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Original Article

Assesment of the relationship between fitness abilities and motor skills of 5-year-olds by taking into account dimorphic differences

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Abstract:
As it is very important to learn about the factors conditioning motor skills so that children have the best opportunities for their development, the aim of the study was to assess the relationship between the level of physical abilities and motor skills of five-year-olds, taking into account dimorphic differences. 435 five-year-old children participated in the study, including 180 girls and 255 boys. Physical fitness (PF) was assessed according to the Polish Physical Fitness Test for preschoolers. The Gross Motor Skills Test (TGMD II) (Urlich 2000) was used to assess motor skills. Statistica 13.0 software was used for statistical data processing. In the sex groups, descriptive statistical parameters (mean, standard deviation) were calculated. To evaluate the dimorphic differences, the Mollison index was used. The statistical significance of the differences between the results of girls and boys was assessed according to the t-Student test. In order to standardize the units, the individual results of girls and boys were normalized on the T scale to the mean and statistical dispersion of all subjects. Next, children were divided into the following groups: low physical fitness (PFI), average physical fitness (PFII), high physical fitness (PFIII). The statistical significance of differences between the above-mentioned groups was assessed by the ANOVA analysis of variance and the Newman Keuls test. The analysis of fitness abilities revealed significant differences between girls and boys in trials assessing running speed and agility. On the other hand, such relationships were not noted in the strength of the arms and the power of the lower limbs. Among the five-year-olds in Biała Podlaska, a higher level of gross motor skills was noted in girls compared to boys, which was mainly influenced by the results of locomotor skills. In the ability to control sports equipment, similar results were observed in both sexes. However, there were significant differences in the individual exercises. Since no significant distances in locomotive skills and control of instruments were noted in five-year-old girls and boys characterized by different levels of physical fitness, it should be assumed that the 5th year of life is still too early a period in ontogenesis to look for such relationships.
Key Words: preschoolers, sexual dimorphism, physical fitness, gross motor skills

Introduction

An increasing number of observations is being carried out on the physical fitness and motor skills of preschool children. Researchers are in particular examining changes in psychophysical development over past decades. The results obtained this way can be analyzed in connection with changes within other areas of life. This allows for a greater probability to draw conclusions about the relationship between the development of a young body and the impact of individual exo- and endogenous factors (Kaczmarek, Wolański 2018).

It is commonly believed that around the age of five, the so-called "golden age of motor skills" begins. Compared to previous periods of life, the development of motor skills significantly accelerates. However, when we compare five-year-olds with six-year-olds, considerable differences can still be observed (Godoy-Cumillaf et al. 2020). Moreover, sexual dimorphism starts to play an increasingly important role (Latorre Román et at. 2016). In professional literature, there are studies showing the interrelationships between motor skills or physical fitness and other factors. Some of the factors which have been analyzed are racial differences (Brian et al. 2017, Webster et al. 2019) and dimorphic differences in motor abilities (Ruzbarska, Piątkowska 2008), as well as motor skills (Hardy et al. 2010, Brian et al. 2017, Aye et al. 2018, Niemistö et al. 2019). Moreover, researchers have observed a negative influence of excessive weight and obesity on motor skills of preschoolers (Morano et al. 2011, Castetbon, Andreyeva 2012, Robinson et al. 2015, Ji et al. 2018) and no influence of body weight on gross motor skills (Brian et al. 2017). Children's motor skills were also assessed against the background of other reference groups (Valentini 2012, Aye et al. 2017). It was found that the environment of the place of residence differentiated the level of gross motor skills of preschool children (Cieśla et al. 2012, Trzcińska et al. 2013, Aye et al. 2017, Niemistö et al. 2019). Moreover, it was noted that children's motor skills were positively related to their physical activity, but inversely related to the time spent in front of a TV or computer screen (Webster et al. 2019).

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In the period of progressive development, children's motor skills are directly related to their biological development. In addition, the results obtained in fitness abilities should be correlated with motor skills. A child whose motor development enables competition with peers performs better in a group and is more independent than one who lacks motor skills. Children with lower physical fitness are relatively often afraid of new challenges. They perform worse when competing, which may adversely affect their self-esteem.

