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The stabilizing system of the spine

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Abstract

The spatial orientation of the lumbar part of spine determines the position of central axis of the human skeleton, which in turn is closely related to the position of the pelvis. In a biomechanical aspect, the pelvis should be connected with the lumbar spine but also with the hip joints (lumbo-pelvic-hip complex – LPH) . This area is intended to provide the body with the stability needed to carry the load with simultaneous maintaining the mobility required to perform locomotive functions. Stabilization means the maintenance of balance in both static and dynamic conditions, where the complex moves along a specific track. In the last decades of 20th and early 21st century there was a discussion whether stabilization of the LPH complex was more about the activation of deep muscles (local) or combination of deep and superficial muscles contraction (global). It is now known that both global and local muscles play an important role in stabilization. The stabilizing system of the spine, which was introduced by Panjabi in 1992, works on the cooperation of those three systems: neural, which is the control system; muscular-fascial, which is the active system; osteoarticular - ligamentous, which creates a passive system. Hoffman and Gabel [22] proposed a new, extended theoretical model in which the new mobility system is placed beside the existing stability system and subsystems. Harmonious work of stability and mobility systems determines the quality of movement, but the malfunction of these systems affects other subsystems and thereby the quality of movement. The authors of this theoretical model suggest that both rehabilitation and mobility systems should be involved in rehabilitation exercises, with the movement being at a possible level but without pain and discomfort. LPH stabilization exercises are used in physiotherapeutic procedures in patients with pain and traumas, with stress urinary incontinence and in pregnant women.

Key words: lumbo - pelvic – hip region, the stabilizing system of the spine

Introduction

The spatial orientation of the lumbar part of spine determines the position of central axis of the human skeleton, which in turn is closely related to the position of the pelvis. In a biomechanical aspect, the pelvis should be connected with the lumbar spine but also with the hip joints (lumbo - pelvic – hip comlex - LPH). This area is intended to provide the body with the stability needed to carry the load with simultaneous maintaining the mobility required to perform locomotive functions. [1,2].

Biomechanics of LPH complex

Biomechanics of the lumbar spine should be considered in terms of free motion of each lumbar vertebrae. 12 degrees of free motion of the lumbar vertebrae is the result of movements in 3 planes and around 3 axes. Around the frontal axis (sagittal plane) there take place bending and straightening movements, the lateral bend (right and left) occurs around the sagittal axis (frontal plane) and the rotation (left and right) takes place around the longitudinal axis (transverse plane). Along the axes there are also other movements: back-to-front / front-to-back translation (sagittal axis), parallel lateral translation / parallel medial translation (front axis), distortion / compression (transverse axis). This model should include anatomical factors that modify theoretically possible movement. The sacral-lumbar joint in practice has four degrees of free motion: 2 degrees of free flexion combined with rear-front translation and extension combined with front-rear translation. The next two degrees of free motion are: right lateral bend / rotation combined with medial lateral translation, left lateral bend / rotation combined with medial lateral translation [3]. Pearsy et al. [4] have shown that in the section above L4-L5 the rotation occurs in the opposite direction to lateral flexion. In L5-S1, the rotation occurs in the direction of lateral flexion whereas the transition level is L4-L5, rotating once as the segments below and once as the segments above. Bogduk et al. [5] believe that the axial rotation of the motion segment on the level of lumbar spine is possible in the 3 degree range: the smallest at the L-S boundary, gradually increasing in higher lumbar segments and moreover, that there are individual distinct features that contradict the existence of any principles for section mobility.[5]. The movement also changes under the influence of age and pathological changes (eg degenerative changes) [6,7].

Troke et al. [8] have developed the norms of the active range of lumbar spine motion (AROM - active range of motion) on the basis of examination of the group of 405 people between 16 and 90 years of age. There are clear differences in mobility among age groups in the study, but there is no significant difference in the range of mobility between men and women. For lumbar flexion the median was 73° in the youngest group, while for the oldest group it was 40 °. For extension motion the median in the youngest group was 29°, while in the oldest group it was 6°. The range of side bending for the youngest group was 28° and it decreased to 16° in the oldest group. However, the rotation range in both age groups remained at a constant 7°.

Another element of the LPH complex is: the pelvis, the sacral bone and the cross-iliac joints which constitute a functional integrity with the spine. In a biomechanical aspect, pelvic motion can be divided into two groups: spontaneous pelvic motion when the pelvis is moving as a whole and internal motion (sacroiliac joint mobility and pubic symphysis mobility). The flexion of sacral bone in regard to hip bone is referred as nutation, while the extension is defined as contrenutation. When this movement is disordered, a dysfunction of the sacroiliac joint can occur. The motion of the hip joint is based on bone-ligament stabilization, what is based on two complementing mechanisms:

- structural locking (spontaneous) - spatial arrangement of structures prevents the central element from moving downwards;
- force locking (forced) - the central part of the system remains stable in case of transverse friction forces [1-3,9].

The combination of these two mechanisms results in stabilization which is characteristic for the sacroiliac joint and which is particularly important in sitting, walking, spine rotation and bent torso rising.[10]. The pelvis is connected with the femur at the hip joint - the acetabulum spherical joint. From a biomechanical point of view it is a joint of twelve degrees of free motion. The movement of hip bone in relation to the pelvis is a combined movement. During the following phases of the walk there occur: in the transfer phase - flexion, adduction and external rotation in the transfer phase, and in the support phase - extension, abduction and internal rotation.

