LATERALITY REFLEXION ON FORCE PRODUCTION OF ANTAGONISTIC MUSCLES AT THE LEVEL OF VERTEBRAL COLUMN

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Abstract
Laterality reflexion on force production of antagonistic muscles at the level of vertebral column
Background: Identification of maximal isometric force manner production, at the level of vertebral column, in relation with consequent preferential utilization of right and left superior and inferior limbs, can be useful for corect optimization of rehabilitation training.
Aims: The aims of this study is to determine, the manner of maximal isometric force production, at the level of vertebral column, in relation with consequent preferential utilization of right and left superior and inferior limbs, in Romanian female subjects.
Methods: This study used 16 Romanian sedentary females (8 subjects with right superior and inferior dominant limbs and 8 subjects with left superior and inferior dominant limbs), white caucasian, with age between 30 and 40 years old.
Body height was estimated with an error of 0,5cm. and body weight was evaluated with a calibrated digital scale, with an error of 0.05 kilograms. The body fat percentage was estimate using a bioelectric impedance method (Omron BF-306). Maximal isometric force of the lumbar/thoracic column was measured with special machines in all three planes – flexion with David F130 Lumbar/Thoracic Flexion at 30º angle and extension with David F110 Lumbar/Thoracic Extension at 30º angle, in sagittal plane – right lateral flexion and left lateral flexion with David F150 Lumbar/Thoracic Lateral Flexion at 0º angle, in frontal plane – right lateral rotation and left lateral rotation with David F120 Lumbar/Thoracic Rotation at -30º angle, in transversal plane.
Results: Subjects with right superior and inferior dominant limbs, generates maximal isometric force significantly higher for left lateral flexion, then right lateral flexion (t=4,59) and for right lateral rotation, then left lateral rotation (t=4,408). In opposition, subjects with left superior and inferior dominant limbs, generates maximal isometric force significantly higher for right lateral flexion, then left lateral flexion (t=9,744) and for left lateral rotation, then right lateral rotation (t=5,732).
Conclusions: Consequent preferential utilization of right and left superior and inferior limbs, implies a maximal isometric force production, in opposition, between groups, for lateral flexion and lateral rotation movements, at the level of thoracic-lumbar spine, which can be seen like a factor for muscular disbalances production.
Keywords: laterality, maximal isometric force, muscles, vertebral column, flexion, extension, lateral flexion, lateral rotation, women, Romanian.

Introduction

Aproximately 80% from the adult population has right superior limb dominant, 10% has left superior limb dominant (Hardyck C. and Petrinovich L. F., 1977) and 10% are ambidextrous (Noback C.R., Strominger N.L., Demarest R.J., Ruggiero D.A., 2005). McManus I. C., (1991), concluded that, only 8% of entire population has left superior limb dominant. Reiss M. and Reiss G., (1997), in a study conducted on 506 male and 430 female subjects, had shown 91% of subjects with right superior limb utilisation and 74% of subjects with right inferior limb utilisation; correlation between these two limbs was 0,44. Thereby, the number of subjects which presents left superior and inferior limbs preference, is very small.

Also, in the late adolescence, is shown a significantly change for right dominance, follwed by a relative stabilization of this behavior. Another studies showed that, adults recorded a significantly change from left dominance or without dominance for inferior limbs, to right dominance (Bell J. and Gabbard C., 2000), fact suggested by Porac C., (1996), but at the lavel of superior limbs. The incidence of left superior limb preferential utilization decreases, more or less, in relation with age, for both genders (Gilbert A. N. and Wysocki C. J., 1992).

This shift of dominance, can be generated by additional specific influence on human brain asymmetry, which is materialized by the presence of RS+ gene (Right Shift) for the majority of population (aproximately 80% from population ((Annett M., 2003)), which induces a tipical cerebral specialization, concretized by advantageous functioning of left hemisphere and functional weakening of right hemisphere. The effect of this gene, in superior limbs and brain asymmetry, is probably cumulative. This gene don't determine directly the superior limb preferential utilization, but only incereases the amelioration probability of superior levels of coordination, for the right side functionality (Annett M., 2006).

