DYNAMICS OF COMPREHENSIVE PHYSICAL FITNESS IN ARTISTIC GYMNASTS AGED 7-10 YEARS

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Annotation. *Purpose*: The aim of the study was to evaluate the somatic development and comprehensive physical fitness of artistic gymnasts aged 7-10 years. *Materials and methods:* Gymnasts (n = 307), split up into four age groups performed eight Eurofit tests. The results were evaluated in points according to the development standards prepared in scale T for the Polish girls population. *Results*: The gymnasts obtained the highest growth rate in balance test - FLB (13 points), arm and shoulder muscular endurance test - BAH (7 points) and speed of the upper limb movement test - PLT (4 points) out of eight physical fitness tests. *Conclusions.* High and very high level of performance in the six Eurofit tests and increased total number of points in the subsequent age groups of artistic gymnasts proved high effectiveness of training in shaping the key components of a comprehensive physical fitness in artistic gymnastics - balance, strength, endurance, speed and flexibility. Relatively little progress in isometric hand strength (HGR) and standing broad jump (SBJ) suggests a significant influence of genetic factors on the level of these abilities. The results provide an objective information useful in optimizing control system of training effects in comprehensive physical fitness and optimization of artistic gymnasts training at the comprehensive stage of sports training.
Key words: artistic gymnastics, training, control, women, physical fitness, Eurofit.

Introduction

Specialists dealing with the issues of training in gymnastics emphasize that sports results at different levels require athletes comprehensive fitness preparation [10, 12, 13, 15, 19, 22].

On the basis of the above information, it is logical to adopt the claim that improvement of the management process of training in artistic gymnastics should be based on the reliable control methods of training [10]. Despite the undubitable achievements in this field, the problem of objective control of the training process, especially the control of the effects of artistic gymnastics training, has not been finally resolved. Currently, there are no quantitative criteria for the somatic and physical fitness development of artistic gymnasts.

There is no current normative data for the long-term somatic and physical fitness development of girls practicing artistic gymnastics in the scientific literature. For this reason the study was undertaken which aim was to assess the somatic development and components of comprehensive physical fitness in artistic gymnasts aged 7-10 years.

An important premise of the proposed course of the study are the demands put forward by many specialists in the theory and practice of sport who have repeatedly highlighted the merits of continuous research in the course of sports training. This should enable to determine the growth rate of certain somatic traits and the development of various motor abilities and, consequently, to assess the impact of these abilities on development of sport's level in artistic gymnasts [2, 3, 10, 12, 18, 19].

It was assumed that the obtained results will provide useful information to optimize the selection and training control systems in women's artistic gymnastics at the stage of comprehensive and targeted training, in accordance with the basic requirements of control of training process. It was also assumed that the results of the study will enable an objective verification of the effects of sports training of tested artistic gymnasts in comprehensive physical fitness.

Material and methods

The tested group comprised of 307 girls aged 7-10 years, attending the sport classes at the No. 23 Primary School of Sports Championship in Olsztyn, Poland. Girls execute gymnastics training program compliant with the Polish Gymnastics Association. The selection of girls to I grade was based on the results of anthropometric measurements and a set of performance tests. Training experience of tested girls ranged from 1 to 4 years.

Tested gymnasts were split up into four groups (age categories) according to obtained chronological age (Table 1).

Tested artistic gymnasts represented the high sport's level, which each year has been confirmed by numerous medals in the Polish Championships.

All measurements were performed in the Jozef Rusiecki Olsztyn University College. The study was pursued in accordance with the Helsinki Charter of Human Rights and was approved by the local Ethics Committee. The study was based on results of studies pursued in 2007-2013, twice each year in April and October.

In tested gymnasts anthropometric measurements and body composition were determined.

Participants' body height was measured with a calibrated WB-150 medical weight/stadiometer (ZPU Tryb-Wag, Poland) accurate to within 0.1 cm. Body mass (accurate to within 0.1 kg) and body fat content (accurate 0.1%) were measured by BC 418 MA electronic body composition analyzer (Tanita, Japan) with the use of a bioelectric impedance analysis (BIA). Moreover, the skinfolds measurements were made in two locations to assess the body fat (triceps arm muscle, lower blade-bone angle) in accordance with standard procedure [16]. Measurements were made by

GPM caliper [SiberHegner & Co. Ltd., Switzerland]. Participants were dressed only in underwear and were barefoot during measurements. All anthropometric measurements were made by the same certified investigator and by international standard procedures.

