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Correlations between thoracic elasticity, muscular strength of the trunk and ability to recover after exertion

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ABSTRACT: *This study aimed to determine how the muscular strength of the trunk influences the chest elasticity and the ability to exert and to recover after exertion. For this purpose, we tested 46 female subjects (who were 12, 14 and 16 years old). They were subjected to the following tests: chest elasticity, general trunk strength index, weight and Ruffier index. We calculated 59 correlations between these variables; for each age group, the values of* ***r*** *were between 0.1% and 0.76%. We found, depending on the age, differences of the average values in the weight tests, ET, Ir and IGFT. Only for the16-year-olds we found a development of some muscle groups that influences the breathing phases and implicitly the effort capacity. For the14- year-olds, we obtained a good correlation of ET with Ir (**r** = -0.46%) and the best correlation between Ir and IGFT (**r** = -0.47%). For the12-year-olds, we found only the correlation between Et and Ir (**r** = 0.51%) and almost no correlation between muscle strength and other indices. In conclusion, we can affirm that the increase of the muscular strength without an increase and of the muscular-joint mobility at the trunk level, does not help the development of the capacity of effort. The conclusions to be drawn must be accepted with care, as it concerns only this group of athletes, while the correlations obtained indicate the degree of association between the variables used, and not the cause of the respective links.*
KEYWORDS: *Chest elasticity, muscular strength of the trunk, ability to exert*

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I. INTRODUCTION

All researchers agree that setting benchmarks for a "healthy aging" can only be achieved on young subjects. Thus, we can establish, as far as possible, a level of health at different ages. (Felix J. F., Trudy V. et al., 2014). One such health marker is physical fitness. Physical development is partly genetically determined, but it can be greatly influenced by environmental factors. (Ortega, F., Ruiz, J., Castillo, M. et al., 2008). We were interested to study how muscle strength, measured at the trunk level, influences the quality of fitness, knowing that all children have a lower muscle mass than adults. (Rate, S., Duché, P. & Williams, C.A. Sports Med, 2006).

Related to the thoracic elasticity, an important landmark in the dynamics of the respiratory act, studies have shown that the diaphragm provides the force of expansion while the abdominal and intercostal muscles help the forced expiration. (Feher, 2017). By synthesising the role of the trunk muscles in the phases of the respiratory act we can enumerate: the diaphragm muscle is the most important inspiratory muscle; the abdominal muscles are very strong expiratory muscles and produce forced exhalation; the abdominal muscles are perfect antagonists of the diaphragm because they simultaneously reduce the three diameters of the thorax; the lateral inclination of the trunk produces an opening of the hemitorace; flexion helps the costal closure and extension raise the sternum and the rib cage, favouring the inspiration. (Marcu V., Stan Z., Baştiurea E., Chiculiţă C., 2008).

In this study, we evaluated the fitness capacity by applying the Ruffier test. In 2018, Pérez et al., demonstrated that this test is valid in subjects older than 12 years old. Therefore, the Ruffier test is considered as an effective measuring tool for assessing physical fitness in healthy children. (Pérez et al., 2018).

The effects of cardiorespiratory endurance on health are well known (Gajewska et al., 2015) so that these aspects related to the capacity of effort in correlation with the level of muscular strength development at the trunk level, can be used to select children for sports, to improve the physical condition in sports, to assess the capacity of effort and its evolution in patients undergoing kinetic treatment or for highlighting some undetectable cardiovascular dysfunction at rest. (Stan, Z., 2009).

We assumed that there are significant correlations between thoracic elasticity, muscular strength in the trunk and effort capacity, with clear differences depending on the age of the subjects.

II. METHODOLOGY

Subjects

We tested 46 female athletes, who were 12 to16 years old.

Applied tests:

Chest elasticity: The thoracic perimeter consists of measuring the thoracic perimeter at rest, inhaling deeply and exhaling deeply. The thoracic elasticity is calculated from the difference of the last two parameters. (Cordun, M., 2009).

