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PERSPECTIVES

Why is so important to balance the muscular dysbalance in mm. coxae area in osteoporotic patients?

(Biomechanical analysis, clinical application)

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Abstract: The article presents a biomechanical model of articulatio and mm. coxae with the characteristics of the vectors of reaction forces generated in flexors and extensors 1) in muscular balance; 2) in muscular dysbalance; 2a) with permanent load of the model of a hip by the body weight; 2b) with simulated live load during a fall or an impact. In case of muscular dysbalance the application of action force on a hip during a fall results in a sharp increase of the reaction compressive force in flexors and the tensile force in extensors. Muscular dysbalance of external (extensors) and internal (flexors) muscles of mm. coxae facilitates in this way complicated splintered fractures in the collum femoris area, and in the pertrochanteric and subtrochanteric areas.

Muscular balance achieved by balancing exercises and mechanical protection of the joint reduce the risk of splintered and complicated fractures in the described area *(Tab. 1, Fig. 5, Photo 9, Ref. 9).* Full Text (Free, PDF) *www.bmj.sk*

Key words: osteoporosis, muscular dysbalance, mm. coxae, biomechanics, hip fracture, therapeutic exercise.

The collum femoris fracture is one of the most frequent complications of osteoporosis. The incidence of fractures in the femoral area increases exponentially with age and it is higher in women. In women it increases after the onset of menopause, in men after the age of 70 (1, 2).

Increased incidence of fractures in the area of collum femoris, pertrochanter and subtrochanter acquires a world-wide importance, as it brings about an increase of the number of days in hospital beds as well as of costs for treatment of these patients. That is the reason why the prevention of osteoporotic fractures comes to the forefront of attention.

This article describes muscular dysbalance in mm. coxae area (Tab. 1, Fig. 1), which until now has been a less discussed factor contributing to splintered fractures of coli femoris, pertrochanter and subtrochanter. Human musculoskeletal system is demonstrated as a biomechanical construction transfering external load evenly from one part of the system to another. Basic knowledge of technical mechanics is applied in the study, namely the laws of statics. We simulate the magnitude and orientation of vectors of action and reaction forces in the biomechanical model of articulatio and mm. coxae. We use the method of composition and resolution of concurrent forces acting to a point in a plane, while the resultant of the forces is represented by a diagonal of a parallelogram, the so-called polygon of forces (3, 4).

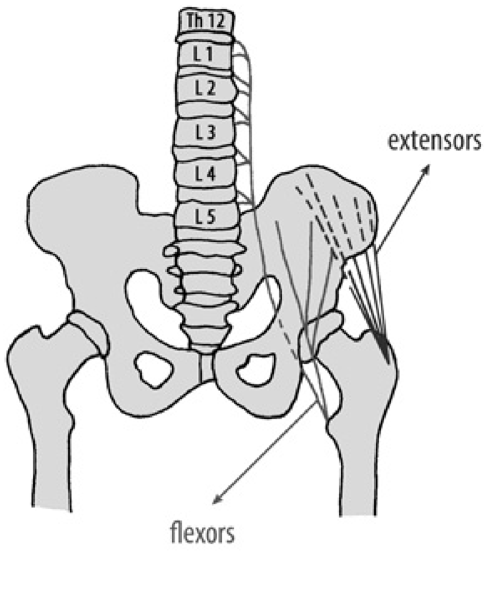

Fig. 1. Anatomical scheme of mm. coxae (flexors, extensors).

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Table 1.

	Muscles with tendency towards reduction of length.	
A)	**Flexors**	
	m. iliopsoas:	– m. psoas major – m. iliacus – m. psoas minor
	Muscles with tendency towards weakening	
B)	**Extensors**	
		– m. gluteus maximus – m. gluteus medius – m. gluteus minimus

