

DEVELOPMENT OF STRENGTH ABILITIES IN CHILDREN AND YOUTHS

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Abstract. The aim of the research was to compare the development of various types of skeletal muscles in children and youth of the school age and in the process of the natural biological development, as well as under the effect of a systematic, specialist training process. The aim defined in such way was to be achieved by using the following research method: The maximal strength capacities were defined with the use of a dynamometric method and based on the results of the measurements of the strength of the *flexor muscles of the finger flexors*, in other words, called more generally as the “hand dynamometer”. Strength endurance was defined following the use of two tests - a pull up test and a sit-up test. In order to analyse the statistic differences between children practicing sports and those who do not practice, as well as the differences between every investigated year, we used the programme “Statystyka 6”. In these studies 224 young judo athletes participated. They were divided into groups - between 11 and 17 years of age. Sportsmen aged between 11-12 trained usually 3 times a week, those between 13-15 trained usually 3-4 times a week and those between 16-17 trained usually 6 times a week. Training lasted - depending on the age - from 90 to 120 min. Examinations were made at the end of the so-called period of preparation. Only these athletes were selected to the groups (conventionally called experimental groups - EG), whose astrological age fully corresponded to the biological age (evaluated by medical doctor, specialist in sport medicine) [6]. The results of own research were compared to the results of cross-sectional (for the Polish population) research elaborated by Trzeźniowski and Pilicz [24]. We assumed that the data obtained by those authors should be treated by us as the level of examined features of the reference group. It was established that in the process of the many years of training of the judo athletes, the strength endurance of the muscles of the shoulder girdle undergoes significant changes. Young athletes achieved considerable improvement of these results in test exercises. This proves that specialist loads applied in the process of training of the junior judo athletes created significant adaptation changes in these groups of muscles. Statistically significant differences between athletes and those who do not practice sport confirm diagnostic

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possibilities of this exercise. These results may be used in the training practice to recruit beginner athletes, to control the training process in micro-cycles of various types and to guide the elaboration of the strength endurance norms in relation to age, evaluation of the rate of development of this particular motor trait and in relation to the perspective development of the athletes.

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Key words: School period of the ontogenesis - Dynamics of the strength indexes of children practicing sport and those who do not practice

Introduction

Uniformity of views as far as the comprehension of the definition of “human strength” has long existed in sport science. The term is understood as the ability to overcome resistance or to oppose it at the cost of muscle tension [23,28].

If in the definition of strength the differences are insignificant, then in the assessment of the tendencies, dynamics of development along with age, and in the mechanisms of strength exhibition the differences are considerable. They apply both to the treatment of these processes, and they result as well from the specific performance of the athlete and the specificity of the given sport discipline. The majority of specialists who investigate the dynamics of the exhibition of the muscle strength from the bio-chemical point of view, interpret similarly the impact of the various aspects of the training process. This applies particularly to researches that determine the energetic protection of the muscle contraction [7,8,16].

In specialist literature, there is a substantial number of works dealing with various aspects of the physical preparation of athletes: their general strength capacities [2,9,21], dynamics of specific motor abilities [11,12,13], and others. It is important to emphasize that in the majority of those works, the observations refer to athletes in a relatively short period of time – maximum of one year (usually during a macro-cycle). However, most of the previously and presently published works deal with physically mature athletes. There are incomparably fewer publications showing research results of qualified athletes in the period of physical development [10,13,14], which would include the dynamics of the various indexes characteristic of motor abilities related to age.

It is known that in the period of sexual maturation, intensive and frequently opposing changes of the vegetative and motor functions of man, take place [17,18,22,26]. In this period, when “struggle” for energy between various functional systems of the organism takes place, the importance of information on the dynamics of development of the specific function of the organ or of the motor



ability, grows incommensurably. Such information constitutes the foundation in the management of the training process of junior athletes.

The principle methodological difficulty concerning the investigation of the phenomenon, in relation to athletes, may be formulated including two aspects. At first, there is lack of any premise that would allow us to determine who out of the junior athletes will continue their long term sport career, and how long it would last. Secondly, long-term observation of certain athletes provide reliable observation, although it extends the period between the acquired knowledge about the phenomenon and the implementation of the results into practice.

