

DYNAMICS OF SCHOOLCHILDREN'S SPINE SAGITTAL CURVES, PARAMETERS OF CARDIOVASCULAR SYSTEM AND THEIR COHERENCE

Vilma Mauricienė¹, Arūnas Emeljanovas², Kristina Bačiulienė¹, Algė Daunoravičienė¹
Kaunas University of Medicine¹, Lithuanian Academy of Physical Education², Kaunas, Lithuania

Vilma Mauricienė, PhD in Biomedical Sciences, Lecturer at the Department of Kinesiology and Sports Medicine, Kaunas University of Medicine. Research interests — interrelation between different body posture parameters of children and adolescents, factors influencing body posture.

ABSTRACT

Objective. We aimed to investigate the peculiarities of cardiovascular system parameters and changes in spine sagittal curves with age in schoolchildren and also possible interrelation between parameters in those two systems.

Material and methods. 124 schoolchildren (aged 7—18 years) were divided into three groups according to their age. For evaluation of cardiovascular system the bicycle ergometry test with modified Bruce protocol was performed and computerized functional test analysis system “Kaunas — Load” was used. Load, arterial blood pressure, ECG in 12 standard derivations were synchronously recorded at every step. Evaluation of spine sagittal plane was performed using flexible ruler-cirtometer. Angular values of thoracic kyphosis and lumbar lordosis were measured.

Results. Parameters of sagittal spine had few differences according to gender and age. Changes in sagittal plane curves with age were greater in boys than in girls. In the group of boys the expression of both sagittal curves had decreasing tendencies with age. Changes in girls' sagittal curves were inconsistent with age. However, we found many significant differences in the parameters of cardiovascular system's depending on gender and age. Different correlations between spinal sagittal curves and cardiovascular parameters according to gender and age could be associated with different state in musculoskeletal system and development, different physical activity level and many other factors, which vary among girls and boys and also changes with age.

Conclusions. There was no significant difference of lumbar lordosis according to gender in all age groups. The thoracic kyphosis had significant different expression only among boys and girls in 7—10 years age group. We found significant difference of such cardiovascular system parameters as index of health, maximal power, pressure rate index, half recovery period of heart rate and change of double product according to gender. Thoracic kyphosis had more correlations with cardiovascular system parameters than lumbar lordosis. Blood pressure reactions had more correlations with spine sagittal curves in older girls and younger boys.

Keywords: sagittal spine curves, cardiovascular system, lumbar lordosis, thoracic kyphosis.

INTRODUCTION

The organism of developing children is unique in its functions and structure. The organism of a growing child shows many alterations in different systems. A lot of changes occur in musculoskeletal and cardiovascular systems while the child becomes grown-up (Milicevic et al., 2003; Rogol, 2003).

The cardiovascular system of children responds to exercise differently than does that of an adult (Turley, 1997; Turley, Wilmore, 1997 a, b). Some differences were also established in blood pressure distribution. Research data lends some support to the concept of the evolution from a hyperkinetic circulation in early childhood to a circulation with

lower cardiac output and more elevated systemic vascular resistance at an older age (Schieken et al., 1983). Differences in cardiovascular responses to dynamic exercise between young boys and girls have also been reported (Obert et al., 2003). The majority of studies report that heart rate is lower and systolic volume is higher in boys than girls at a given rate of work, although data to the contrary have been reported. These differences seem to be related to larger hearts in the boys (Turley, 1997). Other researchers found no significant differences between boys and girls in maximal oxygen consumption or physical characteristics except for a significantly larger left ventricular mass in the boys versus the girls (Turley, Wilmore, 1997 a). They concluded that in sample of 7- to 9-yr-old boys and girls there are few significant differences in submaximal cardiovascular responses to exercise on either exercise modality. Girls demonstrate a lower stroke volume than boys, which has been compensated for by a higher heart rate at each observation (Armstrong, Welsman, 2002).

Body posture of children also has its peculiarities comparing with adults (Poussa et al, 2005). Asymmetric body posture is a common musculoskeletal disorder among children. Abnormalities of frontal or sagittal plane posture influences children's physical and psychological health.

