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Correlations between somatic features, anteroposterior spinal curvatures and trunk muscle strength in schoolchildren

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Background: Evaluation of body posture and strength of spinal muscles in children during their progressive ontogenesis is significant for the evaluation of their physical health condition and physical fitness. It is also a reference point in a process of control and medical care. *Purpose*: The aim if this study was to evaluate correlation between the selected features of somatic body structure, shape of anteroposterior spinal curves and force-velocity (FV) parameters of trunk muscles in school children. *Participants and methods*: The sample involved 104 children aged 10–11 years, 60 females (10.74 ± 0.7) and 44 males (10.50 ± 0.9). Body posture was assessed using the Moiré photogrammetry while trunk muscles (flexors and extensors) strength was measured isokinetically. *Results*: The results of the research revealed the existence of many average and strong correlations observed between the analysed somatic characteristics and force-velocity (FV) parameters of trunk muscles. Correlation between the volume of the spinal curvatures in the sagittal plane and force-velocity parameters of trunk extensors and flexors were average or weak for both groups of children. *Conclusion*: Somatic features indicated stronger correlation with trunk muscles' strength than with the size of the anteroposterior spinal curves.

Key words: *spinal curvatures, photogrammetry, posture, muscle strength*

1. Introduction

Body posture as well as the shape and position of certain body parts in unconstraint, standing position are unique characteristics of each individual. Maintaining such a labile position means constant balancing of the body so that the energy expenditure of the working muscles is as low as possible [5]. The normal spine consists of a curve that is convex backward in the upper back and a curve that is convex forward in the low back. In a faulty postural position, the pelvic may be in an anterior, posterior or lateral tilt. Any tilting of the pelvis involves simultaneous movements of the back and hip joints [13].

Descriptions provided by many researchers of the position of the pelvis and anteroposterior curvatures in various age groups include their examination methods [18]. Their research results indicate there is a direct correlation between the position of pelvis in relation to the lumbar spine. Other researchers search for a correlation between the volume of the spinal curvatures in the sagittal plane and muscle force of the trunk in various disorders and conditions affecting the motor system [1], [11], [24]. Inherent in the concept of good body mechanics are the inseparable

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qualities of alignment and muscle balance. Examinations and treatment procedures are directed toward restoration and preservation of proper body mechanics in posture and movement in anterior and posterior muscles attached to the pelvis maintaining it in an ideal alignment [13]. There are no available studies evaluating the correlations between somatic characteristics, shape of the spinal curvatures in the sagittal plane and the force and velocity parameters of the flexor and extensor muscles of the trunk in healthy school children. Measurement of trunk muscle strength and endurance contributes to clinical evaluation of low back pain (LBP) patient; however, their physiological and individual variability effectively complicates appraisal and comparison [4]. Strength testing of children is routinely performed by researches to monitor the determinants and development of strength during childhood but also by physiotherapists to assess the degree of muscular pathology or diagnose treatment effectiveness [9]. A practical purpose of the study would be to determine correlations which occur between body height, body weight, anteroposterior spinal curves, trunk muscles' strength and direction of those correlations. Results obtained in the study will enable the researchers to determine effective prophylactic actions against body posture disorders in school children. The effectiveness of the prophylactic and therapeutic treatment is often influenced by time. The earlier such treatment is introduced, the higher the chance of success and positive effects.

From 10 to 11 years of age children start to move from childhood and gradually enter the first phase of adolescence. That time is called latent period. During that time a child quite easily learns new, even complicated motor activities. This period is characterized by balanced body proportions, good reflex, purposefulness of actions and extensive motor interests. At the same time it is an optimum stage of learning specific motor movements which frequently ends along with the first signs of puberty. This period is also important due to clearly marked, yet not that strong, sexual dimorphism in motor activities [2], [19].

The aim of this study was to evaluate correlations between selected somatic characteristics, shape of anteroposterior spinal curves and parameters of trunk muscles' strength in females and males aged 10–11 years old.