Selection procedure of physical exercises for muscular disbalances correction, is based on factors identification which produces those disbalances, on safety or load minimalization at the level of thoracic-lumbar column, and on an optimal muscular action, necessary to develop muscular strenght and endurance.

Inferior and superior limb preferential utilization could have a major impact in muscle development, for sedentary subjects and, also, for subjects who practice sports. (Renkawitz T., Boluki D., Linhardt O., Grifka J., 2007; Andersson E., Swärd L., Thorstensson A., 1988). The major impact, which suprior and inferior limb preferential utilization could have, on antagonistic muscle disbalances, could play an important role in appearance and development of back problems.

Thereby, the determination of muscle force, at the level of the vertebral column, in concordance with inferior and superior preferential utilization, could have an important role in physical exercises programs development necessary for muscular disbalances correction, in sedentary subjects, in subjects who practice sports and in wokers.

Hypothesis

Subjects with consequent preferential utilization of right superior and inferior limbs, is showing a maner of maximal isometric force generation, in frontal and saggital panes, at the level of thoracic-lumbar column, totally oposed, then subjects with consequent preferential utilization of left superior and inferior limbs.

Research Methods and Procedures

Participants

The transversal study was conducted in May 2008, in Constanta. The aims and methods of the study were explained to the participants, who chose freely to participate in this study. As a result, the sample included 16 subjects (8 subjects with superior and inferior left dominant limb (3,1%) and 8 subjects with superior and inferior right dominant limb, resulted after tests application of laterality estimation and after calculation of Hildreths' laterality index (Dougas M., 1965), from a total of 254 subjects), white Caucasian, sedentary Romanian women, with age between 30 and 40 years old, with no pain at the level of lumbar-thoracic column. The mean age for subjects with superior and inferior right dominant limb was $34^{4} \pm 2^{4}$ (years $^{\text{months}}$) and for subjects with superior and inferior left dominant limb was $35^{8} \pm 1^{9}$ (years $^{\text{months}}$).

Table 1. Physical characteristics of the subjects

	Women (n = 16)			
	Superior and inferior right dominant limb **(n = 8)**		Superior and inferior left dominant limb **(n = 8)**	
Variables	**M ± SD**	**CV(%)**	**M ± SD**	**CV(%)**
Body height (cm.)	163,25 ± 4,95	3,032	162,5 ± 4,309	2,652
Body weight (kg.)	66,088 ± 7,343	11,111	67,038 ± 5,352	7,984
BMI (kg/m^2)	24,745 ± 1,827	7,383	25,368 ± 1,439	5,673
Body fat (%)	26,625 ± 2,873	10,791	26,55 ± 2,964	11,164
Fat mass (kg.)	17,739 ± 3,56	20,069	17,91 ± 3,235	18,063

BMI, body mass index; M, mean; SD, standard deviation; CV, coefficient of variability; n, number of subjects.

Anthropometry

Body height was evaluated with an error of 0.5 centimeters and body weight was evaluated with a calibrated digital scale (Phillips HF-351, China), with an error of 0.05 kilograms. BMI was calculated to estimate the category of weight for each subject by using the Quetelet formula (Dumitru G., 1997; Dumitru G. and Suciu A., 1999). BF was estimated using bioelectrical impedance method, with Omron BF-306 (bodyfat analyser). Omron BF-306 offers strong corelated results with DEXA (Dual-Energy X-ray Absorptiometry), for bodyfat estimation

(Lintsi M., Kaarma H., Kull I., 2004). Fat mass was calculated by dividing the product of body weight and BF at 100.

Maximal isometric force estimations and analysis for lumbar-thoracic column

Maximal isometric force, at the level of lumbar-thoracic column, was estimated, for extension at 30 degrees, using F 110 Lumbar/Thoracic Extension device (Fig. 1) (David Fitness & Medical Ltd., Karitie 9, 01530 Vantaa, Finland), for flexion at 30 degrees, using David F 130 Lumbar/Thoracic Flexion device (Fig. 2), for lateral flexion at 0 degrees, using David F 150 Lumbar/Thoracic Lateral Flexion device (Fig. 3) and for lateral rotation at -30 degrees, using David F 120 Lumbar/Thoracic Rotation device (Fig. 4).

