an increase in the pace of development regarding the remaining components of physical fitness. For example, in the whole group between the age of 11 and 12, it was at the

Table 3. Arithmetic means of measurements regarding somatic features, physical fitness indicators of the level of non-verbal intelligence in the studied boys aged 7-14 years, division with and without regard to place of residence

Age/ Measurement		7	8	9	10	11	12	13	14
Barcice									
RAV	pts	20.76	24.82	27.69	31.50	30.00	40.69	42.50	41.64
HEI	cm	124.48	130.37	137.50	141.25	145.05	151.41	162.13	165.39
MASS	kg	25.70	28.11	30.88	33.66	35.88	39.53	50.06	55.55
LONG	cm	103.76	119.64	129.54	141.30	145.32	161.23	165.42	170.82
30-m RUN	s	7.00	6.16	6.16	5.82	5.67	5.44	5.05	4.89
BALL	cm	335.59	345.91	485.00	499.75	507.73	460.00	564.58	622.27
FITNESS	pts	37.93	43.29	47.50	50.48	51.70	53.20	57.64	60.19
Sławkow									
RAV	pts	24.15	24.94	28.24	27.45	32.10	37.50	37.79	38.42
HEI	cm	125.73	128.31	135.09	140.75	143.71	152.68	154.26	163.17
MASS	kg	27.09	30.10	34.51	37.58	38.70	45.05	46.43	53.36
LONG	cm	102.31	113.06	112.52	132.27	132.87	163.25	160.89	168.33
30-m RUN	s	7.06	6.69	6.59	6.11	6.08	5.54	5.36	5.32
BALL	cm	292.31	375.00	422.80	522.27	596.00	511.25	532.37	639.17
FITNESS	pts	36.53	41.10	42.53	48.85	50.70	54.16	55.13	58.51
Krakow									
RAV	pts	23.54	25.64	29.93	29.61	32.81	42.77	42.72	45.31
HEI	cm	124.45	131.40	136.60	142.69	145.40	155.26	159.81	168.44
MASS	kg	27.06	29.61	33.41	38.28	39.10	46.38	49.98	59.25
LONG	cm	96.79	108.23	115.37	125.45	139.95	155.68	163.21	173.56
30-m RUN	s	7.07	6.71	6.31	6.21	5.84	5.57	5.36	5.23
BALL	cm	286.67	399.32	468.70	528.23	614.76	542.27	611.40	676.67
FITNESS	pts	35.82	41.06	45.07	47.85	52.87	53.96	57.20	60.30
Total									
RAV	pts	22.81	25.22	28.83	29.48	31.67	41.16	41.57	42.97
HEI	cm	124.77	130.16	136.20	141.71	144.60	153.61	159.23	166.58
MASS	kg	26.64	29.43	33.33	36.80	37.97	44.06	49.22	57.08
LONG	cm	100.31	112.37	117.11	131.85	138.66	158.77	163.31	171.80
30-m RUN	s	7.04	6.58	6.39	6.07	5.89	5.52	5.27	5.14
BALL	cm	303.43	379.39	454.31	518.63	574.79	511.63	580.87	653.14
FITNESS	pts	36.65	41.57	44.58	48.87	51.63	53.77	56.86	59.96

Explanation of abbreviations: Raven Test - RAVEN; height – HEI; mass – MASS; speed abilities - 30-m RUN; the ability to develop dynamic strength of the upper limbs – BALL; explosive strength of the lower limbs – LONG; point indicator of overall physical fitness – FITNESS

level of: d = 20.88 cm in the ability to develop explosive strength of the lower limbs [LONG] and d = 0.57 s in the ability to develop speed in running [30-m R] .

An even greater lack of coordination of psychological development with the pace of biological development in the studied girls occurred during their adolescence: age 13-14 years. Thus, apart from those living in the countryside, with a clear increase in the rate of motor and physical development, a stage of relative stability could be seen in the dynamics of non-verbal intelligence development. It was characterized by short periods of slower development of a trait or even regression. The scale of the low growth between the age of 12-14 years can be shown by the range of growth characteristics recorded at this time (d): ( ) = 1.29 pts, along with low environmental diversity: Slawkow (small town): 2.56 pts., Barcice (village): 1.09 pts., Krakow (big city): -1.69 (!) pts.

In the light of our own research, it would be difficult to look for other than environmental reasons (number of positive cases) for the lack of compatibility in the rhythm as well as direction of changes in the mental and motor development of the studied girls. It can be assumed that such a lack of coordination can affect the degree of manifestation of the relationship strength between the level of mental and motor development.

Boys

Table 3 presents the variability in measurements of non-verbal intelligence among the studied boys during the course of the considered period of ontogenesis, against the background of the development of selected indicators of somatic and motor development. Even conducting cursory analysis of the contained results, we can observe similar developmental trends as in the girls. They can be generally characterized as follows: until the completion of the pubertal spurt, apart from the force of the upper limbs [BALL], a parallel period of progressive development of the traits and motor skills taken into account occurred. In adolescence of the boys following the pubertal spurt, a one-way, slowed period of physical and motor development took place (except in one case in mental development). Surprisingly, it has been found that biological puberty occurred early in boys. Based on the growths in body height, it can be assumed that most of the studied boys entered a period of accelerated biological development, similarly as the girls between 11-12 years of age. Only in boys living in rural areas did this trend occur a year late. On this basis, it can be assumed that in the males, there was very strong acceleration of biological development. In previous studies [89,90], the phenomenon of the pubertal spurt in body height was found between 13-14 years of age.

On closer analysis of the data presented in Table 3., it is shown that for males, the progressive period of physical growth was accompanied by a growth in the indicator of non-verbal intelligence. In particular, such a phenomenon intensified during the body height pubertal spurt between 11-12 years of age. Then, with a very similar direction of diversity in environmental range, the "spurt" ratio of non-verbal intelligence was lower in boys than in girls (Barcice: d = 10.69 pts., Slawkow: d = 5.4 pts., Krakow: d = 9.56 pts., the average d = 9.49 pts.). It should also be noted that in the period of greatest growth in height and non-verbal intelligence, the only disturbance regarded pace of development of the dynamic force of the upper limbs [BALL]. Comparing the characterized phenomenon in somatic development to the pace of motor and mental development, strong similarities in the line of development can be found, but only at certain periods of ontogeny.

In light of the cited test results regarding the dynamics of mental development compared to variability of somatic and motor skills, it should be stated that during the period of the boys' ontogenesis, as well as in the females, there was deregulation in certain periods of ontogeny concerning their track of development, especially after the pubertal spurt period. This may prove the structure independence of psychological and biological development, as well as varying susceptibility of their components to environmental factors.

It should be assumed that the lack of coherence can cause reduction in the relationship strength between motor and mental development. Confirmation of the expressed supposition or it falsification was attempted to be found in analysis of the collected material regarding the relationship strength between the level of non-verbal intelligence and the potential of fitness capacities.

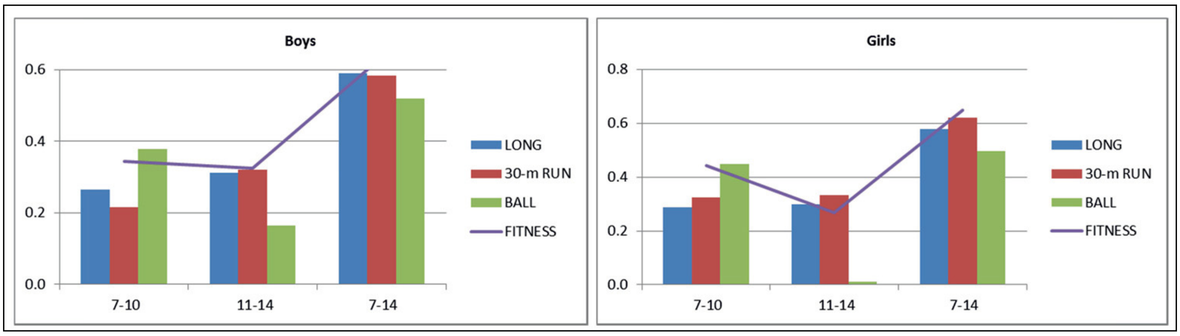
2. The strength of correlations between the indicator of non-verbal intelligence and the level of physical fitness and the fitness motor skills in the studied children

2.1. Non-verbal intelligence and physical fitness as well as its components in the group of boys and girls aged 7-14 years

In Table 4, the simple correlation coefficients between non-verbal intelligence (evaluated using the Raven test) and physical fitness as well as its components are presented (speed and strength abilitiy meaurements), which were calculated on the basis of point values (T-Scores scale) in three age groups of the studied children: 7-10, 11-14 and 7-14 years.

Their graphic comparison is presented in Fig. 1.

