A RELATIONSHIP BETWEEN HAMSTRING SHORTENING, BODY POSTURE AND BODY MASS INDEX IN BOYS UNDERTAKING FOOTBALL TRAINING

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Abstract
Adequate length and tension of postural muscles are necessary to maintain proper body posture and enable basic movement patterns to be correctly carried out. These muscles include the hamstrings. Research results show that these are often characterised by reduced elasticity and excessive passive stiffness. The aim of our study was to assess the relationship between hamstring shortening, body posture and excessive body weight in physically active boys. The study involved 69 boys aged from 6 to 19 years who regularly took part in football training (at least three times a week) for at least 12 months. Body height (calibrated anthropometer), body weight (electronic balance TANITA), torso positioning in three planes (ultrasonic system ZEBIS Pointer) and the flexibility of the hamstrings (goniometer) were analysed. Descriptive statistics, cardinality tables, the Kruskal-Wallis test and an effect size were used in statistical analysis. The reduction of hamstring elasticity in both legs was diagnosed in 50.72 % and in one leg in 13.05 % of the boys studied, while 24.65 % were overweight and 4.35 % were obese. No significant differences in the torso position were found in the groups distinguished by hamstring flexibility. However, subjects with hamstring shortening tended to have increased pelvic torsion, increased angular kyphosis and lumbar lordosis, have greater asymmetry of the right and left pelvis and shoulders, and increased scoliotic deformities. A significant correlation was found between hamstring flexibility, body weight and body mass index (BMI). Common hamstring shortening in boys taking part in football training does not significantly affect body posture but significantly correlates with body weight and BMI. Stretching exercises and soft tissue mobilisation techniques should be included in the football training of young players.

Keywords: *body posture, hamstring, body weight, football player*

Introduction

The posterior thigh muscles consist of: biceps femoris, semitendinosus and semimembranosus. Their proximal attachments are located on the ischial tuberosity, and the distal ones are on the fibula head and the medial condyle of the tibia. These muscles, with the exception of the short head of the biceps muscle, are two-joint muscles responsible for bending the knee joint and straightening the hip joint. Under closed kinematic chain conditions, they control the anterior pelvic and torso tilts, and also play a role in stabilising the knee joint. These muscles are often characterised by reduced elasticity and excessive passive stiffness. Although this problem increases with age, it not only affects adults but adolescents too (Kuraczowska & Ligarska, 2014; Kuszewski et al., 2008; Muyor et al., 2011). Due to the global effect of the hamstrings, their shortening not only limits the mobility of the knee and hip joints, but can also lead to excessive load on the adjacent joints and periarticular structures.

Some authors also note a relationship between the proper functioning of the posterior thigh muscle group and body posture. Due to the location of the proximal attachments, it seems logical that the shortening of these muscles will affect the position of the pelvis (Congdon et al., 2005; P. López-Miñarro et al., 2012). Thus, reduced hamstring flexibility can also directly translate into the position of the spine in the sagittal plane, resulting in a deepening of thoracic kyphosis and shallowing of the lumbar lordosis (P. A. López-Miñarro & Alacid, 2010). In the future, disturbances of the physiological balance of the spine in the sagittal plane may manifest themselves as back pain causing deterioration in the quality of life (Fasuyi et al., 2017; Janusz et al., 2013).

The literature also draws attention to the relationship between hamstring shortening and the risk of injury, which is particularly important in the context of sports training (Heiderscheit et al., 2010).

Limiting natural muscle flexibility is a complex problem whose mechanisms are not fully understood. Body mass index (BMI) is among the factors taken into consideration that can potentially affect tissue elasticity. Research results in this area are varied. While some authors point to this relationship, others do not confirm it (Castro-Piñero et al., 2013; L.-J. Chen et al., 2006; W. Chen et al., 2002; Ponce-González et al., 2020).

Another factor contributing to the shortening of the posterior thigh muscle group is a sedentary lifestyle and reduced physical activity (Fatima et al., 2017; Saulicz et al., 2008). This problem is also observed in representatives of various sports disciplines, particularly those training for stop-and-go sports, including football (Espejo-Antúnez et al., 2019).