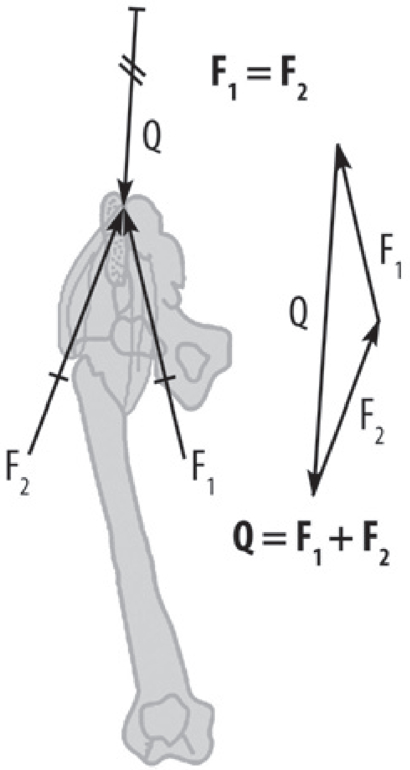


Fig. 2. Biomechanical scheme of force resolution in muscular balance. Q – the force vector, which simulate the action of the weight of the upper part of the body on articulatio and mm. coxae. Force Q resolutes into force F_1 acting on flexors and F_2 acting on extensors. F_1 – the force vector transferred into flexors, F_2 – the force vector transferred into extensors.

Biomechanical model of articulatio and mm. coxae (5, 6, 7)

We simplified articulatio and mm.coxae schematically to a biomechanical construction, which we used to simulate the aplication of individual forces and their assumed effects. We divided the loads applied to the biomechanical construction as follows:

1) internal permanent load – the weight of the construction itself (muscles, skeleton)

2) external permanent load – body weight minus the weight of muscles and skeleton

3) external live load – physical work, exercise, fall, impact, blow – applied to the construction only for limited time.

All external forces influencing the musculoskeletal construction are called action forces. These forces induce internal forces of the same quantity in the musculoskeletal system, which function against original action forces and we call them reactions, reaction forces. The stability of any construction, including a biological one, is preserved when the action and reaction forces are in balance. In our diagram of a biomechanical model articulatio and mm. coxae the force vector F_1 simulates a reaction compressive force in flexors and the vector F_2 in extensors in permanent load of the weight of the upper part of the body (Q) over articulatio coxae (Fig. 2). In the paper we do not give concrete values of Q and F forces in Newtons ($N = m.kg.s^{-2}$), but only their vectors, as the main purpose of the paper is to demonstrate clearly the changes in the magnitude and orientation of individual vectors a) in muscular balance, b) muscular dysbalance, c) in simulation of external live load (a fall) and their influence on the risk of fractures in the area of proximal femur. For the concrete values of Q and P forces it is possible with the help of polygons of forces [a scale is to be selected: *x (cm) = y (N)*] to calculate corresponding values of forces F_1, F_1', F_1'' and F_2, F_2', F_2'', which are discussed in the paper.

In case of regular motoric activity the reaction forces F_1 and F_2 (i.e. their tonus) are of the same magnitude ($F_1 = F_2$). It means that there is a balance between muscular groups of agonists and antagonists. Reaction forces F_1 and F_2 are also in balance with permanent load Q ($F_1 + F_2 = Q$), while the sum of F forces is to be considered in the sense of the sum of vectors (the method of composition and resolution of concurrent forces) (Fig. 2).

Sedentary life style of today's civilised society results almost in general dysbalance between muscular groups of agonists and antagonists. Also flexors of mm. coxae are shortened and their neutral tonus is growing. The vector of reaction compressive force F_1 is gradually increasing to the vector of F_1' force ($F_1 < F_1$'). External muscles of mm. coxae become flabby and have a tendency to elongation. Their neutral tonus decreases. The magnitude of the vector of compressive reaction force F_2 is diminished to the vector F_2' ($F_2 > F_2$'). Muscular dysbalance is the result, demonstrated by a change of force effect on the site of muscle tendons attached to a corresponding bone (Fig. 3).

