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Relationship between Hand Strength and Anthropometrical Features of Upper Extremity in 9-15 Years Old Schoolchildren

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The dependence between hand strength and body circumferences, subcutaneous fat tissue thickness and features characterizing muscle fat ratio of upper extremity in 9-15 years old schoolchildren (552 boys and 531 girls) from Sofia city are investigated during the period 2000-2002. Analyzing the data obtained is established that hand strength apparent increased with age, as the age differences are statistically significant at $P > 0.05$ after 10 years of age in boys and between 10-11 years and 12-13 years of age in girls. In the 13, 14 and 15 years old boys all the investigated features have statistically significant higher values except the arm and forearm skinfolds, which are considerably thicker in girls from all age groups. Significant dependence between hand strength and circumferences of upper extremity is established, while it is low for the contractile difference of arm circumferences (excepting the 15 years old boys).

Key words: hand strength, skinfolds, muscle circumferences, muscle-fat ratio, relationships.

Introduction

The hand strength is one of the main indicators, which are used to characterize the human physical development and activity especially in children and adolescents.

There are a series of publications, which analyze the hand strength in relation to the impact of age, body size and body composition on the physical ability of actively and non-actively sport training schoolchildren [3, 5]. The data of hand strength serve as a base to study age dynamics and specificity of functional asymmetry in the upper extremities of children and growing up individuals [7]. Data exists about hand strength of Bulgarian boys and girls from different generations in the last century that, make it possible to study the secular changes of this feature [6, 8, 9, 10]. We could not find data about the relationships between hand strength and subcutaneous fat thickness; muscle circumferences and muscle-fat ratio of upper extremity and this defined the aim of our study.

The aim of the present study is to examine the dependence between hand strength of right hand and basic anthropometrical features of upper extremity, and to determine the metric age specificity of this feature in 9-15 years old schoolchildren from Sofia at the beginning of the XXI century.

Materials and Methods

In the present work are analyzed anthropometrical data (collected in 2001-2002) for upper extremity in 9-15 old right-handed schoolchildren (522 boys and 531 girls) from Sofia town. The material was distributed in seven age groups. The following features were studied: upper arms circumferences, skinfolds on biceps, triceps and forearm. Anthropometrical measurements were performed by the standard method of M a r t i n, S a l l e r [1]. To determine the skinfold thickness of triceps, biceps and forearm were used a Holtain caliper, as well as for hand strength – hand dinamometer.

Muscle upper arm circumference (MUAC) and muscle forearm circumference (MFC) were calculated by the formulae:

$$MUAC = \pi\left(\frac{\text{upper arm circ.-relaxed}}{\pi} - \frac{\text{SF-biceps} + \text{SF} - \text{triceps}}{2}\right),$$

$$MFC = \pi\left(\frac{\text{forearm circ.}}{\pi} - \text{SF-forearm}\right).$$

Muscle-fat ratio of upper arm (MFRUA) and muscle-fat ratio of forearm (MFRF) were calculated by the formulae:

$$MFRUA = MUAC/\left(\frac{\text{SF-biceps} + \text{SF} - \text{triceps}}{2}\right),$$

MFRF = MFC/SF-forearm.

To determine the sexual differences we used index for sexual differences (ISD = $\bar{x}_{(girls)} \cdot 100/\bar{x}_{(boys)}$) and the significance of sexual and interage differences were estimated by the t-criterion of Student ($p<0.5$; $p<0.05$; $p<0.01$). Additionally were calculated yearly increase for the assessment of the rate differences of the hand strength increment with ages. Secular changes of hand strength were studied comparing our data with data of schoolchildren from Sofia at the same age investigated in 60s, 70s, 80s and 90s [6, 8, 9, 10].

Results and Discussion

The statistical data of the investigated features are presented in Table 1; the data about ISD – in Table 2, and the significant differences between boys and girls are singed with "*" (*-$p<0.5$; **-$p<0.05$; ***-$p<0.001$).

Circumferences of upper extremity (Figs. 1 and 2)

There is a regular increase of the circumferences of upper arm and forearm with ages, which is higher in boys group. Only the 10 years old boys make an exception, with lower upper arm circumferences, than these of the girls. The contracted upper arm circumferences and the circumferences of forearm are significantly higher for boys than for girls at 12, 13, 14 and 15 years of age. The sexual differences for the upper arm circumferences - relaxed are significant only at 14 and 15 years of age.