In football players, trauma to the posterior thigh muscle group is one of the most common reasons for taking a break in training and the inability to participate in sports competitions (Ekstrand et al., 2011; Orchard & Seward, 2009; Witvrouw et al., 2003). It is estimated that in professional football the frequency of hamstring injuries ranges from 12 % to even 37 % (Ekstrand et al., 2011; Woods et al., 2004). This topic is of interest to specialists in various fields, primarily due to the huge costs associated with the indisposition of leading players during sports competitions. (Hickey et al., 2014).
Studies on hamstring shortening are conducted relatively less frequently among children and adolescents. It seems that the relationship between the function of this muscle group and the position of the pelvis and spine may be of particular importance in the context of their proper functioning and possible future health problems. Despite the huge interest in various aspects of posture disorders in children and adolescents, there is a lack of data regarding these issues in the literature. Given the popularity of football in all age groups, it seems necessary to broaden knowledge on every aspect of the training process. The aim of the study was to determine the relationship between hamstring shortening and body posture in boys taking part in football training. The relationship between the elasticity of the posterior thigh muscle group and body weight was also assessed.

Methods

Characteristics of the studied group

Eighty-two boys taking part in football training at a local sports club were invited to participate in the study. The inclusion conditions for the study were the consent of a participant and his guardian, systematic participation in training confirmed by the trainer (at least 80 % attendance throughout the entire training period), well-being, the absence of any pain on the day of the study and good general health. Boys treated for chronic disease (asthma, diabetes or other) and those who had trauma to the musculoskeletal system within the six months preceding the study were excluded from examination.

Finally, 69 boys undertaking football training at least three times a week for 1.5 hours were subjected to the tests. The training period of the subjects varied (from 1 to 10 years) and depended on the age of the boys studied. Among the examined were: 20 boys aged from 6.0 to 8.9 years; 22 aged from 9.0 to 11.9 years; 25 aged from 12.0 to 14.9 years; and 12 aged from 15.0 to 19.0 years. The average age of the subjects was 11.22 ± 3.8 years.

All boys agreed to participate in the study and their parents gave written consent to their child's participation in the study. Each participant knew that they could withdraw from the tests at any time without giving a reason. Parents were present during the study and informed in detail about their results. The study was carried out in accordance with the uniform ethical and scientific standards set out in the Declaration of Helsinki.

Research methods

Body height (a calibrated Martin type anthropometer, with a precision of 0.01 m, measured from the Basis point to the Vertes point in an upright position with the feet and head positioned in the Frankfurt plane) and body weight (a TANITA electronic scale, with a precision of 0.1 kg, the subjects dressed in their sports clothes, barefoot) were measured. The body fat percentage (precision of 0.01 %) was estimated using the same scales. Using the height and body mass values, the BMI was calculated according to a standard formula. Body weight status (norm, overweight or obese) was determined based on the norm values developed for children and adolescents by Cole et al (Cole et al., 2000).

During the hamstring elasticity testing, the subjects were in the supine position, the lower limbs were straightened at the hip and knee joints. The tested lower limb was flexed at the hip joint, while not allowing flexion in the knee joint. The appearance of the first resistance indicated that the range of motion limit was reached. The range of motion was measured using a goniometer, the axis of which was placed on the greater trochanter of the femur, the movable arm of the goniometer was directed at the fibula head and the fixed arm was placed along the trunk, parallel to the ground. Hamstring shortening was indicated by a result of less than 80˚ (Chaitow, 2019).

The torso position was examined in three planes using the Zebris Pointer system with WinSpine software (Zebris, 2009).

Zebris consists of a measuring sensor placed on a tripod, an ultrasonic point indicator with two transmitters and a reference marker attached at the height of the subject's pelvic girdle. During the study, each participant stood shirtless, barefoot, in a free-standing position with his back to the measuring sensor which was about 80 cm away. The measurement was carried out by one

experienced physiotherapist (other than the one who conducted the muscle elasticity test) under conditions ensuring privacy and thermal comfort. The study lasted about two minutes.
The following variables were analysed: pelvic torsion, pelvic tilt, pelvic/shoulder tilt, thoracic kyphosis angle, lumbar lordosis angle, sagittal trunk inclination, sacral angle, pelvic height difference, shoulder height difference, lateral trunk inclination and scoliosis angle.