Physical fitness was determined by the following eight tests included in the Eurofit physical fitness battery [5]:
1. Static Balance (FLB – Flamingo Balance). Balancing for one minute on one leg on a beam of set dimensions. Gymnasts performed this test standing on a wooden beam without shoes, which is a derogation from the standard procedure.
2. Speed of limb movement (PLT – Plate Tapping).
3. Flexibility. Reaching forward as far as possible from a seated position (SAR – Sit-and-Reach).
4. Explosive strength (SBJ – Standing Broad Jump).
5. The isometric hand strength (HGR – Hand Grip). The isometric hand strength was measured in static conditions with the use of the hand dynamometer DR4-P integrated with tensometric amplifier WTP3 and a computer program MAX_v_5.5 (JBA-Zbigniew Staniak, Poland).
6. Abdominal muscular strength and endurance (SUP – Sit-ups).
7. Arm and shoulder muscular endurance (BAH – Bent Arm Hang).
8. Running Speed - Agility. Shuttle run 10 x 5 m (SHR – Shuttle Run)

An assessment of cardio-respiratory endurance was not performed due to the research task. The reliability of performance tests was verified on a selected group of 46 girls at the age of 14. The obtained values of reliability coefficients (r_{tt}) in the individual tests were above 0.86.

For all variables basic statistical parameters were calculated: arithmetic means (M), standard deviations (SD), coefficients of variation (CV), the minimum values (Min), the maximum values (Max) and the differences of results expressed as a percentage in relation to the youngest group of gymnasts (7 years). In order to estimate the effect of independent variables on the dependent variables the values of coefficients of determination (R^2) were calculated. Statistical analysis was executed by STATISTICA 7.1 software package (Stat Soft, Inc.., USA).

Results

Table 1 shows the basic anthropometric characteristics of four tested groups of gymnasts. The somatic development was evaluated by current point tables (in scale T) of Polish girls population [7]. Gymnasts obtained the smaller number of points with respect to the body mass (BM) and body height (BH) in subsequent age groups. Number of points in BH decreased much faster in relation to the number of points in BM, which resulted in the increasing scores of body mass index (BMI) and lower scores of slenderness index (SI).

Table 2 shows the participants' results in the eight Eurofit tests. The results obtained in the individual tests are characterized by a great diversity, as evidenced by the value of the coefficient of variation (CV). The greatest variability was characterized by arm and shoulder muscular endurance test (BAH) - from 39.71 to 71.89% and static balance (FLB) - from 39.80 to 64.36%. The lowest variability was characterized by agility test (SHR) - from 6.60 to 8.97% and explosive strength test (SBJ) - from 9.21 to 10.78%.

Table 3 shows the percentage differences between the results of further groups of gymnasts in relation to the performance of the youngest group (gr. I). The largest differences were noted in the arm and shoulder muscular endurance test (BAH) - 204.75% and absolute isometric hand strength test (HGR) - 51.73%. Simultaneously in the same tests in which the slightest variation of results was observed within individual groups of gymnasts, the smallest differences between groups were showed in agility test (SHR) - 6.24% and explosive strength test (SBJ) - 25.22%.

The values of the coefficients of determination (R^2) of the results obtained by tested gymnasts in the individual tests according to age varied widely from 0.1465 in the relative isometric hand strength - HGR (N / kg) to 0.4677 in absolute isometric hand strength - HGR (N). Very varied results of the individual tests obtained groups of gymnasts in relation to the standards of the Polish girls population (Table 4). As expected, the tested gymnasts presented higher level of physical fitness compared to the untrained girls. The greatest differences were found in the arm and shoulder muscular endurance test (BAH), and a very high rating in the youngest group - gr. I (71 points) systematically increased in subsequent age groups, reaching 78 points in the oldest group - gr. IV. Gymnasts obtained very high point scores in the abdominal muscular strength and endurance test (SUP) - from 68 to 70 points and in the flexibility test (SAR) - from 64 to 66 points. Very dynamic improvement of the results in static balance test (FLB) draws attention. It should be emphasized that gymnasts performed test without shoes, which constituted a significant impediment. The purpose of this procedure was to avoid a situation in which most of the athletes perform the test faultlessly. Due to the non-standard procedure for performing this test the scores presented in Table 4 were inserted in brackets.