In our own researches we accepted key assumptions: every year and in certain environmental circumstances, young people (as an entirety) with similar biological, psychical and health predispositions to a particular sport are selected to training groups. Moreover, other factors are distributed similarly – i.e. motivation, level of nourishment, competence of the teachers etc. Hence, we assume that a 14-year-old “statistical athlete” from a big city, district, school (with a two-year training experience), when being 12-years-old did not differ significantly from a 12-year-old who presently takes up training in the same sport club. As a result, we assume that after two years the 12-year-old youngster, subject to similar stimuli of the environment, will achieve the same level of adaptation as the presently 2 year older peer athlete.

This way of comprehending – being aware that it might be faulty - allows us to compare junior athletes differing in age (and proportionally to age - in training experience – as an indispensable condition) as far as particular training effects. The obtained data, consequently, may be justly compared to the level of analogous features of people of the same age, who yet do not practice sport.

Aim and tasks of the research

The aim of the work was to conduct a comparative research on the development of various types of strengths of children and youth in their school years, and under the influence of the natural development process and systematic sport activities.

The key tasks of the work consisted of :

1. Studying the impact of systematic sport activities (judo) on the strength development of school age children.
2. Comparative analysis of the rate of development of strength abilities in the investigated period of ontogenesis.
3. Defining the properties of co-operation between various strength abilities in school age period in children who practice and do not practice any sports.



Material and Methods

The maximal strength capacities were defined with the use of a dynamometric method and based on the results of the measurements of the strength of the *flexor muscles of the finger flexors*, in other words, called more generally as the “hand dynamometer”.

Strength endurance was defined following the use of two tests - a pull up test and a sit-up test.

In order to analyse the statistic differences between children practicing sports and those who do not practice, as well as the differences between every investigated year, we used the programme “Statystyka 6”. The following basic statistical indexes were calculated: arithmetical mean (\bar{X}), standard deviation ($\pm\delta$), Student’s criterion (t, p), minimal and maximal values (min, max) variability index ($V_s, \%$). Linear and non-linear correlation, as well as linear and non-linear regression were calculated [2].

In these studies 224 young judo athletes (boys) participated. They were divided into groups - between 11 and 17 years of age. Sportsmen aged between 11-12 trained usually 3 times a week, those between 13-15 trained usually 3-4 times a week and those between 16-17 trained usually 6 times a week. Training lasted - depending on the age - from 90 to 120 min. Examinations were made at the end of the so-called period of preparation.

Only these athletes were selected to the groups (conventionally called experimental groups - EG), whose astrological age fully corresponded to the biological age (evaluated by medical doctor, specialist in sport medicine) [12].

The results of own research were compared to the results of cross-sectional (for the Polish population) research elaborated by Trzeźniowski and Pilicz [24]. We assumed that the data obtained by those authors should be treated by us as the level of examined features of the reference group.

Results

Dynamics of indexes of the absolute strength: The dynamics of the results is characterized by a constant increase, along with the age of the judo athletes, of the absolute index of strength (Fig. 1). However, both the highest individual indexes of the athletes, as well as the lowest values, show identical tendency. And though the value of the changeability index attains significant levels (apart from the ages 15 and 17), the differences of the tests results are statistically significant in all groups (Table 1).



Table 1

Results of testing strength indexes of judo athletes 11-17 age

Statistic indexes	Age (Years)						
	11	12	13	14	15	16	17
Muscle strength of finger flexors, kg							
n	50	38	34	27	25	20	30
Mean	25.33	28.55*	34.38***	40.15	46.28	52.40*	57.30*
Maximal	38	42	45.5	51	56	67	64
Minimal	11.5	10	21	22	32	35	48
$\pm \delta$	7.16	7.70	6.52	7.38	6.17	9.64	5.08
Vs [%]	28.27	26.98	18.97	18.39	13.34	18.39	8.88
Standing long jump, cm							
Mean	177.58	190.05	202.71**	214.56	229.20***	241.80	246.13
Maximal	221.5	230	244	253	268	272	273
Minimal	110	105	150	135	150	168	205
$\pm \delta$	32.0	30.5	25.4	27.3	28.0	26.5	16.9
Vs [%]	18.03	16.06	12.55	12.73	12.22	10.94	6.86
Pull-ups, number							
Mean	43.26	7.00***	8.62	9.19	12.52*	15.30	18.43*
Maximal	95	13	18	16	25	25	25
Minimal	4	1	0	1	3	7	8
$\pm \delta$	24.1	3.6	4.6	5.0	5.5	6.1	4.7
Vs, %	55.78	52.09	53.90	54.69	44.06	40.07	25.59
Sit ups, number							
Mean	25.16	28.45*	30.44	32.55	33.92	34.75	35.53
Maximal	37	38	39	39	39	39	39
Minimal	11	8	11	18	20	22	30
$\pm \delta$	8.4	8.3	8.1	6.4	4.9	4.3	2.5
Vs, %	33.49	29.33	26.51	19.58	14.74	12.31	7.00