Recently decreased physical activity level of children strongly influences the functioning of their cardiovascular and musculoskeletal system (Sukhareva et al., 2002; Eisenmann, 2004; Ribeiro et al., 2004). The prevalence of different trunk asymmetries is increasing in Lithuania (Lindišienė, Murauskienė, 1999) and in other countries (Nissinen et al., 2000) as well.

Very often the functions of these important systems are analyzed separately and the data of integrated evaluation are missing. As the functions

and the structure of human organism are always closely connected it is very important to evaluate their relationship and coherence in the growing organism. The aim of this article was to reveal the coherence between some parameters in the cardiovascular system and spine sagittal alignment among schoolchildren.

MATERIALS AND METHODS

Subjects. One hundred and twenty four schoolchildren (aged 7—18 years) participated in the study. The participants were divided into three groups according to their age (Table 1). Assessment of schoolchildren's body posture and the parameters of their cardiovascular system was performed according to the standards of medical ethics (Declaration of Helsinki).

Methods. For the evaluation of cardiovascular system the bicycle ergometry test was performed and computerized functional test analysis system "Kaunas — Load" was used. In our investigation we used the modified Bruce protocol with decreased to one minute time interval for one step. The maximal load was usually limited by the submaximal heart rate. Load, arterial blood pressure, ECG in 12 standard derivations were synchronously recorded at every step. Such parameters as developed maximal power (N_{max}), index of health (S_v) indicating integrated body reaction to load, adaptation (in percent), pressure rate index (PRI), which shows how arterial blood pressure increases when the heart rate increases and change of double product (ΔDP) were analyzed. Also half recovery periods of heart rate ($T_{rec HR \frac{1}{2}}$) and systolic blood pressure ($T_{rec S \frac{1}{2}}$), i.e. alterations in quantity during recovery until half of their previous values, the time being counted in seconds, were evaluated (Vainoras et al., 1999; Vainoras et al., 2003).

Table 1. The distribution of participants according to gender and age groups

Group	Age group	Gender group	Number (%) of children
A	7—10	girls	17 (13.7)
B		boys	20 (16.13)
C	11—14	girls	19 (15.32)
D		boys	27 (21.77)
E	15—18	girls	21 (16.94)
F		boys	20 (16.13)

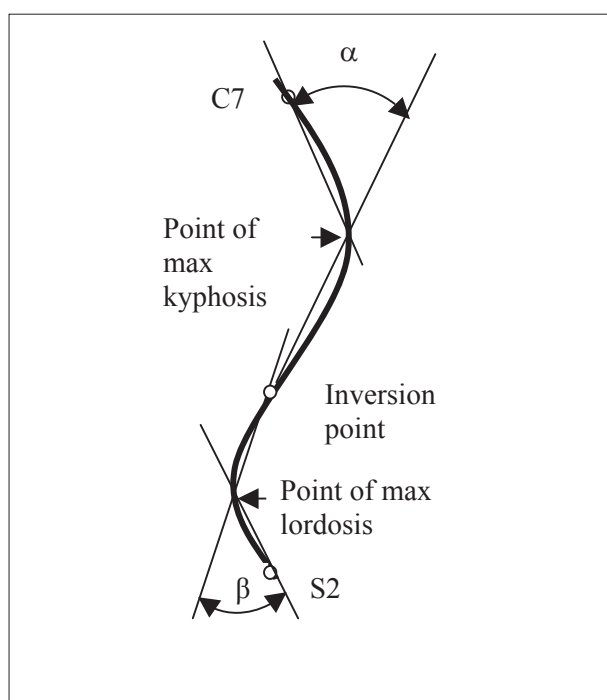


Figure 1. Assessment of thoracic kyphosis and lumbar lordosis

The evaluation of spine sagittal plane was performed using cirtometer — flexible ruler. The cirtometer was shaped placing it on the spinal apophyses points on the skin (from the seventh neck vertebra till first sacral vertebra), while child was in standing position. The curve obtained was reproduced on a paper sheet, and the angular values of thoracic kyphosis and lumbar lordosis were measured (Figure 1).