The analysis of correlations between non-verbal intelligence and physical fitness and its components show that the strength of the inter-characteristic correlations of boys and girls in the whole 7-14 age group was very similar: the indicator of physical fitness: ♀ r_{xy} = 0.65, ♂ r_{xy} = 0.63, long-jump: ♀ r_{xy} = 0.58, ♂ r_{xy} = 0.59, medicine ball throw: ♀ r_{xy} = 0.50, ♂ r_{xy} = 0.52, 30-m run: ♀ r_{xy} = 0.62, ♂ r_{xy} = 0.58. The scope of the variability of correlation coefficients was therefore within the range: r_{xy} = 0.50 – 0.65. In the case of a quite large number of study participants (n = 1039 and ♀ n = 526, ♂ n = 513), all correlation coefficients were statistically significant ($p<0.05$). As a result, taking J. P. Guilford's proposal into account, it appears that in the entire cohort of children from Malopolska, there was a significant relationship dependency with moderate correlation. The very similar correlation between non-verbal intelligence



Explanation of abbreviations: Raven Test - RAV; height – HEI; mass – MASS; speed abilities - 30-m RUN; the ability to develop dynamic strength of the upper limbs –BALL; explosive strength of the lower limbs – LONG; point indicator of overall physical fitness – FITNESS

Fig. 1. The strength of correlations between non-verbal intelligence and physical fitness in terms of motor ability and its structure in the studied boys and girls from the 7-10, 11-14 and 7-14 age groups

and two of the somatic features: height (♀ $r_{xy} = 0.76$, ♂ $r_{xy} = 0.73$) and body mass (♀ $r_{xy} = 0.61$, ♂ $r_{xy} = 0.58$) should also be emphasized. On this basis, it can be thought that fitter children and more advanced in biological development with higher non-verbal intelligence are characterized by improved FITNESS and vice versa. On this basis, it is possible to verify the earlier hypothesis developed according to the cited model from dynamic psychology (S-O-R): the mediating factor (O) – non-verbal intelligence - supporting motivation for physical exercise (forms of physical activity) - (S), positively effects physical fitness (R). Thus, the more physically fit child should also be smarter and vice versa.

More detailed statistical analysis of the collected material, however, casts doubt on such a clear statement and makes it necessary to show some distance towards the statistical calculations and the simplified inference conducted on its basis. In a sense, this decision supports the established similarities between correlation coefficients of non-verbal intelligence and physical fitness as well as its components such as those which took somatic features into account. As it is known, they are also indicators of biological development in children. This phenomenon may lead to the suggestion that the strength and direction of the correlation between mental and motor development is affected by the maturation factor - both biological and psychological. Subsequent stages of analysis of the collected materials were undertaken to solve the problem of the effect of age on the strength of correlations between the level of non-verbal intelligence and physical fitness and its components in the children from Malopolska.

2.2. Non-verbal intelligence and physical fitness as well as its components in groups of boys and girls aged 7-10 and 11-14

Fig. 1 and Tab. 4 present the variation in Pearson's linear correlation coefficients between measurements of: non-verbal intelligence evaluated using the Raven test [RAVEN] and basic somatic features: body mass [MASS], body height [HEIGHT], physical fitness [FITNESS] and its motor components (medicine ball throw test [BALL], long-jump [LONG] and the 30-m run [30-m RUN].

The analysis of the valued shows that in both gender and age groups (7-10 and 11-14), the widely-used test showed poor inter-characteristic statistical significance and low correlations, except for the strength of the association of non-verbal intelligence with the results of medicine ball throw measurements ($r_{xy} = 0.01$). Certainly, this could be due to the number of considered cases in the different age and gender groups (age 7-10 years: ♀ n = 241, ♂ n = 240; age 11-14 years: ♀ n = 272, ♂ n = 286). As previously stated, the traditionally used test for statistical significance of the correlation curve is extremely "sensitive" to the number of cases under consideration. Additionally, even considering the smallest number of cases included in the group of females (240 girls), the correlation coefficient demonstrating the weak relationship and insignificance of the correlation at the level $r_{xy} = 0.13$ (using the proposal by J. P. Guilford), could have been statistically significant [100-101]. It may be added that in order for the exceptionally low value of the non-verbal intelligence correlation coefficient and measurement of the medicine ball throw $r_{xy} = 0.01$ to be considered as statistically significant, 38,416 cases would have to be analyzed. In both sexes, similar development of the non-verbal intelligence correlation strength with body mass occurs compared to the above mentioned correlation coefficients, and is lower than in the case of body height (Table 4).

In the 11-14 age group, the correlation of intelligence with physical fitness was lower than in the younger group (7-10 years), which should be associated with the extremely low strength of relationships of non-verbal intelligence with the medicine ball throw test results. Apart from this case, in the 11-14 age group, a very similar to

Table 4. Correlation matrices between the results of measurements of basic somatic features and indicators of physical fitness and the level of non-verbal intelligence in girls and boys divided according to 7-10, 11-14 and 7-14 age groups

RAVEN→		Girls			Boys	
MEASUREMENT	7-10	11-14	7-14	7-10	11-14	7-14
HEIGHT	**0.50**	**0.49**	**0.76**	**0.44**	**0.48**	**0.73**
MASS	**0.27**	**0.26**	**0.61**	**0.28**	**0.36**	**0.58**
LONG	**0.29**	**0.30**	**0.58**	**0.26**	**0.31**	**0.59**
30m RUN	**0.32**	**0.33**	**0.62**	**0.22**	**0.32**	**0.58**
BALL	**0.45**	0.01	**0.50**	**0.38**	**0.16**	**0.52**
FITNESS	**0.44**	**0.27**	**0.65**	**0.34**	**0.33**	**0.63**

Explanation of abbreviations: Raven Test - RAV; height – HEI; mass – MASS; speed abilities - 30-m RUN; the ability to develop dynamic strength of the upper limbs –BALL; explosive strength of the lower limbs – LONG; point indicator of overall physical fitness –FITNESS

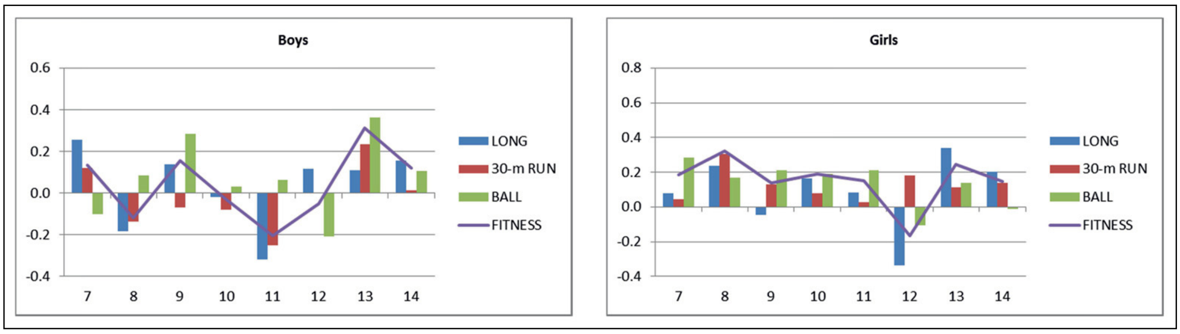
Note: Colour red font indicate statistical significance of the correlation coefficients at the level of $p < 0,05$

the group of younger children and statistically significant but low correlation was found for the girls. A higher correlation appeared for the boys in the same group.

In such a situation, the following question arises: can we draw such far-reaching, generalizing conclusions about the relationship between the child's intelligence and physical fitness based on such low, although statistically significant correlation coefficients? Surely this is a matter worthy of discussion. Doubts are also intensified by the results of comparative analysis of the strength of correlations in the entire cohort aged 7-14 years and the age groups: 7-10 and 11-14 years. In addition, the occurrence of significantly lower values of correlation coefficients in the following age groups: 7-10 and 11-14 years in boys and girls compared to the entire age group of 7-14 years deserves attention. It seems that it could be due to different distribution of the correlation matrix, which in a sense confirms the previously expressed idea that the strength of correlations in the statistical calculations is impacted by the physical and mental development factors in children. To a large extent, such a suggestion may be evidenced by the previously characterized rate of motor, somatic and mental development (Table 2-3). Importance of assuming a very cautious approach to the interpretation of the results of statistical analyzes can only be indicated by the results of test regarding correlation coefficients in the studied girls and boys in different generations of the 7-14 age group.

2.3. Non-verbal intelligence and physical fitness as well as its components in groups of boys and girls in following generations of children from Malopolska between 7-14 years of age

As is can be deduced from the data in Fig. 2 and Tab. 5-6, for the specific generations of studied boys as well as girls, there was a very weak and varied strength of correlations between their non-verbal intelligence and the results of measurements regarding somatic characteristics, motor skills and the general indicator of physical fitness. Including its relationship with physical fitness and its components, the following range of variability of the correla-



Explanation of abbreviations: Raven Test - RAV; height – HEI; mass – MASS; speed abilities - 30-m RUN; the ability to develop dynamic strength of the upper limbs –BALL; explosive strength of the lower limbs – LONG; point indicator of overall physical fitness -FITNESS

Fig. 2. Variation in boys and girls along with the age regarding Pearson correlation coefficients between non-verbal intelligence and physical fitness and its components

tion can be noted: in males: r_{xy} min. (-0.32) – max. (0.36) and in the females: r_{xy} min. (-0.34) – max. (+0.34). Also worth noticing is the negative correlation strength regarding body height in girls throughout the considered period: r_{xy} min. (-0.08) – max (-0.41), with minor exceptions in body mass: r_{xy} min. (-0.08) – max (-0.41).

This suggests that the earlier maturation of girls does not go hand in hand with an increase in non-verbal intelligence. In turn, their higher level of non-verbal intelligence was beneficial in achieving better results in the measurement of motor skills and physical fitness. Assuming the earlier hypothesis based on the model of dynamic psychology by Robert Session Woodworth: S-O-R, it can be assumed that the higher the level of development of this mental development indicator in girls may have affected the increase in motivation for physical activity, which in turn, allowed to achieve better motor effects in physical fitness tests. However, it should be noted that in most cases, the used traditional test did not show statistically significant correlations.

A slightly different situation was documented in the boys. Above all, with the same low coefficients of correlation, high lability of correlations between non-verbal intelligence and physical fitness and its components could be detected during the period of ontogenesis. More often, it was a negative correlation, unlike in the relationship between intelligence with indicators of the level of somatic development. On this basis, one could, in turn, believe that along with the biological development of the studied boys, the level of non-verbal intelligence also increased. Based on the pre-characterized model by R.S. Woodworth: S-O-R, it can be assumed that the level does not, however, have great significance for the improvement of motivation to increase physical activity, and thus, physical fitness. In most cases, there was a negative direction in the correlation intensification.

