Analysis and Detection of the Degrees and Direction of Correlations between Key Indicators of Physical Fitness of 10-12-year-old Hockey Players

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Abstract: *In this paper an investigation of the relationships and correlations between the 11 indicators of physical fitness, the level of which has a leading role in the sports training of 10-12-year-old hockey players. The obtained results show that there is a tendency of a slight increase of the existing correlations from weak to moderate, moderate to significant, and from significant to strong in the first year of the experiment (age 10-11). Such correlation was also observed in the second year (age 11-12) when even very strong correlations were found between 4 indicators for boys and 3 for girls.*

Keywords: *Hockey, Physical training, Indicators, Relationships, Speed, Endurance, Agility, Correlation analysis.*

Introduction

Sports training is a multifactorial process in which each of the components – technical, physical, tactical, psychological and theoretical – plays an essential role for the progress of hockey players. These five key components of sport training function in close cooperation and in certain relationships with each other, but each of them has a leading role and significance at the different levels from a beginner to an elite player [2, 17].

The motor control of human movements is determined by the level of development of motor skills, strength, endurance, speed, agility, and flexibility. The indicators reflecting the level of development of physical qualities characterize the main aspects of physical fitness (PF), have a different role and factor weight in the growth of the competitor depending on the specifics of the particular sport, and are in varying degrees of dependence, both with each other and with some indicators characterizing the technique, tactics, and psyche of the athletes [2, 7, 8, 10, 13, 15].

In the field of elite sport, a number of studies have presented established and repeatedly proven by practice degrees of correlation between the PF indicators. In teens, in particular, the picture is quite varied. Considering hockey research conducted in this field in Bulgaria, we can find that studies on the correlations between indicators of sports performance have been made predominantly among adolescents from 8 to 16 years of age but access to these results is difficult because they have not been published in referenced journals. That is why, we believe that any research on the issue is significant and up-to-date, and the results will enable specialists to optimize the pattern of sports training in teenage hockey.

Methods

Between 2009 and 2018 years, 600 children aged 10 to 12 were tested using a test battery of 11 control tasks for physical fitness assessment (see Table 1). The reliability of the tests was confirmed by the method of retesting in the period of 1998-2003, and after the approbation of some of them, the latter have been used for control and assessment of basic indicators of general and special physical fitness of adolescent hockey players.

Table 1. Experimental group (2009-2018)

№	Year	10-year-olds		11-year-olds		12-year-olds		Total
		M	F	M	F	M	F	
1	2009	10	10	10	10	10	10	60
2	2010	10	10	10	10	10	10	60
3	2011	10	10	10	10	10	10	60
4	2012	10	10	10	10	10	10	60
5	2013	10	10	10	10	10	10	60
6	2014	10	10	10	10	10	10	60
7	2015	10	10	10	10	10	10	60
8	2016	10	10	10	10	10	10	60
9	2017	10	10	10	10	10	10	60
10	2018	10	10	10	10	10	10	60
Total		100	100	100	100	100	100	600

The sports-pedagogical studies were conducted with the help of university students specializing in hockey as well as coaches and teachers in physical education and sport, according to schedules prepared in advance at the beginning of the calendar year (see Table 2). The tests for endurance, total strength, and strength of the upper limbs (T6-T11) were conducted in April, and those for general and specific agility and dynamic force of the lower limbs – in October (T1-T5) [10].

Table 2. A test battery of sports-pedagogical control tests for physical fitness

№	Type of test	Unit	Accuracy	Direction	*R*
1	Sprint running – 15 m (SR15)	s	0.01	-	0.987
2	Sprint running – 30 m (SR30)	s	0.01	-	0.989
3	Sprint running with a stick – 15 m (SRS15)	s	0.01	-	0.975
4	Sprint running with a stick – 30 m (SRS30)	s	0.01	-	0.982
5	Standing long jump (SLJ)	m	0.01	+	0.994
6	Standing triple jump (STJ)	m	0.01	+	0.977
7	Right hand dynamometry (RHD)	kg	1.00	+	0.991
8	Left hand dynamometry (LHD)	kg	1.00	+	0.988
9	Medicine ball throw with two hands (MBT)	m	0.10	+	0.971
10	Shuttle run – “Star” 120 m (SS120)	s	0.01	-	0.985
11	Cooper 6 min (C6`)	m	10.0	+	0.965

Correlation analysis is applied to:

- determine the existence of a correlation between the variables;
- measure its strength (degree) and direction.