The Ruffier test is based on the heart rate response to an effort consisting of 30 squats performed in 45 seconds, at a metronome rate of 90. The heart rate is monitored at rest and after exertion for 1 minute. (Zanevskyy, et al., 2017). Ruffier index = [(p1 + p2 + p3) -200] / 10. The index refers to a subject whose resting heart rate is about 65 beats / minute (the number 200 represents 3 times the value of the resting heart rate). We didn't perform the test on tired, sick, emotional or nervous subjects.

Table 1 - Ruffier index interpretation

Mark	Values	Meaning
Very good	< 0	Very good adaptation to the effort
Good	0,1-5	Good adaptation to the effort
Average	5,1-10	Average adaptation to the effort
Satisfactorily	10,1-15	Insuficient adaptation to the effort
Unsatisfactory	15,1-20	Poor adaptation to the effort

General index of the trunk strength

We applied 9 tests for measuring the muscular strength at the trunk level (Marcu, Stan, Baştiurea, Chiculiță, 2008) as shown in table 2. Based on these tests, we elaborated a strength index for the trunk muscles who complements the other existing force indices: Divided force index of the finger flexors; Scapular divided force index; Lumbar divided strength index. All these indices are found in the IFG - Global Strength Index. (Stan Z., Baştiurea Eugen, Rizescu C., 2016). The value of this index must be as close to 1 or even exceed this value in the case of performance athletes.

Table 2. Abbreviations used for testing of the muscle strength at the trunk level

Position/side	*Abbreviations*	*Testing of the muscular force at the trunk level (kgf)*
SITTING	**T1**	*Testing of the muscular force on flexion from sitting*
	T2	*Testing of the muscular force on left lateral tilt, from sitting*
	T3	*Testing of the muscular force on extension, from sitting*
	T4	*Testing of the muscular force on lateral right tilt, from sitting*
STANDING	**T5**	*Testing of the muscular force on flexion, from standing*
	T6	*Testing of the muscular force on lateral left tilt, from standing*
	T7	*Testing of the muscular force on extension, from standing*
	T8	*Testing of the muscular force on lateral right tilt, from standing*
	T9	*Testing of the muscular lombar force (the classical test)*
IGFT	**[(T1+T2+T3+T4+T5+T6+T7+T8+T9)/9]/G**	*The average of the T1-T9 weight values*

III. FINDINGS

Data analysis

We processed the collected data by using SPSS v. 23 for Windows. We obtained all the measured values for the tests included in the previous chapter, for all subjects, by age groups, as follows: Table 3 for the 16-year-olds and Table 4 for the correlation of the coefficient values; Table 5 for the 14-year-olds and Table 6 for the correlation of the coefficient values; Table 7 for the 12-year-olds and Table 8 for the correlation of the coefficient values.

Table 3 – Test results for the 16-years-olds group

G (kg)	ET (cm)	Ruffier Index				Muscular strength measured at the trunk level (kgf)									
		P1 (fc)	P2 (fc)	P3 (fc)	Ir	T1	T2	T3	T4	T5	T6	T7	T8	T9	IGFT
46.5	**11**	96	160	108	**16**	12	11	17	13	36	29	46	33	67	**0.56**
44.6	**7**	104	136	112	**15**	15	9	32	10	15	23	32	23	64	**0.50**
74.5	**8**	60	92	60	**1**	19	15	36	18	48	35	41	33	92	**0.66**
50.0	**8**	88	148	88	**4**	19	14	43	14	31	32	39	25	78	**0.48**
57.3	**7**	88	148	84	**12**	20	16	26	14	36	24	30	28	56	**0.51**
51.4	**5**	84	144	92	**12**	16	11	24	11	30	22	24	20	77	**0.64**
60.4	**10**	72	112	72	**6**	2	18	43	20	41	34	50	37	85	**0.51**
63.1	**7**	104	140	128	**17**	19	15	32	14	30	26	34	30	92	**0.40**
56.0	**6**	92	152	100	**14**	14	12	25	13	20	16	17	18	65	**0.56**
58.0	**7**	92	132	88	**11**	17	18	27	19	37	28	33	33	82	**0.69**
44.0	**6**	100	140	108	**15**	14	14	34	11	30	25	29	29	87	**0.62**
50.5	**7**	84	116	88	**9**	18	12	22	11	34	35	42	31	78	**0.56**
40.0	**11**	100	152	100	**15**	20	12	27	10	27	23	33	25	64	**0.50**
54.0	**9**	80	132	120	**13**	22	15	29	13	42	39	39	35	89	**0.66**
50.2	**8**				**11.4**										**0.56**