The Zebris Pointer system is a device with proven suitability for the non-invasive assessment of body posture (Grzegorczyk et al.,2012; Rusek et al., 2010; Walicka-Cupryś et al., 2010).
Statistika v13 was used for data analysis. The study was conducted using basic descriptive characteristics, the Shapiro-Wilk test to test the normality of the distribution, the Kruskal-Wallis test to compare three independent groups, cardinality tables and the Spearman's rank-order correlation (a study of relationships between variables). The effect size was calculated for statistically significant differences. The level of significance was α = 0.05.

Table 1. Age and somatic features depending on hamstring flexibility (Kruskal-Wallis test)

Variable	Hamstring flexibility	Mean	Median	Min	Max	SD	p ES
Age [years]	correct in both legs	10.18	10.00	6.01	17.54	3.13	ns
	reduced in both legs	11.46	11.00	6.07	19.00	3.76	
	reduced in one leg	13.15	12.00	6.55	18.99	5.09	
Body height [cm]	correct in both legs	135.89	133.40	113.00	178.60	18.21	ns
	reduced in both legs	146.49	145.40	114.20	181.90	19.23	
	reduced in one leg	153.46	170.50	117.90	177.60	26.22	
Body weight [kg]	correct in both legs	35.02	32.30	19.00	81.30	15.31	both correct vs both reduced p = 0.01 ES = -0.68
	reduced in both legs	46.87	45.00	21.60	77.80	16.94	
	reduced in one leg	48.12	56.60	23.70	75.00	19.96	
BMI [kg/m^2]	correct in both legs	17.99	17.39	14.10	29.04	3.03	both correct vs both reduced p < 0.01 ES = -0.76
	reduced in both legs	20.77	20.64	14.86	33.76	3.89	
	reduced in one leg	19.31	18.97	16.26	25.95	3.05	
Fat tissue [%]	correct in both legs	18.77	18.40	10.40	32.20	5.62	ns
	reduced in both legs	21.14	19.30	10.60	49.30	8.89	
	reduced in one leg	15.60	14.90	9.70	25.00	5.38	

* statistically significant difference, ns – not significant, ES – effect size

The selected parameters describing the torso position did not significantly differentiate participants with normal and limited hamstring flexibility. However, there was a tendency to increased pelvic torsion, an increased angle of thoracic kyphosis and lumbar lordosis, increased asymmetry of the right and left side of the pelvis and shoulders, and increased scoliotic deformation in subjects with hamstring shortening in one or both legs (Table 2).

Table 2. Selected features of torso position depending on hamstring flexibility (Kruskal-Wallis test)

Variable	Hamstring flexibility	Mean	Median	Min	Max	SD	p
Pelvic torsion [°]	correct in both legs	3.68	2.00	0.00	18.20	4.49	ns
	reduced in both legs	5.45	4.20	0.00	16.70	4.40	
	reduced in one leg	4.44	2.70	0.60	15.10	4.82	
Pelvic tilt [°]	correct in both legs	2.57	2.00	0.30	8.50	2.26	ns
	reduced in both legs	2.19	2.00	0.10	7.20	1.44	
	reduced in one leg	1.88	1.20	0.20	5.30	1.66	
Pelvic/shoulder tilt [°]	correct in both legs	2.73	1.70	0.00	9.90	2.71	ns
	reduced in both legs	2.36	2.30	0.10	7.20	1.62	
	reduced in one leg	1.97	1.90	0.20	4.40	1.21	
Thoracic kyphosis angle [°]	correct in both legs	34.14	31.60	7.20	59.70	13.28	ns
	reduced in both legs	38.62	40.10	13.50	63.80	10.68	
	reduced in one leg	40.29	36.60	28.20	56.50	9.44	
Lumbar lordosis angle [°]	correct in both legs	27.16	25.60	15.30	43.70	8.11	ns
	reduced in both legs	28.63	29.00	13.90	44.60	7.32	
	reduced in one leg	29.49	31.20	17.60	39.90	7.71	
Sagittal trunk inclination [°]	correct in both legs	3.19	2.80	0.20	8.00	2.15	ns
	reduced in both legs	3.95	3.20	0.20	9.30	2.55	
	reduced in one leg	3.03	2.70	0.10	7.20	2.54	
Sacral angle [°]	correct in both legs	21.57	22.80	6.00	44.10	8.25	ns
	reduced in both legs	22.92	23.40	6.10	38.60	8.30	
	reduced in one leg	21.76	21.70	12.70	34.40	7.25	
Pelvic height difference [mm]	correct in both legs	8.12	6.90	0.90	24.30	6.18	ns
	reduced in both legs	8.37	7.60	0.30	22.50	5.51	
	reduced in one leg	8.29	4.10	0.60	23.10	7.66	
Shoulder height difference [mm]	correct in both legs	5.83	5.30	0.60	22.40	5.22	ns
	reduced in both legs	8.72	5.60	0.10	29.60	8.24	
	reduced in one leg	10.32	9.10	0.00	27.80	7.72	
Lateral trunk inclination [°]	correct in both legs	1.28	1.20	0.20	3.00	0.71	ns
	reduced in both legs	1.09	1.10	0.10	2.70	0.75	
	reduced in one leg	1.51	1.00	0.40	4.10	1.27	
Scoliosis angle [°]	correct in both legs	1.67	0.00	0.00	12.80	4.01	ns
	reduced in both legs	2.41	0.00	0.00	19.30	4.87	
	reduced in one leg	2.32	0.00	0.00	11.70	4.65	

