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Analyze of relation between passive stiffness of pelvic girdle muscles and foot architecture in preschool children

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Abstract

Background: The aim of the study is assessment of relation between passive stiffness of chosen pelvic girdle muscles and formation of heel angle (gamma) and medial longitudinal arch (MLA; determined by the Clarke's angle (AC)).

Material/Methods: 124 preschool children underwent observation. The examined group included 46 five years old children and 78 six years old children (girls (n=53); boys (n=71). Passive stiffness of chosen muscles that have insertions within pelvis were assessed in participants and gamma and Clarke's angles were evaluated with use of plantography.

Results: Analysis of ANOVA variance showed significant diversification ($p<0.01$) of iliopsoas muscles stiffness between groups designated in regard to gamma angle (between body sides). Statistically substantial differences of passive stiffness of hamstrings and adductors ($P<0.01$, respectively) was also obtained in these groups. In case of analyze of passive stiffness of pelvic girdle muscles in the groups appointed in regard to Clarke's angle the only essential effect ($P<0.01$) was noted within iliopsoas between body sides, but without important interactions.

Conclusions: Examination demonstrated substantial effects between passive stiffness of some muscles of pelvic girdle region and the value of gamma and Clarke's.

Keywords: foot, gamma angle, Clarke's angle, muscles passive stiffness

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INTRODUCTION

The function of foot is subjected to many studies both in aspect of factors that influence its formation (Evans , 2011)1 and in biomechanical aspect related to body balance maintenance (Raine et al., 2009). Many authors emphasize connections between foot and individual elements of locomotor system even those localized in the considerable distance from this peripheral part of body (Chaitow , 2006; Myers, 2001). Dynamic relations are also interpreted in this aspect. Forces are shifted during walking by system of joints and soft tissues in the closed kinematic chains. Interruption of mechanic of any link causes chain reaction within all the joints of a lower limb (Chaitow , 2004).

Taking into consideration above mentioned reports authors made and attempt to assess relation between passive stiffness of muscles controlling pelvis and axis of heel alignment (gamma angle) and medial longitudinal arch (MLA; determined by the Clarke's angle) in children. Observations have been made in order to find out whether increased stiffness of some muscles of pelvic girdle can influence foot architecture. Revealing such connections may potentially bring changes in concept of management of children with feet disorders. In the clinical practice excessive attention is still dedicated to correction of isolated faults without spatial analyze of all muscle-fascia complexes (Chaitow, 2003). It is especially important during developmental period that is characterized by high plasticity both in central nervous system and muscle-fascia system (Raine, 2009). From the holistic point of view there are interactions and correlations between individual body regions. Taking this fact into consideration authors made an attempt to assess relation between passive stiffness of chosen muscles of pelvic girdle and foot architecture.

MATERIAL AND METHODS

Participants

Observations have been carried out in the group of 124 preschool children (Tab. 1). The examined group included 46 five years old children (37.1%) and 78 six years old children (62.9%), where girls comprised 42,7% (n=53); and boys 57,2% (n=71). The criterion of including to the examined group was age, while criteria of exclusion were: congenital feet disorders, obesity (BMI higher than 22kg/m3), neurogenic or genetic disorders, bone fractures.

Table 1. Profile of examined group with consideration of body height and weight.

N	Age (years)\ $\bar{X}$, SD min-max	Weight (kg) $\bar{X}$, SD min-max	Height (cm) $\bar{X}$, SD min-max
124	5.62±0.48 5-6	22.64±5.48 14.4-35.7	119.95±5,48 107-135

$\bar{X}$ - average, SD - standard deviation, min - minimum, max - maximum

Measures

Passive stiffness of flexors, adductors, and abductors muscles of hip joint, hamstrings and rectus femoris was evaluated with use of tests commonly applied in physiotherapy. Thomas test (Hislop et. al., 2013) was used to measure passive stiffness of hip flexors, Patrick test (Hislop et. al., 2013) was used to measure hip abductors, and Ober test (Schamberger et al., 2002) was used to measure hip adductors, passive knee extension test was used to measure hamstrings and passive knee flexion test to measure rectus femoris passive stiffness (Gnat et al., 2010). Parameters characterizing foot architecture were assessed by plantografic method in static conditions. Examination consist in taking a photo of feet plantar of a child that was standing on the podoscope (Fig. 1). Gamma angle that determines alignment of heel axis (Fig. 2) and Clarke's angle (Fig. 3) that indicates medial longitudinal arch (MLA; determined by the Clarke's angle) were obtained from plantograms with use of computer program (Foley et al., 1995).