Even in muscular dysbalance the balance status is preserved between reaction forces F_1', F_2' and permanent load Q, however,

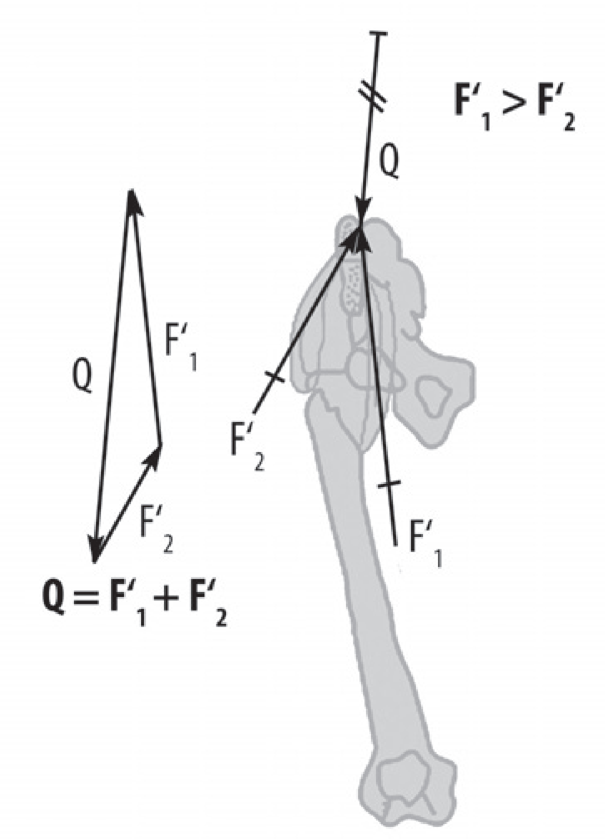


Fig. 3. Biomechanical scheme of force resolution in muscular dysbalance. Tonus of flexors is greater than that of extensors. F_1' – the force vector transferred into flexors, F_2' – the force vector transferred into extensors.

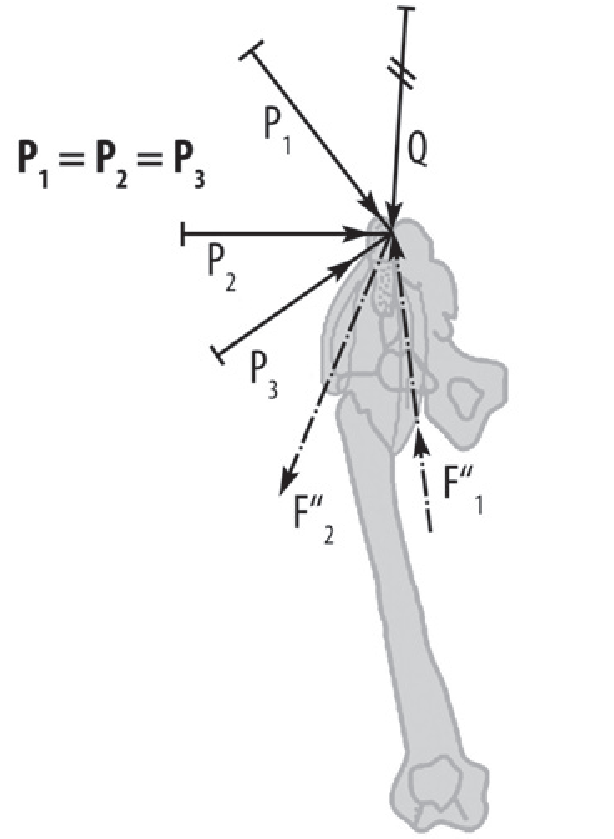


Fig. 4. The different direction of application of impact forces P1, P2 and P3 on the hip. Q – the force vector of the upper part of the body, P1, P2, P3 – the force vectors of live load (blow, impact, fall), F1" – the force vector in flexors, F2" – the force vector in extensors.

the flexors are overburdened by a growing compressive reaction force F_1' (F_1'>F_2', F_1'+F_2'=Q).

Muscular dysbalance in patients with osteoporosis becomes clinically significant:

1) in case of the increase of permanent load Q (weight gain)

2) in case of the increase of live load
   a) physical work, exercise
   b) fall, impact

3) in case of reduction of bone mass.

In these cases there is a distortion of balance status between reaction forces of external load (body weight, physical work, fall, impact) and reaction forces in muscles and bones.