Although we are observing a systematic increase in interest in the development of this age group, there are still few studies devoted to the assessment of the relationship between the acquired motor skills of preschoolers and their level of physical fitness. As it is very important to learn about the factors conditioning motor skills so that children have the best opportunities for their development, the aim of the study was to assess the relationship between the level of physical abilities and motor skills of five-year-olds, taking into account dimorphic differences.

Material & methods

Participants

435 five-year-old children participated in the study, including 180 girls and 255 boys. They all attended kindergartens in the city of Biała Podlaska. The results were collected in April and May 2016 as part of research project No. DS 246 AWF branch in Biała Podlaska. The legal guardians of the children gave their consent for participation in the research. The study was preceded by a medical examination during which children's health was assessed. The research was carried out in accordance with the principles of the Helsinki Declaration and received a positive opinion of the Senate Committee on Ethics of Scientific Research of the University of Physical Education in Warsaw and the Science Committee of the Faculty of Physical Education and Sport in Biała Podlaska.

Measure

Research in the field of physical fitness and gross motor skills was conducted by employees of the Department of Human Biological Development from the Faculty of Physical Education and Sport in Biała Podlaska. It was carried out in the morning at the sports facilities of the AWF branch in Biała Podlaska.

Physical fitness (PF) was assessed according to the Polish Physical Fitness Test for preschoolers (Sekita 1988). It consisted of four trials: 20m dash (20mR); standing broad jump (SBJ); 4x5m shuttle run with carrying blocks (4x5mSR); throwing a 1 kg medicine ball with both hands from above the head (1kgTB).

The Gross Motor Skills Test (TGMD II) (Urlich 2000) was used to assess motor skills, in which the examiner rated the technique of performing exercises. This test allows the assessment of mobility capabilities with the help of 6 tests

- run (8 points)
- forward gallop and forward delivery steps (8 points)
- jumping on one leg (10 points)
- jumping over an obstacle (8 points)
- slides - side-loading steps (8 points)
- long jump from place (8 points)

Six trials with the use of sports equipment were carried out:

- hitting the ball in place (10 points)
- dribbling in place (8 points)
- catching the ball (6 points)
- kicking the ball (8 points)
- throwing the ball with a swing (8 points)
- ball rolling on the floor (8 points)

Statistical analysis

Statistica 13.0 software was used for statistical-data processing. In the sex groups, descriptive statistical parameters (mean, standard deviation) werecalculated. To evaluate the dimorphic differences, the Mollison index was used, in which it was assumed that the differences are large when they exceed 0.5 of the standard deviation, and very large when they exceed 1 SD. The statistical significance of the differences between the results of girls and boys was assessed according to the t-Student test.

$$\text{Mollison index} = \frac{M_g - M_b}{SD_b}$$

M_g – arithmetic mean of the feature value in girls

M_b – arithmetic mean of the feature value in boys

SD_b – standard deviation of the feature in boys

The individual results of 4 physical fitness trials (PF) were converted into points on the T scale. In order to standardize the units, the individual results of girls and boys were normalized on the T scale to the mean and statistical dispersion of all subjects using the formula:

$$T = \left(\frac{x_i - \bar{x}}{SD}\right) * 10 + 50$$

T- number of points; x_i - measurement result; $\bar{x}$ - sample mean; SD - standard deviation.

Next, taking into account the criterion $\bar{x} \pm 0{,}5\ SD$ from all the points obtained in four trials of the physical fitness test (PF), children were divided into the following groups:
low physical fitness (PFI) up to ($\bar{x} - 0{,}5\ SD$);
average physical fitness (PFII) of ($\bar{x} - 0{,}5\ SD$) to ($\bar{x} + 0{,}5\ SD$);
high physical fitness (PFIII) above ($\bar{x} + 0{,}5\ SD$).
The statistical significance of differences between the above-mentioned groups was assessed by the ANOVA analysis of variance and the Newman Keuls test.