Contractile differences of upper arm muscles (Figs. 3 and 4)

The contractile difference of upper arm muscles is an important indicator for the morphological and functional characterization of the upper extremity. Its values increase progressively with ages, too. The boys from all age groups have significantly higher contractile differences of upper arm muscles than the girls have.

Table 1. Data about upper extremity anthropometrical features in 9-15 years old scoolcildrens

BOYS

No	Features	9 (n=73) mean	SD	10 (n=70) mean	SD	11 (n=73) mean	SD	12 (n=78) mean	SD	13 (n=75) mean	SD	14 (n=76) mean	SD	15 (n=77) mean	SD
1	Upper arm circ.-contracted	22.11	2.65	22.37	2.53	23.97	3.15	24.74	3.06	26.28	3.09	27.71	3.56	28.50	3.25
2	Upper arm circ.-relaxed	20.75	2.68	20.87	2.51	22.49	3.23	22.85	3.36	24.23	3.10	25.53	3.65	25.96	3.22
3	Contractive diff.of the arm circ.	1.35	0.46	1.51	0.60	1.48	0.47	1.89	1.15	2.05	0.62	2.18	0.89	2.54	0.62
4	Maximal forearm circumference	20.14	1.74	20.42	1.61	21.62	2.03	22.40	2.13	23.37	2.00	24.28	2.15	24.85	1.81
5	SF-biceps	6.01	3.06	5.74	2.71	6.62	3.23	5.93	3.23	5.72	2.73	5.53	2.50	4.46	2.19
6	SF-triceps	10.52	4.52	10.29	4.51	11.98	5.06	11.29	5.49	11.39	5.09	11.07	4.93	9.46	4.37
7	SF-forearm	6.27	2.46	6.21	2.18	6.15	2.06	6.08	2.23	5.71	1.69	5.68	1.66	5.01	1.01
8	MUAC	18.16	1.74	18.35	1.61	19.57	2.22	20.14	2.48	21.55	2.43	22.92	2.86	23.77	2.57
9	MFC	18.17	1.40	18.47	1.27	19.69	1.64	20.49	1.85	21.58	1.77	22.50	1.94	23.28	1.67
10	MFRUA	25.33	8.55	25.99	7.95	23.73	7.01	27.57	9.83	29.16	10.43	31.59	10.29	38.35	10.92
11	MFRF	31.72	8.15	32.21	8.08	34.37	7.96	36.98	10.16	40.48	10.22	42.38	10.42	47.93	7.89
12	Hand strength	13.80	3.06	14.46	3.76	6.82	4.48	19.81	6.35	24.03	7.30	29.17	7.50	35.96	7.12

GIRLS

No	Features	9 (n=77) mean	SD	10 (n=75) mean	SD	11 (n=73) mean	SD	12 (n=75) mean	SD	13 (n=79) mean	SD	14 (n=77) mean	SD	15 (n=75) mean	SD
1	Upper arm circ.-contracted	21.84	2.89	22.48	2.64	23.67	2.68	23.74	2.71	25.13	2.77	25.54	2.83	25.14	2.06
2	Upper arm circ.-relaxed	20.75	2.91	21.42	2.73	22.42	2.66	22.38	2.81	23.79	2.85	24.22	2.89	23.69	2.15
3	Contractive diff.of the arm circ.	1.09	0.36	1.06	0.38	1.26	0.38	1.36	0.43	1.34	0.48	1.32	0.51	1.45	0.51
4	Maximal forearm circumference	19.71	1.80	20.23	1.69	21.41	1.71	21.58	1.83	22.47	1.79	22.50	1.75	22.22	1.32
5	SF-biceps	6.55	2.85	7.17	3.32	6.94	2.77	6.19	2.51	6.89	2.33	7.16	2.91	6.42	2.60
6	SF-triceps	12.43	5.22	12.96	5.43	12.98	4.71	12.51	4.68	13.74	4.78	15.19	8.20	14.18	4.27
7	SF-forearm	6.62	2.09	6.44	2.07	6.76	1.70	6.04	1.93	6.89	2.33	7.09	2.42	6.37	1.83
8	MUAC	17.77	1.89	18.26	1.73	19.30	1.79	19.45	2.08	20.55	2.04	20.71	2.58	20.45	1.57
9	MFC	17.63	1.41	18.20	1.32	19.29	1.42	19.68	1.55	20.30	1.45	20.27	1.38	20.22	1.10
10	MFRUA	21.02	6.29	20.84	7.24	21.51	6.51	22.95	6.55	21.55	5.51	20.95	6.74	21.63	6.47
11	MFRF	28.82	7.71	30.69	8.45	30.09	6.68	35.28	10.05	31.83	7.87	31.18	8.41	34.03	8.87
12	Hand strength	11.32	2.92	12.17	3.33	14.89	3.99	15.47	4.41	18.52	5.30	19.78	4.53	20.99	4.58