The statistical indicators which are used are called correlation coefficients. Depending on the nature and number of the variables, they may vary, but their value always ranges from -1 to +1. The absolute value of the coefficient carries information about the degree of correlation: 0 – no correlation, up to 0.3 – weak, 0.3 to 0.5 – moderate, 0.5 to 0.7 – significant, 0.7 to 0.9 – strong, over 0.9 – very strong, and 1 – functional (absolute) correlation [11].

The sign of the coefficient carries information about the direction of the correlation:

- If it is +, the correlation is uphill.
- If it is –, the correlation is downhill.

A key moment when applying correlation analysis is the choice of an appropriate correlation coefficient:

- In case the variables are quantitative and normally distributed, and the relationship between them is linear, the Pearson correlation coefficient (*R*) is applied.
- In case the variables are ranked or quantitative but are not normally distributed, the Spearman's rank correlation coefficient (*Rs*) is applied.
- In case the variables are nominal and ordinally scaled, the contingency coefficient (*C*) is applied.

In practice some other derivative coefficients are also used:

- The coefficient of determination ($r2.100$) expresses the degree of correlation (in percentage) and reveals what the percentage of variance of one variable can be explained by the variance of the other variable (this is so-called explained dispersion).
- The impact of unforeseen factors is described by the coefficient of uncertainty $k2.100 = 100 - r2.100$. It presents the so-called unexplained dispersion.

In our case, the task of the correlation analysis was to reveal the Pearson's correlation coefficient *R* between indicators with quantitative variables, normal distribution, and linear relationship.

The aim of our study was to detect the relationships and correlations between the 11 indicators of physical fitness, the level of which in our point of view has a leading role and significance in the sports training of 10-12-year-old male and female hockey players.

Results

Detecting the relationships and correlations was performed using correlation analysis with Pearson's correlation coefficient *R* for simple, linear, and quantifiable features under the following correlation scale: weak (*R* of 0 to 0.3) moderate (*R* of 0.3 to 0.5), significant (*R* of 0.5 to 0.7), strong (*R* of 0.7 to 0.9), and very strong (*R* above 0.9). The results of study have been summarized chronologically in Tables 3 and 4 for 10-year-old boys and girls, Tables 5 and 6 for 11-year-olds, and Tables 7 and 8 for 12-year-olds.

The detected correlations between the indicators of physical fitness when the coefficient $R \geq 0.5$ are shown in Figs. 1-6, according to the sex and age of the tested children.

Table 3. Correlations – boys aged 10, PF

	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11
T1	1										
T2	**0.77**	1									
T3	**0.68**	**0.55**	1								
T4	**0.60**	**0.64**	**0.69**	1							
T5	**0.70**	**0.65**	**0.55**	0.47	1						
T6	**0.51**	**0.72**	**0.55**	**0.66**	**0.88**	1					
T7	0.34	0.27	0.48	0.25	0.34	0.26	1				
T8	0.35	0.26	0.49	0.35	0.34	0.20	**0.84**	1			
T9	0.32	0.35	0.48	0.24	**0.50**	0.45	**0.59**	**0.51**	1		
T10	**0.57**	**0.65**	0.47	0.42	0.48	**0.55**	0.20	0.19	0.37	1	
T11	0.41	**0.51**	0.33	0.42	0.38	0.45	0.07	0.02	0.25	**0.56**	1