Figure 1. David F110 Lumbar/Thoracic Extension device

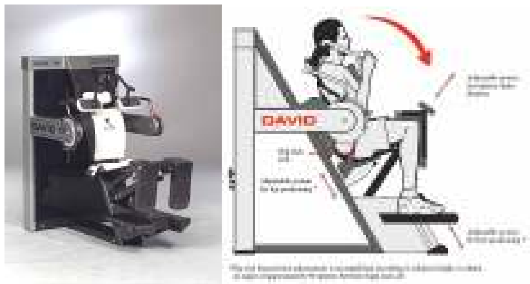

Figure 2. David F130 Lumbar/Thoracic Flexion device

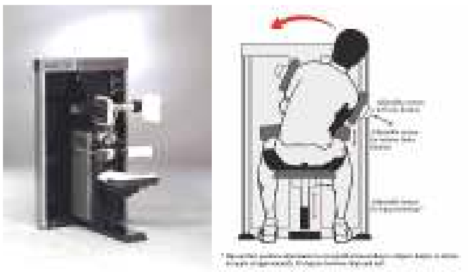

Figure 3. David F150 Lumbar/Thoracic Lateral Flexion device

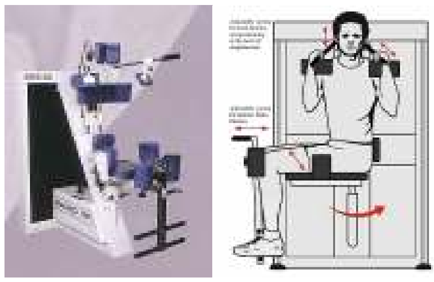

Figure 4. David F120 Lumbar/Thoracic Rotation device

Maximal isometric force results were recorded on MC-3 microcomputer (Fig. 5), which was connected on each DAVID device.

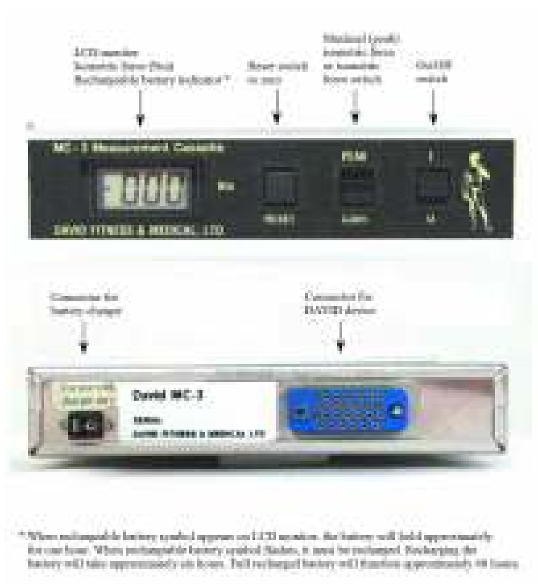

Figure 5. Digital test module MC-3

Maximal isometric force estimation, for all DAVID devices, at the level of lumbar-thoracic column, was estimated with hip and inferior limbs locked in a sitting position. Subjects were instructed to execute all the movements (flexion, extension, lateral flexion and lateral rotation), at the level of lumbar-thoracic column, by developing a progresive isometric force, avoiding sudden or uncontrollable movements (which could lead to eronated values of maximal isometric force), for 5 seconds, maximal isometric force being recorded in the last second of the test.

Preferential utilization estimation of superior and inferior limb

Limb dominance can be determined, under the aspect of preferential utilization and also, under the aspect of preferential utilization coordination of the limbs; these two aspects are separated, but with common characteristics. Also, is much complex to determine the preferential utilization of inferior and superior limb, using a questionnaire. In contrast, preferential utilization coordination of inferior and superior limb is a quantitative measure for motor dominance strength of one of the limbs, reported to the other limb (Medland S. E., Duffy D. L. Wright M. J., Geffen G. M., Martin N. G., 2005).