*difference statistically approved at the level of $P < 0.05$;**difference statistically approved at the level of $P < 0.01$;***difference statistically approved at the level of $P < 0.001$ 

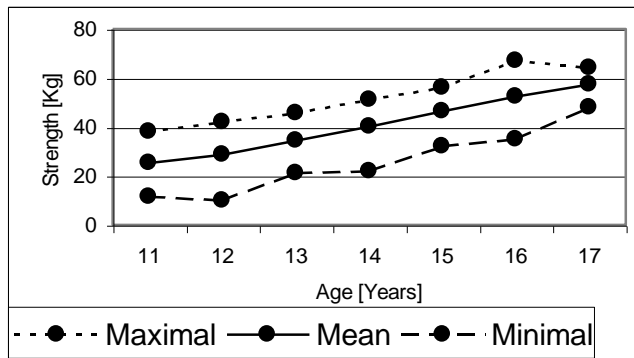


Fig. 1
Level of absolute strength of judo athletes aged between 11-17

The comparison of the dynamics of the development of the absolute strength along with age, demonstrate that judo athletes, according to the test results, excel those pupils, of all group age, who do not practice sports systematically (Fig. 2).

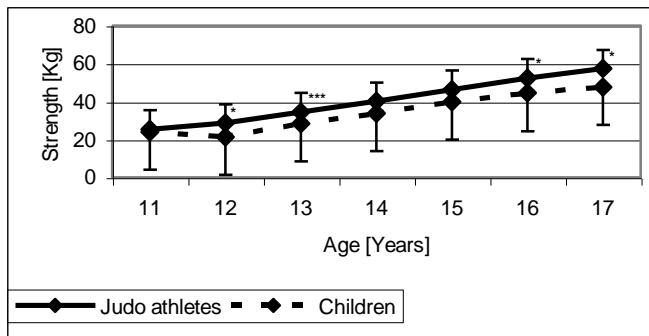


Fig. 2
Comparison, as regards the absolute strength of judo athletes aged 11-17, with teenagers of the same age who do not practice sport

*difference statistically approved at the level of $P < 0.05$; **difference statistically approved at the level of $P < 0.01$; ***difference statistically approved at the level of $P < 0.001$

The rate of annual increments does not show, however, such a simple course as in the case of absolute strength. As far as the rate of strength increment, 11-12 year-old and 13-15 year-old judo athletes give way to those children who do not play sports (Fig. 3).



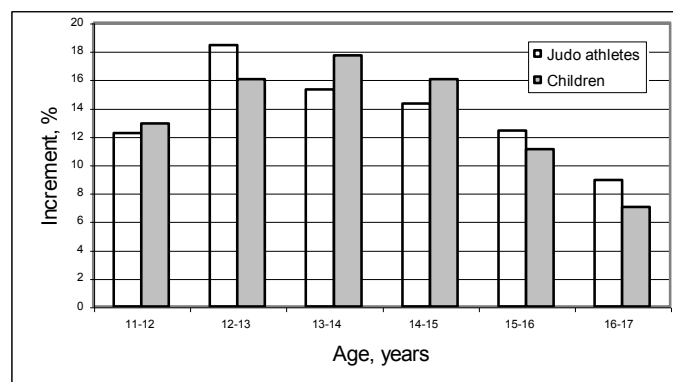


Fig. 3

Comparison of the dynamics of increments of absolute strength of judo athletes aged 11-17 with teenagers who do not practice sport

As a result of the research conducted and the analysis of the literature on the subject, one may assume that in the process of development of the absolute muscle strength it is necessary to:

A. Take into account development properties of the organism, specificity of the effects of exercises typical of one or another sport discipline,

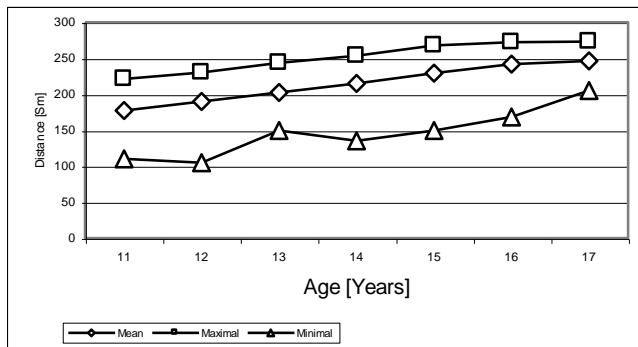
B. Pay particular attention to the development of the strength of neglected muscle groups.