By the standards of the Polish population girls, examined gymnasts achieved the average level of absolute isometric hand strength - HGR (51-53 points). However, it should be noted that all of the tested groups of gymnasts were characterized by low body mass and thus low skeletal muscle mass. Allowedly, muscle strength correlates with their mass and therefore should also be included level and increase of the relative hand strength - HGR/kg in the assessment of the tested gymnasts' strength. The level of relative hand strength was higher by only 17.55% in the oldest group of gymnasts (group IV) in comparison with the youngest group (group I) (Table 3).

Table 1.

Basic anthropometric characteristics of artistic gymnasts aged 7-10.

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Group	SP	Age (yrs)	BM (kg)	Pts.	BH (cm)	Pts.	BMI (kg/m²)	Pts.	SI (cm/kg)	Pts.
I	M±SD	7.43±0.30	23.48±2.61	46	128.29±11.70	55	14.27±1.26	41	50.52±6.91	91
n = 94	Min-Max	7.00-7.90	17.30-39.80		112.3-158.5		13.32-19.31		35.37-64.74	
	CV (%)	4.05	11.12		9.12		8.83		13.68	
II	M±SD	8.45±0.29	26.10±3.75	46	130.54±8.74	49	15.32±1.37	45	48.82±6.08	80
n = 85	Min-Max	7.96-8.93	19.40-42.70		111.2-155.7		13.16-19.11		34.14-60.19	
	CV (%)	3.40	14.37		6.70		8.94		12.45	
III	M±SD	9.44±0.28	28.72±4.39	45	132.64±7.63	43	16.32±1.36	47	47.28±5.54	70
n = 71	Min-Max	8.99-9.91	18.70-46.40		112.2-135.3		13.70-19.82		32.97-59.89	
	CV (%)	3.0	15.29		5.75		8.42		11.72	
IV	M±SD	10.44±0.29	30.45±5.27	42	135.43±11.34	39	16.60±2.52	47	45.29±8.25	59
n = 57	Min-Max	10.00-10.93	19.80-51.10		116.2-161.1		13.12-23.48		28.55-60.24	
	CV (%)	2.78	17.30		8.37		15.18		18.21	

Explanations: SP – statistical parameters; CA – chronological age; BM – body mass; BH – body height; BMI – body mass index; SI – slenderness index; Pts. – point evaluation of variable based on the standards of somatic development of Polish girls population [7].

Table 2

The results of eight physical fitness Eurofit tests of artistic gymnasts aged 7-10.

Group	SP	FLB (n/60 s)	PLT (s)	SAR (cm)	SBJ (cm)	HGR (N)	HGR/kg (N/kg)	SUP (n/30 s)	BAH (s)	SHR (s)
I	M±SD	15.65±6.23	17.87±2.51	11.82±4.56	122.84±13.24	110.93±20.34	4.73±0.69	22.61±3.83	22.12±15.90	24.52±2.15
	Min-Max	5.-31	13.02-26.00	0.-21	98-166	71.0-178.0	2.81-6.24	14-29	1.80-73.00	20.59-29.90
	CV (%)	39.80	14.05	38.61	10.78	18.33	14.59	16.95	71.89	8.75
II	M±SD	11.17±8.82	15.82±2.08	13.11±3.47	131.89±13.67	132.04±22.69	5.06±0.67	25.64±3.57	30.71±16.64	23.62±1.80
	Min-Max	2.-31	11.55-21.00	5.-19	85-158	92.0-225.0	3.71-7.31	17-33	4.25-82.62	19.49-29.78
	CV (%)	52.10	13.14	26.48	10.36	17.19	13.32	13.90	54.18	7.63
III	M±SD	6.33±3.54	14.41±1.61	14.38±2.35	143.01±13.17	148.64±26.19	5.19±0.79	27.84±3.11	36.45±18.65	23.38±1.54
	Min-Max	1.-14	11.30-18.44	10.-19	117-175	100.0-225.0	3.81-7.49	20-34	8.81-89.11	20.22-27.22
	CV (%)	55.93	11.14	16.36	9.21	17.62	15.16	11.17	51.16	6.60
IV	M±SD	4.69±3.02	12.91±1.28	15.12±3.76	153.82±15.90	168.31±25.04	5.56±0.81	29.25±3.24	45.29±17.98	22.99±2.06
	Min-Max	0.-11	10.90-16.78	7.-25	112-183	124.0-230.0	4.23-7.67	20-36	18.24-106.64	19.27-28.87
	CV (%)	64.36	9.92	24.88	10.34	14.88	14.56	11.06	39.71	8.97

Explanations: FLB – Flamingo Balance, PLT – Plate Tapping, SAR – Sit-and-Reach, SBJ – Standing Broad Jump, HGR – Hand Grip, SUP – Sit-ups, BAH – Bent Arm Hang, SHR – Shuttle Run 10 x 5 m.