Statistical analysis. Data were analyzed using SPSS 10.0 for Windows. Student's test was used for the estimation of statistical differences between the groups. Spearman's correlation analysis was used to estimate correlation between the measurements of cardiovascular system and spine sagittal plane. P value < 0.05 was considered statistically significant.

RESULTS

Analysis of sagittal spine parameters. Parameters of sagittal spine had few differences according to gender and age (Figure 2). We found no significant difference in lumbar lordosis between girls and boys in all age groups, although lordosis in girls was greater than in boys, except the 11—14 year age group. We also found no significant differences of lordosis according to age in both gender groups.

Thoracic kyphosis had significant different mean values according to gender only in 7—10

years group. In other age groups the mean values of kyphosis were similar. Thoracic kyphosis significantly decreased in the group of 11—14 year old boys compared to the younger group.

Lumbar lordosis was greater than kyphosis in all age and gender groups. The difference between these two sagittal curves expression was greater in girls, and it was significant in all age groups. As to boys, significant difference was in the groups of 11—14 and 15—18 years.

Analysis of cardiovascular system's parameters. We observed Sv increasing both in girls and boys during their growth. In boys we found significant difference ($p < 0.05$) between the youngest and the oldest age groups. Sv significant increased in 11—14 year old girls and stabilized at this age, although in boys it was still increasing with age. Significant differences were established among girls and boys in 7—10 year age and 15—18 year age groups. In all age groups, Sv of boys was greater than girls.

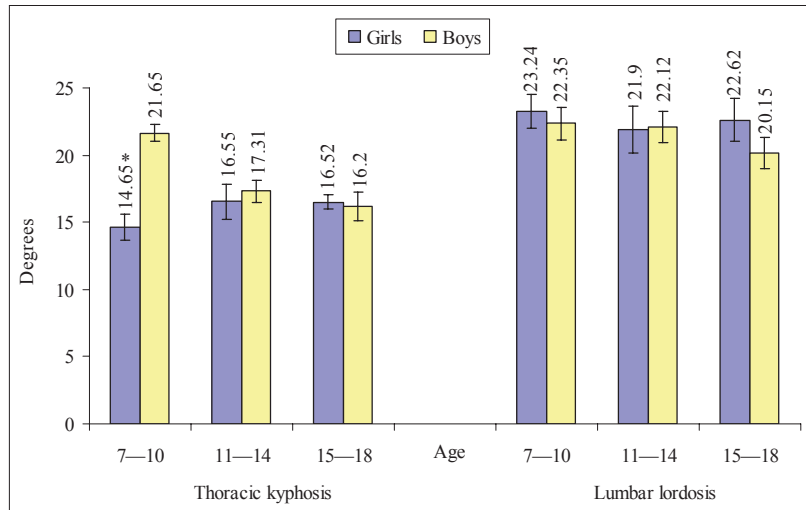
Changes of N_{max} with age in both genders were similar to Sv changes. N_{max} of girls also had stabilizing pattern at the age of 11—14 years, in boys it was statistically significantly increasing with age. N_{max} was greater in boys in all age groups ($p < 0.05$) (Figure 3). At 15—18 years of age N_{max} in boys was 1.82 times greater than in girls.

Adaptation to physical load was more or less constant in both boys and girls and its mean values were about 15%. This shows that girls and boys are able to maintain constant organism reaction to physical load in different age groups. The smallest value (13.89 ± 1.2) of adaptation was observed in 7—10 year old girls. There was no statistically significant difference as between genders in different age groups.

We observed pronounced increase of PRI with age in both gender groups (Figure 4). We established statistically significant difference of PRI among all age groups of boys. PRI was greater in boys in all age groups, but significant difference was only in the age group of 15—18 years. Pronounced dynamics of PRI is associated with better organization and development of regulation processes in children during their growth.