It was assumed that there were close relationships between body weight, body height, shape of anteroposterior spinal curves and trunk muscles' strength. The direction of those correlations depended on the feature discussed.

2. Material and methods

2.1. Participants

This study was carried out in two randomly selected primary schools. The information about the research was given during the meetings with parents. The initial age inclusion criterion required children with a chronological age over 9.50 years but less than 11.49 years. Only children who passed the preliminary orthopedic examination and did not suffer from the following qualified for the study: shortening of one of lower limbs, scoliosis, distinct deepening of spinal curves of the opposite in the sagittal plane and other musculoskeletal disorders. Based on the above criteria, the final sample involved 104 children aged 10–11 years old, 60 females (10.74 ± 0.7) and 44 males (10.50 ± 0.9). The study protocol was approved by the Ethics Committee of the University of Physical Education.

All parents gave written informed consent for research.

2.2. Postural examination

In all the patients height and weight and BMI were measured [17]. Posture examination was accomplished by means of photogrammetric method [3] using a computerized kit for photogrammetric postural evaluation. The examination consisted of visual assessment and measuring of the anteroposterior spinal curves by means of photogrammetry according to the protocol as follows:

- marking of spinous processes of C_7-S_1 vertebrae on the back of each child;
- child positioned parallel to camera at a distance of 2.6 m, back facing the camcorder, the child maintains natural posture so that the trunk is within the camera's field of view;
- image of each child's back is saved;
- dedicated software provides 3D visualization based on the saved images and postural parameters of the children.

The following parameters were analysed (Fig. 1):

1. angular parameters (°):
   - thoracic spine inclination angle (γ),
   - thoracolumbar spine inclination angle (β),
   - lumbosacral spine inclination angle (α).
2. depth (mm):
   - depth of thoracic kyphosis (GKP),
   - depth of lumbar lordosis (GLL)

   (see Fig. 1).

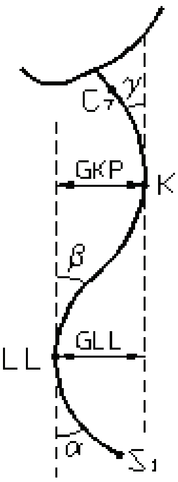

Fig. 1. Key points and parameters necessary to compute the shape of the anteroposterior spinal curves (source: own material)
Legend: γ – thoracic spine inclination angle, β – thoracolumbar spine inclination angle, α – lumbosacral spine inclination angle, GKP – depth of thoracic kyphosis, GLL – depth of lumbar lordosis

2.3. Functional examination of trunk muscles

The examination of force-velocity (FV) parameters of trunk flexors and extensors was performed using Biodex Multi Joint 3 (Fig. 2).

The FV test began with a warm-up: each subject performed 3 sub-maximal actions of flexion and extension of the trunk in order to determine the preset load, which was followed by testing at 60°/s (5 repetitions) and 120°/s (10 repetitions). This method enabled to explore the potential of muscles' strength without their excessive fatigue [9], [10].

Fig. 2. Isokinetic examination of the trunk muscles – position and stabilization of the body (source: own material)

Torque values were measured during the proper test.

All of the measurements of trunk flexion and extension in the sagittal plane performed with maximum force, at the shortest possible time were recorded at every angular speed. There was a 30 s rest between each repetition and upon the change of angular velocity the rest was elongated to 3 minutes time.

Before each test, the chair and dynamometer was reset, so that the arm of dynamometer was located at L_5/S_1 height. Each time the motion range was set to approximately 90° (35° extension, 55° flexion). The trunk and thighs of a child were stabilized by means of tapes attached to the chair in order to eliminate auxiliary movements [8].