C. In the period when most of the increase of the muscle force takes place, it is indispensable to, plan adequately various parameters of the training loads.

Dynamics of indexes of speed and strength abilities: At work, as well as in sport activities, an important role is played, not only by indexes of absolute strengths of one or another group of skeletal muscles, but also by indexes of speed and strength abilities, that is the ability to exhibit strength in the shortest time span [19]. This is typical of such exercises as: jumps, throws, etc.

The analysis of changes of the index along with age demonstrates that along with age, constant but uneven changes of the speed and strength abilities of children practicing judo take place (Fig. 4).

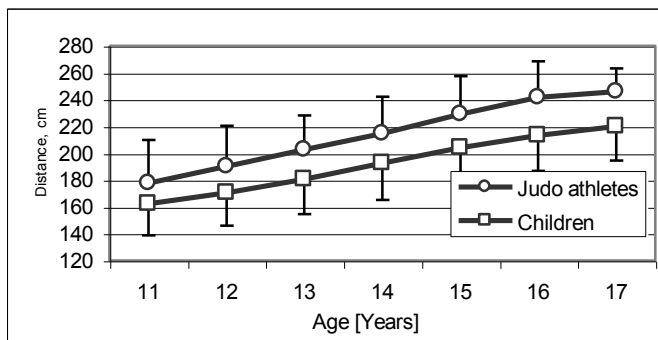


**Fig. 4**

Level of results of the standing long jump of judo athletes aged 11-17

Starting with the 12th year of age, in all age groups a uniformity of indexes, in spite of considerable maximal and minimal values of the results, is observed (Table 1). At the age of 17 the index of variability of the tested judo athletes demonstrates the lowest values, and not only in this particular test. Such compactness of results confirms the significant diagnostic effectiveness of the exercise in judo, and the selective influence of loads favouring such adaptation changes.

Absolute mean values of group results of judo athletes exceed the results of those who do not play sports, in all age categories (Fig. 5).

**Fig. 5**

Comparison of results of standing long jumps performed by judo athletes aged 11-17, with the results obtained by teenagers who do not practice sport

*difference statistically approved at the level of $P < 0.05$; **difference statistically approved at the level of $P < 0.01$; ***difference statistically approved at the level of $P < 0.001$

The biggest increment of results in this exercise can be observed at the age of 11-12 (6.8%), and then this high rate is continued until the age of 16. After this period a violent fall is recorded. The dynamics of increment of results in the standing long jump of children who do not train is more uneven (Fig. 6).

The presented data concerning speed and strength abilities (in the aspect of age), show that depending on the sport discipline, sensor periods possess their own properties. In young judo athletes, the level of development of the speed and strength abilities of the lower extremities exceed the indexes of the young people not training, at the analogous age, and while maintaining general tendencies of the sensor periods of their development.

