

Original Article

Correlation between the muscle strengths of the trunk and upper limbs

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Abstract:

This study aimed to determine the relationships between muscle chains from the trunk and those of the upper limbs during certain motive actions. We tested 44 female athletes who were 12 to 16 years old. Eighteen subjects were 12 to 14 years old (right-handers), 16 subjects were 15 to 16 years old (left-handers) and 10 subjects were 12 to 16 years old (left-handers). They were subjected to 13 tests that measure muscle strength at the trunk level, 2 tests that measure the isometric force of the upper limb (of the intra- and extra-rotators muscles with Dynatorq) and 2 tests that measure the isometric force of the upper limbs (flexion and extension with Dynatorq). We calculated 312 correlations between the measured values (in kgf) for the trunk and upper limbs. For the right-handers, the values for r were as follows: intra-extra rotation for the 12 to 14-year-olds (0.12%-0.85%), intra-extra rotation for the 15 to 16-year-olds (0.20%-0.69%), flexion-extension for the 12 to 14 year-olds (0.20%-0.84%), and flexion-extension for the 15 to 16 year-olds (0.12%-0.70%). For subjects with a skilled left arm, we obtained the following values for r : intra-extra rotation for the 12 to 16 year-olds (0.02%-0.77%) and flexion-extension for the 12 to 16 year-olds (0.04%-0.89%). For the subjects from 12 to 14 years old, there were significant correlations between the intra-extra rotation and flexion-extension of the arm, which shows that the entire musculature of the trunk is involved. For the group of 15 to 16-year-olds, we noticed a specialized right arm movement with intra rotation only (specific for throwing the ball). For the extension-flexion actions of the right-handers, there was a certain orientation of forces to the left side of the trunk (good values for the left arm extension and weak values for the flexion of the right arm). This study could be a starting point for improving specific technical training for handball players. These findings should be considered with care because they are specific to this group of subjects.

Key words: trunk muscle strength, upper limb muscular strength, muscular torso relationship with upper limb

Introduction

The study of the relationships between body segments constitutes a permanent research topic for the specialists in the field (McEvoy & Grimmer, 2005). Generally, all researchers highlight the importance of the trunk to create a solid ground for the limb movement (Kane & Barden, 2012). The importance of the spine's stability and of the trunk's functions in the static and the dynamic of the human body are explained by McGill, Grenier, Kavcic, and Cholewicki (2003). The increase of trunk strength with age is highlighted by Manini, Sagendorf, Mayer, and Ploutz-Snyder (2005).

It is known the fact that the normal activity of a muscle is a combination of contraction and relaxation (Bottas, Nicol, Komi, & Linamo, 2009). In 2001, Parkin, Nowicky, Rutherford, and McGregor showed asymmetry of muscle activity in the frontal plane of erector muscles. A study in 2011 (Baștiurea, Stan, Mihailă, & Crețu) outlines the mobility and muscle strength of the trunk in achieving the efficient technical elements of handball. In 2008, Peper, de Boer, de Poel, and Beek demonstrates that from all of the physical attributes, muscle strength has the most influence on the speed execution, strength and coordination abilities. The importance of sensorial information in the adaptation of force is evidenced by Latash, Scholz and Schoner (2002).

Mobility of the upper limb is provided by the pectoral arch. This one, is not directly related to the spine and together with scapula-humeral joint it forms one of the most complex gears in the body. The summarizing of the convergent activities will ensure the multiple variation of the upper limb movement. For this reason, studying the separated biomechanics of each joint part is not correct. In this context it is interesting to study the correlation between this specialized gear (pectoral arch-shoulder-arm-fingers) and the trunk which ensures its stability during movements.

One can observe how different muscle groups are involved depending on the arm activity. They can be explained and corrected some correlations that unbalance the body during the motive activity. You can see certain relationships between muscles, according to the "Brauss's scheme".

Material & methods*Participants*

They were tested 44 female athletes aged 12-16 years as follows: 18 subjects 12 to 14 years (right-handers), 16 subjects 15 to 16 years (right-handers) and 10 subjects 12 to 16 years (left-handers).

Procedure

They were applied 9 measuring tests for muscle strength of the trunk (Marcu, Stan, Baștiurea, & Chiculiță, 2008) and presented in Stan, Baștiurea, and Rizescu (2016). Abbreviations of the used tests are in Table 1. In addition they were aggregated values measured on flexion, extension and lateral tilt, from sitting and standing, to better observe the relationship between muscle strength with the strength of the entire torso arm during movements (table 1).