For the calculation of preferential utilization (dominance) of superior and inferior limb, was used Hildreth laterality index formula, which has two extremities for values: +1 for consequent right and -1 for consequent left. Also, the values between -1 and 0 is linked to left tendencies of preferential utilization, the values between +1 and 0 is linked to right tendencies of preferential utilization and 0 is linked to mixt preferential utilization. Zero value is obtained, only if the number of tests is paired. Hildreth laterality index formula is (R-L)/(R+L), where R represent the number of tests executed with the superior or inferior right limb and L represent the number of tests executed with the superior or inferior left limb (Dougas M., 1965; Bishop D. V. M., 2001).

As a fundamental condition, to realise the superior and inferior preferential utilization estimation, the subjects will not be informed about the tests aims, after the tests application, so that the data cannot be altered, as a consequence of physiologic influences of the subjects, regarding the final aims of these tests.

Tests for estimation of superior limb dominance

Test no. 1 Handclap

The subjects will handclap, with the mention that this handclap will be realised from the top to bottom and not laterally. When the right hand is active and is actionable from the top to bottom, then right superior limb is dominant and when the left hand is active and is actionable from the top to bottom, then left superior limb is dominant (Horghidan V., 1997).

Test no. 2 Cut with scissor a model (square) from the paper.

The subjects will cut whit a scissor a model (square) from the paper. When the scissor is held with the right hand, then the right superior limb is dominant and when scissor is held with the left hand, then the left superior limb is dominant (Bishop D. V. M., 2001).

Test no. 3 Tennis ball throwing, form above the head, with one hand to a target

The subjects will execute 3 tennis ball throwings, form above the head, with one hand to a circle (target) with 50cm. in diametre, from a distance of 6m. from the circle. When the throwings are executed with only the right hand, then the right superior limb is dominant and when the throwings are executed with only the left hand, then the left superior limb is dominant (Horghidan V., 1997; Bishop D. V. M., 2001).

Test no. 4 Write your name, surname, address, telephone number and e-mail on your paper sheet

The subjects will write the name, surname, address, telephone number and e-mail on a paper sheet. When the writing is executed with the right hand, then the right superior limb is dominant and when the writing is executed with the left hand, then the left superior limb is dominant

Tests for estimation of inferior limb dominance

Test no. 1 Kicking a tennis ball with the foot, between two landmarks

The subjects will kick the tennis ball (situated equally from the toes) with the foot, 3 times, between two landmarks (50cm. between them), situated at 4m. from the starting point of the tennis ball. When the kickings are executed with only the right foot, then the right inferior limb is dominant and when the kickings are executed with only the left foot, then the left inferior limb is dominant (Horghidan V., 1997).

Test no. 2 Executing a big step forward

On the soil is drawned a rectangle, with the feet contour inside. Two lines are drawned parallel with the long side of the rectangle, at 40cm. and 80cm. from nearest long side of the rectangle. The subjects, with the feet inside the rectangle on the contour of the feet, will execute a big step towards the lines, to go over the lines. When the big step is executed with the right foot ahead, then the right inferior limb is dominant and when the big step is executed with the left foot ahead, then the left inferior limb is dominant (Horghidan V., 1997).

Test no. 3 Running and takeoff on a single leg to execute a high plyometric skipping (pop-up)

On the soil are drawned two parallel lines with 5m. between them. The subjects, situated on the first line, will run towards the second line and execute a high plyometric skipping (pop-up). When the takeoff is realised on the right foot, then the right inferior limb is dominant and when the takeoff is realised on the left foot, then the left inferior limb is dominant (Horghidan V., 1997).

Test no. 4 Stair climbing

The subjects are positioned with the toes at 40cm. from the first stair. The subjects will climb the stairs. When the contact with the first stair is realised with the right foot, then the right inferior limb is dominant and when the contact with the first stair is realised with the left foot, then the left inferior limb is dominant.

Statistical analisys

Data are presented as the mean (M) ± standard deviation (SD). Dependent student t test was used to examine the differences of maximal isometric force between flexion and extension at 30º, right lateral flexion and left lateral flexion at 0º and right lateral rotation and left lateral rotation at -30º, for both groups. Independent student t test was used to examine the differences of maximal isometric force between groups, for all movements. Also, this test was used to examine the differences between perfect balanced means ratio and means ratio of right lateral flexion/left lateral flexion and right lateral rotation/left lateral rotation, for both groups. (Thomas R.J. şi Nelson J.K., 1996; Sheskin D. J., 2004).