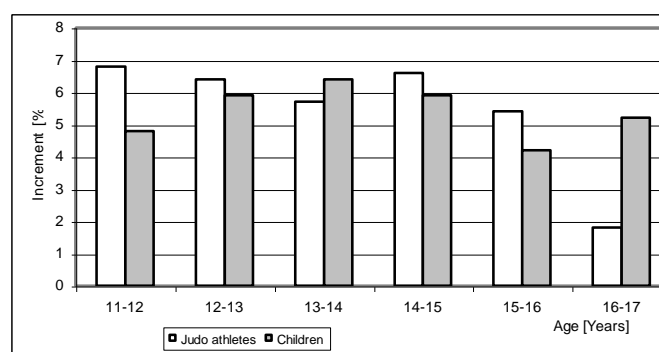


Fig. 6

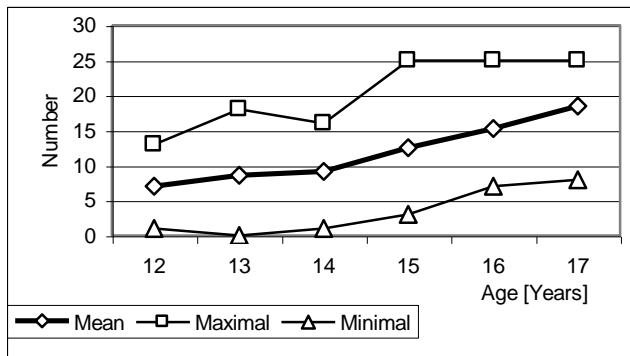
Comparison of the dynamics of the increment of results of the standing long jump performed by judo athletes aged 11-17, with the results obtained by teenagers who do not practice sport

The dynamics of strength endurance indexes: In many disciplines of life and sport, including combat sport, such an ability as strength endurance – the ability to maintain high strength indexes for a long time – is very important [9,23].

The level of strength endurance is exhibited through the ability of the athlete to overcome fatigue when performing a number of movements, or through exerting prolonged force in conditions of struggle against internal resistance.

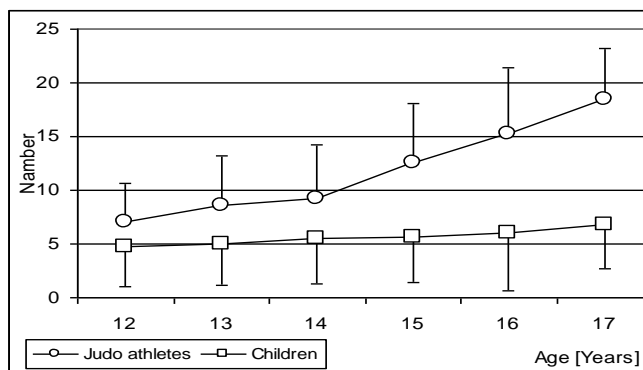
Testing results in pull ups shown in Fig. 7.



**Fig. 7**

Level of results of the pull-ups performed by judo athletes aged 11-17

The tested indexes grow with age, at considerable variations inside the groups. Taking into consideration the variation indexes, the tested groups are statistically diversified, and the smallest index value is recorded at the age of 17-25.5%. Statistically significant results occur at the age of 15 and 16-17 ($P \leq 0.05$). In all age categories, judo athletes excel children who do not practice sports. Since the 14th year of age, the distance between the two groups dynamically increases (Fig. 8).

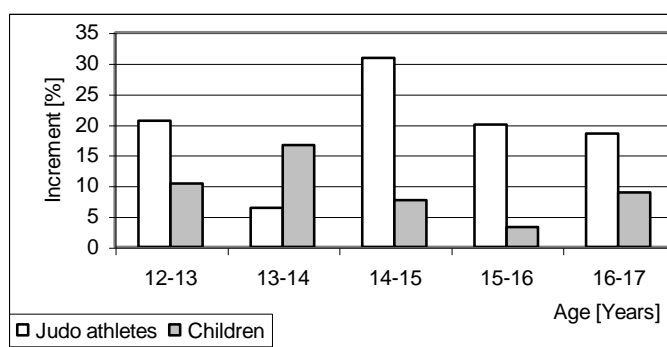
**Fig. 8**

Comparison, as regards the results of pull-ups performed by judo athletes aged 11-17, with the results of those teenagers who do not practice sport

*difference statistically approved at the level of $P < 0.05$; **difference statistically approved at the level of $P < 0.01$; ***difference statistically approved at the level of $P < 0.001$

The differences between those practicing and those not practicing are also recorded in the rate of increment of the results of the pull ups (Fig. 9).