Table 1. Abbreviations used for testing of the muscle strength at the trunk level

<i>Position/side</i>	<i>Abbreviations</i>	<i>Testing of the muscular force at the trunk level (kgf)</i>
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
	T5	Testing of the muscular force on flexion, from standing
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)
FLEXION	T1+T5	Testing of the muscular force on flexion (sitting and standing)
LAT. LEFT	T2+T6	Testing of the muscular force on lateral left tilt (sitting and standing)
EXTENSION	T3+T7	Testing of the muscular force on extension (sitting and standing)
LAT. RIGHT	T4+T8	Testing of the muscular force on right lateral tilt (sitting and standing)

For measuring the upper limb muscle strength was used a Dynatork apparatus (therapeutic first class medical device designed to be used for physical rehabilitation therapies based on elastic resistance). The tests were carried out in orthostatic position. Muscle strength was measured on intra-extra arm rotation and flexion-extension arm. Abbreviations of the tests are found in Table 2.

Table 2. Abbreviations used for testing the upper limb muscle strength

<i>Movement</i>	<i>Abbreviations</i>	<i>Testing of the muscular force at the trunk level (kgf)</i>
HORIZONTAL	EXTRAROTATION	Outward rotation of the arm, horizontally
	INTRAROTATION	Inward rotation of the arm, horizontally
VERTICAL	EXTENSION	Extension of the arm, vertically
	FELXION	Flexion of the arm, vertically

Statistical analysis

The obtained data were processed using SPSS v. 20 program for Windows. It was calculated the Pearson's correlation coefficient [$r \in (-1.1)$] the results being distributed as follows: correlation values for age 12 to 14 years (intra-extra rotation for right-handers) in Table 3; correlation values for age 15 to 16 years (intra-extra rotation for right-handers), in Table 4; correlation values for age 12 to 16 years (intra-extra rotation for left-handers) in Table 5; correlation values for age 12 to 14 years (extension-flexion for right-handers), in Table 6; correlation values for age 15 to 16 years (extension-flexion for right-handers) in Table 7; correlation values for age 12 to 16 years (extension-flexion for left-handers), in Table 8.

Table 3. Values correlations between torso and right upper limb (12 to 14 years)

TTUNK MAX TORQUE (kgf)		ISOMETRIC / HORIZONTAL MOVEMENT			
		EXTRAROTATION/ STAND UP		INTRAROTATION/ STAND UP	
		MAX TORQUE - (kgf)		MAX TORQUE - (kgf)	
		L	R	L	R
SITTING	T1	0.36	0.77	0.80	0.81
	T2	0.5	0.78	0.74	0.65
	T3	0.49	0.69	0.76	0.57
	T4	0.41	0.70	0.67	0.55
	T5	0.12	0.51	0.37	0.33
STANDING	T6	0.52	0.80	0.69	0.64
	T7	0.46	0.66	0.73	0.70
	T8	0.32	0.76	0.70	0.53
	T9	0.34	0.60	0.55	0.66
FLEX	T1+T5	0.42	0.71	0.63	0.61
LAT. LEFT	T2+T6	0.57	0.85	0.79	0.74
EXT.	T3+T7	0.49	0.71	0.80	0.64
LAT. RIGHT	T4+T8	0.37	0.82	0.69	0.56

* **T1** - Testing of the muscular force on flexion, **T2** - Testing of the muscular force on left lateral tilt, **T3** - Testing of the muscular force on extension, **T4** - Testing of the muscular force on lateral right tilt, **T5** - Testing of the muscular force on flexion, **T6** - Testing of the muscular force on lateral left tilt, **T7** - Testing of the muscular force on extension, **T8** - Testing of the muscular force on lateral right tilt, **T9** - Testing of the muscular lombar force, **FLEX.** - Testing of the muscular force on

flexion (sitting and standing), LAT. LEFT and RIGHT - Testing of the muscular force on lateral tilt (sitting and standing), EXT. - Testing of the muscular force on extension (sitting and standing), EXTRAROTATION - Outward rotation of the arm, horizontally, INTRAROTATION - Inward rotation of the arm, horizontally, EXT. - Extension of the arm, vertically, FLEX. - Flexion of the arm, vertically

Table 4. Values correlations between torso and right upper limb (15 to 16 years)