Table 5. Coefficients of linear correlation between the measurement results of basic somatic features and indicators of physical fitness and the level of non-verbal intelligence, as measured by the Raven in boys according to age of the subjects

MEASUREMENT/AGE	RAVEN→							
	7	8	9	10	11	12	13	14
HEI	-0,04	**0.35**	0,13	**0.25**	0.03	-0.02	**0.29**	0.15
MASS	-0.17	**0.26**	0.08	0.15	0.16	-0.19	**0.31**	0.10
LONG	0.25	-0.18	0.14	-0.02	**-0.32**	0.12	0.11	0.16
30-m RUN	0.12	-0.14	-0.07	-0.08	**-0.25**	0.00	**0.23**	0.01
BALL	-0.10	0.08	**0.28**	0.03	0.06	-0.21	**0.36**	0.10
FITNESS	0.13	-0.12	0.15	-0.03	-0.21	-0.05	**0.31**	0.12

Explanation of abbreviations: Raven Test - RAVEN; height – HEI; body mass – MASS; speed abilities - 30-m RUN; the ability to develop dynamic strength of the upper limbs – BALL; explosive strength of the lower limbs – LONG; point indicator of overall physical fitness –FITNESS

Note: Colour red font indicate statistical significance of the correlation coefficients at the level of $p < 0,05$

Table 6. Correlation coefficients between the results of measurements regarding basic somatic features and indicators of physical fitness and the level of non-verbal intelligence, as measured by the Raven in girls according to the age group of the subjects

MEASUREMENT/AGE	RAVEN→							
	7	8	9	10	11	12	13	14
HEI	-0.08	-0.20	**-0.26**	-0.16	**-0.41**	-0.27	**-0.28**	-0.17
MASS	0.10	-0.12	-0.07	-0.04	-0.19	-0.23	-0.18	0.18
LONG	0.08	**0.24**	-0.05	0.16	0.08	**-0.34**	**0.34**	0.20
30-m RUN	0.04	**0.30**	0.13	0.08	0.03	0.18	0.11	0.14
BALL	**0.28**	0.17	0.21	0.19	0.21	-0.10	0.14	-0.01
FITNESS	0.19	**0.32**	0.14	0.19	0.15	-0.17	**0.25**	0.15

Explanation of abbreviations: Raven Test - RAVEN; height – HEI; body mass – MASS; speed abilities - 30-m RUN; the ability to develop dynamic strength of the upper limbs –BALL; explosive strength of the lower limbs – LONG; point indicator of overall physical fitness – FITNESS

Note: Colour red font indicate statistical significance of the correlation coefficients at the level of $p < 0,05$

It should be emphasized (similarly as in the group of females) that correlations were significant in only in a few cases, usually at the final stage of observation. Speaking of statistical significance, we should bear in mind that it was effected by the low number of studied children from individual generations, as was mentioned earlier.

Its variation range was between: n = min. 43 – max. 86 in boys and in girls, n = min. 47 – max. 91. As it is known, the traditionally used test for statistical significance, giving the considered number of studied subjects, could have shown statistically significant correlation coefficients in the upper ranges: r_{xy} = 0.22 – 0.31 for boys and r_{xy} = 0.21 – 0.29 for girls [100, 101]. In conclusion, we should emphasize that the found level of correlation coefficients for each age group (Tab. 4), their statistical significance and their variability over time, are not comparable to the previously characterized state in the 7-10, 11-14 age groups or over the whole studied time period of 7-14 years. This makes it difficult to interpret the phenomenon that was supposed to be under the premise of mutual positive influence on the intellectual capacity of physical activity, reflected in the image of physical fitness and its components (and vice versa). Generally, in individual generations, there was no statistically significant relationship between non-verbal intelligence and fitness. To a large extent, the probability of a lack of correlation confirms the result from the new statistical [101].

This indicated issue will be further discussed in the summary of the test results. In accordance with the intended objectives of our own research, it seems important to further discuss the problem of the influence of environmental factors on the size, the direction and strength of correlations between non-verbal intelligence and physical fitness, anthropological indicators of biological maturation and physical fitness as well as its components.

2.4. Environmental determinants of relationships between non-verbal intelligence, physical fitness and its components in groups of boys and girls from Malopolska in consecutive generations between 7-14 years of age

In Table 7-8 and Fig. 3-4 we presented, similarly as in the whole collected material, coefficients of correlation between the results of measurements of non-verbal intelligence and indicators of motor and somatic development in subjects from three Malopolska areas (village, small town, big city) based on calculations of point values from the T-Scores scale, with the division of the collected material according to age group: girls aged 7-10, 11-14 and 7-14 (Fig. 3, Tab. 7) and boys (Fig. 4, Tab. 8).

Table 7. Correlation coefficients between the results of measurements regarding basic somatic features and indicators of physical fitness and the level of non-verbal intelligence, as measured by the Raven in girls according to place of residence and age group: 7-10, 11-14 and 7-14 years

		RAVEN→					
GROUP	**AGE**	**HEI**	**MASS**	**LONG**	**30-m RUN**	**BALL**	**FITNESS**
Barcice	7-10	**0.48**	0.20	**0.31**	**0.28**	**0.30**	**0.36**
	11-14	**0.40**	**0.26**	0.08	**0.25**	-0.07	0.09
	7-14	**0.76**	**0.63**	**0.49**	**0.64**	**0.44**	**0.60**
Slawkow	7-10	**0.46**	**0.31**	**0.33**	**0.23**	**0.51**	**0.47**
	11-14	**0.54**	**0.40**	**0.41**	**0.43**	0.10	**0.38**
	7-14	**0.77**	**0.65**	**0.66**	**0.61**	**0.59**	**0.71**
Krakow	7-10	**0.53**	**0.27**	**0.38**	**0.49**	**0.46**	**0.52**
	11-14	**0.50**	0.16	**0.39**	**0.37**	-0.02	**0.30**
	7-14	**0.75**	**0.54**	**0.63**	**0.64**	**0.44**	**0.64**
Total	7-10	**0.50**	**0.27**	**0.29**	**0.32**	**0.45**	**0.44**
	11-14	**0.49**	**0.26**	**0.30**	**0.33**	0.01	**0.27**
	7-14	**0.76**	**0.61**	**0.58**	**0.62**	**0.50**	**0.65**

Explanation of abbreviations: Raven Test - RAVEN; height – HEI; body mass – MASS; speed abilities - 30-m RUN; the ability to develop dynamic strength of the upper limbs –BALL; explosive strength of the lower limbs – LONG; point indicator of overall physical fitness – FITNESS

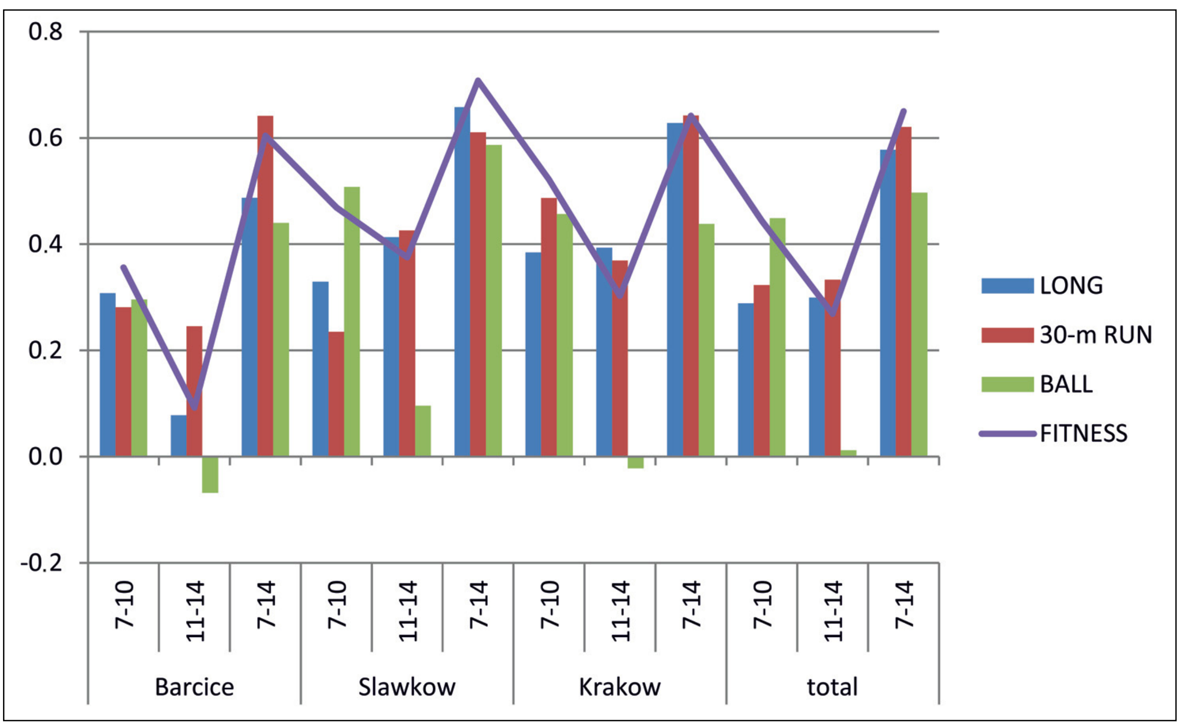
Note: Colour red font indicate statistical significance of the correlation coefficients at the level of $p < 0,05$