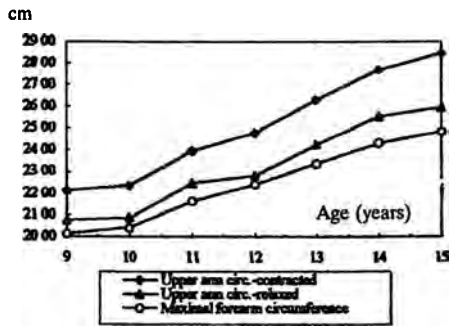

Fig. 1. Circumferences of upper extremity (boys)

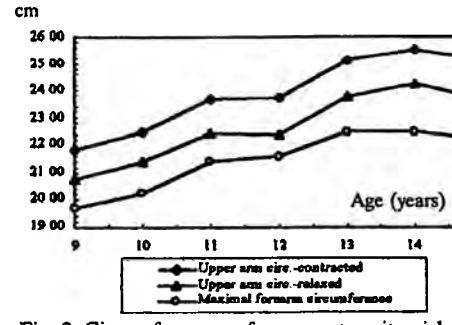

Fig. 2. Circumferences of upper extremity girls

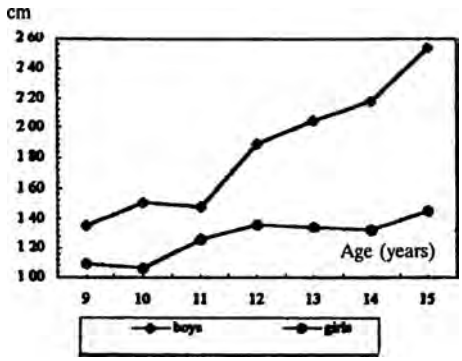

Fig. 3. Contractile difference of the upper arm circumferences

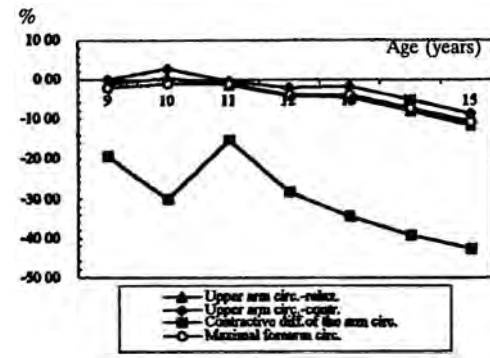

Fig. 4. Sexual differences in circumferences of upper extremity – ISD data

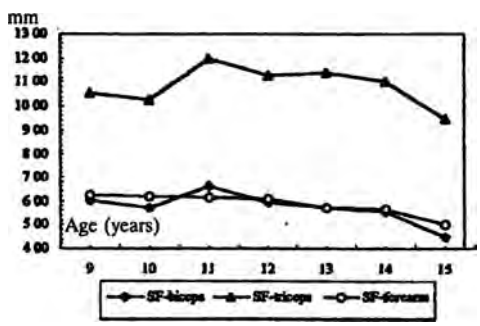

Fig. 5. Skinfolds - boys

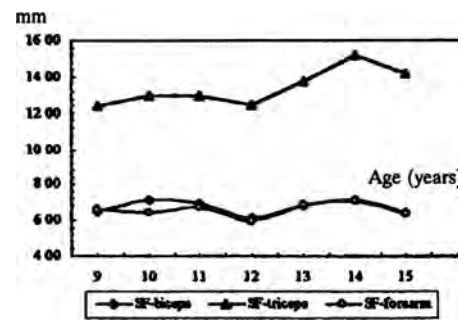

Fig. 6. Skinfolds - girls

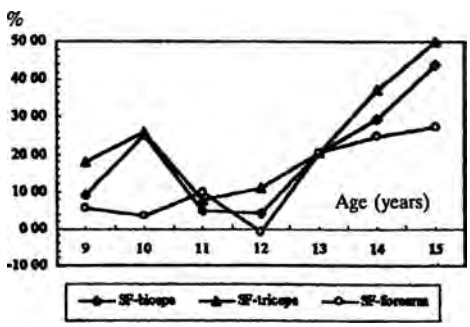

Fig. 7. Sexual differences according to the skinfolds thickness – ISD data

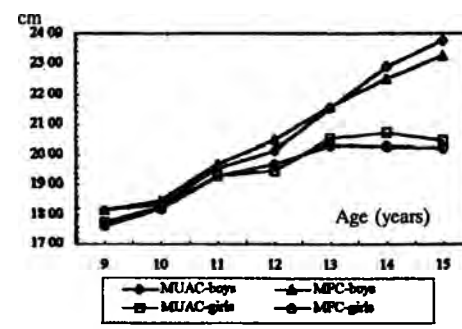

Fig. 8. Muscle circumferences of upper arm and forearm

Skinfold thickness (Figs. 5, 6 and 7)

The thickness of skinfolds in girls from all age groups have higher values than boys in contrast with upper extremity circumferences that dominate in boys. Statistical significant sexual differences in the skin folds thickness are found for the triceps skinfold (at 9 and 10 years) and for the biceps skinfold (at 10 years). The skinfolds of forearm are significantly thicker in girls at the age of 13, 14 and 15. It is noteworthy that the differences in the subcutaneous fat tissue thickness on the upper extremity in both sexes at 11 and 12 years old schoolchildren are most low expressed. These results support the specificity of age and sexual differences about basic features of body structure which were determined in our previous studies (namely the stature, body weight, BMI and the percent body fat) in girls and boys during the first phase of their puberty when the differences between sexes are not clearly defined yet [2, 4].

Muscle circumferences and muscle-fat ratios of upper extremity (Figs. 8, 9 and 10)