Results

Table 1 shows the absolute values of the results of the physical fitness test and the Gross Motor Skills Test for boys and girls. These comparisons show that statistically significantly better results were obtained by boys compared to girls in the trials of the 4x5m shuttle run while carrying blocks (by 0.50s, p≤0.01) and the 20m dash (by 0.45s, p≤0.01). In the remaining parts of the physical fitness test, the differences between genders were small. They only indicate slightly better results in the long jump from place in boys (by 2.49 cm) and in throwing a medicine ball with both hands from above the head in girls (by 0.56 cm). On the other hand, taking into account the values of the Mollison index, there were large gender differences only in the 20 m dash. On the other hand, when assessing the sum of the results obtained in all fitness abilities, no statistically significant differences were found. On the other hand, when assessing the dimorphic differences in the locomotor skills of five-year-olds, it was observed that girls obtained statistically significantly better results in all trials (p≤0.01). According to the Mollison index, great differences were recorded only when assessing the long jump from place, as the girls scored 0.80 points more compared to the boys. In the remaining test samples, the differences did not exceed 0.5 SD.

When analyzing the results of control over sports equipment, it was found that girls achieved statistically significantly better results compared to boys. These included: dribbling the ball (by 0.53 points, p≤0.05), catching the ball (by 0.71 points, p≤0.01) and rolling the ball (by 0.52 points, p≤0.01). On the other hand, girls obtained worse results in kicking the ball (by 0.61 points p≤0.01). Small, statistically insignificant differences between the groups of girls and boys were noted in hitting the ball (by 0.30 points) and throwing the ball with a swing (by 0.20 points). According to the Mollison index, all dimorphic differences in the attempts to control the instruments were small and did not exceed 0.5 SD.

In terms of the sum of all points obtained in locomotive abilities, girls obtained statistically significant, higher results than boys (by 4.40 points, p≤0.01). However, in the control of sports equipment, a similar level of skill was observed, with the difference being 1.04 points. The mean of the points obtained from all the gross motor skills trials was higher in girls than in boys (by 5.44 points, p≤0.01).

Table 1. Results of physical fitness (PF) and motor skills (TGMD II) of five-year-olds from Biała Podlaska and the Mollison and t-Student index values calculated for dimorphic differences.

test attempts	Girls (n186)	Boys (n 255)	Value of the t-Student	Value of the Mollison index
	$\bar{x}$ ±SD	$\bar{x}$ ±SD		
Physical fitness				
4x5mSR	10.93±1.54	10.43±1.24	3.77**	0.405
1 kg TB	206.10±63.71	205.54±55.77	0.10	0.010
20mR	6.33±0.87	5.88±0.81	5.58**	0.562
SBJ	90.24±22.23	92.73±22.87	1.14	-0.109
PF	201.37±29.19	198.95±30.25	0.84	0.080
Locomotive abilities				
run	7.03±2.01	6.41±2.01	3.47**	0.312
gallop	5.89±2.26	5.18±2.26	3.21**	0.313
jumping on	6.96±2.61	5.51±2.61	6.17**	0.552
jumping over	5.18±1.49	4.76±1.49	2.94**	0.287
long jump	6.62±2.28	5.95±2.28	3.11**	0.293
slides	6.07±2.09	5.54±2.09	2.62**	0.255
total	37.75±6.92	33.35±8.05	6.01**	0.089
Control over sports equipment				
hitting the ball	7.27±2.13	7.57±2.13	1.45	-0.139
dribbling in	4.62±2.93	4.09±2.93	1.94*	0.180
catching	5.11±1.47	4.40±1.47	5.08**	0.483
kicking	5.83±1.64	6.44±1.64	3.64**	0.371
throwing	6.08±1.60	5.88±1.60	1.32	0.123
ball rolling	5.36±1.77	4.84±1.77	3.12**	0.292
total	34.27±5.76	33.23±7.07	1.65	-0.374

**statistically significant differences at p≤0.05*
***statistically significant differences at p≤0.01*

When analyzing the influence of physical fitness on motor skills of preschool children, it was noticed that both in boys (Table 2) and in girls (Table 3) the best results were recorded in the PFIII group, and the worst in the PFI group. Moreover, in the evaluated trials of the physical fitness test, statistically significant differences were noted between all the analyzed groups.