Table 8. Correlation coefficients between the results of measurements regarding basic somatic features and indicators of physical fitness as well as the level of non-verbal intelligence, as measured by the Raven in boys according to place of residence and age group: 7-10, 11-14 and 7-14 years

		RAVEN→					
GROUP	**AGE**	**HEIGHT**	**MASS**	**LONG**	**30-m RUN**	**BALL**	**FITNESS**
Barcice	7-10	**0.56**	**0.30**	**0.51**	**0.49**	**0.54**	**0.59**
	11-14	**0.46**	**0.43**	**0.29**	**0.40**	**0.24**	**0.36**
	7-14	**0.72**	**0.62**	**0.60**	**0.66**	**0.53**	**0.67**
Slawkow	7-10	0.20	0.19	-0.05	-0.07	0.15	0.02
	11-14	**0.31**	0.15	0.22	**0.27**	0.02	0.23
	7-14	**0.55**	**0.39**	**0.40**	**0.39**	**0.36**	**0.45**
Krakow	7-10	**0.54**	**0.36**	**0.35**	**0.26**	**0.48**	**0.43**
	11-14	**0.48**	**0.33**	**0.32**	**0.26**	0.08	**0.26**
	7-14	**0.78**	**0.62**	**0.68**	**0.64**	**0.58**	**0.69**
Total	7-10	**0.44**	**0.28**	**0.26**	**0.22**	**0.38**	**0.34**
	11-14	**0.48**	**0.36**	**0.31**	**0.32**	**0.16**	**0.33**
	7-14	**0.73**	**0.58**	**0.59**	**0.58**	**0.52**	**0.63**

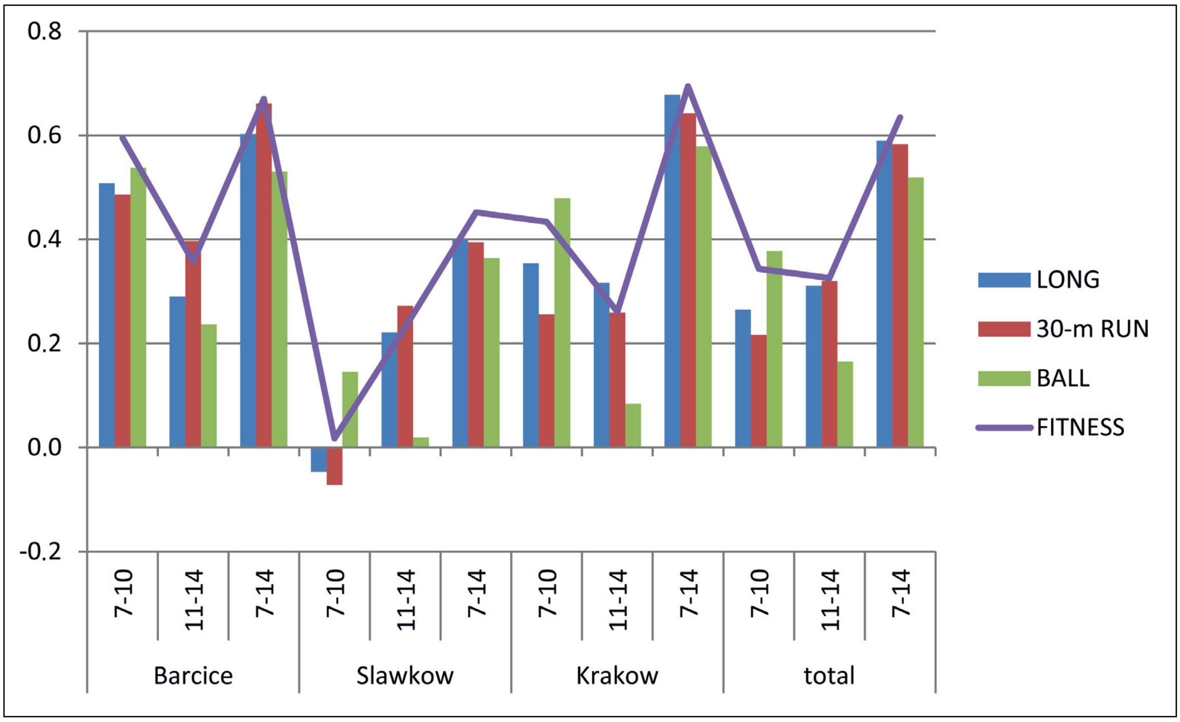
Explanation of abbreviations: Raven Test - RAVEN; height – HEI; body mass – MASS; speed abilities - 30-m RUN; the ability to develop dynamic strength of the upper limbs –BALL; explosive strength of the lower limbs – LONG; point indicator of overall physical fitness – FITNESS

Note: Colour red font indicate statistical significance of the correlation coefficients at the level of $p < 0{,}05$



Explanation of abbreviations: Raven Test - RAVEN; height – HEI; body mass – MASS; speed abilities - 30-m RUN; the ability to develop dynamic strength of the upper limbs – BALL; explosive strength of the lower limbs – LONG; point indicator of overall physical fitness – FITNESS

Fig. 3. Variation of correlation coefficients in the girls' age groups (7-10, 11-14 and 7-14) from three different areas in Malopolska (village - Barcice, small town - Slawkow, big city - Krakow) between non-verbal intelligence and physical fitness as well as its components compared to the results of studies with no division according to place of residence (total)



Explanation of abbreviations: Raven Test - RAVEN; height – HEI; body mass – MASS; speed abilities - 30-m RUN; the ability to develop dynamic strength of the upper limbs – BALL; explosive strength of the lower limbs – LONG; point indicator of overall physical fitness – FITNESS

Fig. 4. Correlation coefficient variability in the age groups of boys (7-10, 11-14 and 7-14) from three different areas in Malopolska (village - Barcice, small town - Slawkow, big city - Krakow) between non-verbal intelligence and physical fitness and its components compared to the results of studies with no division according to place of residence (total)

According to the aim of research and the model by S.R. Woodworth (S-O-R), we attempted to confirm the adopted research hypothesis assuming the possibility of blurring environmental differences in the strength of physiological determinants of physical fitness. Analyzing the material developed without considering the distribution of the subjects' age (7-14 years), we can conclude that the test result was positive. In both sexes, we found a significant relationship between non-verbal intelligence and physical fitness as well as its components: strength and speed abilities.

The used test showed statistical significance of the correlation coefficients. Similar results were obtained in the strength of the relationship between non-verbal intelligence and indicators of biological development: body height and mass.

On this basis, it is difficult to draw far-reaching conclusions about the importance of a higher level of non-verbal intelligence in fostering the motivation to engage in exercises to improve motor performance in all the places of residence of the children. The diversity of environmental variation regarding the strength of relationships in gender and age groups can be seen.

As it can be concluded from the data presented in Tab. 7 and Fig. 3, in girls, regardless of their place of residence, in measurements of overall fitness and in the distinguished age groups (7-10 and 11-14 years), we can find the lowest correlation coefficients in the older age group (11-15), while only in Barcice (village), the weak correlation relationship strength r_{xy} = 0.09 was not statistically significant. Additionally, in the females, the level of correlation coefficients in both age groups allowed to notice the constant maintenance of typical social gradients: large city > small town > village.

In turn, in the boys (Tab. 7, Fig. 4), there was disorder of such environmental gradients due to the occurrence of low, insignificant correlations between non-verbal intelligence and the indicator of physical fitness, its components and somatic features of the subjects from Slawkow (small town) in the 7-10 age group. The same situation could be found in the older group (11-15 years), with the exception of body height and speed measurements (30-m run). What draws attention is not only the higher correlation in the younger age group (7-10 years) in boys from Krakow and Barcice, but also the significantly higher and statistically significant correlation of coefficients in all relationships among boys living in the rural area (Barcice).

On the basis of the collected materials, it would be difficult to blurring the environmental differences into the strength of correlations between the level of motor development and its important determinant of mental health. It should be remembered that it is difficult to ignore gender when considering the environmental determinants in the impact of mental factors on the process of strengthening the motivation for physical activity, the main determinant of physical fitness. The presented results indicate that gender differentiates the strength of correlations of non-verbal intelligence, physical fitness and its structural elements and their variability during the studied period of ontogenesis. This may be evidence of the girls' higher susceptibility to pedagogical influence aimed at developing awareness of the importance of caring for one's own physical fitness, considered as a measurable health indicator.

By adopting such an assumption, it should be considered that in this respect, the girls with higher intelligence levels from large and small cities make better use of intellectual potential in shaping the foundations of physical fitness than their counterparts living in rural areas. In turn, in boys such trends were found in the rural and big city populations.

It is also difficult in this case not to pay attention to the developmental conditions of correlation coefficients. As in the situation of not including the environmental factor, it is worth paying attention to the relationship of the level of correlation coefficients according to its way of calculation. As previously stated, their value in both sexes in the entire cohort (7-14 years), regardless of place of residence, was greater than when considering only the two age groups (7-10 and 11-14 years). As earlier affirmed, solving this problem is not simple.

Interpretation of the environmental determinants of the test results is complicated by the question of statistical significance of the correlation coefficients. As we know, it depends on the number of tested individuals. The analysis of the commonly used formula for the statistical significance of the correlation coefficient (chap. II. 4.5a) shows that the value of the test statistics of the correlation coefficient depends solely on the size of the analyzed sample. Therefore, instead of verifying whether the result is statistically significant, we should formulate the question of how large the trial should be for a particular value of the correlation coefficient and the predetermined significance level to reject the null hypothesis in favor of the alternative. Of this, we are informed by ready-made tables. Most often, however, it does not pay notice to the scope of the identified statistical correlation in the given correlational relationship. This is stated by the coefficient of determination.

