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Anthropometric Parameters as Predictors for Iliopsoas Muscle Strength in Healthy Girls and in Girls with Adolescent Idiopathic Scoliosis

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A B S T R A C T

In this study iliopsoas muscle strength was measured by portable dynamometer and it was explored to what extent independent predictors (age, body weight, body height and body mass index) affect iliopsoas strength in healthy subjects and in subjects with adolescent idiopathic scoliosis. The study population was consisted of 183 girls (90 healthy girls and 93 girls with adolescent idiopathic scoliosis). Student t test analysis showed no differences in maximal voluntary isometric contraction between healthy girls and girls with scoliosis. Independent variables predicted significantly iliopsoas strength in healthy group ($r=0.96$, $p<0.01$) and in scoliosis group ($r=0.94$, $p<0.001$). Separate analysis with respect to types of scoliosis demonstrated that independent variables significantly predict iliopsoas strength in right thoracic ($r=0.97$, $p<0.01$), left thoracic ($r=0.98$, $p=0.004$), right thoracic lumbar ($r=0.97$, $p<0.01$) and left lumbar ($r=0.96$, $p<0.01$) scoliosis subgroups. In healthy girls iliopsoas strength was mostly predicted by body weight, followed by body height and body mass index. In girls with scoliosis body weigth was the strongest predictor of iliopsoas strength and was followed by curvature angle degree.

Key words: *adolescent girls, scoliosis, dynamometer, iliopsoas muscle, reliability, multiple regression analysis*

Introduction

Adolescent idiopathic scoliosis (AIS), a structurally fixed lateral curvature of the spine with a rotary component, is diagnosed after the onset of puberty. There is at least a 10 degree curvature as demonstrated by the upright spine roentgenograms using the Cobb's method[1]. Deformities that affect certain fragments of the spine usually lead to trunk asymmetry, which could be presented with altered head position or disproportional length of the limbs[2]. It could be expected that unstable curves in lateral position tend to be progressive and lead to unbalanced muscle activity. If continued paraspinal muscles alterations are recognized as a weakness on the concave versus to increased tonic activity on the convex side of the scoliosis curve[3,4]. Skeletal muscles play an important role in static and dynamic maintenance of spinal stability and upright posture in humans. Deep muscles of the back such as multifidus mm. and erector spine mm. largely contribute to spine stability with their static functions. Among other muscles of the lower limb, iliopsoas is an important antigravity postural muscle. Iliopsoas muscle acts in the hip joint as a flexor and lateral rotator of the leg[5,6]. The psoas portion originates from the bodies of the lumbar vertebrae and therefore, this muscle is generally considered an active postural muscle[7,8]. With respect to above mentioned facts we hypothesize that scoliosis deformity could change the psoas major in a same manner as it affects paraspinal muscles. Accordingly, our specific aims were: 1. To explore differences in iliopsoas strength between healthy subjects and subjects with scoliosis 2. To explore to what extent independent predictors (age, body weight, body height and body mass index – BMI) affect iliopsoas strength in healthy subjects and to explore the same in scoliosis examinees, including influence of variable curvature angle degree.