Table 4. Correlations – girls aged 10, PF

	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11
T1	1										
T2	**0.72**	1									
T3	**0.60**	**0.53**	1								
T4	**0.51**	**0.61**	**0.76**	1							
T5	**0.61**	**0.56**	**0.53**	0.49	1						
T6	**0.55**	**0.65**	0.44	0.48	**0.89**	1					
T7	0.15	0.21	0.27	0.34	0.27	0.22	1				
T8	0.21	0.31	0.14	0.25	0.12	0.28	**0.70**	1			
T9	**0.51**	0.39	0.42	0.29	**0.59**	**0.51**	**0.52**	**0.59**	1		
T10	0.49	**0.61**	0.45	0.42	**0.53**	**0.57**	0.21	0.28	0.48	1	
T11	0.29	0.42	0.32	**0.52**	0.24	0.37	0.21	0.11	0.21	**0.52**	1

Table 5. Correlations – boys aged 11, PF

	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11
T1	1										
T2	**0.76**	1									
T3	**0.75**	**0.71**	1								
T4	**0.72**	**0.87**	**0.87**	1							
T5	**0.78**	**0.75**	**0.68**	**0.62**	1						
T6	**0.73**	**0.84**	**0.59**	**0.65**	**0.88**	1					
T7	0.37	0.23	0.31	0.34	0.32	0.27	1				
T8	0.36	0.25	0.25	0.42	0.39	0.31	**0.90**	1			
T9	0.46	0.39	0.32	0.32	**0.61**	**0.57**	**0.61**	**0.59**	1		
T10	**0.60**	**0.70**	**0.50**	**0.57**	0.45	**0.50**	0.31	0.34	0.15	1	
T11	0.49	**0.53**	0.45	**0.52**	0.35	0.37	0.33	0.34	0.18	**0.69**	1

Table 6. Correlations – girls aged 11, PF

	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11
T1	1										
T2	**0.86**	1									
T3	**0.75**	**0.63**	1								
T4	**0.63**	**0.56**	**0.84**	1							
T5	**0.71**	**0.52**	**0.68**	**0.50**	1						
T6	**0.55**	**0.67**	0.44	**0.53**	**0.88**	1					
T7	0.33	0.22	0.28	0.33	**0.50**	0.45	1				
T8	0.41	0.30	0.17	0.45	**0.57**	0.49	**0.91**	1			
T9	0.48	0.42	0.34	0.37	**0.71**	**0.62**	**0.64**	**0.69**	1		
T10	**0.65**	**0.57**	**0.51**	**0.56**	**0.55**	**0.55**	0.27	0.33	0.36	1	
T11	0.25	0.47	0.32	**0.55**	0.22	0.31	0.09	0.15	0.29	**0.58**	1

Table 7. Correlations – boys aged 12, PF

	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11
T1	1										
T2	**0.91**	1									
T3	**0.95**	**0.73**	1								
T4	**0.61**	**0.82**	**0.91**	1							
T5	**0.82**	**0.72**	**0.62**	**0.57**	1						
T6	**0.71**	**0.88**	**0.55**	**0.61**	**0.88**	1					
T7	0.41	0.35	0.44	0.30	0.21	0.17	1				
T8	0.31	0.26	0.32	0.20	0.11	0.34	**0.90**	1			
T9	**0.50**	0.41	0.32	0.41	**0.61**	**0.52**	**0.65**	**0.61**	1		
T10	**0.69**	**0.73**	**0.58**	**0.65**	0.47	**0.56**	0.23	0.19	0.34	1	
T11	0.45	0.37	0.47	**0.51**	0.21	0.15	0.11	0.25	0.19	**0.75**	1

Table 8. Correlations – girls aged 12, PF

	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11
T1	1										
T2	**0.93**	1									
T3	**0.88**	**0.83**	1								
T4	**0.75**	**0.71**	**0.92**	1							
T5	**0.82**	**0.70**	**0.77**	**0.68**	1						
T6	**0.67**	**0.77**	**0.56**	**0.63**	**0.95**	1					
T7	0.32	0.25	0.36	0.18	0.41	0.45	1				
T8	0.38	0.22	0.18	0.25	0.45	0.38	**0.93**	1			
T9	**0.51**	0.43	0.48	0.40	**0.68**	0.47	**0.59**	**0.68**	1		
T10	**0.61**	**0.53**	**0.60**	**0.52**	**0.59**	0.47	0.26	0.19	0.49	1	
T11	0.18	0.24	0.19	0.29	0.11	0.29	0.09	0.11	0.09	**0.78**	1

Discussion

Correlation structure of physical fitness of 10-year-old hockey players

Each of the studied indicators of physical fitness carries information about the basic motor qualities and their forms of manifestation.