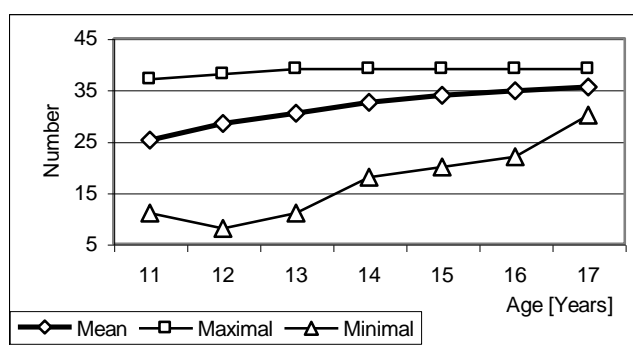


**Fig. 9**

Comparison of the dynamics of the increment of results of pull-ups performed by judo athletes aged 11-17, with the results obtained by teenagers who do not practice sport

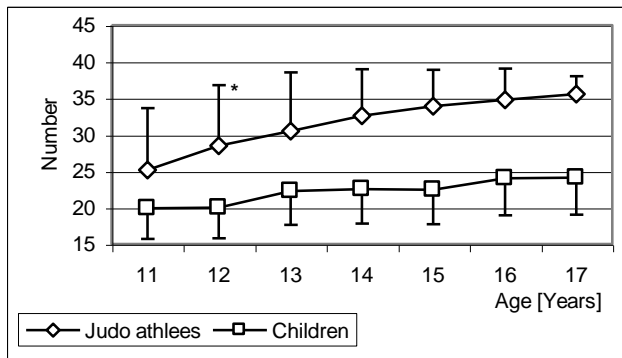
At the age of 12-13 the annual increment amounts to 20.6%, and the highest rate falls upon the period between the ages 14-15 (30.8%). Then at the age of 15-16 the rate falls to 20% and remains on that level until the end of the investigated period.

Sit up tests: The dynamics of changes, along with age, of the second test results (defining the strength endurance of the abdomen muscles) in young judo athletes is presented in Fig. 10.

**Fig. 10**

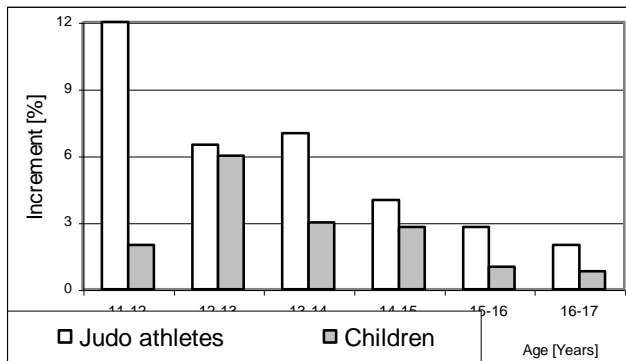
Level of results of the sit-ups performed within 30s by judo athletes aged 11-17

Along with the age of the judo athletes, the results of the tests rise smoothly and do not reveal statistically significant differences between the testing results. Both the absolute values, as well as the rate of increment of the strength endurance indexes of the judo athletes, exceed those of the children not practicing sport, in all age categories (Fig. 11-12).

**Fig. 11**

Comparison, as regards the results of sit-ups performed within 30s by judo athletes aged 11-17, with the results of those teenagers who do not practice sport

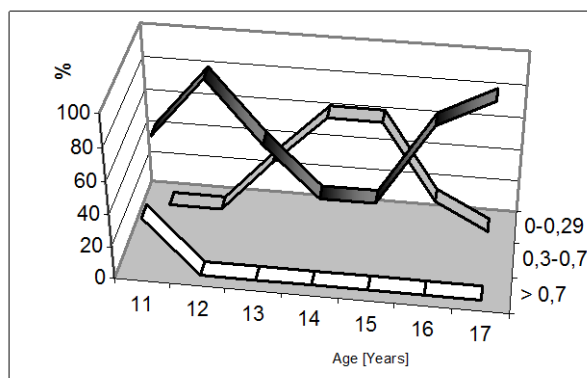
*difference statistically approved at the level of $P < 0.05$; **difference statistically approved at the level of $P < 0.01$; ***difference statistically approved at the level of $P < 0.001$

**Fig. 12**

Comparison of the dynamics of the increment of results of sit-ups performed within 30 s by judo athletes aged 11-17, with the results obtained by teenagers who do not practice sport

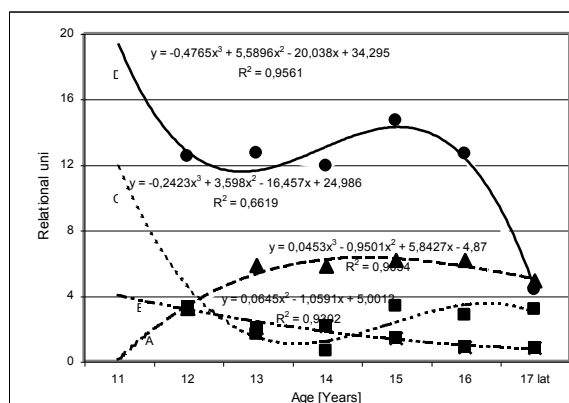
The differences undergo an increase along with age, attaining the highest value at the age of 17. The tendency to standardize testing results along with age is maintained (Table 1). The variability coefficient at the age of 17 has one of the smallest values (7%).