The analysis of FV parameters included:

- Peak torque [Pt] (Nm): peak torque of extensors (Pt E60°/s and Pt E120°/s) and flexors (Pt F60°/s and Pt F120°/s);
- Peak torque/body mass [Ptb] (%): relative torque of extensors (Ptb E60°/s and Ptb E120°/s) and flexors (Ptb F60°/s and Ptb F120°/s);
- Total work [TW] (J): total work from all repetitions of extensors (TW E60°/s and TW E120°/s) and flexors (TW F60°/s and TW F120°/s).

2.4. Methods used for statistical analysis

Statistical analysis was performed using Excel and Statistica 9.0 software by StatSoft. The Shapiro–Wilk and Kolmogorow–Smirnow tests were used to evaluate statistical distribution of the results. The critical level of statistical significance was set at $p \leq 0.05$. Obtained results were subjected to a statistical analysis. The pattern of distribution and homogeneity of variance were checked. Mean values and standard deviations were computed. Next, the researchers calculated the Pearson r correlation coefficient describing the strength and direction of correlation between the values of thoracic kyphosis, lumbar lordosis and the FV parameters of flexors and extensors of males and females. The following interpretation of results was implemented [21]:

- no correlation $r < 0.1$,
- weak correlation $0.1 \leq r < 0.3$,
- average correlation $0.3 \leq r < 0.5$,
- strong correlation $0.5 \leq r < 0.7$,
- very strong correlation $0.7 \leq r < 0.9$,
- nearly complete correlation $0.9 \leq r < 1.0$.

3. Results

Table 1 presents the descriptive statistics of height, mass and BMI, where no significant sex differences were observed.

The associations between the somatic variables and trunk FV characteristics and spinal curvatures are given in Table 2, where the majority of the observed correlations in both groups were average with few strong correlations. Height, mass, and BMI positively correlated with extensor and flexor Peak torque (Pt) and Total work (TW) at both angular speeds (60°/s and 120°/s). Additionally, in both males and females a strong positive correlation was present between height and TW at F60 and height and TW F120. The remaining significant correlations between the somatic measures and trunk flexor and extensor FV characteristics were weak or average (Table 2).

Table 1. Means and standard deviations and statistical differences between the somatic variables in the female and male groups

Variable	Females		Males		p
	mean	sd	mean	sd	
Body height [cm]	141.79	5.61	142.53	5.21	0.7423
Body weight [kg]	37.02	6.41	37.81	6.98	0.8871
BMI	18.18	3.22	17.97	3.36	0.4112

Table 2. The Pearson correlation coefficient of selected features of somatic body structure parameters and strength-velocity parameters and selected parameters of curvature of the spine in group of females and males ($p < 0.05$)

Variable		Females			Males		
		Body height	Body weight	BMI	Body height	Body weight	BMI
Peak torque [Pt] (Nm)	E 60	0.24	**0.34**	0.31	**0.34**	0.31	0,32
	F 60	**0.34**	**0.41**	**0.34**	**0.51**	**0.41**	0,31
	E 120	0.20	0.31	0.28	**0.34**	**0.38**	**0,34**
	F 120	0.11	0.17	0.11	**0.42**	0.11	0,10
Total work [TW] (J)	E 60	0.27	0.27	**0.41**	**0.47**	**0.34**	0,17
	F 60	**0.54**	**0.41**	**0.34**	**0.58**	0.29	0,10
	E 120	**0.34**	**0.38**	**0.34**	**0.41**	**0.34**	0,21
	F 120	**0.51**	**0.37**	**0.37**	**0.57**	0.31	**0,34**
Angle α		0,10	0.28	0.32	**0.35**	**0.55**	**0.55**
Angle β		**–0,49**	**–0.38**	–0.23	–0.18	–0.04	0.11
Angle γ		0,16	**0.32**	**0.32**	–0.12	–0.12	–0.06
GKP		**–0,39**	**–0.35**	–0.24	–0.19	–0.10	0.05
GLL		**0,38**	**0.34**	0.23	0.18	0.05	–0.15

Legend: γ – thoracic spine inclination angle (°), β – thoracolumbar spine inclination angle (°), α – lumbosacral spine inclination angle (°), GKP – depth of thoracic kyphosis (mm), GLL – depth of lumbar lordosis (mm); E60 – extensors 60°/s, E120 – extensors 120°/s, F60 – flexors 60°/s, F120 – flexors 120°/s.