The muscle circumferences and the muscle fat ratios of upper arm and forearm are significant indicators for the morphological and functional characteristics, too. In the present study they show a steady increase with age in both sexes. The values of the muscle circumferences of upper arm are significantly higher in the boys group than in girls one at the age of 13-15, while the muscle circumferences of forearm in boys are significantly higher for the 9 years old ones and for every age group after 12 years. The statistically significant higher values of muscle fat ratios of upper arm and forearm in the boys from almost all ages support the better development of their muscles. The boys compared to girls have insignificantly higher values of muscle fat ratios of forearm only at 10 and 12 years of age.

The summarized analysis of the data concerning muscle circumferences and muscle-fat ratios of the upper arm and forearm during the period of 9-15 years shows, that the development of muscles in upper extremity in boys is most strongly expressed between 13-15 years of age, when the thickness of the subcutaneous fat tissue on upper extremity in girls increases significantly.

Hand strength (Figs. 11 and 12)

The manual dynamometry is intended to measure the static strength of the hand. The improvement with ages of the morphological and functional characteristics of upper arm and forearm muscles defines the progressive increase of the hand strength ability of schoolchildren. The boys have significantly higher values for the right hand strength even at pre-puberty period. At the age of 15 the strength abilities of boys are about 35.96 kg and these of girls are 20.99 kg or with 14.97kg less than it is in boys.

The yearly increase of hand strength changes proportionally with ages, too. It increases from 0.66 kg between the ages of 9-10 up to 6.79 kg between the ages of 14-15. The year increases of boys' hand strength is statistically significant begins at the age of 10 and it goes on without exception up to 15 years. As for girls a significantly higher increase is determined only between 10 and 11 years (2.72 kg) and between 12 and 13 years (3.05 kg), after that it decreases to 1.26 kg between the age of 13-14 and to 1.21 kg between the age of 14-15.