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Subjects and Methods

This study comprised 183 school and college girls, aged 15–19 years. All subjects were divided in two groups: controls (n=90) and scoliosis (n=93) (Table 1). Prior to investigation, scoliosis was diagnosed during regular physical examination, which includes upright visual inspection of the back and the Adams forward – bending test. Standing roentgenograms of the vertebral column were obtained to determine the degree of lateral spine curvature by the Cobb's method and a curvature of 10 degrees or higher was defined as structural scoliosis. None of the girls with scoliosis had positive history of Chiari malformation or any other neurological disease that could alter muscle strength including iliopsoas. Ninety healthy girls underwent the same investigation protocol as girls with scoliosis did. Also, none of the examinees participated any of organized form of the physical activity. Informed consent was obtained from school authorities and the children's parents, while verbal consent was obtained from all the examinees after testing procedure was explained. The local ethic committee approved this study. Standing height was measured by a portable stadiometer on subjects without shoes in an upright posture with heads in horizontal position and shoulders relaxed. Height was measured with an accuracy of ±0.5 cm. Weight was measured on subjects without shoes who wore indoor clothing and presented in portable scales with an accuracy of ±0.1 kg. BMI was calculated for each participant as weight in kilograms divided by the square of height expressed in meters. Maximal voluntary isometric contraction of the iliopsoas muscle was measured with a portable electronic dynamometer (Kinedyne S1, Smith & Nephew Kinetec S.A., Tournes, France). This dynamometer is a measuring and exercising device, designed for the upper and lower limbs. It measures muscle force at a range of 0 to 390 Newton's (N) (to the nearest 0.1 Newton's). A single female tester performed all measurements on the subjects. Examinees were placed in a supine body position with tight abducted and laterally rotated hip joint and an extended knee joint. The opposite iliac crest was stabilized by the assistant's hand. Such testing positions were selected to minimize the effect of agonist muscles and were originally proposed by Kendall and Walther[9,10]. The dynamometer cuff was applied on the anterior aspect of the distal third of the thigh and fixed on the table below the subject's leg. Hip flexion was tested bilaterally and any possible lifting of the legs was prevented during testing. Subjects were told to stop contracting when the tester finished counting to five. Three measurements were obtained within 10 seconds of the rest intervals and an average value was noted. Each person was tested twice. Two assessments were performed in the morning and repeated six hours later during the afternoon. Distance between anterior spine of the iliac crest and medial malleolus of the ankle was measured to exclude unequal length of the lower limbs.

Statistics

Statistica 7.1 (StatSoft) computer software (StatSoft Inc, Tulsa, United States) was used for statistical analyses. After the data were tested for normal distribution, Student t test for independent samples was used to explore differences in iliopsoas strength between girls with scoliosis and controls. Multiple linear regression analysis was used to explore to what extent independent variables predict iliopsoas strength in controls and scoliosis. Separate multivariate analysis with respect to different types of scoliosis was used to expore the effect of independent predictors on the iliopsoas strength in five subgroups which include right thoracic, left thoracic, right thoracic lumbar, left thoracic lumbar and left lumbar scoliosis.

Results

Characteristics of the study participants are presented at the table 1. No significant difference was found in age, weight, height and BMI between girls with scoliosis and controls. Although iliopsoas strength did not differ between given groups of subjects, healthy girls had for 10.5 % stronger iliopsoas muscle than scoliosis group did (Table 1). Out of the 93 diagnosed scoliosis, 51 (84%; 41 right and 10 left) were thoracic; 23 (24.73%; 16 right and 7 left) were thoracic lumbar; and 19 were lumbar (20.43%; all with left curves) (Table 2). Both iliopsoas muscles responded almost equally during testing, irrespective of whether scoliosis or controls performed it. Inter-rater reliability coefficients were obtained after the first and second measurements. Yield ICC values were very acceptable, with values above 0.96 (Table 3). Independent predictors (age, body weight, body height, BMI) had significant effect on the iliopsoas muscle strength in

TABLE 1
DIFFERENCES BETWEEN HEALTHY AND SCOLIOSIS GROUP

Characteristic	Scoliosis (n=93) (X ± SD)	Controls (n=90) (X ± SD)	P level
Age (years)	17.23 ± 1.24	17.34 ± 1.25	0.52
Weight (kg)	60.50 ± 8.19	60.30 ± 8.24	0.86
Height (cm)	167.6 ± 6.92	1.678 ± 6.98	0.87
Body mass index (kg/m^2)	21.43 ± 1.38	21.30 ± 1.43	0.52
Iliopsoas strength (N)	145.8 ± 44.89	163.0 ± 54.1	0.02