Analysis of the correlations between the somatic and spinal curvature variables showed significant correlations primarily in the females. Height and mass both negatively correlated with thoracolumbar spine inclination angle (β) and thoracic kyphosis depth (GKP) whereas mass and BMI showed positive average correlations with lumbar lordosis depth (GLL). In the group of males, the only significant correlation was positive between height, mass and BMI and lumbosacral spine inclination angle (α) (Table 2).

Table 3 presents the correlations between the size of spinal curvatures in the sagittal plane and extensor and flexor FV characteristics in the female group, where most were of weak or average value. Average correlations were observed between lumbosacral spine inclination angle (α) and Pt F60 and Pt E120 and between thoracolumbar spine inclination angle (β) and TW F60. For these associations in the male group, additional significant correlations were found (Table 4) although correspondingly weak or average as in the female group. Average positive correlations were indicated between lumbar lordosis depth (GLL) and Pt F120, Ptb 120, TW F60, TW E120 and TW F120. Among the angular variables, average positive correlations were also determined between lumbosacral spine inclination angle (α) and Pt F60 as well as thoracic spine inclination angle (γ) and Ptb F120. Among the negative yet significant average correlations were thoracolumbar spine inclination angle (β) and Pt F120, TW F60 and TW F120. Lastly, average negative correlations between thoracic kyphosis depth (GKP) and Pt F120, Ptb F120, and TW E60 were also observed in the males.

Table 3. The Pearson correlation coefficient of selected parameters of curvature of the spine and strength-velocity parameters flexor and extensor muscles in the trunk of a group of females ($p < 0.05$)

Variable		Angle α	Angle β	Angle γ	GKP	GLL
Peak torque [Pt] (Nm)	E 60	0.28	–0.24	–0.17	–0.14	0.21
	F 60	**0.34**	–0.17	–0.18	–0.20	0.24
	E 120	**0.34**	–0.11	–0.24	–0.21	0.20
	F 120	0.10	–0.24	0.10	–0.20	0.20
Peak torque/body mass [Ptb] (%)	E 60	–0.10	–0.20	0.10	–0.09	0.17
	F 60	0.10	0.14	–0.10	–0.10	0.10
	E 120	0.11	–0.12	0.11	–0.14	0.11
	F 120	–0.24	–0.17	0.24	–0.14	0.31
Total work [TW] (J)	E 60	0.21	–0.20	–0.24	–0.18	0.11
	F 60	0.17	**–0.34**	–0.10	–0.31	0.21
	E 120	0.24	–0.27	–0.24	–0.11	0.04
	F 120	0.19	–0.14	–0.14	–0.11	0.17

Legend: γ – thoracic spine inclination angle (°), β – thoracolumbar spine inclination angle (°), α – lumbosacral spine inclination angle (°), GKP – depth of thoracic kyphosis (mm), GLL – depth of lumbar lordosis (mm); E60 – extensors 60°/s, E120 – extensors 120°/s, F60 – flexors 60°/s, F120 – flexors 120°/s.