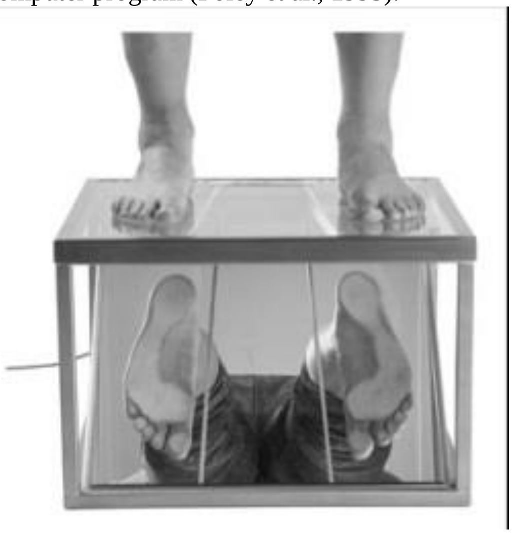

Figure 1. Computer program created for calculation of the values of individual foot angles

Heel gamma angle (AG) is marked by two tangents drawn to the inner and outer foot edge. The tangents cross beyond the heel and form an angle. The standard for heel angle amounts to 15-18 degrees. According to criteria used in literature three categories of heel axis alignment were specified: pigeon-toed (below 15°), normal (15-18°) and knock-kneed (over 18°) (Friends et al., 2008).

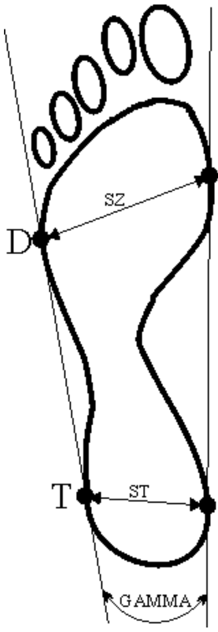

Figure 2. Measurement of angle determining alignment of heel angle (gamma angle) (Clarke, 1933)

There are a lot of methods used for evaluation of prints by drawing a number of auxiliary lines. The most popular and simplest is Clarke's angle indicator (CL) method (Clarke, 1933). It consists in drawing a straight line (C-S). This line crosses the inner tangent (Q-q) and

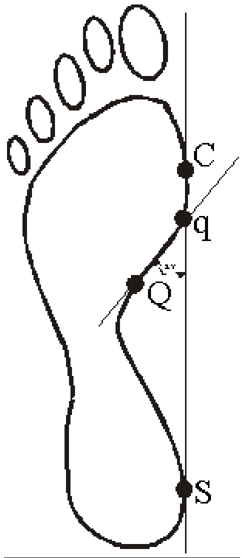

Figure 3. Measurement of medial longitudinal arch (MLA; determined by the Clarke's angle) (Clarke, 1933)

forms the Clarke's angle. The value of this angle looks as follows: foot with diminished arching (flat foot) 31°-41°, normal foot 42°-54°, foot with increased arching (pes cavus) 55°- x [Pauk et al., 2014; Ozer and Barut, 2012)].
Mentioned parameters were assessed by two independent researchers.

Statistical Analysis

Analyze of ANOVA variance was used in the statistic report of the results in order to determine dependency of heel angle and Clarke's angle on body height and weight as well as in order to compare basic parameters (height, body weight). Analysis of ANOVA/MANOVA variances with repeat measurements were used in order to determine differences of muscles passive stiffness between groups designated in regard to gamma and Clarke's angles. In order to determine between which groups the diversification occurs - post hoc analysis were carried out with use of Bonferroni test. In order to check measurements accuracy with use of computer program for setting down of foot angles - analysis of reliability and repeatability of measurements were carried out. Interclass Correlation Coefficient (ICC) was used for this purpose. In the statistical analysis $p<0.05$ was acknowledged as statistically significant.