Table 4 – Values of the Pearson correlation coefficient in the 16-year-olds group (%)

	ET	P1	P2	P3	Ir	T1	T2	T3	T4	T5	T6	T7	T8	T9	IGFT
G	-0.04	-0.65	-0.62	-0.44	-0.52	-	-	-	-	-	-	-	-	-	-
ET	-	0.09	0.02	-0.03	-0.04	-0.18	0.09	0.04	0.17	0.33	0.40	0.69	0.50	-0.08	-0.19
P1	-	-	-	-	-	0.12	-0.41	-0.30	-0.59	-0.76	-0.60	-0.40	-0.41	-0.39	-0.45
P2	-	-	-	-	-	0.13	-0.39	-0.42	-0.53	-0.57	-0.62	-0.45	-0.52	-0.60	-0.31
P3	-	-	-	-	-	0.24	-0.36	-0.30	-0.57	-0.49	-0.25	-0.26	-0.17	-0.02	-0.28
IR	-	-	-	-	-	0.08	-0.39	-0.57	-0.58	-0.57	-0.56	-0.42	-0.27	-0.34	-0.22

We found the following results shown in tables 3 and 4:

- The average weight is 50.2 kg. The average ET is 8 cm. The average Ir is 11.4 (satisfactory). The IGFT average is 0.56.
- A negative, significant correlation between weight and Ruffier index (**r** = -0.52%).
- Chest elasticity is closely related to trunk extension (**r** = -0.69%).
- Many significant values of the correlations between the muscular strength Ruffier index (values of **r** between 0.40% and 0.76%) but we did not find it in the correlation with the general strength index (IGFT).

Table 5 – Test results for the 14-years-olds group

G (kg)	ET (cm)	Ruffier Index				Muscular strength measured at the trunk level (kgf)									
		P1 (fc)	P2 (fc)	P3 (fc)	Ir	T1	T2	T3	T4	T5	T6	T7	T8	T9	IGFT
60.0	**7**	96	128	100	**12**	14	14	29	14	21	30	30	32	72	**0.47**
59.3	**7**	88	120	92	**10**	17	12	28	12	28	29	42	30	55	**0.47**
41.0	**6**	88	140	112	**14**	14	9	16	8	22	25	32	27	56	**0.57**
50.3	**7**	72	124	76	**7**	15	13	35	16	35	35	38	35	82	**0.67**
87.7	**6**	104	128	120	**15**	29	25	51	24	21	33	41	29	61	**0.40**
47.5	**7**	88	120	116	**12**	17	9	19	8	28	29	29	25	43	**0.48**
69.0	**7**	104	124	120	**15**	22	18	32	17	34	33	36	36	89	**0.51**
49.3	**6**	108	152	112	**17**	17	15	30	16	29	25	22	22	53	**0.51**
42.2	**6**	104	124	120	**15**	13	12	24	14	26	30	32	29	56	**0.62**
62.8	**6**	72	104	96	**7**	19	15	22	12	24	24	33	26	76	**0.44**
59.8	**9**	72	104	72	**5**	17	12	39	11	31	21	32	27	71	**0.48**
59.7	**8**	80	160	112	**15**	23	17	31	20	30	28	35	32	68	**0.53**
76.1	**8**	60	120	80	**6**	22	19	39	16	40	35	55	34	107	**0.47**
60.4	**8**	100	132	104	**14**	20	14	35	14	34	41	45	35	77	**0.47**
59.0	**7**				**11.7**										**0.51**