Table 3

Percentage differences of the results of eight physical fitness Eurofit tests in consecutive groups of artistic gymnasts at the age of 8-10 in relation to the results of gymnasts at the age of 7.

Group	FLB	PLT	SAR	SBJ	HGR	HGR/kg	SUP	BAH	SHR
I	100	100	100	100	100	100	100	100	100
II	71.37	88.53	109.8	107.37	118.90	106.98	113.40	138.83	96.33
III	40.45	80.64	120.44	116.42	134.26	109.94	123.13	164.78	95.35
IV	29.97	72.24	126.63	125.22	151.73	117.55	129.37	204.75	93.76

Table 4

Rating points (in scale T) of results of eight physical fitness Eurofit tests of artistic gymnasts aged 7-10 based on Polish girls population norms [8].

Group	FLB	PLT	SAR	SBJ	HGR	SUP	BAH	SHR	Points (Σ)
I	(38)	57	64	61	52	68	71	56	467
II	(42)	59	65	61	53	70	76	56	482
III	(50)	59	66	61	53	70	76	53	488
IV	(51)	61	66	61	51	68	78	52	488

Discussion

One of the fundamental objectives of gymnastics training at the initial stage of training is a comprehensive and harmonious development of physical fitness including the development of motor abilities (strength, speed, endurance, agility, flexibility, coordination and others). Simultaneously the importance of somatic built in gymnastics is emphasized [6, 10, 12, 15]. Di Cagno et al. [6] pointed out the relationship between somatic built and physical fitness of gymnasts and pointed to the need for diagnosis of somatic built indicators to identify fitness predispositions of children at the selection stage to gymnastics. Different conclusions arise from the Fjørtoft et al. [9] work which was aimed to assess the physical fitness of children aged 5-7, assessed by the Eurofit tests battery. This research shows that the basic somatic features – body height and body mass - did not have a significant impact on the results of the individual physical fitness tests. On the other hand, a strong correlation was found between the results of the individual tests and the age of the children.

In our research evaluation in points of body height and body mass of gymnasts decreased with age, which among other things was associated with a decreasing number of tested gymnasts in the subsequent years of the study. The decreasing number of gymnasts was mainly due to the resignation from artistic gymnastics and to a lesser extent from injury that prevented from taking part in the research. Lower body height makes it easier to perform technically difficult evolutions in artistic gymnastics. Therefore tendency for the relative (relative to development standards) decrease in body size, found in our study, should be considered as a positive effect of natural selection. In the recent study Camargo et al. [4] analysed the physical growth and body composition of 136 Brasilian rhythmic gymnastics athletes relative to their level of somatic maturation. The z scores for mass were negative during all ages according to both WHO and Brazilian references, and for body height were also negative for all ages according to WHO reference but only until 12 years old according to Brazilian reference. The conclusion was these athletes had a potential to gain mass and body height several years after peak height velocity, which indicated late maturation. Thereupon, one should keep in mind the significant impact of biological development pace both on the physique dimensions, as well as physical fitness. This implies the need for a practical application of the biological age determination in girls at selection stage in gymnastics. This will enable the identification of girls with the most beneficial features of the somatic built and facilitate an objective assessment of physical fitness in terms of predictive value.

Specialists dealing with the issues surrounding gymnastics training emphasize that sports results at the highest level require comprehensive physical and mental preparation [2, 10, 13, 15]. Zaporozhanov et al. [21] recommend complex of five the most informative indicators for evaluation of gymnasts' special fitness, which meet specific requirements of artistic gymnastics and metrological requirements of reliability and informative character. They include indicator of relative force in elbow joints; stability in Romberg test after rotating around longitudinal axis of the body; anticipation response to moving object; sum of ranges of the tested in this complex. Kochanowicz [10] proposed a complex set of indicators to assess motor preparation at the initial stage of training in gymnasts aged 6-7. These included an evaluation of balance function, agility and special technical skills. The basis for selecting these indicators were results of author's earlier studies ben the physical fitness of gymnasts [11, 13].

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The results of numerous works have shown that physical fitness is improving with age during childhood and adolescence, but the pattern of improvement is not identical for all motor tasks. Moreover, a very large variability of the dynamics of results in individual tests of physical fitness was shown in our study. Very large differences between tested groups, identified in the static balance test (FLB) were undoubtedly the result of numerous physical exercises aimed at the development of this ability.