ns – not significant

A qualitative assessment of the torso position indicates a less frequent occurrence of flattened thoracic kyphosis and lumbar lordosis in subjects with reduced hamstring flexibility in one or both legs (Table 3).

Table 3. Qualitative assessment of torso position depending on hamstring flexibility

Hamstring flexibility	Thoracic kyphosis angle N (% in row)		
	flat	normal	round
correct in both legs	13 (52.00 %)	5 (20.00 %)	7 (28.00 %)
reduced in both legs	9 (25.71 %)	15 (42.86 %)	11 (31.43 %)
reduced in one leg	1 (11.11 %)	5 (55.56 %)	3 (33.33 %)
	Lumbar lordosis angle N (%)		
	flat	normal	round
correct in both legs	7 (28.00 %)	9 (36.00 %)	9 (36.00 %)
reduced in both legs	8 (22.86 %)	10 (28.57 %)	17 (48.57 %)
reduced in one leg	2 (22.22 %)	1 (11.11 %)	6 (66.67 %)
	Sagittal trunk inclination N (% in row)		
	backwards	normal	forwards
correct in both legs	9 (36.00 %)	16 (64.00 %)	0 (0.00 %)
reduced in both legs	6 (17.14 %)	29 (82.86 %)	0 (0.00 %)
reduced in one leg	4 (44.44 %)	5 (55.56 %)	0 (0.00 %)
	Sacral angle N (% in row)		
	steep	normal	flat
correct in both legs	2 (8.00 %)	8 (32.00 %)	15 (60.00 %)
reduced in both legs	4 (11.43 %)	7 (20.00 %)	24 (68.57 %)
reduced in one leg	0 (0.00 %)	3 (33.33 %)	6 (66.67 %)

Analysis of the relationship between the variables examined indicates a significant correlation between hamstring flexibility, body weight and BMI. No significant correlation was found between hamstring flexibility and the features describing the torso position (Table 4).

Table 4. Relationships between hamstring flexibility and the variables studied (Spearman's rank-order correlation, correlations are significant for $p < 0.05$).

Correlated variable	R	t(N-2)	p
Age [years]	0.23	1.90	0.06
Body height [cm]	0.30	2.58	0.01*
Body weight [kg]	0.31	2.71	0.01*
BMI [kg/m^2]	0.28	2.41	0.02*
Fat tissue [%]	-0.07	-0.59	0.56

Pelvic torsion [°]	0.17	1.44	0.15
Pelvic tilt [°]	-0.07	-0.61	0.55
Pelvic/shoulder tilt [°]	-0.01	-0.08	0.94
Thoracic kyphosis angle [°]	0.18	1.49	0.14
Lumbar lordosis angle [°]	0.11	0.92	0.36
Sagittal trunk inclination [°]	0.04	0.35	0.73
Sacral angle [°]	0.04	0.30	0.76
Pelvic height difference [mm]	0.03	0.21	0.83
Shoulder height difference [mm]	0.22	1.83	0.07
Lateral trunk inclination [°]	-0.06	-0.52	0.60
Scoliosis angle [°]	0.08	0.62	0.54