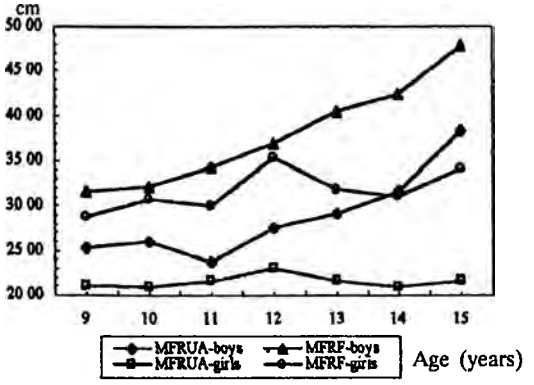

Fig. 9. Muscle - fat ratios of upper arm and forearm

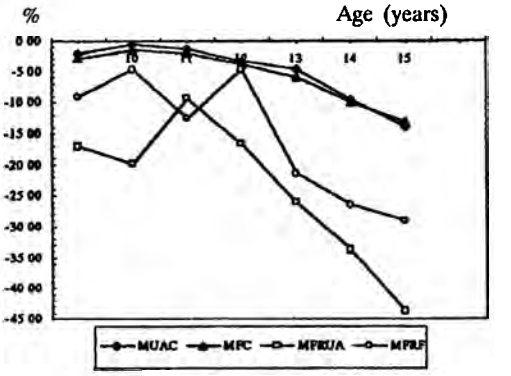

Fig. 10. Sexual differences in muscle circumferences and muscle-fat ratios of upper arm and forearm – ISD data

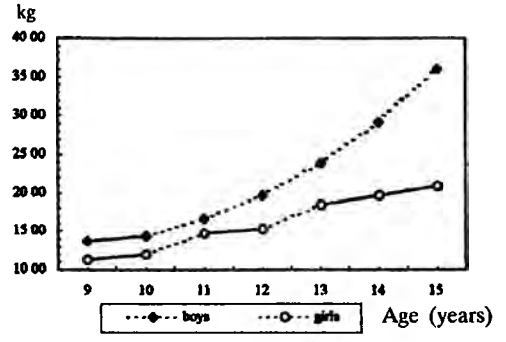

Fig. 11. Hand strength

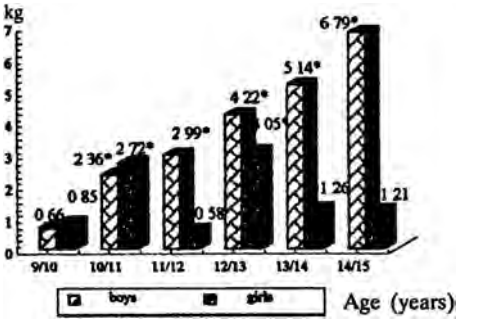

Fig. 12. Hand strength year's increase

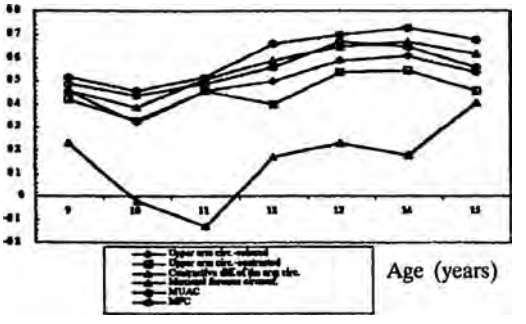

Fig. 13. Correlation between hand strength and other investigated features (boys)

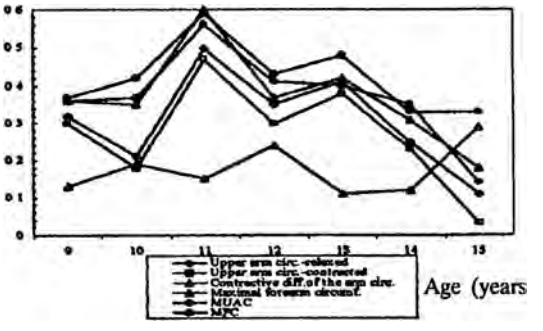

Fig. 14. Correlation between hand strength and other investigated features (girls)

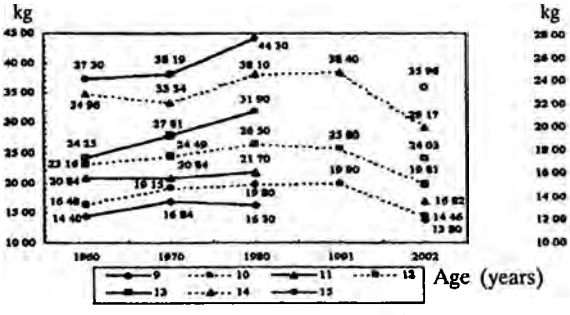

Fig. 15. Secular changes in hand strength (boys)