Table 6 – Values of the Pearson correlation coefficient in the 14-year-olds group (%)

	ET	P1	P2	P3	Ir	T1	T2	T3	T4	T5	T6	T7	T8	T9	IGFT
G	0.20	-0.09	-0.19	-0.08	-0.14	-	-	-	-	-	-	-	-	-	-
ET	-	-0.48	-0.14	-0.57	-0.46	0.12	-0.03	0.35	-0.03	0.61	0.13	0.38	0.41	0.43	-0.12
P1	-	-	-	-	-	0.03	0.11	-0.01	0.22	-0.41	0.15	-0.40	-0.13	-0.49	-0.05
P2	-	-	-	-	-	0.11	0.12	-0.05	0.36	-0.05	0.09	-0.21	-0.01	-0.24	0.23
P3	-	-	-	-	-	0.20	0.15	-0.25	0.20	-0.45	0.06	-0.35	-0.19	-0.49	-0.07
IR	-	-	-	-	-	0.14	0.15	-0.12	0.31	-0.34	0.14	-0.36	-0.11	-0.47	-0.47

We found the following results shown in tables 5 and 6:

- The average weight is 59 kg. The average ET is 7 cm. The average Ir is 11.7 (satisfactory). The IGFT average is 0.51.
- A negative, significant correlation between ET and the Ruffier index (**r** = -0.46%).
- Chest elasticity is much weaker at this age, with trunk extension (**r** = -0.43%).
- We found only a few good values of the correlations between muscle strength and heart rate measurement but a good correlation, even if negative, between Ruffier and IGFT index (**r** = -0.47%).

Table 7 – Test results for the 12-years-olds group

G (kg)	ET (cm)	Ruffier Index				Muscular strength measured at the trunk level (kgf)									
		P1 (fc)	P2 (fc)	P3 (fc)	Ir	T1	T2	T3	T4	T5	T6	T7	T8	T9	IGFT
41.0	**5**	72	108	76	**6**	14	10	22	9	18	19	22	18	48	**0.48**
33.1	**9**	112	176	140	**23**	9	8	12	8	27	24	22	21	38	**0.57**
50.5	**10**	108	132	108	**15**	13	11	21	11	30	21	31	25	67	**0.50**
38.1	**8**	100	140	136	**18**	19	11	26	10	29	18	31	17	61	**0.64**
30.4	**6**	88	128	100	**12**	8	6	12	5	14	15	18	16	43	**0.50**
53.7	**7**	96	124	116	**14**	16	12	19	11	31	25	37	27	58	**0.49**
39.3	**8**	112	164	124	**20**	11	7	14	8	13	15	19	15	44	**0.41**
52.4	**7**	96	136	112	**14**	14	17	26	18	32	25	31	26	59	**0.53**
50.2	**6**	92	136	104	**13**	15	10	31	9	26	21	27	20	50	**0.46**
33.2	**5**	108	132	100	**14**	10	7	17	8	18	13	23	16	35	**0.49**
28.5	**3**	96	72	100	**7**	8	6	9	7	16	16	22	17	40	**0.55**
49.2	**5**	104	136	116	**16**	16	12	25	12	25	28	33	22	40	**0.48**
44.2	**9**	92	132	108	**13**	17	12	32	13	34	28	35	32	65	**0.48**
47.0	**4**	104	160	112	**18**	15	10	18	10	23	27	30	21	44	**0.57**
42.2	**6.5**				**14.5**										**0.51**

Table 8 – Values of the Pearson correlation coefficient in the 12-year-olds group (%)