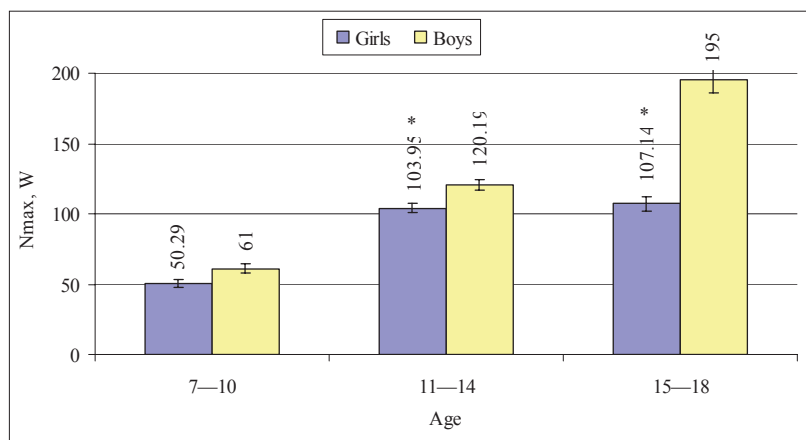
Dynamic changes of T rec HR $\frac{1}{2}$ with age were very similar to changes of PRI. Maximal values of T rec HR $\frac{1}{2}$ were achieved in the age group of 15—18 years. Those mean values are also incident to the adults. T rec HR $\frac{1}{2}$ was shorter in girls only in the age group of 7—10 years and with their growth it became longer than in boys especially

Figure 2. Mean values of thoracic kyphosis and lumbar lordosis among girls and boys of different age groups



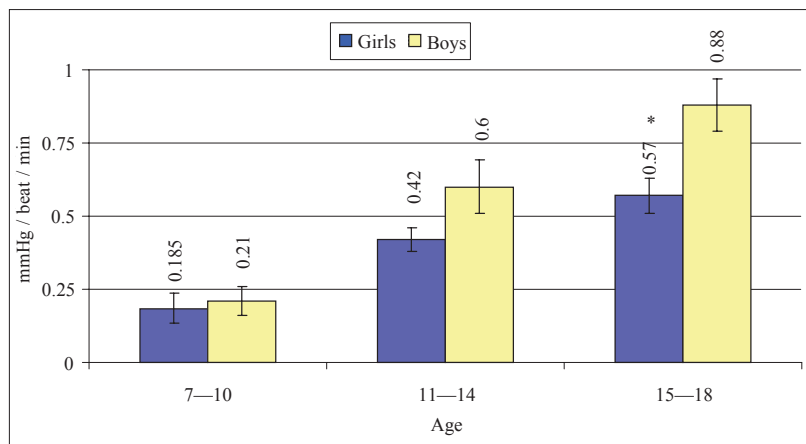
Note. * — $p < 0.05$.

Figure 3. Dynamics of mean values of maximal power (N_{max}) in boys and girls with age



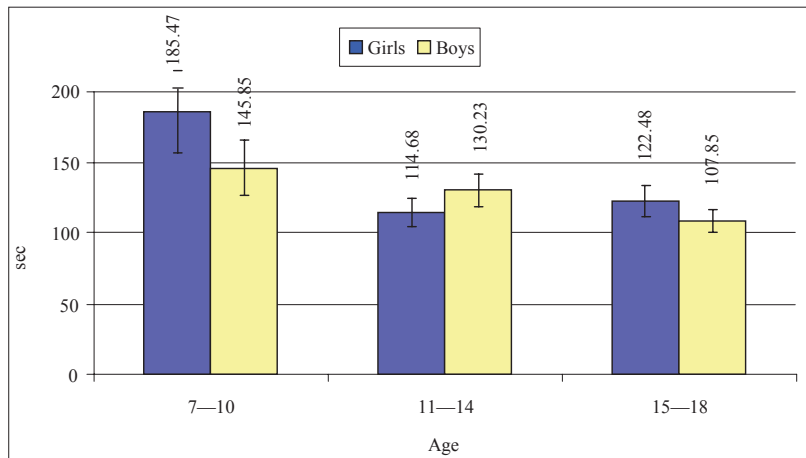
Note. * — $p < 0.05$.

Figure 4. Changes of pressure rate index (PRI) with age among boys and girls



Note. * — $p < 0.05$.