TRUNK MAX TORQUE (kgf)		ISOMETRIC / HORIZONTAL MOVEMENT			
		EXTRAROTATION/ STANDING		INTRAROTATION/ STANDING	
		MAX TORQUE - (kgf)		MAX TORQUE - (kgf)	
		L	R	L	R
SITTING	T1	0.47	0.47	0.45	0.58
	T2	0.28	0.26	0.43	0.66
	T3	0.61	0.38	0.24	0.57
	T4	0.51	0.37	0.37	0.62
	T5	0.27	0.30	0.41	0.56
	T6	0.43	0.46	0.41	0.50
STANDING	T7	0.41	0.55	0.56	0.69
	T8	0.50	0.30	0.37	0.69
	T9	0.20	0.23	0.32	0.54
FLEX	T1+T5	0.43	0.50	0.57	0.65
LAT. LEFT	T2+T6	0.34	0.37	0.52	0.62
EXT.	T3+T7	0.57	0.56	0.50	0.60
LAT. RIGHT	T4+T8	0.33	0.34	0.42	0.39

Table 5. Values correlations between torso and left upper limb (12 to 16 years)

TRUNK MAX TORQUE (kgf)		LEFT UPPER LIMB			
		ISOMETRIC / HORIZONTAL MOVEMENT		INTRAROTATION/ STANDING	
		EXTRAROTATION/ STANDING		MAX TORQUE - (kgf)	
		L	R	L	R
SITTING	T1	0.36	-0.05	-0.05	0.48
	T2	-0.11	0.46	0.41	0.37
	T3	0.52	0.13	0.54	0.69
	T4	0.40	0.62	0.73	0.48
	T5	0.53	-0.11	0.44	0.43
	T6	0.56	0.42	0.66	0.66
STANDING	T7	0.51	-0.27	0.35	0.47
	T8	-0.20	0.87	0.59	0.06
	T9	0.05	0.65	0.77	0.36
FLEX	T1+T5	0.55	-0.28	0.34	0.51
LAT. ST.	T2+T6	0.45	0.47	0.66	0.65
EXT.	T3+T7	0.59	0.02	0.55	0.72
LAT. DR.	T4+T8	0.71	-0.08	0.18	0.58

* **T1** - Testing of the muscular force on flexion, **T2** - Testing of the muscular force on left lateral tilt, **T3** - Testing of the muscular force on extension, **T4** - Testing of the muscular force on lateral right tilt, **T5** - Testing of the muscular force on flexion, **T6** - Testing of the muscular force on lateral left tilt, **T7** - Testing of the muscular force on extension, **T8** - Testing of the muscular force on lateral right tilt, **T9** - Testing of the muscular force on extension, **FLEX.** - Testing of the muscular force on flexion (sitting and standing), **LAT. LEFT and RIGHT** - Testing of the muscular force on lateral tilt (sitting and standing), **EXT.** - Testing of the muscular force on extension (sitting and standing), **EXTRAROTATION** - Outward rotation of the arm, horizontally, **INTRAROTATION** - Inward rotation of the arm, horizontally, **EXT.** - Extension of the arm, vertically, **FLEX.** - Flexion of the arm, vertically

Table 6. Values correlations between torso and right upper limb (12 to14 years)