In the biomechanical model of mm.coxae we simulated the influence of live load in the form of a vector of P force (blow, impact, fall). In case of low energy of the injury and normal density of bone mass the P value is submaximal, so there is a balance between action and reaction forces ($P+Q=F_1+F_2$) and, therefore, muscle fibres are not damaged and the bone is not broken. The magnitude of impact force P, which does not cause a fracture in healthy bone, increases the risk of fractures in osteoporotic patients just with the disruption of the balance of forces. In Figure 4 we simulated a different direction of application of impact forces P, having a vector of the same magnitude ($P_1=P_2=P_3$). In Figure 5 it can be seen how the vector of impact force P changes the magnitude and direction of force vectors in flexors (F_1") and extensors (F_2") in muscular dysbalance. Uniting the effects of vectors of impact force P and permanent load Q gives their resultant R. The influence of R resultant vector on mm.coxae (resolution of force effects of the R vector) results in the increase of reaction compressive force in flexors F_1" and, at the same time, there occurs an important phenomenon, when the compressive force in extensors is changed into tensile force F_2", because the vector of this force is oriented in opposite direction from the resultant R. Growing force F_2" in traction is transferred to muscle tendons in the trochanter major area.

The most unfavourable direction of the vector of the P force is the one with a perpendicular action upon the hip, as not only the reaction compressive force increases in F_2" flexors, but also tensile force in F_2" extensors. From the mechanical aspect there is a risk of the increase of just the tensile force in extensors weakened by muscular dysbalance, because there is a possibility of disrupting the integrity of muscular fibres as well as of complicated splintered hip fractures by a transfer of tensile force to trochanter major.

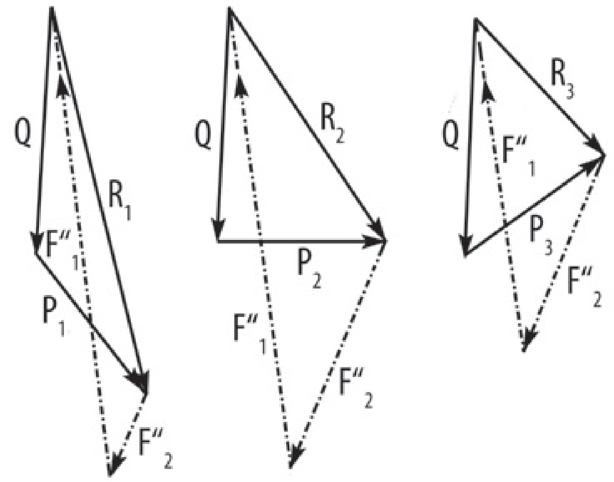


Fig. 5. Polygon of forces shows how can the vector of impact forces P1–P3 change the magnitude an direction of force vectors in flectors (F1”) and extensors (F2”) in muscular dysbalance. R1, R2, R3 – the resultant forces of a vector of Q force and P1, P2, P3 forces.

To prevent a sharp increase of tensile force F_2” which contributes to complicated fractures in the collum femoris area by a fall, it is necessary to remove muscular dysbalance of mm. coxae by balancing exercises. Balancing the muscular dysbalance puts to normal the tonus of extensors, thus improving the muscle quality as a tenacious material and increasing the value of yield stress and tensile strength – the resistance of the muscle against the effects of tensile force is growing. Muscular dysbalance can be diagnosed by tests, evaluating the length of internal muscles (the motion range of flexors) and the power of external muscles (extensors).

To remove muscular dysbalance in the mm. coxae area it is recommended to use the following techniques in balancing exercises for osteoporotic patients (8):

1. for shortened muscles (flexors) we set up a programme of statical stretching exercises on the principle of post-isometric relaxation (tension – relaxation – stretching)

2. for weakened muscles (extensors) we set up a programme of muscle conditioning exercises (slow statical submaximum isometric exercises and slow dynamic conditioning exercises).

Conclusion

An asset of this paper is the new knowledge that muscular dysbalance between flexors and extensors of mm.coxae could contribute during a fall or an impact upon the hip to complicated splintered fractures. In addition to well-known preventive measures against fractures in the collum femoris area as:

1. early diagnosis and therapy of osteoporosis
2. rational nutrition
3. regular motoric activity
4. mechanical protection of hip in risk patients

we would recommend also a targeted therapeutic exercise to balance the muscular dysbalance of mm. coxae.

An important role in providing regular long-term therapeutic exercise for osteoporotic patients is played by trained instructors of therapeutic exercise who manage in a professional way self-helping groups of patients associated in patient’s organisations. Therapeutic exercise should become a very important part of complex care of outdoor osteoporotic patients.