In Fig. 1 only the correlations between the indicators of 10-year-old boys where $R \geq 0.5$ are shown. The presented legend is valid for the Figs. 2-6, too. We can see that there are no indicators with very strong correlation. There are six indicators with strong correlation between each other, namely: T1 – SR15 and T2 – SR30, T5 – SLJ; T2 – SR15 and T6 – STJ; T5 – SLJ and T6 – STJ; T7 – RHD and T8 – LHD. There are also 18 indicators with significant correlation, as follows: T1 – SR15 and T3 – SRS15, T4 – SRS30, T6 – STJ, T10 – SS120; T2 – SR30 and T3 – SRS15, T4 – SRS30, T5 – SLJ, T10 – SS120 and T11 – C6`; T3 – SRS15 and T4 – SRS30, T5 – SLJ and T6 – STJ; T4 – SRS30 and T6 – STJ; T5 – SLJ and T9 MBT; T6 – STJ and T10 – SS120; T7 – RHD and T9 – MBT; T8 – LHD and T9 – MBT; T10 – SS120 and T11 – C6`.

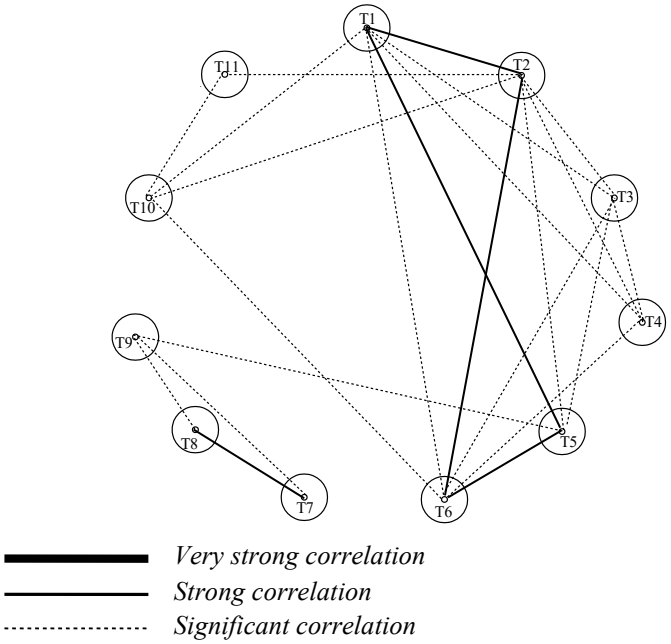

Fig. 1 Correlations between indicators
of physical fitness of boys aged 10 when $R \geq 0.5$

In 10-year-old girls we can also observe no indicators with very strong correlation (Fig. 2). We have registered a strong correlation between four indicators: T1 and T2; T3 and T4; T5 and T6, T7 and T8, and a significant correlation between 19 ones: T1 and T3, T4, T5, T6, and T9; T2 and T3, T4, T5, T6, and T10; T3 and T5; T4 and T11; T5 and T9, T10; T6 and T9, T10; T7 and T9; T8 and T9; T10 and T11.