Balance exercises are an important factor in stimulating the development of vestibular function and proprioceptive sensation, which in total resulted in a rapid improvement of the balance system functions. In addition, through a number of studies it was revealed that as the number of years of training increase, the ability to control balance is affected positively [1, 11, 17]. For instance, Akin [1] found the significant effect (P=0.000) of 12-week gymnastics training on static balance and slalom dynamic balance in 4-6 years of age pre-school students, while there was no significant change observed in their age-matched controls.

The evaluation of the results obtained by the tested gymnasts from the youngest group (gr. I) on the basis of development standards for the Polish girls population [8] showed high and very high levels of performance in the six Eurofit tests at the beginning of training program what confirms the accurate selection of the girls to the artistic gymnastics. At the same time, gymnasts from the oldest group (group IV) also obtained high and very high level of performance in the six Eurofit tests. Furthermore, the evaluations expressed in points increased with age in the four tests, and the total number of points increased in subsequent age groups. This demonstrates the high efficiency of training in key components of physical fitness in artistic gymnastics - strength endurance, balance, speed, and flexibility. An unexpected result of the study was an average level of agility (SHR) in each group of gymnasts. Agility is regarded by experts as one of the leading motor abilities in artistic gymnastics [10, 15].

According to Malina et al. [14] the results of the standing broad jump, shuttle run and the bent arm hang increases linearly with age in both sexes up to the age of adolescence. Considering few hours training daily of tested gymnasts, involving exercises aimed at development of agility, the reasons for lack of substantial progress in the shuttle run is unclear. This points to the need for in-depth analysis of the training process with particular attention to methods, measures and the size of the training loads in terms of improving the effectiveness of training in the field of comprehensive agility. Also the study conducted by Boraczyński et al. [3] showed no statistically significant progress in terms of agility of 7-year-old girls after completing a 12-month artistic gymnastics training program.

The above results of selected studies prove high importance of diagnosis of physical fitness in artistic gymnastics at the selection stage, as well as in later stages of sports development. At the same time, experts highlight that some of the psycho-physical properties only slightly subject to the shaping in the process of longtime sports training [12, 15, 20]. For this reason, it is logical to seek candidates with high predispositions in the field of relevant in gymnastics motor skills and abilities at the selection stage to artistic gymnastics.

Zaporozhanov et al. [18] on the basis of the results of Eurofit tests in artistic gymnasts at the age of 7.7 and 9.3 distinguished four tests (indicators) with the highest predictive value - the speed of upper limb movement (PLT), standing broad jump (SBJ), agility (SHR) and the relative isometric hand strength (HGR). The results of these tests in the least extent differentiated tested groups, reflecting the high genetic conditions of abilities that determine the results of highlighted tests. In other studies, carried out on two groups of artistic gymnasts at the age of 6.9 and 10.0 the same tests as the most useful in assessing fitness predispositions in artistic gymnastics were indicated [2].

In the light of the results presented in this work, the Eurofit battery of tests allows to obtain reliable data useful in the evaluation of a comprehensive physical fitness and effectiveness in artistic gymnastics training at the initial stage of sports training.

Conclusions

Relative (in relation to development standards) decrease with age body height and body mass in tested gymnasts indicates the validity of the determination of biological age of girls at the selection stage in artistic gymnastics. This will enable the identification of girls with the most beneficial features and proportions of somatic built and facilitate the objective assessment of physical fitness in terms of predicting value.

High and very high level of performance in six Eurofit tests obtained by girls in the first year of training (gr. I) proves an accurate selection of these girls to artistic gymnastics.

High and very high level of performance in six Eurofit tests and increasing total number of points in the subsequent age groups of artistic gymnasts proved highly effective workouts in shaping the key components of a comprehensive physical fitness in artistic gymnastics - balance, strength endurance, speed and flexibility.

Relatively little progress in terms of isometric hand strength (HGR) and standing broad jump (SBJ) suggests a significant influence of genetic factors on the level of these abilities.

Reasons for the average level of agility (SHR) in tested groups of artistic gymnasts are unclear. This points the need to verify the gymnasts training program under the terms of greater training efficiency of shaping this ability.

The results provide an objective information useful in optimizing control system of training effects in terms of comprehensive physical fitness and optimization of artistic gymnasts training at the comprehensive stage of sports training.

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