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MUSCULAR DYSBALANCE IN MM. COXAE AREA AND ITS CLINICAL SIGNIFICANCE FOR PATIENTS WITH OSTEOPOROSIS

Zusammenfassung

Dieser Artikel beschäftigt sich mit einem biomechanischen Modell von Gelenken und Mm. coxae und charakterisiert die Vektoren der Reaktionskraft von Flexoren und Extensoren 1) in muskulärer Balance, 2) in muskulärer Dysbalance, 2a) bei permanenter Belastung der Coxa durch das Körpergewicht, 2b) mit simulierter Belastung während eines Sturzes oder sonstiger Einwirkung. Im Falle der muskulären Dysbalance ergibt die Einwirkung einer Kraft auf die Coxa während eines Sturzes einen starken Anstieg der Kompressionskraft der Flexoren und der Entspannungskraft der Extensoren. Eine muskuläre Dysbalance der Mm. coxae ermöglicht auf diese Weise komplizierte Splitterbrüche im Bereich des Oberschenkelhalses sowie des Peritrochanters und Subtrochanters.
Eine muskuläre Balance, die durch Übungen, aber auch durch mechanische Protektoren der Gelenke erreicht werden kann, verringert das Risiko von komplizierten Splitterfrakturen in den beschriebenen Bereichen.

SUMMARY

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 coxa 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 coxa 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 and internal 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.

Table 1
A. Muscles with tendency towards reduction of length: Flexors
– M. iliopsoas – M. psoas major – M. iliacus – M. psoas minor
B. Muscles with tendency towards weakening: Extensors
– M. gluteus maximus – M. gluteus medius – M. gluteus minimus

INTRODUCTION

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 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, which until now has been a less discussed factor contributing to splintered fractures of colli femoris, pertrochanter and subtrochanter. Human musculoskeletal system is demonstrated as a biomechanical construction transferring 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].

BIOMECHANICAL MODEL OF ARTICULATIO AND MM. COXAE

We simplified articulatio and mm. coxae schematically to a biomechanical construction, which we used to simulate the application of individual forces and their assumed effects (Fig 1–5). 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 of articulatio and mm. coxae the force vector F1 simulates a reaction compressive force in flexors and the vector F2 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 F1, F1′, F1″ and F2, F2′, F2″, which are discussed in the paper.

In case of regular motoric activity the reaction forces F1 and F2 (i.e. their tone) are of the same magnitude (F1 = F2). It means that there is a balance between muscular groups of agonists and antagonists. Reaction forces F1 and F2 are also in balance with permanent load Q (F1 + F2 = 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).

Figure 1: Anatomical scheme of Mm. coxae (flexors, extensors)

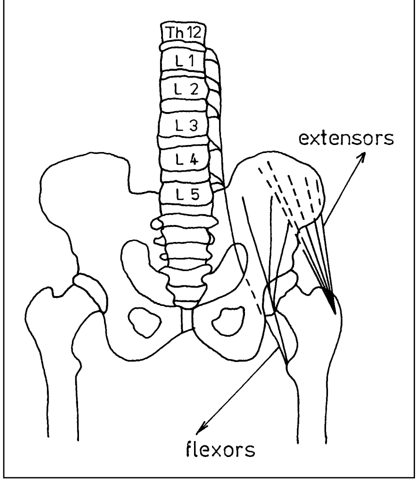
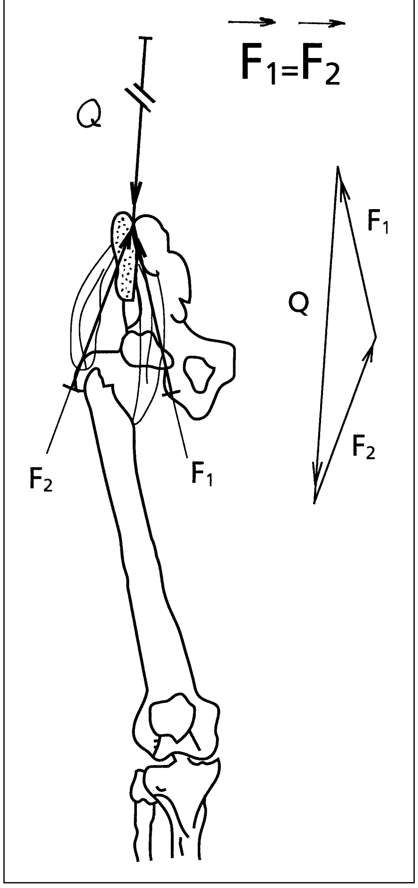


Figure 2: Biomechanical scheme of force resolution in muscular balance: Q = the force vector, which simulates the action of the weight of the upper part of the body on articulatio and mm. coxae. Force Q resolutes into force F1 acting on flexors and F2 acting on extensors. F1 = the force vector transfered into flexors. F2 = the force vector transfered into extensors.



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 tone is growing. The vector of reaction compressive force F1 is gradually increasing to the vector of F1′ force (F1 < F1′). External muscles of mm. coxae become flabby and have a tendency to elongation. Their neutral tone decreases. The magnitude of the vector of compressive reaction force F2 is diminished to the vector F2′ (F2 > F2′). Muscular dysbalance is the result, demonstrated by a change of force effect on the site of muscle tendons attached to a corresponding bone.