n – number of subjects

healthy group (r=0.96, p<0.01). Body weight was the strongest predictor for the iliopsoas strength, followed by body height and BMI (Table 4 and 5). Body weight was positively associated to iliopsoas strength, while body height and BMI were negatively correlated to it, with significance (p<0.01), respectively (Table 4 and 5). Similarly, body weight (p<0.01) was the strongest positive predictor for iliopsoas strength in scoliosis group, followed by curvature angle degree (p<0.05) as negative predictor (Table 4 and 5). Separate analysis for different types of scoliosis showed that body weight was the strongest positive predictor, followed by body height and BMI as negative predictors for iliopsoas strength in the right thoracic (p<0.01) and right thoracic lumbar subgroups (p<0.01), while the opposite was observed in left lumbar subgroup of subjects (p<0.05). All six predictors had significant influence on iliopsoas strength in left thoracic deformities (r=0.98, p=0.004), while given predictors did not affect significantly iliopsoas strength in the left thoracic lumbar scoliosis (r=0.99, p=0.18).

Discussion

The aim of this study was to compare iliopsoas strength between scoliosis subjects and controls and also to estimate the effect of age and anthropometric parameters on iliopsoas strength in both groups. Even there is significant number of studies that have measured skeletal muscle strength in healthy girls[11–15], none has ever estimated strength of any skeletal muscle in scoliosis. To the best of our knowledge this is the first study comparing iliopsoas muscle strength between adolescent subjects with scoliosis and controls. Also this is the first study analyzing the effect of an age, anthropometric parameters and curvature angle degree on iliopsoas strength in girls with scoliosis. All examinees recruited for this study were carefully chosen to be of approximate age and anthropometric characteristics. Also none of them practiced any kind of organized form of physical activity. Iliopsoas strength testing was performed on study subjects when they were from 15 to 19 years of age, which is commonly considered as an age when the growth spurt in girls is finished[16]. Such homogeneity in age and anthropometric characteristics between examined groups of subjects is important argument which supports relevance of the results obtained. Primary curvature in lumbar spine includes torsion of the spinal vertebrae which affects paravertebral muscles in a way that at the convex side of deformity curve muscles are extended, while shortened at the concave side[17]. Iliopsoas muscle originates

TABLE 2
CHARACTERISTICS OF THE SUBJECTS ACCORDING TO DIFFERENT TYPE OF SCOLIOSIS

	Right thoracic scoliosis	Left thoracic scoliosis	Right thoracic lumbar scoliosis	Left thoracic lumbar scoliosis	Left lumbar scoliosis
Total number	41	10	16	7	19
Physical therapy	22	5	10	3	10
Orthosis	19	5	6	3	9
Operation	–	–	–	1	–
Curvature angle size					
10–19°	22	5	10	3	10
20–29°	14	3	5	1	5
30–39°	5	1	1	2	4
40–49°	–	1	–	–	–
50–59°	–	–	–	1	–
Iliopsoas strength (N) (X ± SD)	143.48 ± 47.87	142.76 ± 46.8	162.90 ± 46.45	133.48 ± 42.15	142.65 ± 37.04

°– degree of scoliosis curvature angle

TABLE 3
MEAN AND STANDARD DEVIATION VALUES OF ILIOPSOAS MUSCLE FORCE IN NEWTON (N) AND INTRACLASS CORRELATION COEFFICIENTS

	Controls			Scoliosis		
	Mean force (N)			Mean force (N)		
Side	Test 1	Test 2	ICC	Test 1	Test 2	ICC
Right leg	161.9 ± 17	165.1 ± 17	0.96	145.2 ± 20.2	146.8 ± 19.8	0.97
Left leg	160.9 ± 16.8	164.1 ± 16.9	0.96	143.3 ± 19.5	146.3 ± 19.3	0.96