RESULTS

Interclass correlation coefficient (ICC) for both repeatability of results obtained by one researcher and for compatibility of results obtained by two researchers comprised in the interval (0.91-1) (Tab. 2).

Table 2. Values of measurement rate of Interclass correlation (ICC).

Measuremet repeatability Variable	AG Right	AG Left	AC Right	AC Left
1	0.91	0.92	0.99	0.99
2	0.95	0.95	0.99	0.99

1 / 2- number of carried our measurements, R - right, L - left;

Statistical analyze demonstrated no influence of height and body weight on gamma and Clarke's angle values both in right and left sides ($p>0.05$). Table 3 demonstrates characteristic of examined muscles in aspect of passive stiffness. Table 4. Characteristic of subject in respect of quality of foot formation.

Table 3. Characteristic of subjects in respect of passive stiffness of chosen muscles.

Tests	N	Right Limb	Left Limb
Thomas **$\overline{X}$, SD** **min-max**	124	2.61±2.02 0-10	2.23± 1.55 0-7
Patrick **$\overline{X}$, SD** **min-max**	124	4.10±0.22 1-8	4.14±1.37 1.5-7.5
Passive knee extension **$\overline{X}$, SD** **min-max**	124	28.89±9.06 3-47	29.92±9.1 4 4-49
Passive knee flexion **$\overline{X}$, SD** **min-max**	124	0.70±0.93 0-4	0.71±0.88 0-3.5
Ober **$\overline{X}$, SD** **min-max**	124	0.31±0.57 0-3	0.25±0.56 0-3

N- number of subjects, – average, SD – standard deviation, min - minimal value, max - maximal value

Table 4. Characteristic of subject in respect of quality of foot formation.

Angle	N	Right feet	Left feet
AG **$\overline{X}$, SD** **min-max**	124	16.63±2.57 11-29	16.02±2.50 10-25
AC **$\overline{X}$, SD** **min-max**	124	46.37 ±12.53 5-64	44.72±12.53 5-64

N- number of subjects, – average, sd – standard deviation, min- minimal value, max-maximal value.

In order to answer research queries comparative analyze of muscles passive stiffness in the groups designated in regard to gamma angles (Tab. 5) and Clarke's angles (Tab. 6) was carried out separately for right and left lower limb.

Table 5. Diversification of passive stiffness of examined muscles in regard to gamma angle.

Muscle test	*P* value from ANOVA					
	Main effect Right		Interaction	Main effect Left		Interaction
	Group	Side		Group	Side	
Thomas	0.28	p<0.01*	p<0.01*	0.52	p<0.01*	p<0.05*
Patrick	p<0.01*	0.51	0.76	0.23	0.51	0.22
Passive knee extension	p<0.01*	0.08	0.24	0.24	0.08	0.72
Passive knee flexion	0.48	0.14	p<0.01*	0.64	0.14	0.94
Ober	0.63	0.42	0.79	0.52	0.43	0.87

*result statistically significant

Table 6. Diversification of passive stiffness of examined muscles in regard to Clarke's angle.

Muscle test	P value from ANOVA					
	Main effect		Interaction	Main effect		Interaction
	Group	Side		Group	Side	
Thomas	0.94	p<0.01*	0.51	0.98	p<0.01*	0.82
Patrick	0.67	0.76	0.68	0.66	0.67	0.95
Passive knee extension	0.30	0.07	0.73	0.11	0.07	0.94
Rectus femoris	0.57	0.69	0.53	0.36	0.71	0.52
Ober	0.61	0.24	0.67	0.70	0.24	0.71