The traditional statistical significance test does not take it into account. Using the proposal for its modification [101] presented in the methodical chapter [ch. II. 5b], it turned out that in none of the cases were the Pearson simple correlation coefficients calculated in our study statistically significant (even taking into consideration the relationship between non-verbal intelligence and somatic features). Due to this, we should speak cautiously about the role currently played by non-verbal intelligence of children fromo Malopolska in achieving motor potential, more and more frequently considered as a desired indicator of health.

It is also hard not to pay attention to the only selective research on relationships in simple correlations.

The actual, quantitative share of non-verbal intelligence in the mediating factor, according to the behavioural S-O-R model, can be evidenced only by the result of applying multivariate statistical models.

Summary and discussion

The study presents part of the results of multifaceted research conducted in order to understand the environmental conditions and the kinetic transformation and dynamics of the mental, motor (including the common name of the biological development) development, somatic development of girls and boys living in three villages traditionally classified to environmental niches, which in the past were an important modifier of human development. The same interdisciplinary research had been carried out on a much smaller group of children 40 years earlier [88]. Therefore, there arose the possibility to track the trend changes during the biological and psychological development. The issues connected to manifesting secular trends in the somatic and motor development and the Flynn/Lynn effect were presented in our earlier studies [89-90].

In this study, to develop the pursued objectives, the used materials were collected in three areas of Malopolska: a village, town, city. In a detailed interpretation of the dynamics of the mental and somatic motor development, attention was paid to the occurrence of the phenomenon of the parallel course of their development line to completing the biological maturation process and the lack of biological and motoric coherence during the children's process of maturation. In the interpretation of the established phenomenon, attention was paid to the role of such factors as: the process of acculturation, as well as positive changes in the implementation of the operational objectives of physical education, whose manifestation could be better care for their own physical and mental health mainly in the progressive stage of the development of children from Malopolska. The occurring disorder of the developmental trend in adolescence could be the result of environmental stimuli's impact on the intellectual and physical development of the youth in the context of school physical education, as well as the manifestation of their own activity and initiative in this direction. To a large extent, the importance of the environmental factor has been confirmed in the analysis of the environmental diversity of the kinetics and dynamics of physical and mental development, as well as the assumed in the hypothesis phenomenon of fading social gradients, disclosed formerly in anthropological research: village < small town < big city [3, 89, 90]. On this basis, it was believed that the observed phenomenon may affect the reduction in strength of the relationship between motor development and mental health.

The main part of the work was dedicated to their understanding and determination. This drew attention to the importance of addressing the mental factor in conditioning motor development, in general terms, the indicator of physical fitness, as well as its physical condition components, which consisted of power and speed measurements of motor skills. The genesis and encouragement to undertake such studies were the attempts to confirm the positive impact of physical activity on mental processes of man in the experimental work, as highlighted in the introductory part of this paper [16-18, 26-36, 40-43, 51, 54-56, 59, 66-77].

A review of studies showed that this hypothesis was successfully confirmed in experiments on animals using a simple behavioral research methodology schema: the stimulus (S) - response (R). So far, studies conducted on humans, mostly older ones, have not brought definitive outcomes. In addition, it should be noted that the neurophysiological or biochemical studies in this regard are not performed on children. Most often the attention, mainly of American psychologists and educators, is focused on the study of the simple relationships between physical activity (in various forms) and the intellectual potential of older children and youth, typically limited to the measurement of intelligence or a wider range of cognitive ability [8-15]. The research in this field on a larger scale is also not conclusive.

In our study, referring to such research trends, attention was drawn to the more complex context of the stimulus (S) - response (R) relationship. In addressing the impact of physical activity on the mental potential of a child, it was referred to the simple neobehavioral model of human behavior, developed by Edward C. Tolman [92]. The intervening variable "O" plays an important role in it, which allows to modify the original model of behaviorism to the form of S-O-R. As the purposive neobehaviourism creator believed, a man striving to achieve the objective engages, after all (in an indefinite manner) "the total (overall) organism" (O).

In the search of the position of non-verbal intelligence in the determination of motor skills and, above all, the overall physical fitness of a child (and vice versa) it was based, however, in the adopted research model on the assumptions of the eclectic theory of activity and the human derived from Robert S. Woodworth's dynamic psychology assumptions [94, 95]. According to the creator of the motivation[3] concept, the study should not be limited to just one methodology, but use an eclectic approach to learning activity and human thought. In his concept, it is acceptable to apply the methodology relevant to experimental experience, research tests (including introspection) and primarily to use a range of methods and tools typical for cognitive psychology [95].

Relying on such a methodology gave rise to the broad treatment of the intervening "O" - "body" variable in the S-O-R model. It was possible to place non-verbal intelligence of the examined children in its structure as an important base for motivation to increase physical activity (S), which in turn, determines and therefore is the obverse - (R) of achieving a certain level of physical fitness (including motor skills that define its structure). Furthermore, the level of (R) in terms of the behavioural approach is adequate to strength of training stimulus – the widely recognized physical activity (S). From the adopted R. S Woodworth (S-O-R) model, it can be stated that the effect of physical activity - physical fitness and its components (motor skills) - can be the reverse and obverse of the stimulus (S), but provided the modification by the quality of the organism (O) is taken into account.

In our own reserach, non-verbal intelligence is considered as its important component, which can strengthen motivation to undertake physical activity. Considering these assumptions, we decided to prove the significant role of non-verbal intelligence (O factor) in shaping of its in shaping the other **side** physical fitness. For this purpose, the widely used statistical tool, i.e. Pearson's simple correlation coefficient was used. Confirmation of the adopted hypothesis was supposed to be the high level of statistically significant correlations between the measurements of non-verbal intelligence and physical fitness as well as its motor skill components. The basis for their adoption was the assumption that children with higher levels of non-verbal intelligence will be better motivated to undertake physical activity and therefore, achieve better results in physical fitness.

In our study, an important component of thought nonverbal intelligence, which can strengthen the motivation for physical activity. Starting from these assumptions, it was decided to prove the significant role of nonverbal intelligence (factor O) in the shaping of its reverse

[3] Both the village and small town were randomly selected in studies conducted 30 years earlier by a team of employees from the Institute of Psychology - Developmental and Educational Psychology, and the Department of Anthropology at the Jagiellonian University [88].

- physical fitness. In this regard, a generally applied statistical tool that is simple Pearson correlation was used. The confirmation of the assumed hypotheses was to be a high level of statistically significant correlation between the measurements of non-verbal intelligence and physical fitness with its motor skills components. The basis for their adoption was the assumption that children with higher level of non-verbal intelligence will be better motivated for physical activity and thereby will achieve better results in physical fitness.

Without indulging into the issue of the impact of physical efforts on the psychological level of humans too deeply, it should be assumed that the strength of correlations applies to both the dependent and independent variable in statistical procedures. Under this assumption, demonstrating statistically significant relationships could be a positive answer to the posed question and it can be concluded that children with greater intelligence are more fit and vice versa.

Without going too much into the issue of the impact of physical effort on mental condition it should be assumed that in statistical procedures the strength of correlations applies to both the dependent variable and independent variable. Under this assumption, showing statistical validity of relationships the question posed in the title could be answered positively and it could be concluded that children with greater intelligence are more fit and vice versa.

Analyzing the obtained results, it should be noted that it is very difficult and even dangerous to use the regularities of biological development and mental health of children in the progressive period of ontogenetic development for interpretation, without the necessary methodological reflection such as even a simple statistical tool that is simple correlation. What can such pessimism be attributed to? It results from the obtained results of our own research. An example of this can be the incomparable qualitative and quantitative results of simple correlations between the level of non-verbal intelligence of girls and boys aged 7-14 from three different cities in relation to the created reference groups. In the case of taking into account all the subjects in gender groups aged 7-14 years, high statistically significant correlations between the considered variables were obtained. Significantly lower correlations occurred when taking into account gender of two age groups: 7-10 and 11-14 years. On the other hand, considering the subsequent age groups of subjects (7-14 years) resulted in entirely incomparable correlation coefficients to the previously accumulated groups of children and to the substantially smaller number of subjects in the age classes. It revealed irrelevant and insignificant or weak relationships. A very similar situation occurred when considering the divisions of the collected materials according to place of residence.

It seems that an excessively mechanistic approach to the interpretation of the results of research and thus, to hypotheses verification, would lead to far-reaching irresponsible application and cognition conclusions. In this case, distance towards our own research is necessary as well as reference to the classic foundations of mathematical statistics. Before making a mistake regarding inference, arising as a result of over-interpretation of the study results, we were already warned by J. P. Guilford in his manual for statistics [102] stating: "*It is important that the cautious researcher does not attribute results to the implied actual nature of the psychological or pedagogical phenomenon, when in reality, some feature of statistical study is responsible for it*" [102: 368].

Therefore, it should be noted that correlation coefficients are always relative in nature and always depend on the type of population from which the sample was chosen and the measurement method. When giving correlation coefficients, all the factors affecting their size should be carefully determined and their values referred to the resulting circumstances of the inception of the relationship's strength. In the case of grouping the number of subjects from different age groups, the variability of attributes (variables) increased. As we know, the correlation coefficient increases in proportion to the variation in the correlated sample, which took place in the present study. Moreover, in the interpretation of correlation coefficients derived from the grouping of individual age groups of children, the possibility of so-called spurious-correlation should be considered. In fact, this phenomenon is the effect of the influence of chronological age of the dependent variable and independent variable. A positive correlation will increase in proportion to the span of chronological age.