Test 1 – measures taken immediately, Test 2 – measures taken six hours later, ICC – intraclass correlation coefficient estimating interrater reliability between two measurements from the lumbar vertebral bodies and it could be expected that under described conditions this muscle is affected too. Just opposite to what was expected, our results suggest good muscle adaptation in scoliosis group. Similar iliopsoas strength between left and right muscles is the proof for afore mentioned, as well as the finding that the strength of this muscle does not differ between scoliosis (144.3 N) and controls (161.4 N). Such good iliopsoas adaptation is probably due to compensatory curve which we believe, has been developed in the most of scoliosis cases. With respect to other studies, our results are comparable to those where muscle strength was measured on healthy subjects and similarity in hip flexors strength between both legs was confirmed many times though[11–14]. In a study of Bäckman et al.[11], hip flexor muscle force values for both legs were 246±44 N, respectively. This data was obtained on girls from 17–18 years of age with an average weight of 58 kg and average height of 166 cm. Although some of our healthy examinees were of the same body weight and height as those in the Bäckman survey, we obtained smaller values of muscle strength in both legs (161.4 N). Our results were obtained by a specific iliopsoas test, which minimizes the effect of agonist muscles. We believe that iliopsoas muscle testing was successful and our muscle force data are adequate for it's isolated contraction. Iliopsoas strength was predicted by four independent variables (age, body weight, body height, BMI) in healthy subjects and five in-

TABLE 4
MULTIPLE LINEAR REGRESSION MODELS PREDICTING ILIOPSOAS STRENGTH IN ADOLESCENT GIRLS

Dependent variable	Independent variable	r	r^2	F	p
Iliopsoas strength scoliosis	Age BMI Body height Body weight Curvature angle degree	0.95	0.89	149.03	0.0000
Iliopsoas strength controls	Age BMI Body height Body weight	0.96	0.93	262.87	0.0000
Iliopsoas strength right thoracic scoliosis	Age BMI Body height Body weight Curvature angle degree	0.98	0.96	164.72	0.000
Iliopsoas strength left thoracic scoliosis	Age BMI Body height Body weight Curvature angle degree	0.98	0.97	23.72	0.004
Iliopsoas strength right thoracic lumbar scoliosis	Age BMI Body height Body weight Curvature angle degree	0.97	0.95	37.30	0.000
Iliopsoas strength left thoracic lumbar scoliosis	Age BMI Body height Body weight Curvature angle degree	0.99	0.99	17.21	0.181
Iliopsoas strength left lumbar scoliosis	Age BMI Body height Body weight Curvature angle degree	0.97	0.94	39.99	0.000

BMI – body mass index

TABLE 5
SIGNIFICANT MULTIPLE LINEAR REGERSSION MODELS PREDICTING ILIOPSOAS STRENGTH IN ADOLESCENT GIRLS (ONLY SIGNIFICANT INDEPENDENT VARIABLES ARE SHOWN)

Dependent variable	Independent variable	Beta	r	p
Iliopsoas strength scoliosis	Body weight	1.293	0.274	0.009
	Curvature angle degree	–0.119	–0.267	0.011
Iliopsoas strength controls	Body weight	5.350	0.582	0.000
	Body height	–2.503	–0.473	0.000
	BMI	–2.327	–0.554	0.000
Iliopsoas strength right thoracic scoliosis	Body weight	3.517	0.532	0.000
	BMI	–1.486	–0.491	0.002
	Body height	–1.349	–0.368	0.025
	Curvature angle degree	–0.129	–0.433	0.007
Iliopsoas strength right thoracic lumbar scoliosis	Body weight	5.965	0.747	0.005
	Body height	–2.854	–0.663	0.019
	BMI	–2.515	–0.722	0.008
Iliopsoas strength left lumbar scoliosis	Body height	4.985	0.634	0.011
	BMI	2.751	0.623	0.013
	Body weight	–6.721	–0.603	0.017
	Curvature angle degree	–0.89	–0.744	0.001
	Age	–0.255	–0.599	0.018