*result statistically significant

DISCUSSION

A biomechanical assessment of foot is one aspect of physiotherapy. It involves two main modes of examination: static and dynamic. Aspect of the static mode is described with particular emphasis on the foot (Lang et al., 1997). In the present study statistical assessment of foot architecture was carried out, but in the context of tone of muscles placed in some distance from a foot (that do not indicate direct connections with foot). In the examined sample significant effect between passive stiffness of some muscles in pelvis region and heel axis alignment (AG) as well as medial longitudinal arch (MLA) was observed. Significant effect of diversification of hip muscles stiffness (Thomas test) was observed between groups designated in regard to gamma angle (between body sides). Post hoc analyze showed significant difference of passive stiffness of hip muscles between left and right side ($p<0.01$). Significant diversification of passive stiffness of hamstrings as well as adductors of hip joint in the groups appointed in regard to AG. Detailed analyze demonstrated significant diversification of passive stiffness of hamstrings between the group with pigeon-toe and knock-knee ($p= 0.01$), but only on the right side. Other groups have not demonstrated significant differences in detailed analyze. In case of analysis of passive stiffness of pelvic girdle in the groups appointed in regard to AC the only significant effect was noted in iliopsoas muscles between body sides, but without essential interactions.

The observation that has been carried out implies further studies concerning analyze of influence of some muscles passive stiffness in dynamic conditions, especially during walking. Strength and flexibility of the associated musculature is extremely important. Contrary to popular belief, the majority of muscles function eccentrically, rather than concentrically, during walking. Therefore, their strength and flexibility in controlling motion is extremely important. If muscles are inflexible they will not allow normal function, whilst if they are weak they will be unable to control function (Prior , 1999).

Different variants of gait recognized as physiological occur in children without neurological dysfunctions. It seems that they might constitute the patterns of lower postural tone compensation. Some of them are related to rotational problems and some to angular problems of lower extremities, in other words, disturbances of extremities axis. Rotational problems: in-toed gait (pigeon-toed, bandy legs), outtoeing. Intoeing is caused by one of three types of deformity: metatarsus adductus, internal tibial torsion, and increased femoral anteversion. Outtoeing is less common than intoeing and its causes are similar but opposite to those of intoeing. These include femoral retroversion and external tibial torsion. Angular problems include bowlegs and knock-knees [Sass and Hassan, 2004; Sutherland et al., 1988; Lincoln and Suen, 2003). Children should develop normal gait pattern around 6-7 years of age, but described variants of gait occur in adults sometimes. Furthermore idiopathic toe walking [Sutherland et al., 1988) as a consequence of disturbed tone is mentioned. Authors also observe jumping gait that is mentioned on the Internet Websites, but there are no scientific articles about this kind of gait as a variant of normal gait. It is described only with reference to children with cerebral palsy (Roda and Graham, 2001)]. Clumsy gait, linked to coordination disorders, is also listed (Sigmundsson, 2005).

Results of the carried out studies imply to include influences aimed at tone normalization within all functional anatomy trains in the process of feet disorders correction. Focusing on correction of fault within foot only may be ineffectual. Prior beliefs that mild disorders within a foot may create abnormal patterns in the other body regions (Prior , 1999). Author has observed that lack of dorsiflexion and flexion of metatarsophalangeal joint influence joints, which are placed above (knee and hip joints) that impedes foot movement in stance phase during walking. Sacroiliac joint as well as all segments of spine are also influenced by this mechanism and create overloads. In the light of carried out research and literature it is worth peering over a human as over a chain, in which each link influence the others. Disclosed relations suggest necessity of including into therapy process supports aimed at tone normalization of the muscles that control pelvis. Accurate diagnosis and knowledge of muscle-fascia connections within locomotor system may consist basis of effective and functional physiotherapy.

The results of research demonstrates significant differences of iliopsoas muscles passive stiffness between body sides in the groups designated in regard to gamma angle. In these groups statistically significant differences of passive stiffness of hamstrings and adductors were also obtained. In case of analyze of passive stiffness of pelvic girdle muscles in the groups appointed in regard to Clarke angle - the only significant effect was noted in case of iliopsoas muscles between body sides.

Assessment of foot architecture in 5 and 6 years old children, that is in age of gaining parameters observed in adults, might be a reason of high amount of children with flat foot. Widening of the research with group of older children could possibly explain whether this amount was influenced only by slower maturation speed or the reason arises from developmental abnormalities.

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