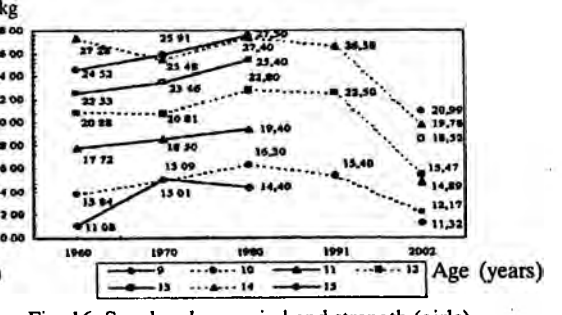

Fig. 16. Secular changes in hand strength (girls)

Table 2. Sexual differences according to the data of ISD in 9-15 years old schoolchildrens

No	Features	Index of intersexual differences							%						
		9	10	11	12	13	14	15	9	10	11	12	13	14	15
1	Upper arm circ.-relaxed	98.82	100.45	98.75	95.95*	95.62*	92.19***	88.21***	-1.18	0.45	-1.25	-4.05	-4.38	-7.81	-11.75
2	Upper arm circ.-contracted	99.99	102.65	99.67	97.96	98.17	94.9*	91.25***	-0.01	2.65	-0.33	-2.04	-1.83	-5.10	-8.75
3	Contractive diff.of the arm circ.	80.8***	70.07***	84.75**	71.73***	65.42***	60.54***	57.08***	-19.20	-29.93	-15.25	-28.27	-34.58	-39.46	-42.92
4	Maximal forearm circumference	97.87	99.03	99.03	96.33*	96.12**	92.66***	89.4***	-2.13	-0.97	-0.97	-3.67	-3.88	-7.34	-10.60
5	SF-biceps	109.09	125.02**	104.86	104.27	120.47**	129.37***	143.94***	9.09	25.02	4.86	4.27	20.47	29.37	43.94
6	SF-triceps	118.14*	125.9**	107.60	110.80	120.63**	137.21***	149.95***	18.14	25.90	7.60	10.80	20.63	37.21	49.95
7	SF-forearm	105.62	103.63	109.91	99.35	120.66***	124.83***	127.28***	5.62	3.63	9.91	-0.65	20.66	24.83	27.28
8	MUAC	97.87	99.50	98.63	96.54	95.38**	90.38***	86.04***	-2.13	-0.50	-1.37	-3.46	-4.62	-9.62	-13.96
9	MFC	97.03*	98.55	97.96	96.05**	94.08***	90.11***	86.84***	-2.97	-1.45	-2.04	-3.95	-5.92	-9.89	-13.16
10	MFRUA	82.98***	80.21***	90.64*	83.23***	73.91***	66.32***	56.39***	-17.02	-19.79	-9.36	-16.77	-26.09	-33.68	-43.61
11	MFRF	90.84*	95.28	87.53***	95.39	78.63***	73.57***	71***	-9.16	-4.72	-12.47	-4.61	-21.37	-26.43	-29.00
12	Hand strength	82.01***	84.13***	88.5**	78.09***	77.04***	67.8***	58.36***	-17.99	-15.87	-11.50	-21.91	-22.96	-32.20	-41.64