BMI – body mass index

dependent variables (age, body weight, body height, BMI, curvature angle degree) in subjects with scoliosis. Body weight is the best predictor for iliopsoas strength. Since body weight is important determinant for normal physiological functions of skeletal muscles in humans, result of positive association between body weight and iliopsoas strength is expected, as it would be for any skeletal muscle. The evidence is found in study of Forbes[18] who suggests that lean mass is logarithmically related to body fat. Thus, heavier subjects of all ages have greater lean mass and they are generally stronger when asked to perform tests of muscle strength. Positive effect of body weight is also observed in subgroups of the right thoracic (n=41) and right thoracic lumbar scoliosis (n=16). Healthy girls are presented with normal weigth values (BMI=21.3 kg/m^2) and BMI is negatively associated to iliopsoas strength. BMI is generally considered as obesity index, and as it was presented by Health, Ageing and Body Composition Study high percentage of fat mass is associated with low muscle quality, especially in the lower limbs[19]. Regardless to significant negative association between curvature angle and iliopsoas strength in subjects with scoliosis, theirs muscle's strength is maintained and well adapted, though. Negative association between iliopsoas strength and body weight in the left lumbar scoliosis is unusual especially after body weight is the strongest positive predictor not only in healthy subjects, but also in overall scoliosis. Even skeletal muscles take the major part in ones body weight, other predictors than body weight, in the first place body height and BMI have mostly contributed to good iliopsoas adaptation in the left lumbar scoliosis during test performance by electronic dynamometer.

Conclusions

Iliopsoas muscle showed good adaptation in subjects with adolescent idiopathic scoliosis. In most adolescent girls, with exception of the left lumbar subgroup body weight was the strongest positive predictor for iliopsoas strength. In subjects with left lumbar scoliosis body height and BMI have mostly contributed to good iliopsoas adaptation during test performance by electronic dynamometer.

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ANTROPOMETRIJSKI PARAMETRI KAO POKAZATELJI JAKOSTI MIŠIĆA ILIOPSOASA KOD ZDRAVIH DJEVOJAKA I DJEVOJAKA S ADOLESCENTNOM IDIOPATSKOM SKOLIOZOM

S A Ž E T A K

U ovoj studiji izmjerna je jakost mišića iliopsoasa prijenosnim dinamometrom te je ispitano u kojem opsegu prediktorske varijable (starosna dob, tjelesna visina, tjelesna težina i indeks tjelesne mase) utječu na jakost mišića kod zdravih djevojaka i djevojaka sa skoliozom. Istraživanjem su obuhvaćene 183 ispitanice (90 zdravih djevojaka i 93 djevojke s adolescentnom idiopatskom skoliozom). Studentskim t testom nije nađena značajna razlika u vrijednostima maksimalne voljne kontrakcije između zdravih djevojaka i djevojaka sa skoliozom. Prediktorske varijable značajno utječu na jakost mišića iliopsoasa u zdravih djevojaka ($r=0,96$, $p<0,01$) i u djevojaka sa skoliozom ($r=0,94$, $p<0,001$). Odvojenom analizom obzirom na tip skoliotičnog zavoja dokazano je da prediktorske varijable značajno utječu na jakost mišića u desnoj torakalnoj ($r=0,97$, $p<0,01$), lijevoj torakalnoj ($r=0,98$, $p<0,004$), desnoj torakolumbalnoj ($r=0,97$, $p<0,01$) i lijevoj lumbalnoj ($r=0,96$, $p<0,01$) skoliozi. Najvažniji pokazatelj jakosti mišića iliopsoasa u zdravih djevojaka je tjelesna težina iza koje slijede tjelesna visina i indeks tjelesne mase. U grupi djevojaka sa skoliozom najvažniji pokazatelj njihove mišićne jakosti je tjelesna težina iza koje slijedi stupanj skoliotičnog zavoja.