The significance level (α – alfa) was set at $p < 0.05$, two-tailed test (Daniel D., Akeson W. H., O'Connor J. J., 1990; Lieber R. L., 1990; Thomas R.J. şi Nelson J.K., 1996).

Results

Table 3. Means of maximal isometric force results for flexion, extension, lateral flexion and lateral rotation, in women (n = 16)

		F130 Flexion (Nm) 30º	**F110 Extension (Nm) 30º**
Right superior and inferior dominant limb **(n = 8)**	M ± SD	79,625 ± 10,623 [a]	116,125 ± 13,271
	CV(%)	13,341	11,428
Left superior and inferior dominant limb **(n = 8)**	M ± SD	85,25 ± 10,82 [b]	125,125 ± 16,565
	CV(%)	12,692	13,239
		F150 Lateral flexion (Nm)	
		Right 0º	**Left 0º**
Right superior and inferior dominant limb **(n = 8)**	M ± SD	100,25 ± 8,498 [c e]	112,125 ± 14,055
	CV(%)	8,477	12,535
Left superior and inferior dominant limb **(n = 8)**	M ± SD	119,125 ± 14,045 [d]	110,5 ± 15,241
	CV(%)	11,79	13,793
		F120 Lateral Rotation (Nm)	
		Right -30º	**Left -30º**
Right superior and inferior dominant limb **(n = 8)**	M ± SD	57,5 ± 10,156 [f]	53,875 ± 11,728 [h]
	CV(%)	17,663	21,769
Left superior and inferior dominant limb **(n = 8)**	M ± SD	60,25 ± 9,161 [g]	66,75 ± 7,489
	CV(%)	15,205	11,233

a - significant different then F110 Extension, 30º, for subjects with right superior and inferior dominant limb, t=10,054;
b - significant different then F110 Extension, 30º, for subjects with left superior and inferior dominant limb, t=11,469;
c - significant different then F150 Left lateral flexion, 0º, for subjects with right superior and inferior dominant limb, t=4,59;
d - significant different then F150 Left lateral flexion, 0º, for subjects with left superior and inferior dominant limb, t=9,744;
e - significant different then F150 Right lateral flexion, 0º, for subjects with left superior and inferior dominant limb, t=3,252;
f - significant different then F120 Left lateral rotation, 0º, for subjects with right superior and inferior dominant limb, t=4,408;
g - significant different then F120 Left lateral rotation, 0º, for subjects with left superior and inferior dominant

limb, t=5,732;
h - significant different then F120 Left lateral rotation, 0º, for subjects with left superior and inferior dominant limb, t=2,616;

Significance level set at p<0,05.

M, mean; SD, standard deviation; CV, coefficient of variability; n, number of subjects; t, student t test; Nm, Newton*metre.

Table 4. Means of maximal isometric force ratios results, in women **(n = 16)**

Raport de forțe		Right superior and inferior dominant limb **(n = 8)**	Left superior and inferior dominant limb **(n = 8)**
F130 Flexion/F110 Extension **(30º)**	M ± SD	0,688 ± 0,078	0,684 ± 0,052
	CV(%)	11,337	7,602
F150 Right lateral flexion/F150 Left lateral flexion **(0º)**	M ± SD	0,898 ± 0,051 [a c]	1,081 ± 0,03 [d]
	CV(%)	5,679	2,275
F120 Right lateral rotation/F120 Left lateral rotation **(-30º)**	M ± SD	1,076 ± 0,054 [b e]	0,9 ± 0,052 [f]
	CV(%)	5,019	5,778