Table 4. The Pearson correlation coefficient of selected parameters of curvature of the spine and strength-velocity parameters flexor and extensor muscles in the trunk of a group of males ($p < 0.05$)

Variable		Angle α	Angle β	Angle γ	GKP	GLL
Peak torque [Pt] (Nm)	E 60	0.31	–0.24	–0.17	–0.21	0.31
	F 60	**0.34**	–0.17	0.31	–0.17	0.24
	E 120	0.24	–0.14	–0.21	–0.17	0.20
	F 120	0.10	**–0.34**	0.10	**–0.41**	**0.41**
Peak torque/body mass [Ptb] (%)	E 60	–0.01	–0.11	0.10	–0.11	0.11
	F 60	–0.10	0.12	–0.17	–0.17	0.11
	E 120	–0.10	–0.13	0.11	–0.18	0.10
	F 120	–0.10	–0.31	**0.34**	**–0.34**	**0.36**
Total work [TW] (J)	E 60	0.10	–0.12	–0.24	**–0.34**	0.27
	F 60	0.11	**–0.34**	0.01	–0.21	**0.34**
	E 120	0.22	–0.30	–0.21	–0.31	**0.37**
	F 120	0.19	**–0.34**	–0.17	–0.27	**0.37**

Legend: γ – thoracic spine inclination angle (°), β – thoracolumbar spine inclination angle (°),α – lumbosacral spine inclination angle (°), GKP – depth of thoracic kyphosis (mm), GLL – depth of lumbar lordosis (mm); E60 – extensors 60°/s, E120 – extensors 120°/s, F60 – flexors 60°/s, F120 – flexors 120°/s.

4. Discussion

The aim of this study was to find correlations existing between trunk muscles' activity, body height, body mass, BMI and shape of thoracic kyphosis and lumbar lordosis expressed by their angular values and depth in healthy children aged 10–11 years. This age marks the end of prepubescent stage, characterized by a plateau in physical growth. However, this period is a time when development equalizes across children of similar chronological age [25], as exemplified by limited variance in the anthropometric measures (height, mass and BMI) we obtained in both sex groups. While the males were slightly heavier and taller, mean BMI was marginally greater in the females. At the same time it is a period of adverse changes in body posture. The changes observed in young people are frequently caused by their sedentary lifestyle, excess of curricular and extracurricular duties, limited physical activity and bad eating habits [4], [7], [14]. It is also alarming that unspecified and unexplainable back pain is more frequently reported in younger and younger children [6], [7], [14].

The results of this study revealed an existence of many correlations between somatic features and FV parameters of trunk flexors and extensors in both males and females. Of interest is the fact that the directions and magnitudes of the observed changes were similar between groups. However, the correlations displayed certain grouping tendencies in both sexes. The majority of the positive correlations we observed were average ($0.3 < r < 0.5$) and primarily between the somatic variables and flexor and extensor Peak torque and Total work at 60°/s and 120°/s. This finding indicates that increased height and mass are associated with enhanced muscular ability to generate greater force and endurance. In turn, negative correlations were found between the somatic variables and Peat torque/body mass for both flexors and extensors at both movement speeds. Furthermore, a strong positive correlation ($r > 0.5$) was also indicated in both groups as regards body height and Total work for the trunk flexors at both angular speeds. It can therefore be posited that gains in body height are accompanied by trunk flexor force development and endurance. Additionally, we can presume that the magnitude of the analysed somatic variables will have a greater effect on flexor and extensor FV characteristics than the development of anteroposterior spinal curvature.

Numerous cross-sectional and longitudinal studies have indicated strong relationships between stature, body mass and isokinetic leg strength [9]. Some studies have suggested that correlations between stature, mass and isokinetic strength vary depending on chronological age and sex [9], [10], [12]. De Ste Croix et al. reported correlations between stature and peak flexion torque ranging from 0.23 in 9-year-old boys to 0.84 in 14-year-old boys. Girls' data from the same study ranged from 0.33 between stature and extension torque in adult females to 0.81 between mass and extension torque in teenage girls [10]. Similar data are presented by Hildebrand et al., with correlations ranging from 0.37–0.76 for stature and 0.18–0.59 for mass in 9- to 12-year-old females [12]. Nonetheless, it is difficult to compare the present results with the findings of the aforementioned authors due to differences in analysed movement structures [9]. It is also difficult to compare results of this study with results of other authors, as there are not many studies on such correlations in population of healthy children and youth, who have no distinct disorders of the motor system. It is a significant problem, as these children are reaching the pubertal spurt period in their lives.