On the other hand, when assessing the locomotor skills and control of sports equipment in the groups of children divided into individual groups, it was observed that regardless of the level of physical fitness (PF), the results of the Gross Motor Skills Test (TGMD II) were at a similar level. No statistically significant differences were found in girls and boys. The above observations are also confirmed by the average sums of points calculated on the basis of the Great Motor Skills Test (TGMD II).

Table 2. The results of the fitness abilities and motor skills of boys according to groups, taking into account the physical fitness of the subjects and the values of ANOVA and the Newmann-Keuls test calculated for the differences between the groups.

test attempts	PF I (n 78)	PF II (n 111)	PF III (n 66)	ANOVA	I-II	I-III	II-III
	$\bar{x}$ ±SD	$\bar{x}$ ±SD	$\bar{x}$ ±SD				
Physical fitness							
4x5mSR	11.23±1.39	10.29±0.97	9.72±0.90	35.28	8.18*	11.61*	4.71*
1 kg TB	147.88±31.05	201.65±20.28	277.29±40.10	337.86	17.27*	36.70*	23.08*
20mR	6.31±0.79	5.81±0.67	5.47±0.82	23.26	6.39*	9.49*	4.13*
SBJ	78.22±20.27	93.24±20.28	109.02±18.37	43.31	7.26*	13.15*	7.25*
Locomotive abilities							
run	6.33±2.10	6.31±2.04	6.67±1.83	0.75	0.10	1.43	1.63
gallop	5.10±2.28	5.23±2.22	5.18±2.34	0.39	0.55	0.30	0.20
jumping on	5.65±2.68	5.45±2.58	5.45±2.63	0.16	0.73	0.64	0.00
jumping over	4.72±1.36	4.77±1.54	4.79±1.56	0.10	0.32	0.40	0.12
long jump	6.08±2.39	5.80±2.27	6.06±2.16	0.44	1.18	0.07	1.04
slides	5.79±1.98	5.27±2.12	5.68±2.15	1.64	2.39	0.45	1.79
total	33.68±8.19	32.83±8.23	33.83±7.64	0.57	1.12	1.24	0.16
Control over sports equipment							
hitting the ball	7.71±1.99	7.40±2.34	7.70±1.89	0.65	1.40	0.04	1.28
dribbling in	4.50±3.02	3.81±3.05	4.09±2.57	1.28	2.26	1.19	0.87
catching	4.59±1.37	4.42±1.53	4.14±1.47	1.70	1.11	2.59	1.74
kicking	6.67±1.45	6.37±1.73	6.29±1.71	1.26	1.75	2.11	0.61
throwing	6.10±1.47	5.78±1.68	5.79±1.59	1.06	1.92	1.64	0.06
ball rolling	4.99±1.69	4.85±1.82	4.67±1.77	0.59	0.76	1.53	0.93
total	34.55±6.04	32.63±7.76	32.67±6.87	1.98	2.61	2.26	0.05

**statistically significant differences at p≤0.05*

***statistically significant differences at p≤0.01*

Table 3. The results of the fitness abilities and motor skills of girls according to groups, taking into account the physical fitness of the subjects and the values of ANOVA and the Newmann-Keuls test calculated for the differences between the groups.