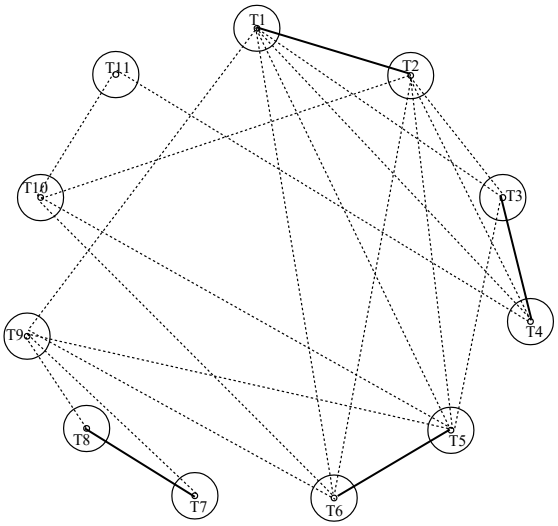

Fig. 2 Correlations between indicators
of physical fitness of girls aged 10 when $R \geq 0.5$

Correlation structure of physical fitness of 11-year old hockey players

Figs. 3 and 4 reflect the correlations between the indicators of 11-year-old boys and girls' physical fitness when $R \geq 0.5$. We can note that the number of significant and strong correlations is higher compared to the results of the 10-year-olds. In both sexes there is a very strong correlation between the indicators of left and right hand strength – T7 and T8. Within the group of boys, there are 12 established indicators with strong correlation, eight of which having significant correlations, and four of them had the same correlations as in the previous year. There are fewer strong correlations among girls – six, four of which were significant the previous year, and five of which can also be found in boys: T1 – SR15 and T2 – SR30, T1 – SR15 and T3 – SRS15, T1 – SR15 and T5 – SLJ, T3 – SRS15 and T4 – SRS30, T5 – SLJ and T6 – STJ.

The indicators with significant correlation between each other are 15 in boys and 22 in girls while 11 of them can be observed in both sexes: T1 – SR15 and T10 – SS120; T3 – SRS15 with T5 – SLJ and T10 – SS120; T4 – SRS30 with T5 – SLJ, T6 – STJ, T10 – SS120 and T11 – C6`; T6 – STJ with T9 – MBT and T10 – SS120; T7 – RHD and T9 – MBT; T8 – LHD and T9 – MBT; T10 – SS120 and T11 – C6`. We can see that significant and large correlations are observed between the indicators of speed and strength, speed and speed endurance, speed endurance and overall endurance. The overall endurance and the strength of the upper limbs have predominantly moderate correlations with the other indicators of physical fitness.

Correlation structure of physical fitness of 12-year-old hockey players

Figs. 5 and 6 show the correlations between the indicators of 12-year-old boys and girls' physical fitness when $R \geq 0.5$. We can note not only an increased number of significant and strong correlations compared to the results of the 11-year-olds, but also the occurrence of very strong correlations which are observed, logically, between the speed and strength indicators.

In boys there are very strong correlations between the following indicators: T1 – SR15 with T2 – SR30 and T3 – SRS15; T3 – SRS15 and T4 – SRS30; T7 – RHD and T8 – LHD, and in girls – between the following indicators: T1 – SR15 and T2 – SR30; T5 – SLJ and T6 – STJ; T7 – RHD and T8 – LHD. When comparing the detected very strong correlations – 4 in boys

and 3 in girls, we find that 2 of them are observed in both sexes: T1 – SR15 and T2 – SR30; T7 – RHD and T8 – LHD.

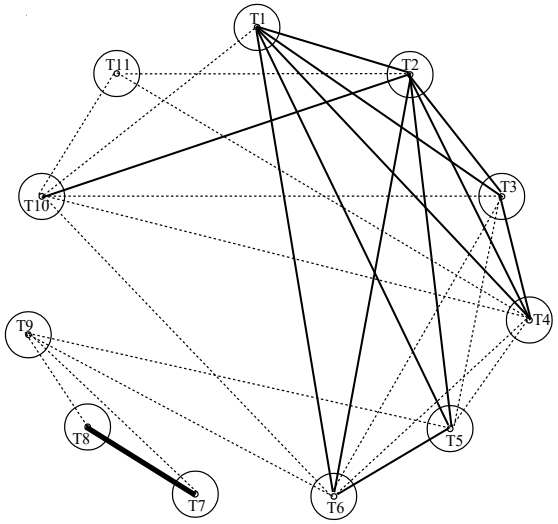

Fig. 3 Correlations between indicators
of physical fitness of boys aged 11 when $R \geq 0.5$