* statistically significant correlation

Discussion

In our study, only 36.23 % of boys had normal hamstring flexibility, 50.72 % had reduced elasticity in both limbs and 13.05 % in one. Neither symmetrical nor asymmetrical hamstring shortening significantly correlated with the quality of the torso position in any of the planes. Only a tendency to increased pelvic torsion, an increased angle of thoracic kyphosis and lumbar lordosis, increased asymmetry of the right and left side of the pelvis and shoulders, and an increased angle of scoliosis in subjects with hamstring shortening in one or both legs was reported but it was not confirmed by statistical significance. However, it was found that hamstring shortening significantly correlates with body weight and BMI.

Shortening of the posterior thigh muscle group is a common phenomenon. This problem relatively often concerns players of various sports.(Adkitte et al., 2016; Weerasekara et al., 2013)

Similar results were observed among 14-year-old boys and girls from sports classes, judo training and athletics. Hamstring shortening was diagnosed in 44 % of studied persons. However, in the non-training group, the problem was not only more common (it affected up to 75 % of people), but also the degree of shortening was significantly higher (Kuszewski et al., 2008). A reduction in hamstring flexibility was also found in 62 % of young men practising cycling, and in 29 % of them it was significant, above 20° (Muyor et al., 2011). Different results were observed in a group of volleyball players aged from 14 to 16 years. Hamstring shortening was diagnosed in 27 % of the studied girls and none of them had reduced flexibility greater than 20° (Kuraczowska & Ligarska, 2014). These differences may be due to additional factors affecting muscle flexibility, such as training methodology, hence the emphasis on stretching exercises and mobilisation techniques seems to be important.

In the literature, there are reports on the impact of reduced hamstring flexibility on individual posture parameters in adults and on lumbar spine ailments (Sadler et al., 2017).

Lasheen et al. (the average age of subjects was 25.8 years) have shown a significant relationship between hamstring shortening (popliteal angle) and a reduction of the lumbosacral angle, lumbar lordosis angle and sacral inclination angle (Lasheen et al., 2017). The relationship between hamstring shortening, pelvic tilt and sacral slope has also been confirmed by Mohamed (Mohamed D.A, 2015). These results have not been confirmed by Beninato et al. who conducted a study on 20-year-old physiotherapy students. In this group, no correlation was observed between pelvic tilt, lumbar lordosis and the length of the hamstrings (Beninato et al., 1993). In our study, there was also no significant effect of reduced hamstring flexibility on any of the posture parameters tested, but boys with hamstring shortening in one or both legs were characterised by a tendency to increase the angle of both thoracic kyphosis and lumbar lordosis. It seems that the results obtained can be influenced by the age of the tested persons and their short training experience. Long-term studies should be carried out to determine whether these changes will increase in the future. Animal studies show that tissue structure not only depends on the function, but changes with age (Shadwick, 1990).

Although limited muscle flexibility is now a common phenomenon, it continues to be a problem with many unknowns. Among the risk factors taken into account, excessive weight raises controversy. While some authors point out the relationship between obesity and the reduction of tissue elasticity (W. Chen et al., 2002), others do not show this kind of relationship (Castro-Piñero et al., 2013; L.-J. Chen et al., 2006), However, it seems that the number of studies in this area is still insufficient. Moreover, all the analyses cited are based on the result of the seat and reach test. This test is very common because it allows a quick assessment to be made using easily available equipment. However, it should be remembered that this evaluates the movement of the whole body and the final result is also affected by lower back flexibility. Participants in our study characterised by proper hamstring flexibility in both legs had significantly lower body weight and BMI. The body fat content did not differentiate people with normal and limited hamstring flexibility.

Limitations

The limitation of our study was the large age diversity of the persons tested. The study should also be extended to observe changes in body posture and the frequency of injuries and pain in athletes with normal and limited hamstring flexibility.

Conclusions

Hamstring shortening occurs in more than half of boys who take part in football training. It is only slightly associated with deterioration of body posture, but significantly correlates with body weight and BMI.

Practical inclination

Stretching exercises and soft tissue mobilisation techniques should be included in the football training of young players.

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