In such a situation - as J. P. Guilford states: "*It is important you correlate variables with full knowledge of how the measurements were obtained, if possible, and give readers the facts necessary for proper interpretation, whether it be a variability of correlated group or the span of CA [chronological age] at stake when the correlations of intelligence quotients were calculated*" [102: 368].

Large relativity of calculated correlation coefficients and difficulties in the interpretation of some of the circumstances of their creation is indicated by the authors of the study*: "Motor and Mental Physical Development of Children and Adolescents"* [88] who state:

"*It should be noted that the estimated coefficients of correlation cannot be considered as an estimate of some 'general' correlation characterizing the relationship between physical and mental development of children in Poland. When the group, whose results were used to calculate the correlation coefficients is heterogeneous in terms of average values of correlated variables, the* *correlation coefficient results not only from the correlation in the subgroups but is also largely dependent on the correlation between the averages, the size of differences between averages, the size of subgroups and other factors*" [88: 85].

On may also find the observation that when the differences between correlated averages are small (as stated in the present study) - then: "*In this situation, the correlation calculated on the basis of the results of all children of the same age and of a particular sex will be much higher than that which would, in turn, result from environmental subgroups*".

Without delving too deeply into the essence of the established phenomenon of increasing correlation coefficients in the cumulative study groups of children and necessary adjustments, it seems that solving the problems of research should be based only on the values of correlation coefficients calculated in different years. As a last resort, they could be used to calculate the average strength of the relation throughout the study period and in different age groups. Calculating the average correlation coefficient is acceptable in statistical proceedings [102; 364]. Its value is always in the range of variability of the partial calculations.

In our own research, it is shown that in each case, the intensification of the correlation depending on the size of the "r_{xy}" factor does not exceed the low correlation threshold and the small dependence. In small generational cohorts, the value of correlation coefficients is not statistically significant in most cases. In the average values, the size of the groups affects the rejection of the null hypothesis about no grounds for refutation of the statistically significant strength of the relation. However, the low value of the average correlation coefficients slightly decreases the threshold of critical value.

Thought must be given to the results checking the statistical significance according to the new proposal by the Wroclaw statisticians [101]. In testing the null hypothesis in such proceedings, the key issue is the adoption of $\rho 0$. According to the creators of this method [101], such value should be about $r_{xy} = 0.7$. It gives the regression model a coefficient determination value of about 50%. Under no circumstances would such a condition be met by the correlation coefficients calculated for individual years, or in the case of averaging them in year blocks and throughout the study period.

The low level of correlation coefficients, and thus their low volatility confirmed the hypothesis regarding the lack of effects of gender or environmental factors.

Therefore, it should be concluded that the results of statistical research do not allow to affirmatively answer the question: is a more intelligent child also fitter? It may not be argued, however, that the intellectual potential of the child was not relevant to the sports achievements and motor effects, which are considered more and more as positive health indicators [103] or important components of physical fitness as reflected in the American convention - Health Related Fitness [104]. In such a sense the value of physical fitness components is assessed in *New core curriculum* of physical education in Poland [105]. Therefore, it should be assumed that for a child with higher intellectual potential, it will be easier to accept modern directional objectives of education to shape the attitudes of lifelong care for one's own body and thereby, for their health. It can also have - as stressed in the adopted research procedure model (S-O-R) - more motivation to exercise - the most important part of physical aptitude. According to our own research and studies carried out in our country so far, "a litmus paper" of the implementation of these educational objectives, which should be considered as the correlation coefficients, does not indicate the very faint educational effects in this field. Leaving aside, at the very least, the disputable artifacts projecting the quality of the statistical calculations and achievement of spurious-correlations, very low strength of the relationship between non-verbal intelligence and physical fitness of the subjects shows that there is still a long road to accomplishing the desired objectives of physical education. Pedagogical failure in this area, occurring not only in our country, as evidenced by the quoted meta-analysis of the American publications in the introduction [8-15, 78-80], cannot be an argument for the removal or reduction of physical education classes. So far, such suggestions are introduced only in some American schools [8, 9, 13, 15].

From a pedagogical point of view, the negative result of our own research forces us to reflect on the existing situation and the reasons for not using the students' potential in the area of achieving the directional objectives of physical education. The revealed very poor strength of correlations between the intellectual potential and physical fitness of children from Malopolska points to the need to take measures changing the unfavorable situation by creating conditions and amenities in educational work regarding the use of intellectual potential of students in shaping pro-health attitudes.

Conclusions:

1. In the auxological research on children during their progressive development, in the transition period at the turn of the century, it can be found that the phenomenon of blurring environmental differences in the biological and psychological development of children occurs and thus, in the image of the rural and urban child's motor skills.
2. The S-O-R model of behaviour, based on the teleological neobehaviourism of E. C. Tolman and activity

resulting from the eclectic psychology assumptions of R.S. Woodworth, may be useful to develop the research concept of determinants of children's mental motor development.

3. We should treat methodological correctness using even such a simple statistical method, i.e. simple correlation, with great concern. Lack of distance in the improper usage of research tools and the resulting artifacts may falsify the image of the existing statistical relationships and lead to false conclusions.
4. The revealed very weak strength of correlations between intellectual potential and physical fitness of children from Malopolska encourages to take measures changing the unfavorable situation by creating conditions and amenities in educational work in the field of intellectual potential of students to shape pro-health attitudes towards physical education classes.

References:

[1] Pieter J: *O stopniu zależności inteligencji od warunków środowiskowych*. Chowanna, 1936: 4-10.

[2] Pieter J: *Poziom inteligencji a środowisko*. Wyd. Instytutu Pedagogicznego, Katowice, 1937.

[3] Szopa J, Mleczko E, Żak S: *Podstawy antropomotoryki*. Warszawa-Kraków, PWN, 2000.

[4] Pieter J: *Uzdolnienia fizyczne a intelekt*. Wychowanie Fizyczne, 1939; 5: 194–199.

[5] Pieter J: *Sprawność ruchowa a intelekt*. Wychowanie Fizyczne, 1939; 6: 245–250.

[6] Nęcka E: *Inteligencja. Geneza, struktura, funkcje*. Gdańskie Wydawnictwo Psychologiczne, Gdańsk, 2003.

[7] Strelau J: *Inteligencja człowieka*. Wyd. Akademickie Żak, Warszawa, 2007.

[8] Sibley BA, Etnier JL: *The relationship between physical activity and cognition in children: a meta-analaysis*. Pediatr Exerc Sci, 2003; 15: 243–256.

[9] Tomporowski PhD, Davis CL, Miller PH, Naglieri JA: *Exercise and Children's Intelligence, Cognition, and Academic Achievement*. Educ. Psychol. Rev. 2008; 20(2): 111–131.

[10] Keeley TJH, Fox KR: *The impact of physical activity and fitness on academic achievement and cognitive performance in children*. Int Rev Sport Exerc Psychol, 2009; 2: 198–214.

[11] Ahn S, Fedewa AL: *A meta-analysis of the relationship between children's physical activity and mental health*. J Pediatr Psychol, 2011; 36: 385–397.

[12] Fedewa AL, Ahn S: *The effects of physical activity and physical fitness on children's achievement and cognitive outcomes: a meta-analysis*. Res Q Exerc Sport, 2011; 82: 521–535.

[13] Biddle SJ, Asare M: *Physical activity and mental health in children and adolescents: a review of reviews*. Br J Sports Med, 2011; 945: 886–895.

[14] Singh A, Uijtdewilligen L, Twisk JW, Van Mechelen W, Chinapaw MJ: *Physical activity and performance at school: a systematic review of the literature including a methodological quality assessment*. Arch Pediatr Adolesc Med, 2012; 166: 49–55.

[15] Howie EK, Pate RR: *Physical activity and academic achievement in children: a historical perspective*. J Sport HealthSci, 2012; 1 (3): 160–169.

[16] Neubauer AC, Fink A: *Intelligence and neural FITNESS*. Neuroscience & Biobehavioral Reviews, 2009; 33: 1004-1023.

[17] Jaśkowski P: *Neuronauka poznawcza. Jak mózg tworzy umysł.* Vizja Press, 2009.

[18] Ziemba AW: *Rola aktywności ruchowej w zapobieganiu zaburzeniom poznawczym [Role of physical activity in preventing cognitive disorders]*. Aktualności Neurologiczne [CurrentNeurology], 2014; 14 (3): 175-180.

[19] Carro E, Trejo JL, Busiguina S, Torres-Aleman I: *Circulating insulin-like growth factor Imediates the protective effects of physical exercise against brain insults of different etiology and anatomy.* J. Neurosci. Off. J. Soc. Neurosci., 2001; 21: 5678–5684.

[20] Bibel M, Barde YA: *Neurotrophins: key regulators of cell fate and cell shape in the vertebrate nervous system*. GenesDev, 2000; 14: 2919–2937.

[21] Park H, Poo M: *Neurotrophin regulation of neural circuit development and function*. Nat. Rev. Neurosci., 2013; 14: 7–23.

[22] Cowansage KK, LeDoux JE, Monfils M-H: *Brain-derived neurotrophic factor: a dynamic gatekeeper of neural plasticity*. Curr. Mol. Pharmacol., 2010; 3, 12–29.

[23] Gottmann K, Mittmann T, Lessmann V: *BDNF signalling in the formation, maturation and plasticity of glutamatergic and GABAergic synapses*. Exp. Brain Res., 2009; 199: 203–234.

[24] Lipsky RH, Marini AM: *Brain-derived neurotrophic factor in neuronal survival and behaviour-related plasticity*. Ann. N. Y. Acad. Sci., 2007; 1122: 130–143.