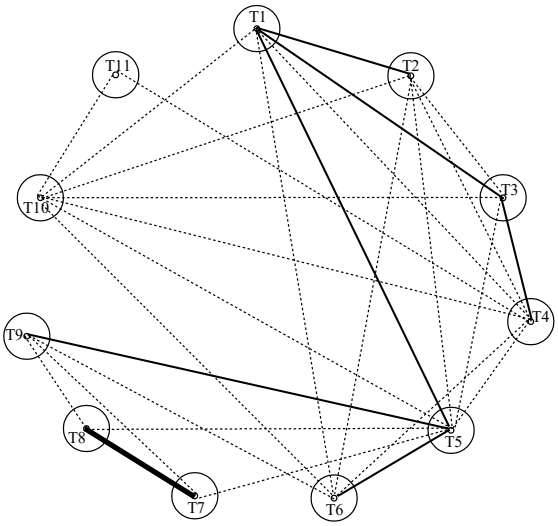

Fig. 4 Correlations between indicators
of physical fitness of girls aged 11 when $R \geq 0.5$

In boys, nine indicators were found to have strong correlations, and their degree of strength was the same as in the previous study (11-year-olds). Three of the indicators which had had strong correlations the previous year showed very strong correlation in this study: T1 – SR15 with T2 – SR30 and T3 – SRS15; T3 – SRS15 and T4 – SRS30. In girls, the number of strong correlations in the third study (12-year-olds) increased significantly – 10 correlations were observed, while in the previous study (11-year-olds) only 6 were present. The strong correlations observed in both sexes are 6: T1 – SR15 and T5 – SLJ; T2 – SR30 with T3 – SRS15, T4 – SRS30, T5 – SLJ and T6 – STJ; T10 – SS120 and C6`.

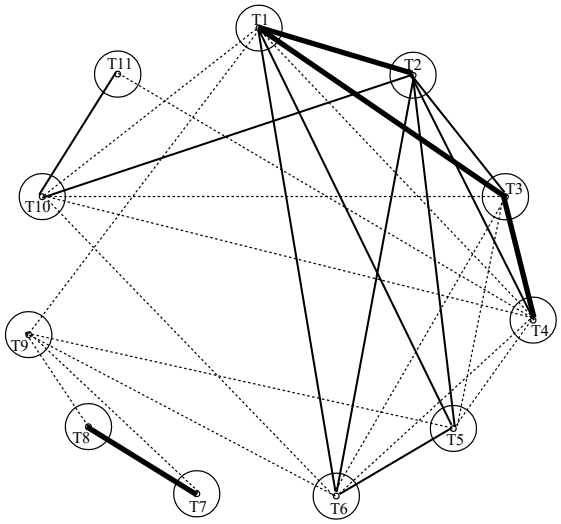

Fig. 5 Correlations between indicators
of physical fitness of boys aged 12 when $R \geq 0.5$

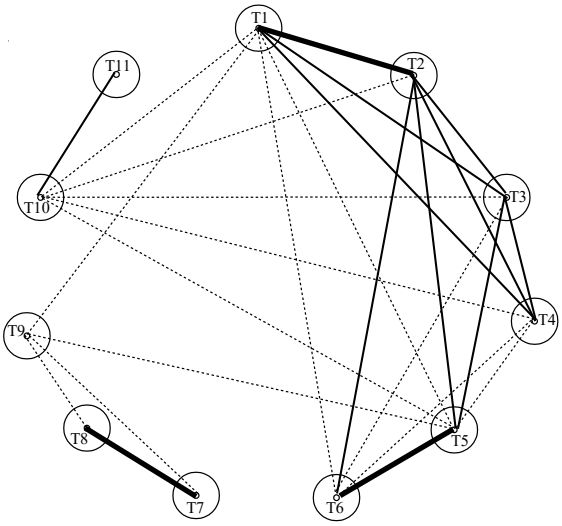

Fig. 6 Correlations between indicators
of physical fitness of girls aged 12 when $R \geq 0.5$