TRUNK MAX TORQUE (kgf)		ISOMETRIC / VERTICAL MOVEMENT			
		ADD/EXT		ADD/FLEX	
		MAX TORQUE - (kgf)		MAX TORQUE - (kgf)	
		L	R	L	R
	T1	0.83	0.60	0.67	0.73
	T2	0.71	0.39	0.57	0.68
* T1 - Testing of the muscular force on flexion, T2 - Testing of the muscular force on left lateral tilt, T3 - Testing of the muscular force on extension, T4 - Testing of the muscular force on lateral right tilt, T5 - Testing of the muscular force on flexion, T6 - Testing of the muscular force on lateral left tilt, T7 - Testing of the muscular force on extension, T8 - Testing of the muscular force on lateral right tilt, T9 - Testing of the muscular lombar force, FLEX. - Testing of the muscular force on flexion (sitting and standing), LAT. LEFT and RIGHT - Testing of the muscular force on lateral tilt (sitting and standing), EXT. - Testing of the muscular force on extension (sitting and standing), EXTRAROTATION - Outward rotation of the arm, horizontally, INTRAROTATION - Inward rotation of the arm, horizontally, EXT. - Extension of the arm, vertically, FLEX. - Flexion of the arm, vertically					
	T3	0.67	0.33	0.50	0.64
	T4	0.63	0.29	0.48	0.61
	T5	0.53	0.49	0.20	0.50
	T6	0.84	0.59	0.39	0.84
STANDING	T7	0.78	0.56	0.60	0.72
	T8	0.77	0.48	0.33	0.84
	T9	0.67	0.73	0.57	0.62
FLEX	T1+T5	0.76	0.62	0.49	0.67
LAT. LEFT	T2+T6	0.83	0.57	0.42	0.83
EXT.	T3+T7	0.78	0.46	0.59	0.73
LAT. RIGHT	T4+T8	0.80	0.45	0.45	0.84
* T1 - Testing of the muscular force on flexion, T2 - Testing of the muscular force on left lateral tilt, T3 - Testing of the muscular force on extension, T4 - Testing of the muscular force on lateral right tilt, T5 - Testing of the muscular force on flexion, T6 - Testing of the muscular force on lateral left tilt, T7 - Testing of the muscular force on extension, T8 - Testing of the muscular force on lateral right tilt, T9 - Testing of the muscular lombar force, FLEX. - Testing of the muscular force on flexion (sitting and standing), LAT. LEFT and RIGHT - Testing of the muscular force on lateral tilt (sitting and standing), EXT. - Testing of the muscular force on extension (sitting and standing), EXTRAROTATION - Outward rotation of the arm, horizontally, INTRAROTATION - Inward rotation of the arm, horizontally, EXT. - Extension of the arm, vertically, FLEX. - Flexion of the arm, vertically					

Table 7. Values correlations between torso and right upper limb (15 to16 years)

TRUNK MAX TORQUE (kgf)		ISOMETRIC / VERTICAL MOVEMENT			
		ADD/EXT		ADD/FLEX	
		MAX TORQUE - (kgf)		MAX TORQUE - (kgf)	
		L	R	L	R
	T1	0.14	0.47	0.39	0.22
	T2	0.27	0.54	0.43	0.27
SITTING	T3	0.00	0.32	0.70	0.30
	T4	0.20	0.56	0.57	0.36
	T5	0.12	0.54	0.38	0.25
	T6	0.18	0.64	0.50	0.32
STANDING	T7	0.21	0.37	0.53	0.42
	T8	0.09	0.61	0.56	0.29
	T9	0.25	0.47	0.48	0.19
FLEX	T1+T5	0.14	0.59	0.43	0.27
LAT. LEFT	T2+T6	0.24	0.68	0.53	0.34
EXT.	T3+T7	0.15	0.41	0.69	0.43
LAT. RIGHT	T4+T8	0.14	0.64	0.60	0.33
* T1 - Testing of the muscular force on flexion, T2 - Testing of the muscular force on left lateral tilt, T3 - Testing of the muscular force on extension, T4 - Testing of the muscular force on lateral right tilt, T5 - Testing of the muscular force on flexion, T6 - Testing of the muscular force on lateral left tilt, T7 - Testing of the muscular force on extension, T8 - Testing of the muscular force on lateral right tilt, T9 - Testing of the muscular lombar force, FLEX. - Testing of the muscular force on flexion (sitting and standing), LAT. LEFT and RIGHT - Testing of the muscular force on lateral tilt (sitting and standing), EXT. - Testing of the muscular force on extension (sitting and standing), EXTRAROTATION - Outward rotation of the arm, horizontally, INTRAROTATION - Inward rotation of the arm, horizontally, EXT. - Extension of the arm, vertically, FLEX. - Flexion of the arm, vertically					

Table 8. Values correlations between torso and left upper limb (12 to 16 years)

TRUNK MAX TORQUE (kgf)		ISOMETRIC / VERTICAL MOVEMENT			
		ADD/EXT MAX TORQUE - (kgf)		ADD/FLEX MAX TORQUE - (kgf)	
		L	R	L	R
SITTING	T1	-0.73	0.29	0.58	-0.13
	T2	0.01	0.60	0.46	0.04
	T3	-0.28	0.82	0.89	0.36
	T4	0.26	0.72	0.55	0.46
	T5	-0.31	0.42	0.42	-0.16
STANDING	T6	0.02	0.75	0.70	0.46
	T7	-0.49	0.46	0.54	-0.18
	T8	0.55	0.33	-0.10	-0.11
	T9	0.17	0.78	0.47	-0.03
FLEX	T1+T5	-0.50	0.44	0.53	-0.17
LAT. LEFT	T2+T6	-0.18	0.67	0.65	0.17
EXT.	T3+T7	-0.38	0.80	0.89	0.22
LAT. RIGHT	T4+T8	0.50	0.47	0.08	0.05