Even in muscular dysbalance the balance status is preserved between reaction forces F1′, F2′ and permanent load Q, however, the flexors are overburdened by a growing compressive reaction force F1′ (F1′ > F2′, F1′ + F2′ = Q) (Fig. 3).

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.

According to mechanical reaction of materials to simple tensile and compressive stress, the materials can be divided into brittle and tenacious ones. Brittle materials can be disrupted by very small permanent deformations. Tenacious materials can be disrupted only after a substantial permanent deformation. Mechanical properties of materials are characterised by a stress-strain curve, which is set up on the basis of testing the materials by a growing tensile and compressive loading. According to these charts the bone ranks among brittle [5] and the muscle among tenacious materials [6, 7]. Stress-strain curve under tensile loading for brittle materials consists of the proportional limit, elastic limit and tensile strength [5]. The curve for tenacious materials is characterised by proportional limit, yield stress (friction) and tensile strength [7]. As regards the definition of flexibility and strength of biomaterials, we can state that when the overall tension generated as the result of external forces load exceeds the yield stress limit of the strained muscle of musculoskeletal biomechanical construction, the result is its plastic deformation and, in case of exceeding the tensile strength limit, the rupture of the muscle (in case of exceeding the strength limits of the bone it results in its fracture).

Figure 3: Biomechanical scheme of force resolution in muscular dysbalance. Tone of flexors is greater than of extensors. F1' = the force vector transfered into flexors. F2' = the force vector transfered into extensors.

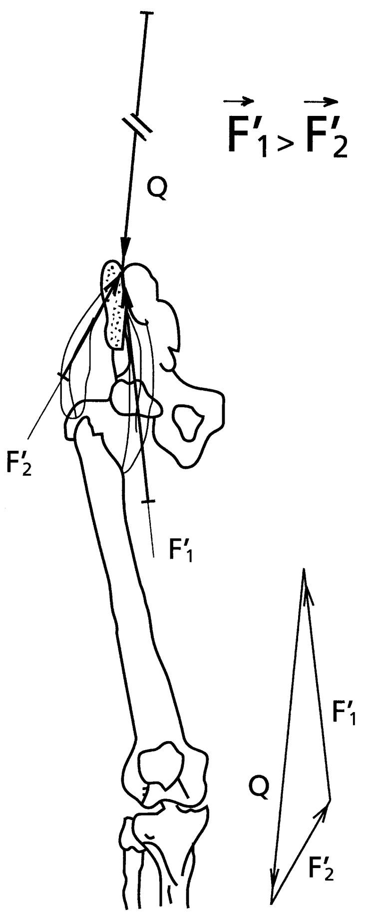
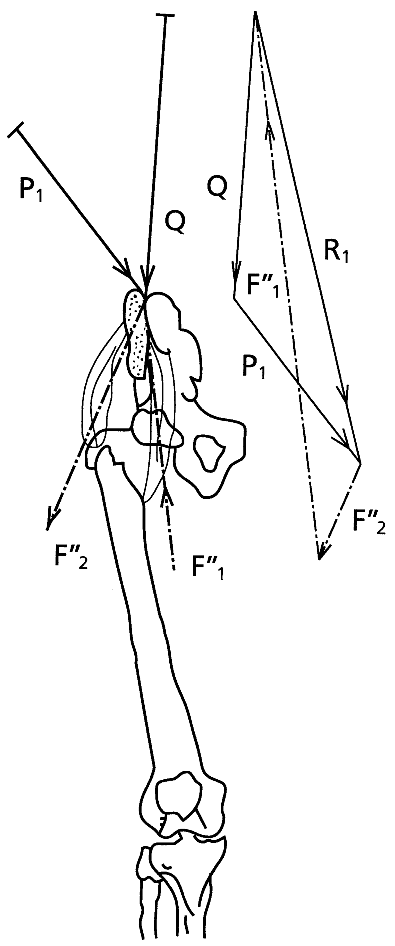


Figure 4: Simulation of the influence of life load (blow, impact, fall) on resultant force in muscular dysbalance. P1 = the force vector of life load (blow, impact, fall). R = the resultant force of a vector of Q force and P1 force. F1" = the force vector transfered into flexors. F2" = the force vector transfered into extensors.



In the biomechanical model of mm. coxae (Fig. 4) we simulated the influence of live load in the form of a vector of P1 force (blow, impact, fall). In case of low energy of the injury and normal density of bone mass the P1 value is submaximal, so there is a balance between action and reaction forces (P1 + Q = F1 + F2) and, therefore, muscle fibres are not damaged and the bone is not broken. The magnitude of impact force P1, 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 Fig. 4 it can be seen how the vector of impact force P1 changes the magnitude and direction of force vectors in flexors (F1″) and extensors (F2″) in muscular dysbalance. Uniting the effects of vectors of impact force P1 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 F1″ and, at the same time, there occurs an important phenomenon when the compressive force in extensors is changed into tensile force F2″, because the vector of this force is oriented in opposite direction from the resultant R. Growing force F2″ in traction is transferred to muscle tendons in the trochanter major area and encourages the onset of complicated splintered fractures in osteoporotic bone.