The indicators with significant correlation between them are 15 in boys and 13 in girls, and 10 of them are observed in both sexes: T1 – SR15 with T9 – MBT and T10 – SS120; T3 – SRS15 with T5 – SLJ, T6 – STJ and T10 – SS120; T4 – SRS30 with T5 – SLJ, T6 – STJ and T10 – SS120; T7 – RHD and T9 – MBT; T8 – LHD and T9 – MBT. We can see that between the indicators for speed and strength, speed and speed endurance, speed and general endurance there are significant, strong, and very strong correlations. In girls, however, there is a decrease in the degree of correlations of indicators T6 – STJ with T9 – MBT and T10 – SS120 from significant to moderate, and there is also a downward tendency in the correlations of the indicator T11 – C6` with the indicators for speed and strength – from moderate to weak correlation. We assume that this slight decline in the correlations of overall endurance with other physical fitness indicators in 12-year-old girls is due to the higher rate of development of speed and strength than that of endurance when entering puberty. The increase from significant to strong and very strong correlations between sprint running at equal distances without a stick

– T1 and T2 – and with a stick – T3 and T4 – is indicative that the methodologies have a positive impact on the ability to move quickly with a stick but the stick still affects the display of speed in children of both sexes.

Conclusion

Considering the fact that in 10-year-olds three of the correlations with a high degree of significance and thirteen with significant can be observed both in boys and girls, we can summarize the following: the correlations between the indicators of physical fitness of the 10-year-old boys and girls have similar values, which allows the development of qualities following a uniform and unified methodology for both sexes. Both in boys and girls, high degrees of correlation are found in speed and strength indicators: speed and strength of the lower limbs, strength of the right and the left hand, speed and speed endurance. A significant correlation is also registered between the indicators for general and speed endurance. It is interesting to note that the strength of the upper limbs (T7 and T8) has a significant correlation only with the indicator of overall strength – MBT (T9), while the correlations with the other indicators are moderate and weak. Even with the indicators for strength of the lower limbs, T5 and T6, T7 and T8 do not correlate significantly. This fact means that the strength of the upper limbs cannot be a significant indicator of the strength potential of 10-year-old hockey players. The lack of a very strong and strong correlation between sprint running with and without a stick at the same distances indicates that in some athletes the stick does not affect the display of speed.

The detected correlations between the indicators of physical fitness of 10 and 11-year-old boys and girls and the slight increase in the value of the correlation coefficient *R* from weak to moderate, from moderate to significant, and from significant to strong, remain the same in 12-year-olds.

In conclusion, we can summarize that the observed tendency of a slight increase of the existing correlations from weak to moderate, from moderate to significant, and from significant to strong in the first year of the experiment (age 10-11) was also observed in the second year (age 11-12) when even very strong correlations were found – between 4 indicators for boys and 3 for girls. This fact gives us grounds to assert that the methodology established in Bulgaria has a positive effect on the existing correlations between the indicators of physical fitness of both sexes during the two-year period of early hockey training. The similar pattern of the correlations between the indicators for both sexes gives us reason to claim that for hockey players aged 10-12 a uniform methodology of general physical training can be applied for the development of basic motor skills. Our findings give us reason to conclude that at this age mixed training for boys and girls is still methodologically acceptable considering the fact that no significant statistical differences have been observed in the average values of the indicators and in their annual growth.

As a further research the dependencies between the considered here 11 indicators of physical fitness could be investigated based on the newly proposed approach InterCriteria Analysis (ICrA). ICrA, proposed by [6], is a recently developed approach for evaluation of multiple objects against multiple criteria and thus discovering existing correlations between the criteria themselves. It is based on the apparatus of the index matrices [3], and the intuitionistic fuzzy sets [4, 5] and can be applied to decision making in different areas of knowledge [18, 20, 22, 25, 26]. Various applications of the ICrA approach have been found in science and practice [1, 9, 12, 14, 16, 19, 21, 23, 24]. Clearly, there is a possibility to expand the current results for the relations between different indicators of physical fitness by applying ICrA.

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