Figure 5. Changes of half recovery period of systolic blood pressure ($T_{rec S \frac{1}{2}}$) with age among boys and girls



Age group	Girls		Boys	
	Thoracic kyphosis	Lumbar lordosis	Thoracic kyphosis	Lumbar lordosis
7—10	N _{max} 0.54	-----	T rec S ½ 0.45 ΔDP 0.43	PRI -0.48 N(W) 0.46
11—14	ΔDP -0.69	-----	N _{max} -0.52	-----
15—18	T rec S ½ 0.6 PRI -0.52	T rec S ½ 0.48	-----	T rec HR ½ 0.45

Table 2. Correlation (Spearman's coefficient) between spine sagittal curves and cardiovascular parameters among boys and girls of different age groups ($p < 0.05$)

in 11—14 year old group, where statistically significant difference was observed.

Dynamic of T rec S ½ had decreasing tendencies (Figure 5). Dynamics of this parameter is slow until blood distribution mechanisms is not developed. T rec S ½ decreased at 11—14 years age (in boys statistically significant) and remained stable. We established no statistical significant differences according to gender.

Changes of ΔDP tended to increase. We found statistically significant increase in both genders comparing the age group of 7—10 and 11—14 years. Significant difference of ΔDP between genders was established only in the age group of 7—10 years, but in all age groups girls had smaller ΔDP than boys.

Analysis of correlation between spine sagittal curves expression and cardiovascular parameters. According to the results we found that thoracic kyphosis in general had more correlations with cardiovascular parameters than lumbar lordosis (Table 2).

In younger boys we established more correlations between these two parameters than in girls. But we found more correlations in older girls vs. boys. In older girls spinal curves mostly correlated with the dynamics of blood pressure reactions. Maximal developed power had positive correlation with thoracic kyphosis in girls, but it was negative in boys. We also found positive correlation between thoracic kyphosis and ΔDP in boys and negative in girls. In boys we found more correlations in the youngest age group and in girls — in the oldest age group.

DISCUSSION

Analysis of sagittal curves revealed that dynamics of kyphosis and lordosis was lower in girls during age. As musculoskeletal system growth spurt is natural to the children of our study, it could show good musculoskeletal adaptation

to growth and some stability of musculoskeletal system functioning. But on the other hand this fact places some doubt on correlations established in our research — it could be some other factors that are more related with cardiovascular system parameters, as sagittal curves dynamics was not expressed in girls during their growth very much.

Thoracic spine with thoracic cage biomechanically serves as a steady support for the heart. This structural feature could influence established correlations between thoracic kyphosis and cardiovascular system parameters. As the dynamics of thoracic kyphosis was more pronounced than lumbar lordosis it also could be the reason why thoracic kyphosis had more correlations with cardiovascular parameters.

Longitudinal studies confirm that maximal power increases in adolescence. These changes are due to better organization of regulation processes, development of neural activation. Gender differences were also estimated (Armstrong et al., 2001). The values for boys are higher than those for girls. It could be associated with different skeletal muscle mass in boys and girls, as it is a very important factor in power generation. Differences of body composition are referred to in many studies (Giugliano, Melo, 2004; Arfai et al., 2002).

As index of health in girls stabilizes at the age of 11—14 years, a very important factor in health strengthening appears to be appropriate physical activity as the pressure reactions become slower at this age. Constant adaptation process established in this work confirms the presence of optimal organism functioning with age in both genders.

Differences of T rec HR ½ regarding age suggest that HR recovery after physical load is influenced by the cardiac parasympathetic nervous activity at rest and that the greater central cholinergic modulation of HR in children than in young adults may be responsible in part for children's faster HR recovery after exercise (Ohuchi et al., 2000).

Stabilizing of Δ DP parameter during maturation period in girls could be due to the influence of estrogens, and it is increasing in boys due to testosterone influence.

Reverse correlations between spinal curves and cardiovascular parameters according to gender and age may be associated with different musculoskeletal system states and development, different organization and development of regulation processes, different physical activity level and many other factors, which differ among girls and boys during their growth (Arfai et al., 2002; Sukhareva et al., 2002). Sagittal curves could be interpreted as a restrictive factor for cardiovascular functioning because of negative correlation. We did not find no such data interpretation in foreign research.