[25] Vaynman S, Ying Z, Gomez-Pinilla F: *Hippocampal BDNF mediates the efficacy of exercise on synaptic plasticity and cognition*. Eur. J. Neurosci., 2004; 20: 2580–2590.

[26] Erickson KI, Miller DL, Roecklein KA: *The aging hippocampus: interactions between exercise, depression, and BDNF*. Neurosci. Rev. J. Bringing Neurobiol. Neurol. Psychiatry, 2012; 18: 82–97.

[27] Cotman CW, Berchtold NC: *Exercise: a behavioural intervention to enhance brain health and plasticity*. Trends Neurosci, 2002; 25: 295–301.

[28] Voss MW, Vivar C, Kramer AF. van Praag H: *Bridging animal and human models of exercise-induced brain plasticity.* Trends Cogn. Sci., 2013; 17: 525–544.
[29] W, Erickson KI, Prakash RS, Chaddock L, Kim JS, Alves H, Szabo A, Phillips SM, Wójcicki TR, Mailey EL, et al: *Neurobiological markers of exercise related brain plasticity in older adults*. Brain Behav. Immun., 2013b; 28: 90–99.
[30] Cotman CW, Berchtold NC: *Physical activity and the maintenance of cognition: learning from animal models.* Alzheimer's Dement., 2007; 3: 30–37.
[31] Cotman CW, Berchtold NC, Christie L-A: *Exercise builds brain health: key roles of growth factor cascades and inflammation*. Trends Neurosci., 2007; 30: 464–472.
[32] Whiteman A, Young DE, He X, Chen TC, Wagenaar RC, Stern Ch, Schon K: *Interaction between serum BDNF and aerobic fitness predicts recognition memory in healthy young adults.* Behav Brain Res., 2014; 259: 302-312.
[33] de M. Coelho FG, Gobbi S, Andreatto CAA, Corazza DI, Pedroso RV, Santos-Galduróz RF: *Physical exercise modulates peripheral levels of brain-derived neurotrophic factor (BDNF): a systematic review of experimental studies in the elderly*, Arch. Gerontol. Geriatr., 2013; 56: 10–15.
[34] Erickson KI, Voss MW, Prakash RS, Basak Szabo CA, Chaddock L, Kim JS, Heo S, Alves H, White SM, *et al: Exercise training increases size of hippocampus and improves memory*. Proc. Natl. Acad. Sci, 2011; 108: 3017–3022.
[35] McGrew KS: *CHC theory and the human cognitive abilities project: Standing on the shoulders of the giants of psychometric intelligence research*. Intelligence, 2009; 37: 1-10.
[36] Schweizer K: *The relationship of attention and intelligence, in Gruszka A, Matthiews G, Szymura B* (ed.), *Handbook of individual differences in cognition: Attention, memory, and executive control*. New York, Springer, 2010: 247-262.
[37] Adams RH, Alitalo K: *Molecular regulation of angiogenesis and lymphangiogenesis*. Nat. Rev. Mol. Cell Biol., 2007; 8: 464–478.
[38] Cao R, Bråkenhielm E, Li X, Pietras K, Widenfalk J, Ostman A, Eriksson U, Cao Y: *Angiogenesis stimulated by PDGF-CC, a novel member in the PDGF family, involvesactivation of PDGFR-alphaalpha and -alphabeta receptors*. FASEB J. Off. Publ. Fed. Am. Soc. Exp. Biol., 2002; 16: 1575–1583.
[39] Vital TM, Stein AM, de Melo Coelho FG, Arantes FJ, Teodorov E, Santos-Galduróz RF: *Physical exercise and vascular endothelial growth factor (VEGF) in elderly: a systematic review.* Arch. Gerontol. Geriatr, 2014; 59: 234–239.
[40] Schobersberger W, Hobisch-Hagen P, Fries D, Wiedermann F, Rieder-Scharinger J, Villiger B, Frey W, Herold M, Fuchs D, Jelkmann W: *Increase in immune activation, vascular endothelial growth factor and erythropoietin after an ultramarathon run at moderate altitude*. Immunobiology, 2000; 201: 611–620.
[41] Trejo JL, Carro E, Torres-Aleman I: *Circulating insulin-like growth factor I mediates exercise-induced increases in the number of new neurons in the adult hippocampus*. J. Neurosci., 2001; 21: 1628–1634.
[42] Fabel K, Fabel K, Tam B, KauferD, Baiker A, Simmons N, Kuo CJ, Palmer TD: *VEGF is necessary for exercise-induced adult hippocampal neurogenesis*. Eur. J. Neurosci., 2003; 18: 2803–2812.
[43] Lorens-Martín M, Torres-Alemán I, Trejo JL: *Exercise modulates insulin-like growth factor 1-dependent and -independent effects on adult hippocampal neurogenesis and behaviour*. Mol. Cell. Neurosci., 2010; 44: 109–117.
[44] Filus A, Zdrojewicz Z: *Insulin-like growth factor-1 (IGF-1) – structure and the role in the human body*. Paediatric Endocrinology Diabetes Metabolism, 2014; 22, 4: 161-169.
[45] Yan H, Mitschelen M, Bixler GV: *Circulating IGF1 regulates hippocampal IGF1 levels and brain gene expression during adolescence*. J Endocrinol., 2011; 211: 27-37.
[46] Cotman CW, Berchtold NC: *Exercise: a behavioural intervention to enhance brain health and plasticity*. Trends Neurosci., 2002; 25: 295–301.
[47] Fernandez AM, Torres-Alemán I: *Themany faces of insulin-like peptide signalling in the brain*. Nat. Rev. Neurosci., 2012; 13: 225–239.
[48] Trejo JL, Piriz J, Llorens-Martin M, Fernandez A.M, Bolós M, LeRoith, D, Nuñez A, Torres-Aleman I: *Central actions of liver--derived insulin-like growth factor I underlying its pro-cognitive effects*. Mol. Psychiatry, 2007; 12: 1118–1128.
[49] Lopez-Lopez C, Le Roith D, Torres-Aleman I: *Insulin-like growth factor I is required for vessel remodelling in the adult brain*. Proc. Natl. Acad. Sci. U. S. A., 2004; 101: 9833–9838.
[50] Sonntag WE, Lynch CD, Cooney PT, Hutchins PM: *Decreases in cerebral microvasculature with age are associated with the decline in growth hormone and insulin - like growth factor 1*. Endocrinology, 1997; 138: 3515–3520.
[51] Bailly-Chouriberry L, Pinel G, Garcia P et al: *Identification of recombinant equine growth hormone in horse plasma by LC--MS/MS: a confirmatory analysis in doping control.* Anal Chem, 2008; 80: 8340–8347.
[52] Stokes K, Nevill M, Frystyk J, Lakomy H, Hall G: *Human growth hormone responses to repeated bouts of sprint exercise with different recovery periods between bouts*. J Appl Physiol 2005; 99: 1254–1261.
[53] Armanini D, Faggian D, Scaroni C, Plebani M: *Growth hormone and insulin- like growth factor I in a Sydney Olympic gold medallist.* Br J Sports Med., 2002; 36: 148–149.
[54] Healy ML, Sönksen PH. *The growth hormone/insulin-like growth factor-I axis in exercise and sport*. Endocr Rev, 2007; 28: 603–624.
[55] Jóźków P, Mędraś M: *Hormon wzrostu i IGF-1 jako substancje dopingujące w sporcie wyczynowym*. Endokrynol Pol., 2009; 5: 389-394.

[56] The World Anti-Doping Code: *The 2016 Prohibited List. International Standard.* World Anti-Doping Agency. January 2016.

[57] McHugh CM, Park RT, Sönksen PH, Holt RIG: *Challenges in detecting the abuse of growth hormone in sport*. Clin Chem., 2005; 51: 1587–1593.

[58] Russell Jones DL, Umpleby AM, Hennessy TR, Bowes SB, Shojaee Moradie F, Hopkins KD, et al.: *Use of a leucine clamp to demonstrate that IGF-I actively stimulates protein synthesis in normal humans*. Am J Physiol., 1994; 267: 591–598.

[59] Barton ER: *Viral expression of insulin-like growth factor-I isoforms promotes different responses in skeletal muscle*. J Appl Physiol, 2006; 100: 1778–1784.

[60] Hameed M, Lange KH, Andersen JL, et al.: *The effect of recombinant human growth hormone and resistance training on IGF-I mRNA expression in the muscles of elderly men*. J Physiol, 2004; 555: 231–240.

[61] Hameed M, Orrell RW, Cobbold M, et al.: *Expression of IGF-I splice variants in young and old human skeletal muscle after high resistance exercise*. J Physiol, 2003; 547: 247–254.

[62] Maass A, Düzel S, Brigadski T, Goerke M, Becke A, Sobieray U, Neumann K, Lövdén M, Lindenberger U, Bäckman L, Braun-Dullaeus R, Ahrens D, Heinze HJ, Müller NG, Lessmann V, Sendtner M, Düzel E: *Relationships of peripheral IGF-1, VEGF and BDNF levels to exercise-related changes in memory, hippocampal perfusion and volumes in older adults*. Neuroimage, 2016; 1 (131): 142-154.

[63] Lee C, Zhang F, Tang Z, Liu Y, Li X: PDGF-C: *Anew performer in the neurovascularinterplay.* Trends Mol. Med., 2013; 19: 474–486.

[64] Li X, Pontén A, Aase K, Karlsson L, Abramsson A, Uutela M, Bäckström G, Hellström M, Boström H, Li H. et al.: *PDGF-C is a new protease-activated ligand for the PDGF alpha-receptor.* Nat. Cell Biol., 2000; 2: 302–309.