Clinical application of the biomechanical analysis

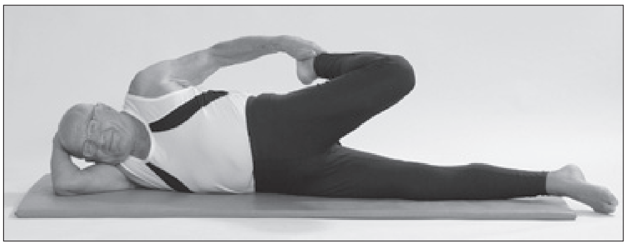
Suggested Compensatory Exercises program To Remove Muscular Dysbalance In The Mm. Coxae Area

In compensatory exercises we have chosen stretching for shortened muscles and strengthening exercises for weakened muscles (9).

Stretching the flexors of mm. coxae

M. iliopsoas

Photo 1



The patient lies down on his/her right side and puts his head on his/her right UL (upper limb). He/she bends his/her left LL (lower limb) in the knee and by his/her left hand grips the end of hi/her bended leg. He/she pulls his/her leg backwards. He/she alternates the limbs in the given position.

Photo 2

Squatting on the left leg with outstretched right leg the patient transfers the weight to the front to his/her right LL until feeling in the bent LL the traction of muscles in the frontal part of the thigh. In this exercise it is not allowed to increase the bending in the lumbo-sacral area (LS).

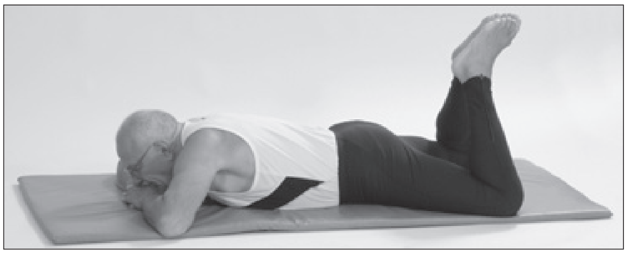
Photo 3

The patient sits astride on a square shape stool and moves his/her leg backwards until feeling the traction in the frontal part of the thigh of that lower limb. The trunk is held straight, the pelvis must not be turned to a side.

Strengthening of mm. coxae abductors

M. gluteus maximus

Photo 4



In a prone position the patient bends the lower limbs in the knees and for a few seconds pushes the soles of his/her feet together, alternating tension and relaxation several times.

Photo 5

The patient leans with his/her hands on the stool, stretches one LL backwards in a horizontal plane. The sole of the stretched LL is relaxed; the point of his/her foot is turned downwards.

Photo 6

In a prone position the patient bends one LL and lifts it slightly above the pad. He/she must not bend in the LS area. The patient alternates the limbs in given positions.

Photo 7

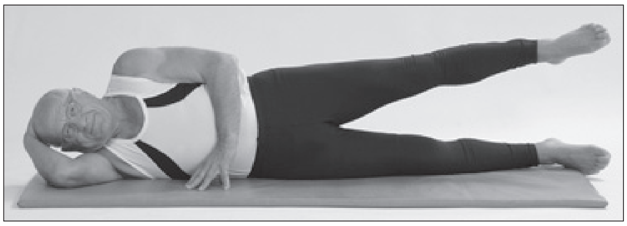
In a kneeling position, leaning on his/her hands, the patient stretches backwards one bent LL, pulling it upwards, the thigh and the spine is in one line, the point of the bent LL is not tense. The positions of limbs are alternated.

M. gluteus medius and minimus

Photo 8 (a – frontal view, b –side view)

In a kneeling position, leaning on his/her hands, the patient puts one leg to the side and bends it, not turning the pelvis and keeping the whole trunk in one plane. The patient pushes him/herself away from the floor with the hands not to allow the chest to protrude between the shoulders. The knee of the bent LL should be positioned higher than the sole. He/she maintains this position for about 5 to 10 minutes.

Photo 9



The patient lies on his/her side. With one outstretched LL he/she slightly swings up and down without entirely putting the legs together. The patient alternates the position of the LL.

Caution

Patients with advanced osteoporosis with wedge-shaped deformations of vertebrae do not perform exercises in Fig. 1, 3, 4, 6, 7 and 8.

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