CONCLUSIONS

There was no significant difference of lumbar lordosis according to gender in all age groups and thoracic kyphosis had significant different expression only between boys and girls in the age group of 7–10 years.

We found significant difference of such cardiovascular system parameters as index of health, maximal power, pressure rate index, half recovery period of heart rate and change of double product according to gender.

Thoracic kyphosis had more correlations with cardiovascular system parameters than lumbar lordosis.

Blood pressure reactions more correlated with spine sagittal curves in older girls and younger boys.

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MOKSLEIVIŲ STUBURO SAGITALINIŲ LINKIŲ, ŠIRDIES IR KRAUJAGYSLIŲ SISTEMOS RODIKLIŲ KITIMAS BEI JŲ TARPUSAVIO SĄSAJOS

Vilma Mauricienė¹, Arūnas Emeljanovas², Kristina Bačiulienė¹, Algė Daunoravičienė¹
Kauno medicinos universitetas¹, Lietuvos kūno kultūros akademija², Kaunas, Lietuva

SANTRAUKA

Tyrimo tikslas — įvertinti skirtingų amžiaus grupių moksleivių stuburo sagitalinių linkių, širdies ir kraujagyslių sistemos rodiklių ypatumus, jų tarpusavio sąsajas.

Buvo tiriami 7—18 metų 124 moksleiviai, pagal amžių suskirstyti į tris grupes. Širdies ir kraujagyslių sistemos rodikliai įvertinti veloergometrinio mėginio metu taikant modifikuotą Briuso protokolą ir naudojant kompiuterinę EKG automatizuotos analizės sistemą „Kaunas—Krūvis“. Stuburo sagitaliniai linkiai išmatuoti naudojant lanksčią juostelę (cirtometrą). Įvertintas krūtininės kifozės ir juosmeninės lordozės linkių išreikštumas.

Tarp sagitalinės plokštumos rodiklių priklausomai nuo lyties ir amžiaus nustatyti tik keli statistiškai reikšmingi skirtumai. Sagitalinių linkių pokyčiai labiau išreikšti tarp berniukų. Berniukų grupėje abu sagitaliniai linkiai bėgant metams turėjo išreikštumo mažėjimo tendencijas. Nustatyta daug reikšmingų skirtumų tirtose lyties ir amžiaus grupėse, lyginant širdies ir kraujagyslių sistemos rodiklius. Skirtingas sagitalinių stuburo linkių, širdies ir kraujagyslių sistemos rodiklių sąsajas lyties ir amžiaus požiūriu galėjo lemti nevienoda griaučių ir raumenų sistemos būklė ir išsivystymas, skirtingas fizinio aktyvumo lygis ir kiti veiksniai.

Nebuvo nustatyta statistiškai reikšmingo skirtumo tarp juosmeninės lordozės išreikštumo lyties požiūriu visose amžiaus grupėse, nors kifozės dydis reikšmingai skyrėsi jauniausiųjų grupėje. Vertinant lyties požiūriu, nustatytas reikšmingas skirtumas tokių širdies ir kraujagyslių sistemos rodiklių, kaip antai: suminio sveikatos indekso, didžiausias išugdyto galingumo, spaudimo — galingumo indekso, širdies susitraukimų dažnio atsigavimo pusperiodžių ir dvigubos sandaugos pokyčio. Daugiau koreliacinių ryšių aptikta tarp širdies ir kraujagyslių sistemos rodiklių ir krūtininės kifozės nei juosmeninės lordozės. Kraujo spaudimo reakcijos labiau susijusios su stuburo linkių išreikštumu vyresnių mergaičių ir jaunesnių berniukų grupėse.

Raktažodžiai: stuburo sagitaliniai linkiai, širdies ir kraujagyslių sistemos rodikliai, juosmeninė lordozė, krūtininė kifozė.

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Vilma Mauricienė
Kaunas University of Medicine
(Kauno medicinos universitetas)
M. Jankaus str. 2, LT-50275 Kaunas
Lithuania (Lietuva)
Tel +370 37 730580
E-mail vilmaur@med.kmu.lt