The number of studies dealing with evaluation of trunk muscles' strength in normally developing population is scarce. Danneskiold-Samsøe et al. made observations on healthy subjects of both sexes that led them to a conclusion that trunk and limb muscles strength is decreasing along with age of subjects [7].

Other authors present results of studies on flexors to extensors torque ratios in healthy subjects in the aspects of age and sex. In healthy people, the forces of the trunk extensor muscles are greater than those of flexors [4]. The Agonist/Antagonist Ratio (Flexors/ Extensors Ratio) has a normal value of 0.8 to 0.96 in both older groups [24]. However, it is difficult to compare results of this study with results of the above authors, as the age groups examined differ significantly. Those authors examined adults, we examined children aged 10–11 years.

Our findings on the associations between anteroposterior spinal curvatures and trunk muscle FV characteristics found overwhelmingly average correlations ($0.3 < r < 0.5$), with a slightly greater distribution among the males. In this group, most correlations were centred on lumbar lordosis depth and extensor and flexor Total work at both movement speeds. As positive correlations, this finding indicates that excessive upper lumbar lordosis may promote lower trunk endurance primarily among flexor muscles. This is confirmed by the significant relationships between the greater angular speed (120°/s) and all of the trunk FV variables. Other studies have also substantiated the observation that children in the present age group present excessive lumbar lordotic curvature and strengthened back musculature [25].

Research conducted on a group of healthy subjects provides results which may serve as a preliminary diagnosis of their motor organs. The results are particularly important since they may be used to compare with those obtained in the examination of subjects diagnosed with musculoskeletal disorders, postural disorders – excessive deepening or shallowing of anteroposterior spinal curves, lateral bending of the spine or changes in the shape of the curves resulting from involution processes. They may also be used as a data base for control of progress of corrective therapy and constitute valuable information for clinicians about normative value of healthy population during growth [15] and adult population [16].

Barczyk-Pawelec et al. evaluated trunk muscles strength in children with normal and abnormal posture. They observed among the males and females with poor posture abnormal anterior-posterior curvature of the spine was associated with lower values of isokinetic trunk muscle strength [3]. Skrzek et al. investigated trunk muscles strength in disorders of body statics. They observed weakening of postural muscles in girls with idiopathic scoliosis in comparison to healthy peers – all results were statistically significant. They also confirmed that static disorders in sagittal or frontal plane reduce trunk muscles' strength in subjects who suffer from these disorders [20]. Studies of Anwajler et al. showed differences in strength of trunk flexors and extensors depending on the size of particular curves of the spine in girls with idiopathic scoliosis – the primary scoliosis was of high importance in this case [1]. Rehabilitation of children with scoliosis is aimed at restoration of muscular balance and coordination of motor patterns. Increasing efficiency of integration processes of the central nervous system enhances stabilization of the spine, control of postural stability and motor coordination [22].

Regardless of limitations, this research may be a valuable guidance to therapists and clinicians since it was conducted on a large homogenous group of children which can also constitute a control group. Comparison of the results obtained may be used to create suitable therapy programmes aiming to improve motor abilities in patients with diagnosed musculoskeletal disorders.

5. Conclusions

Significant correlations were observed between the somatic variables and force-velocity characteristics in both sexes although more in the group of males. Body mass and height were significantly associated with anteroposterior spinal curvature, primarily in females. Only some of the force-velocity characteristics were associated with anteroposterior spinal curvature, where the strongest relationship was between total work and lumbar lordosis depth and thoracolumbar spine inclination angle. Stronger correlations were observed between the somatic variables and force-velocity characteristics of trunk flexors and extensors than between muscle strength and spinal curvature shape in the sagittal plane.

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