test attempts	PF I (n 78)	PF II (n 111)	PF III (n 66)	ANOVA	I-II	I-III	II-III
	$\bar{x}$ ±SD	$\bar{x}$ ±SD	$\bar{x}$ ±SD				
Physical fitness							
4x5mSR	11,29±1,52	10,30±0,71	9,56±0,79	35,53	7,89*	11,81*	5,70*
1 kg TB	149,66±26,09	206,57±18,15	295,36±53,54	246,54	14,22*	31,19*	21,43*
20mR	6,03±0,77	5,67±0,67	5,44±0,73	8,42	4,06*	5,70*	2,51*
SBJ	76,41±22,78	92,15±15,22	108,73±15,59	39,75	7,17*	12,61*	7,29*
Locomotive abilities							
run	6,40±1,62	6,38±1,79	6,56±1,45	0,19	0,10	0,66	0,84
gallop	5,20±2,25	5,30±2,28	5,21±2,54	0,04	0,34	0,03	0,30
jumping on	6,40±1,97	6,11±2,32	6,82±1,86	1,69	1,10	1,36	2,59
jumping over	4,74±1,64	4,38±1,55	4,64±1,37	1,02	1,89	0,45	1,32
long jump	5,72±2,29	5,90±2,23	6,59±1,70	2,25	0,68	2,81	2,51
slides	5,36±2,31	5,45±2,08	5,51±2,13	0,06	0,34	0,48	0,22
total	33,82±7,29	33,53±7,06	35,33±6,08	1,06	0,34	2,02	1,51
Control over sports equipment							
hitting the ball	6,82±2,14	6,80±2,09	6,15±2,08	1,67	0,08	2,19	2,40
dribbling in	4,64±2,42	3,74±2,70	3,56±2,75	2,48	2,74	2,82	0,53
catching	4,78±1,31	4,31±1,38	4,44±1,64	1,76	2,64	1,64	0,71
kicking	5,22±1,89	5,13±1,90	5,31±1,79	0,14	0,39	0,33	0,75
throwing	5,34±1,53	5,42±1,42	5,69±1,56	0,74	0,43	1,62	1,41
ball rolling	4,72±1,62	4,66±1,74	4,85±1,48	0,20	0,29	0,54	0,89
total	31,52±4,90	30,05±6,01	30,00±6,14	1,22	2,05	1,81	0,07

**statistically significant differences at p≤0.05*

Dicussion

Further studies are required to gain a thorough understanding of the impact of endogenous and exogenous factors on children's development. The analysis of the processes taking place in the body with the simultaneous monitoring of individual aspects of a child's life may support its psychophysical development. This is important because, according to many experts, it is up to the age of five that a child shapes its habits and the way it perceives the world to the greatest extent. Directing the child correctly during this period may contribute to better functioning later in life (Šišková et al. 2020).

In studies on the motor skills of preschoolers, different conclusions can be found regarding the impact of gender dimorphism on fitness. There are studies in which the authors confirm the above-mentioned relationships, but there are also those that contradict them. According to Ruzbarska and Piątkowska (2008), boys in selected tests of physical fitness obtain significantly better results in comparison with girls. According to the authors mentioned, this is a manifestation of what will be more clearly observed in adulthood, when men, due to a higher content of androgens in the body (e.g. testosterone), will achieve much better results (Handelsman et. Al. 2018). The above observations were also confirmed in the observations of Spanish children aged 3-6 years tested by Cadenas-Sanchez et al. (2019) and Portuguese preschoolers tested by Reyes et al. (2018). Kotarska (2010), who conducted a study of the physical fitness of children aged 4-6 years old and analyzed results from 1996 and 2006, is of a different opinion. In the first research period, boys in each age category achieved significantly better results in all fitness abilities. However, according to research carried out in 2006, this trend turned in favor of girls. On the other hand, differences in physical fitness between girls and boys in preschool age were not found by Asienkiewicz et al. (2005). In our observations on fitness abilities, statistically significantly better results were noted in boys in two out of four test trials. On the other hand, in the Gross Motor Skills Test, the results for both sexes were at a similar level. Thus, at this stage of ontogenesis, the reasons for the above-mentioned differences should be sought in genetic conditions, and not in the level of acquired skills. Better results for boys were recorded in the 20m dash and the 4x5m run, i. e. in trials considered anaerobic. It should be remembered that motor skills are directly related to the genotype we inherit, but also indirectly to the body composition and dimorphic differences, which are a manifestation of the Silventoinen et al phenotype. (2020). Szopa (1990) documented high heritability rates of maximal anaerobic power, which is under strong genetic control of the muscle structure, i.e. the ratio of fast-twitch to slow-twitch fibers. The phosphagen-non-lactic acid component is genetically controlled to a degree similar to the height of the body, which is a trait commonly considered to be strongly genetically determined. Also Skład (1977), when examining twins aged 8 to 15 years in terms of fitness abilities, showed that in relation to speed heritability the correlation was 0.62 to 0.9.