Table 3. Correlation between hand strength and other investigated features

No	Features	9		10		11		12		13		14		15	
		Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
1	Upper arm circ.-relaxed	0,46	0,32	0,32	0,21	0,46	0,50	0,50	0,35	0,59	0,41	0,61	0,25	0,54	0,11
2	Upper arm circ.-contracted	0,42	0,3	0,33	0,18	0,46	0,47	0,40	0,30	0,54	0,38	0,55	0,23	0,46	0,03
3	Contractive diff.of the arm circ.	0,23	0,13	-0,02	0,19	-0,13	0,15	0,17	0,24	0,23	0,11	0,18	0,12	0,41	0,29
4	Maximal forearm circumference	0,46	0,36	0,39	0,35	0,51	0,60	0,59	0,37	0,65	0,42	0,67	0,31	0,62	0,18
5	SF-biceps	0,21	0,09	0,13	-0,11	0,32	0,18	-0,03	-0,02	0,03	0,22	0,11	0,05	-0,02	-0,11
6	SF-triceps	0,21	0,18	0,09	-0,12	0,31	0,21	-0,04	0,01	0,05	0,23	0,16	-0,20	0,08	-0,15
7	SF-forearm	0,10	0,2	0,06	0,07	0,29	0,36	0,06	0,02	0,13	0,09	0,07	0,12	-0,03	-0,21
8	MUAC	0,49	0,36	0,44	0,37	0,49	0,56	0,56	0,41	0,67	0,40	0,65	0,35	0,56	0,14
9	MFC	0,52	0,37	0,46	0,42	0,52	0,59	0,66	0,43	0,70	0,48	0,73	0,33	0,68	0,33
10	MFRUA	-0,15	-0,06	0,08	0,21	-0,14	-0,04	0,21	0,15	0,11	-0,08	0,02	0,07	0,15	0,23
11	MFRF	-0,05	-0,06	-0,01	0,02	-0,08	-0,19	0,13	0,17	0,10	0,05	0,10	-0,16	0,30	0,25

*p< 0.5; **p<0.05; ***p<0.001

Correlation relationships (Figs. 13 and 14)

One of the tasks in the present work was to study the relationships between anthropometrical features of upper extremity and the hand strength abilities. The coefficients of correlation between hand strength and other features of the upper extremity are presented in Table 3. Significant positive relationships are determined only between hand strength and upper arm and forearm circumferences. For boys these relationships during pre-puberty period are moderate (r from 0.31 to 0.5) and during the puberty these relationships intensify to significant degree (r from 0.51 to 0.7). Biggest is the correlation between hand strength and forearm muscle circumferences ($r = 0.73$) in the 14 years old boys. As for the girls, there is a significant correlation of hand strength with the forearm and upper arm circumferences in the 11 years old girls only. For all other age groups the correlation relationships between the studied features are moderate. The dependencies of the hand strength from the circumferences of the upper arm in relaxed and contracted state is a weak one (r from 0.00 to 0.3).

It is interesting to note, that the hand strength has very weak positive relationships with the contractile difference of upper arm muscles for almost all age/sex groups, which are even negative for boys at the age of 10 and 11. Only the boys at 15 years of age make an exception ($r = 0.41$). This fact could be explained to a certain extent with the different pose for measuring the contracted arm circumferences in a flexed elbow joint position and the position for measuring the hand strength when the upper extremity is in a maximal extension near the body. The positive correlation between hand strength and the thickness of subcutaneous fat tissue (manifested as in the thickness of skinfolds, so in the muscle-fat ratios) are predominantly very weak or are totally absent for both sexes. There are moderate relations only between hand strength and skinfolds thickness on biceps and triceps in 11 years old boys and with the forearm skinfold thickness in girls at the same age.

Secular changes of schoolchildren's hand strength (Figs. 15 and 16)

The comparative analysis of data from hand dynamometry in schoolchildren from Sofia at the beginning of the XXI century and their coevals from past generations showed a tendency for an increase of hand strength abilities for both sexes during the period 1960-1980. Between 1980 and 1991 there is a retaining of hand strength abilities and after the 90s there is a tendency for a decrease of hand strength in boys and girls from all age groups. The results obtained for secular changes in the hand strength correspond to the secular changes of basic morphological features, characterizing the physical development of schoolchildren [2, 4].

Conclusions

The analysis of our data in the present study leads to the following conclusions:

Boys from all age groups have a significantly better development of the upper extremity muscles while for girls the thickness of subcutaneous fat tissue is expressed to a considerable extent.

The strength abilities of right hand in boys are considerably higher starting in the pre puberty period and the differences increase proportionally with ages and are significant during the whole puberty period.

The significant yearly increase of boys' hand strength starts at the age of 10 and lasts without exceptions until the age of 15. As for the girls a significant yearly increase is determined only for the ages between 10 and 11, and between 12 and 13 years.

There are significant correlations between hand strength and common circumferences, muscle circumferences of upper arm and forearm in both sexes. These relations change from moderate during the pre-puberty period to significant and high during the puberty period for boys.

No significant dependencies have been established between hand strength and contractile difference of upper arm muscles, thickness of skinfold and muscle-fat ratio of upper arm and forearm.

There is a tendency to a decrease of hand strength abilities in boys and girls from all age groups after 90s of the past century.

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