The following step in studying the obtained results was the correlation and regression analysis, in which the data referring to judo athletes was presented. As it was revealed in the correlation analysis, the degree of relationships between the examined strength indexes in athletes contains both similarities and differences (Fig. 13).

**Fig. 13**

Distribution of the level of correlation (%) between 4 independent trial tests in judo athletes aged 11-17 (0-0.29 – low, 0.3-0.69- average and 0.7-1.0 –high)

Basing on the data presented in fig. 13, the most crucial moment is the dynamics of the high (0.7 and over) correlation coefficients. The percentage of such correlation coefficients is the highest at the age of 11 and then remains stable at a low level during the investigated age period. What such phenomenon may suggest? Basing on the principle of the “lowest co-operation” of the functions of the organism, which explains the degree of independency in the working of various functional systems of the organism, at the age of 11 the autonomy in the exhibition of strength indexes is the lowest. Along with age, the degree of independency is high and remains as such between the ages 12-17. As what concerns correlation coefficients at the average and low level, the period of sexual maturation (ages 14-15), when the relationship between average and high correlation coefficients are inverse, constitutes an interesting moment (Fig. 14).

**Fig. 14**

Model of the regression of dynamics of the strength indexes of judo athletes

Basing on the results of the mathematical modeling from the obtained empirical data (Fig. 14), it was confirmed that every manifestation of the muscle strength measured through various trial tests is expressed by different characteristics in athletes from 11 to 17 years of age. Only trial B (sit-ups performed within 30 s) demonstrate a slightly marked linear dependence (negative), though higher values of this dependence are observed in 11-12 year-old judo athletes, whereas the lowest values are observed in 17 year-old athletes. Hyperbolic distribution refers to the regression line "A" – results of the trial of hand strength. In case of the pull-ups and standing long jump (C, D) the distribution of results assumes the form logarithmic function.

Discussion

When taking up the discussion of results of the research, it is worth stressing that the elementary stage of training of the judo athletes is characterised by significant changes in the function of the organism, which determine the development of motor abilities. For example, at the age of 11 changes in strength capacities is characterised by a harmony of development. These capacities possess strong mutual relationships, which are the result of the development of the organism of those training, as a total biological system, with multiple sub-systems. Such development is typical of the pre-pubescence period of the ontogenesis.

The specificity of the age of 12 is the fact that the structure of motor abilities (precisely- strength) undergoes significant changes. Decreased is the number of tight relationships between every parameter characterising strength capacities – whereas the autonomy of the development of the functions of the organism increases. Most probably the phenomenon is connected with the commencement of the violent biological development of the organism of the judo athletes – the beginning of the pubescence period of the ontogenesis, as well as with the growing importance of the guided physical preparation.

When analysing the relationships between age and strength, it was demonstrated that the highest correlation (over 0.7) takes place only in the group of 11- year-old judo athletes. However, it constitutes a proportion of 33.3% of the total examined correlations (Fig. 13). In this age group, the most represented is the proportion of the correlation of parameters of age and strength (63.7%) – this applies to the correlation ranging from 0.3-0.69. However, the highest representation of this correlation occurs in 12 and 17-year old judo athletes (100%).



On the other hand, the lowest level of the parameters of age and strength (i.e. 0-0.29) is mostly apparent within the population of 14-15-year-old judo athletes (63.7%).

As the presented results show, at the ages 11-12, 15-16 and 16-17 – $P < 0.05$, and 13-15 – $P < 0.01$. The biggest significance of differences is recorded between the ages 12-13 ($P < 0.001$). This indicates to the significant changes in the strength in the studied period of the children's and youth's development. Out of all age groups, 17 year old judo athletes represent the most homogeneous – as far as this index – group.

The phenomenon is confirmed also by other specialists, who show that in the process of individual development, strength abilities of children grow considerably. For example W.P.Filin [4] demonstrated that in the period from the 12th to the 17th year of age, the absolute strength in basketball players experiences an increase of 99,13%.