There is also no unanimity in the literature regarding the dimorphic differences in the gross motor skills of preschoolers. Aye et al. (2017, 2018), when studying five-year-olds in Myanmar and Japan, observed that girls had much better locomotor skills, while boys had much better control over sports equipment. Similar relationships were found in preschoolers from Finland (Niemistö et al. 2019). Among US children, Brian et al. (2017) reported a higher level of locomotor skills only in girls. On the other hand, no significant dimorphic differences were found in the control of sports equipment. This is contradicted by the results of British observations (Morley et al. 2015) and Belgian observations (Bardid et al. 2016), according to which boys had a higher level of control skills. On the other hand, in terms of locomotion skills, no differences were found between girls and boys. However, Morano et al. (2011) in southern Italian boys and girls, Jiang et al. (2018) among Chinese preschoolers, and Tomaz et al. (2019) based on African studies, found no differences in test results. In the presented study of five-year-olds in Biała Podlaska, the mean score obtained in all trials of the TGMDII test was higher in girls than in boys. It was mainly influenced by the results of locomotor skills. In the control of sports equipment, a similar number of points was observed in both sexes. However, significant differences in individual exercises could be observed. The results of locomotor skills we have described are consistent with the results of research presented above by other authors. Therefore, it can be assumed that girls, compared to boys, have a genetically better predisposition to natural movement. However, there is no such unanimity in the control of sports equipment, as described above. Therefore, we should look for other factors which could affect these aspects of children's gross motor skills. It is assumed that excessive weight and obesity have a negative impact on the motor skills of preschoolers. This has been documented by Morano et al. (2011) and by Castetbon and Andreyev (2012) on the basis of studies of Italian and American preschoolers. The search for further modifiers requires more research. The assumed relationships between the level of fitness abilities and motor skills of 5-year-olds were not confirmed in our observations. Both in girls and boys, no significant differences were found between groups with different levels of physical fitness. During the evaluation of fitness abilities, the absolute value of the result obtained in motor skills tasks is taken into account, without the technique of its execution. On the other hand, TGMDII assesses the technique of performing the exercise. Since a five-year-old child is at the beginning of its path when it comes to motor development, the differences in motor skills between particular skill groups may be small. Freitas et al. (2018), on the basis of studies of American children aged 3-6 years, only in some fitness abilities have documented links with motor skills. However, these relationships differed between boys and girls.

It should be emphasized that all the children we studied were inhabitants of cities. The environment in which children live affects their motor skills. Aye et al. (2017) and Niemistö et al. (2019) found that children

from the countryside achieved better results in gross motor skills compared to those from the cities. Similar observations were presented by Trzcińska et al. (2013) describing the differences in fitness abilities. According to the quoted authors, preschoolers from the countryside, apart from compulsory classes in kindergarten, spent more time outdoors, while children from urban areas limited themselves to participating in organized sports activities, the time of which was restricted. Moreover, it was noted that children's motor skills were positively related to their physical activity, but inversely related to the time spent in front of a TV or computer screen (Paudel 2017, Webster et al. 2019). Five-year-olds from Biała Podlaska are not sports-active children. 41.75% of girls and 30.71% of boys participate in additional physical activities outside the compulsory program in kindergarten. These children spend a lot of free time in front of the TV or computer, especially in the autumn and winter period (Dmitruk et al. 2017). Therefore, it can be assumed that the motor skills of the five-year-olds we assessed are still at a low level and do not affect their motor skills.

Conclusions

The analysis of fitness abilities revealed significant differences between girls and boys in trials assessing running speed and agility. On the other hand, such relationships were not noted in the strength of the arms and the power of the lower limbs.

Among the five-year-olds in Biała Podlaska, a higher level of gross motor skills was noted in girls compared to boys, which was mainly influenced by the results of locomotor skills. In the ability to control sports equipment, similar results were observed in both sexes. However, there were significant differences in the individual exercises. Since no significant distances in locomotive skills and control of instruments were noted in five-year-old girls and boys characterized by different levels of physical fitness, it should be assumed that the 5th year of life is still too early a period in ontogenesis to look for such relationships.

Conflicts of interest - The authors declare no conflict of interest.

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