a - significant different then mean of F150 Right lateral flexion/F150 Left lateral flexion maximal isometric force ratio, 0º, for subjects with left superior and inferior dominant limb, t=8,748;
b - significant different then mean of F120 Right lateral rotation/F120 Left lateral rotation maximal isometric force ratio, -30º, for subjects with left superior and inferior dominant limb, t=6,64;
c - significant different then mean of F150 Right lateral flexion/F150 Left lateral flexion perfect balanced maximal isometric force ratio (when all maximal isometric force ratios are equal with 1), 0º, t=5,657;
d - significant different then mean of F150 Right lateral flexion/F150 Left lateral flexion perfect balanced maximal isometric force ratio (when all maximal isometric force ratios are equal with 1), 0º, t=7,637;
e - significant different then mean of F120 Right lateral rotation/F120 Left lateral rotation perfect balanced maximal isometric force ratio (when all maximal isometric force ratios are equal with 1), -30º, t=3,981;
f - significant different then mean of F120 Right lateral rotation/F120 Left lateral rotation perfect balanced maximal isometric force ratio (when all maximal isometric force ratios are equal with 1), -30º, t=5,439;

Significance level set at p<0,05.

M, mean; SD, standard deviation; CV, coefficient of variability; n, number of subjects; t, student t test.

Discussion

Maximal isometric force for extension, was significantly higher then maximal isometric force for flexion (table 3, a, b), in both groups. Keller T. S. and Roy A. L., (2002) and Straton A., (2007), showed that extensor muscles has a significantly higher force then flexor muscles, at the level of vertebral column.

An interesting aspect and close related with the dominance of inferior and suprior limbs, is showed by the significantly differences of maximal isometric force recorded, between right lateral flexion and left lateral flexion, for both groups. Subjects with right inferior and superior dominant limbs, generates a maximal isometric force significantly higher for left lateral flexion, then right lateral flexion (table 3, c). For subjects with left inferior and superior dominant limbs, this fact is inverted, so that, the generation of maximal isometric force is significantly higher for right lateral flexion, then left lateral flexion (table 3, d). These observations were consolidated by the significantly difference recorded, between groups, regarding right lateral flexion (table 3, e).

This opposed generation of force between groups, is also showed by the significantly differences recorded, between groups, regarding means ratio between right lateral flexion and left lateral flexion (table 4, a). Those disbalances were consolidated by the significantly differences recorded, between perfect balanced means ratio and means ratio of right lateral flexion/left lateral flexion, for both groups (tabelul 4, c, d).

The same as lateral flexion, dominance of superior and inferior limbs, impose a genaration of force, significantly higher for right lateral rotation in subjects with right dominant superior and inferior limbs, then left lateral rotation (table 3, f) and a genaration of force, significantly higher for left lateral rotation in subjects with left dominant superior and inferior limbs, then right lateral rotation (table 3, g). These observations were consolidated by the significantly difference recorded, between groups, regarding right lateral rotation (table 3, h). Also, these facts were accentuated, by the significantly difference recorded, between groups, for means ratio between right lateral rotation and left lateral rotation. The significantly differences between perfect balanced means ratio and means ratio of right lateral rotation/left lateral rotation (table 4, e, f) show off the antagonistic muscle force disbalances responsible for lateral rotation.

Superior and inferior limbs dominance, imply a tipical generation of force for muscles at the level of vertebral column. Is very well known that, resistance opposed in shoulder joint for superior limb - extension-adduction - will activate the oblic extern abdominal muscle from the same side with the superior limb that execute the movement and the oblic intern abdominal muscle from the opposite side with the superior limb that execute the movement. The dominance of suprior limb, implies a generation of force in opposition with the dominant suprior limb for lateral flexion and in the same side (oblic extern abdominal muscle) with the dominant suprior limb for lateral rotation (Mader S.S., 2004; Seeley R. R., Stephens T. D., Tate P., 2004). Frequent usage of dominant siperior limb in some movements (pull-up, carry, push, drag and maintain) can determine a tipical development of force for lateral flexion and lateral rotation. Also, frequent change of neutral positon, associated with superior limb dominance, concretized by bending and rotation of the trunk, can lead in a tipical development for muscle force, responsible for lateral flexion and lateral rotation movements.

Anyway, trunk muscle force corelation for lateral flexion and lateral rotation, with preferential utilization of superior and inferior limbs, is yet disputable and need more future research on this topic.

Conclusion

Consequent preferential utilization of right and left superior and inferior limbs, implies a maximal isometric force production, in opposition, between groups, for lateral flexion and lateral rotation movements, at the level of thoracic-lumbar spine, which can be seen like a factor for muscular disbalances production.

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