The dynamics of the results of the hand dynamometer of the judo athletes is characterized by a considerable rate of development in the entire period examined. The highest rate of the strength development is observed at the ages of 12-13 years (18.4%). Next at the age of 15 stabilization follows, during which the rate of increment slightly falls attaining 8.9% annually at the age of 16-17.

Similar regularity was revealed in the researches of Balcewicz, Zaporozanow [1], Wołkow [27], Sonkin, Zajcewa [20] and others.

For example Filin [4] thinks that the highest increment of strength indexes occurs between the ages 13-15, both in competitors as well as in not practicing individuals. He explains the fact by the effect of the puberty period, which is characterised by violent increase of all human functional indexes, including muscle strength.

Such results may testify to the fact that at the age 16-17, because of very high initial speed and strength indexes of judo athletes (in comparison to children who do not practice sports), the rate of increment along with age of this strength feature decreases dramatically.

The results of this research confirm the tendency revealed by Filin [4]. The author demonstrates that the highest increments of results of the high jump of young swimmers are observed between the ages 12-15 (they increase by 42.1%), in boxers between the ages 12-17 (they increase by 48.11%).

The increase of speed and strength abilities proceeds in an uneven way. The highest increment is observed between the ages 12-13, during the first stages of training activities. During this period, the increment of results of the standing high jump is 14.09%. In the period between the ages 13 and 14 it still rises by 8.52%. At



the ages of 14-15 – the rate of increments rises again by - (9.23%). In the following years the rate of increments is subject to a decrease. The lowest increment occurs between the ages 15-16 (3.77%).

In boys the increment of standing long jumps, at the ages of 8 to 12 amounts to (9.9%), and the highest values are recorded at the ages of 13-14 [15].

Gużałowski [6], as well as Sonkin and Zajcewa [20] ascertain that the biggest increments of speed and strength abilities in young people occur between the ages 12-13, that is at the end of the puberty leap in their development.

Scientists have never obtained identical changes related to age. For example, while studying the average group indexes of the logging strength, Wołkow [27] revealed a different chronology of periods. According to him, boys attain maximal values at the ages between 15-17. He also registered significant increments of the logging strength between the ages 13-15.

Only between the ages 13-14 the indexes of the rate of increments of athletes give way to those of the not practicing children. Despite that, it is worth stressing that the strength endurance of the upper girdle undergoes very big changes in the process of the long term sport training. Among the procedures applied in this test, athletes achieved the best improvements of results. This proves that directed loads applied in the process of the athletes' training (judo athletes) caused biggest adaptation changes, whereas the existing statistical differences between the athletes and those not practicing sports, just confirm the particular diagnostic role (accuracy) of the exercise. Considering all this, the results of this fragment of research may be used as criteria for the selection of those just taking up sport activities, and the elaborated norms and the rates of developments – may be used as criteria of the perspectives for those who already train combat sports.

The rate of increment demonstrates an unusual tendency, which was not observed in other strength indexes. The maximal increase takes place at the age of 11-12 and then the rate of development decreases with age. At the age of 11-12 it is 11.9%, at the age 12-13 – 6.8% and at the age of 16-17 it is only 2%. In children not practicing sports the maximal increase is observed at the age of 12-13 (6.1%), and in the following years it ranges between 1-3%.

The researches of Gużałowski [5, 6] confirm our tendency. The author, on the basis of extensive studies conducted on schoolchildren, discovered that sensitive periods in the development of strength endurance occur at the age of 11-12.

The correlation analysis have demonstrated what characteristic features may be revealed during the analysis of the presented model of regression;

A. At first, all without exception, strength indexes of the judo athletes (boys) change linearly along with age.



B. Secondly, these changes are not synchronized in time, at different age periods.

C. Thirdly, until the age of 17 all indexes, with various strength, have the tendency to converge in one point – at the age of 17.

The presented analysis of the structure of physical preparation, which takes into account a number of independent trial tests of junior judo athletes (basing on the correlation analysis), demonstrates that during the process of many years' of physical preparation, its fundamental components undergo changes. These changes refer both to the magnitude as well as quantity of mutual interactions.

At every age characteristic and leading indexes of strength preparation occur.

The obtained results allow for a selective determination of means (exercises) when planning individual training loads aimed at the increase of the level of physical preparation of junior judo athletes.

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