In Fig. 5 we simulated a different direction of application of impact forces P, having a vector of the same magnitude (P1 = P2 = P3). The most unfavourable direction of the vector of the P force is the one with a perpendicular action upon the coxa, as not only the reaction compressive force increases in F1″ flexors, but also tensile force in F2″ 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 fractures by a transfer of tensile force to trochanter major.

To prevent a sharp increase of tensile force F2″ 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 flexors (the movement range of flexors) and the strength of extensors.

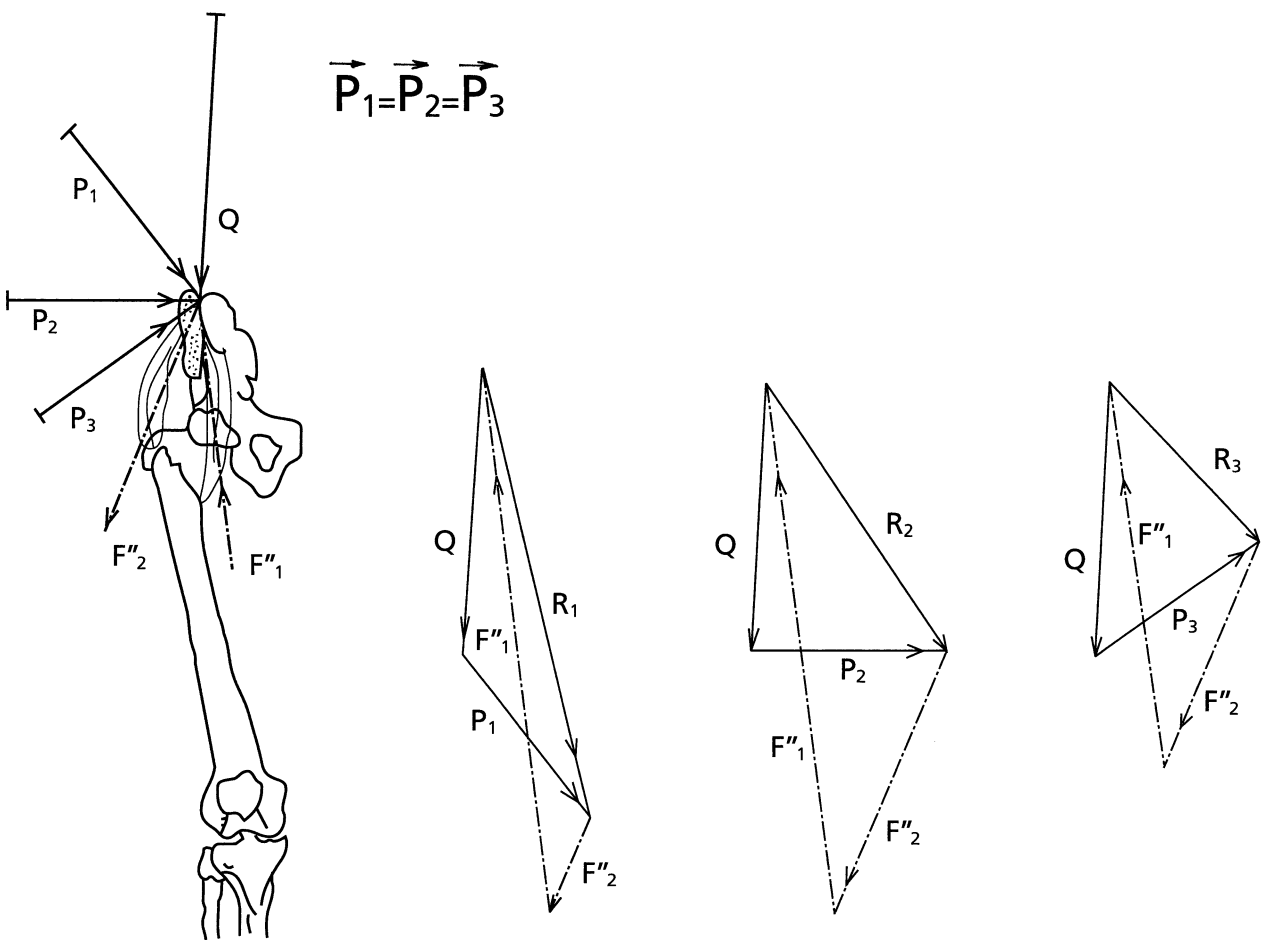
To remove muscular dysbalance in the mm. coxae area it is recommended to use the following techniques in balancing exercises for osteoporotic patients [8]:

1. for shortened muscles (flexors) we set up a programme of static 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 static 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

Figure 5: Influence of different direction of application of impact forces P1, P2 and P3 on the resolution of forces (F1”, F2”) in dysbalanced flexors and extensors.



Mm. coxae could contribute during a fall or an impact upon the coxa 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 patients' organisations. Therapeutic exercise should become a part of complex care of outdoor osteoporotic patients.

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