	ET	P1	P2	P3	Ir	T1	T2	T3	T4	T5	T6	T7	T8	T9	IGFT
G	0.23	-0.03	0.18	0.02	0.08	-	-	-	-	-	-	-	-	-	-
ET	-	0.31	0.50	0.51	0.51	0.21	0.28	0.26	0.26	0.54	0.18	0.24	0.44	0.62	-0.03
P1	-	-	-	-	-	-0.17	-0.13	-0.28	0	0.06	0.01	0.03	-0.05	-0.18	0.10
P2	-	-	-	-	-	0.13	0.10	0.07	0.10	0.19	0.27	0.02	0.05	-0.05	-0.05
P3	-	-	-	-	-	0.26	0.10	-0.05	0.12	0.35	0.23	0.21	0.07	0.07	0.41
IR	-	-	-	-	-	0.09	0.04	-0.06	0.06	0.23	0.23	0.09	0.02	-0.06	0.20

We found the following results shown in tables 7 and 8:

• The average weight is 42.2 kg. The average ET is 6.5 cm. The average Ir is 14.5 (satisfactory). The IGFT average is 0.51.

• A positive, significant correlation between ET and Ruffier index (**r** = 0.51%).

• The thoracic elasticity has a significant relation, at this age, with the trunk extension (**r** = -0.62%).

• Almost missing the links between the trunk force and the beginnings of effort, the only better value being between P3 and IGFT (**r** = 0.41%).

IV. DISCUSSION

Considering the influence of age and weight on the effort capacity, we found a correlation between weight and effort capacity only at the 16-year-olds although Gelbart et al. in 2016, found that age does not influence heart rate, but only body weight. Physical activity seems to be a good way of preventing health in the healthy child and should include (Edouard P. et al., 2007) two to five sessions from 30 to 60 min / week. The lack of this physical activity contributed to a higher frequency of pediatric obesity, a decrease in fitness (eg, flexibility, muscle strength, cardiorespiratory capacity) and a higher risk of illness (Malina, 2007; Steele et al., 2008). A study carried out in 2017 by Stan, Z. and Baştiurea, E., shows that there is a permanent change in the relationship between the large muscular forces of the trunk and the muscles involved in the respiratory process (ensuring the value of vital capacity), depending on the age of the measured subjects.

V. CONCLUSION

We found that depending on the age, they are differences of the average values in the weight tests, ET, Ir and IGFT. While ET grows slightly with age, we observed that Ir improves insignificantly but decreases the value of this index. IGFT has a value of 0.5 higher in the 16-year-olds subjects. According to the research hypothesis, we found correlations between the measured parameters, but they are more significant only at the 16-year-olds.

We found clear links between the muscular strength of the different groups of muscles that participated separately in the phases of the respiratory act but not with the general index of trunk strength. In the 16-year-olds, there is a development of some muscle groups that influence the breathing and implicitly the capacity of exertion. In the 14-year-olds, we found a good correlation of ET with Ir, so the capacity of effort and recovery after effort depends on the elasticity of the chest (**r** = -0.46%). Also, at this age, we found the best correlation between Ir and IGFT (v = -0.47%) although it is negative.

Therefore, according to this correlation, we found that the stiffening of the trunk due to the increase of the muscular strength, does not help the development of the capacity of effort and recovery after the effort. We found that it is also important to increase the elasticity of the rib cage by performing the respiratory act frequently and at sufficiently high intensity. In the 12-year-olds subjects there is only the correlation between Et and Ir (v = 0.51%). Everything about the relationship between muscle strength and the other indices, almost does not exist. Only the values of the strength of the extensor muscles (participating in the inspiration) it is pretty well correlated with the other measured variables. We concluded that the increase of the muscular strength without an increase and of the muscular-joint mobility at the level of the trunk does not help the development of the capacity of effort.

These findings should be considered with care, because they are specific to this group of subjects, while the correlations obtained indicate the degree of association between the variables used, and not the cause of the respective links. This study demonstrates the validity and efficiency of the system of measuring the muscular forces at the trunk level.

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