[65] Tang Z, Arjunan P, Lee C, Li Y, Kumar A., Hou X, Wang B, Wardega, P, Zhang F, Dong Let al.: *Survival effect of PDGF-CC rescues neurons from apoptosis in both brain and retina by regulating GSK 3β phosphorylation*. J. Exp. Med., 2010b; 207: 867–880.

[66] Coelho FG de M, Gobbi S, Andreatto CAA, Corazza DI, Pedroso RV, Santos-Galduróz RF: *Physical exercise modulates peripheral levels of brain-derived neurotrophic factor (BDNF): a systematic review of experimental studies in the elderly*. Arch. Gerontol. Geriatr., 2013; 56: 10–15.

[67] Vital, TM, Stein AM, de Melo Coelho FG, Arantes FJ, Teodorov E: Santos-Galduróz RF: *Physical exercise and vascular endothelial growth factor (VEGF) in elderly: a systematic review*. Arc,. Gerontol. Geriatr., 2014; 59: 234–239.

[68] Berg U, Bang P: *Exercise and circulating insulin-like growth factor* I. Horm. Res., 2004; 62 (Suppl. 1): 50–58.

[69] Voss MW, Erickso KI, Prankash RS, Chaddock L, Kim JS, Alves H, Szabo A, Phillips, SM, Wójcicki TR, Mailey EL, et al.: *Neurobiological markers of exercise related brain plasticity in older adults*. Brain Behav. Immun., 2013b; 28: 90–99.

[70] Voss MW, Vivar C, Kramer AF, van Praag H: *Bridging animal and human models of exercise-induced brain plasticity*. Trends Cogn. Sci., 2013a; 17: 525–544.

[71] Leckie RL, Oberlin LE, Voss MW, Prakash RS, Szabo-Reed A, Chaddock-Heyman L, Phillips SM, Gothe NP, Mailey E, Vieira-Potter VJ et al.: *BDNF mediates improvements in executive function following a 1-year exercise intervention.* Front. Hum. Neurosci., 2014; 8: 985.

[72] Maass A, Düzel S, Goerke M, Becke A, Sobieray U, Neumann K,Lövden M, Lindenberger U, Bäckman L, Braun-Dullaeus R, Ahrens D, Heinze H-J, Mülle NG Düzel E: *Vascular hippocampal plasticity after aerobic exercise in older adults*. Molecular Psychiatry, 2015; 20: 585–593.

[73] Żołądź JA, Pilc A, Majerczak J, Grandys M, Zapart-Bukowska J: *Endurance training increases plasma brain-derived neurotrophic factor concentration in young healthy men*. J Physiol Pharmacol. 2008 Dec; 59 Suppl 7: 119-32.

[74] Rasmussen P, et al.: *Evidence for a release of brain-derived neurotrophic factor from the brain during exercise*. Exp Physiol., 2009; 94: 1062–1069.

[75] Smith JP, James MA, Blumenthal A, Hoffman BM, Cooper H, Strauman TA, Welsh-Bohmer K, Browndyke JN, Sherwood A: *Aerobic Exercise and Neurocognitive Performance: a Meta-Analytic Review of Randomized Controlled Trials*. Psychosom Med., 2010 Apr; 72(3): 239–252.

[76] Kozakowski J: *Funkcje poznawcze w zależności od wieku. Wpływ hormonu wzrostu oraz insulinopodobnego czynnika wzrostowego pierwszego.* Geriatria, 2007; 1: 37-44.

[77] Osiński W: *Aktywność fizyczna – czy może zmieniać mózg*. Wychowanie Fizyczne i Zdrowotne, 2011; 4: 5-8.

[78] Hillsman CH, Castelli D, Buck SM: *Physical fitness and neurocognitive function in healthy preadolescent children*. Medicine &Science in Sports & Exercise, 2005; 37: 1967–1974.

[79] Hillman CH, Kramer AF, Belopolsky AV, Smith DP: *A cross-sectional examination of age and physical activity on performance and event-related potentials in a tasks witching paradigm*. International Journal of Psychophysiology, 2006; 59: 30–39.

[80] Dustman RE, Emmerson R, Shearer D: *Physical activity, age, and cognitive-neuropsychological function*. Journal of Aging and Physical Activity, 1994; 2: 143–181.

[81] Żurek G: *Zdolności motoryczne i cechy somatyczne a osiągnięcia szkolne uczniów wiejskich szkół podstawowych z Dolnego Śląska*. Studia i Monografie, Wrocław, AWF,2012; 105.

[82] Ismail AH: *The effects of a well-organized physical education programme on intellectual performance*. Research in PhysicalEducation,1967; 1: 31–38.

[83] Strzyżewski S: *Sprawność umysłowa dzieci z miast Górnośląskiego Okręgu Przemysłowego i wsi województwa kieleckiego oraz jej związki z rozwojem fizycznym, uzdolnieniami ruchowymi, sprawnością fizyczną i wybranymi komponentami środowiska rodzinnego*; w Wołoszynowa L (red.): *Materiały do nauczania psychologii*, Seria II, Warszawa, PWN, 1983; 10: 325–359.
[84] Zieliński J: *Sprawność umysłowa i sprawność motoryczna dzieci i młodzieży*. Kultura Fizyczna, 1981; 4: 7–9.
[85] Szopa J, Rdzanek-Golonka A: *Związki pomiędzy inteligencją niewerbalną a poziomem rozwoju wybranych cech somatycznych i psychomotorycznych u 11-12 letnich chłopców i dziewcząt.* Roczniki Naukowe, Kraków, AWF, 1992; 25: 239-244.
[86] Ignasiak Z, Wlazło E: *Rozwój fizyczny i motoryczny dzieci wiejskich w świetle zróżnicowanego poziomu inteligencji niewerbalnej*. Antropomotoryka, 1996; 14: 27–39.
[87] Gierat K, Górska B: *Biopsychiczne podstawy zdolności motorycznych*. Katowice, AWF, 1999.
[88] Przetacznik-Gierowska M, Kaczanowska A, Makiełło-Jarża G, Przetacznik J: *Rozwój fizyczny, motoryczny i umysłowy dzieci i młodzieży. Badania pięcioletnie ze szczególnym uwzględnieniem akceleracji rozwoju*. Zeszyty Naukowe Uniwersytetu Jagiellońskiego, Prace Psychologiczne, Kraków – Warszawa, PWN, 1986.
[89] Mleczko E, Gradek J, Nieroda R, Zdebski J: *Długookresowe tendencje zmian związków między rozwojem umysłowym, fizycznym i motorycznym dzieci w wieku 4–14 lat z różnych miejscowości Małopolski*. Antropomotoryka, 2013; 64 (23): 11-34.
[90] Mleczko E, Blecharz J, Gradek J. Płatek A, Supernat K: *Intergenerational variability of strength habilities in children from three Malopolska agglomerations in the context of their somatic and mental development.* Antropomotoryka*,* 2013; 61:81–96.
[91] Haleczko A, Jezierski R, Korzewa L, Misiołek E, Włodarczyk U: *Sprawność umysłowa i poziom zdolności motorycznych 11-letnich dzieci.* Antropomotoryka, 2010; 52: 39-50.
[92] Tolman EC: *Principles of performance*. Psychological Review, 1955; 62: 315-326.
[93] Woodworth ES, Schlosberg H: *Psychologia eksperymentalna*. Warszawa, PWN, 1963.
[94] Woodworth ES: *Dynamic Psychology*. Marrickville. New South, Wentworth Press. AustLit, 2016.
[95] Woodworth RS, Schlosberg's H, Riggs LA, J Kling JW, Riggs LA: *Woodworth & Schlosberg's Experimental Psychology: Learning, Motivation, and Memory*. New York,Rinehart and Winston. Holt, 1971.
[96] Denisiuk L: *Tabele Punktacji Sprawności fizycznej.* Warszawa, Wydawnictwa Szkolne i Pedagogiczne, 1995.
[97] Szecówka-Nowak M: *Jakościowa analiza odpowiedzi w Teście Matryc Ravena w wersji dla zaawansowanych*. Testy Psychologiczne w Praktyce i Badaniach, 2015; 1: 76-95.
[98] Szustrowa T, Jaworowska A: *Podręcznik do Testu Matryc Ravena*. Wersja Kolorowa (1956). *Polska standaryzacja 1991* (3;11–9;11). Warszawa, Pracownia Testów Psychologicznych PTP, 1992.
[99] Jaworowska A, Szustrowa T: *Test Matryc Ravena w wersji Standard TMS. Formy: Klasyczna, Równoległa, Plus. Polskie standaryzacje*. Warszawa, Pracownia Testów Psychologicznych PTP, 2000.
[100] Krysicki W, Bartos J, Dyczka W, Królikowska K, Wasilewski M: *Rachunek prawdopodobieństwa i statystyka matematyczna w zadaniach*. Warszawa, Wydawnictwo Naukowe PWN, 2000.
[101] Peternek P, Kośny M: *Kilka uwag o testowaniu istotności współczynnika korelacji.* Zeszyty Naukowe Wyższej Szkoły Bankowej we Wrocławiu, Uniwersytet Ekonomiczny, Wrocław, 2011; 2.
[102] Guilford JP: *Podstawowe metody statystyczne w psychologii i pedagogice*. Warszawa, PWN, 1960.
[103] Przewęda R., Dobosz J: *Kondycja fizyczna polskiej młodzieży*. Warszawa, AWF, 2003.
[104] Pate RR., Hohn RC. (eds.): *Health and fitness through physical education*. Human Kinetics1994.
[105] Kierczak U: *Koncepcja wychowania fizycznego dla wszystkich etapów edukacji.* Zdrowie-Sport- Rekreacja. Kraków, Impuls, 2012.

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