* **T1** - Testing of the muscular force on flexion, **T2** - Testing of the muscular force on left lateral tilt, **T3** - Testing of the muscular force on extension, **T4** - Testing of the muscular force on lateral right tilt, **T5** - Testing of the muscular force on flexion, **T6** - Testing of the muscular force on lateral left tilt, **T7** - Testing of the muscular force on extension, **T8** - Testing of the muscular force on lateral right tilt, **T9** - Testing of the muscular lombar force, **FLEX.** - Testing of the muscular force on flexion (sitting and standing), **LAT. LEFT and RIGHT** - Testing of the muscular force on lateral tilt (sitting and standing), **EXT.** - Testing of the muscular force on extension (sitting and standing), **EXTRAROTATION** - Outward rotation of the arm, horizontally, **INTRAROTATION** - Inward rotation of the arm, horizontally, **EXT.** - Extension of the arm, vertically, **FLEX.** - Flexion of the arm, vertically

Results

They were calculated 312 correlations between the measured values (in kgf) at the trunk and upper limb level. For right-handers, the values of r were comprised as follows: intra-extra rotation 12 to 14 years (0.12%-0.85%); intra-extra rotation 15 to 16 years (0.20%-0.69%); flexion-extension 12 to 14 years (0.20%-0.84%); flexion-extension 15 to 16 years (0.12%-0.70%). For subjects with skillful left arm were obtained the following values of r : intra-extra rotation 12 to 16 years (0.02%-0.77%); flexion-extension 12 to 16 years (0.04%-0.89%).

It can be observed that in case of the extra rotation for 12 to 14 years, they are very good correlation between the right arm and torso on all tests (0.51% -0.85%) and a weak left arm significance (0.12%-0.57%)

At intra-rotation, the correlations are significant for both arms. At the age of 15 to 16 years they are very good correlations just for the right arm and only on intra-rotation (0.39%-0.69%). At the test for the extension of the arm, for age 12 to 14, good correlations are observed between both arms and torso on all tests (53% -84%) and a very good meaning for right arm flexion (50%-84%). For the extension, for 15 to 16 years they are good correlations between the left arm and torso (39%-68%) and a low significance for right arm flexion 19%-43%.

For left handed, they are observed disparate correlation values on intra and extra rotation and significant values on the right arm extension and flexion for the left arm.

Discussion

It can be observed in the correlations above a specific activity, by age group, like co-activation "agonist-antagonist" as highlights Cholewicki, Panjabi and Khachatryan (1997). It is known the evolution of the adjustment capacity of the parameters of time, space and those of the force from 6-7 years to 10-12 years. Teenage decrease these skills both in girls and boys, and by the end of puberty, this capacity increases again to 17 to 18 years, and further stabilizes. Relaxing capacity and the ability of voluntary muscle contraction are based on neuromuscular control (Madeleine, Mathiassen & Arendt-Nielsen, 2008). Subjects studied in this work are aged 12 to 16 years, so they are during the growing capacity of coordination and muscle strength. Tests at the arm level are based on visual feedback, voluntary control of muscles (pectoral arch-trapezius) and fine coordination of the hands (Jacob, Afshin, Klaus, & Pascal, 2011). They are highlighted relations between the lumbar, pelvic and femoral fixation and the functioning of the upper limb.

Conclusions

For the age of 12 to 14 years there are significant correlation in extra rotation and flexion-extension of the arm which shows participation of the whole musculature of the trunk at arm actions. For the age of 15 to 16 years, it can be observed a specialization of the right arm for intra rotation only (specific for the throwing of the ball). For the extension-flexion, in case of right handed subjects, there is observed is a certain orientation of forces to the left side of the trunk (good values in left arm extension and weak for the flexion of the right arm). Because no work is done in training with both arms for throwing at the gate, throws with his right arm only

develop muscle strength on the left side of the trunk (diagonals helping to fix pectoral belt, shoulder and right arm during the throw). Muscle imbalances are seen on the trunk and they automatically influences and is influenced by the actions of the handy upper limb. This study could be a starting point for improving technical training specific handball players. These findings should be accepted with care since they are just for this group of subjects.

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