The stabilizing system of the spine

According to Reeves et al. [11] stabilization means the maintenance of balance both in static and dynamic conditions, where the complex moves along a specific track. In the last decades of the 20th and early 21st century, a discussion has been taken on whether isolated deep muscle activity (local muscles) or combined deep and superficial muscle contraction (global muscles) is of greater importance in achieving full stabilization of the LPH complex. It is now known that both global and local muscles play an important role in the stabilization mechanism [12].

Comerford [13,14] has divided the muscles of the lumbar spine region into: local stabilizers, one-joint global stabilizers and multi-joint global stabilizers. Local muscles increase the stiffness of the segment and contribute to the control of segmental translation. Their activity is constant and independent of the direction of movement. They function in the feedforward system - they turn on earlier than the corresponding muscle generates significant torque. Global muscles are characterized by a high threshold of excitability, they generate the necessary force to control the range of motion, their activity depends on the direction of movement and it is not constant. In the physiological situation, the local stabilizing muscles (transverse abdomen, multifidus muscle, pelvic floor muscles) are activated first. Their activation occurs shortly before the movement, protecting the spine from overload. These muscles work together with the global stabilizing muscles (external fibers of the quadriceps muscles of the lumbar, piriformis muscle). However, the global motor muscles (rectus abdominis muscle and erector spinae muscles) cause spinal movements without any effect on spine stabilization. When pain occurs, deep muscle activity is inhibited. Hides et al. [15] compared transverse section of lumbar part of multifidus muscle in patients with lower back pain and in healthy subjects. Patients with chronic spinal disorders showed a significantly lower transverse section of the examined muscle at the level of the two lowest segments. The biggest disproportion between right and left sides at L5 level occurred in patients whose symptoms referred to one side of the body. The analysis of the results confirmed that pain in the lumbar spine is associated with local atrophy of multifidus muscle.

Hodges et al. [16] evaluated muscular changes as a result of spinal injury. The atrophy of multifidus muscle causes damage to the intervertebral disc as well as the nerve root. The location of changes in this muscle (reduction in transverse section area) was different depending on the level and the type of injury. Moseley et al. (17) showed that stimulation of the lumbar section with pain stimulus causes delayed activation of the transverse abdominal muscle and abdominal internal oblique muscle during dynamic movements of the upper limb. After the elimination of the pain, the muscle activation time returned to the norm in most cases.

Also Richardson et al. [18] suggested categorizing the muscles in a functional motion pattern into two groups: stabilizers and mobilizers. Stabilizers maintain the static placement of a particular body segment. The ones that act on one joint are local stabilizers (eg, multifidus muscle), while those that work on at least two joints are global stabilizers (abdominal muscles - internal and external oblique). Mobilizers are responsible directly for any movement (abdominal muscle, thigh muscles from a back group). To stabilize the LPH complex, all local stabilizers, global stabilizers and mobilizers should work together.

The stabilizing system of the spine, which was introduced by Panjabi in 1992, works on the cooperation of those three systems (Fig.1):

- neural, which is the control system;
- muscular-fascial, which is the active system;
- osteoarticular - ligamentous, which creates a passive system.

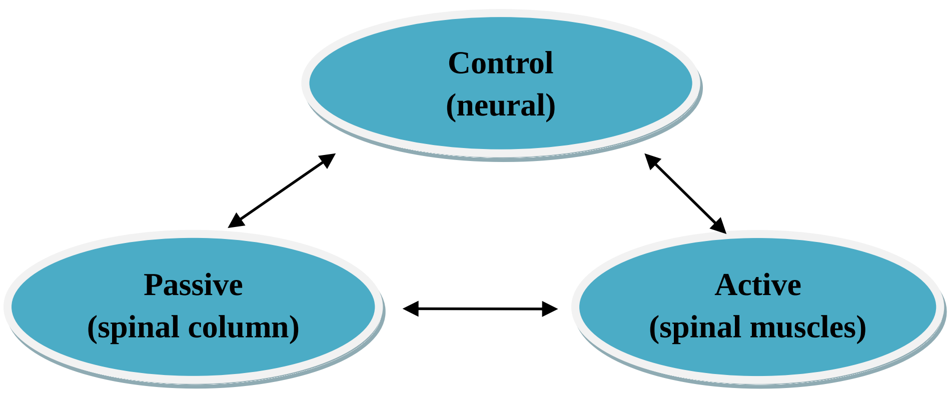

Fig. 1. Subsystems of stabilization according to Panjabi [19]

The correct functioning of the stabilization system depends on the efficiency of these three systems and they are interrelated. Thus, malfunction of one element leads to compensation overload of other elements, which may result in derivate dysfunctions. Another element that determines stability is, according to Panjabi's definition, the neutral zone (Fig. 2). The definition of the neutral zone explains that it as a small range of motion near the zero position of the joint, where no proprioreceptors are stimulated around the joint and osteoligamentous resistance is minimal (lack of centripetal response and, consequently, lack of central muscle stimulation).

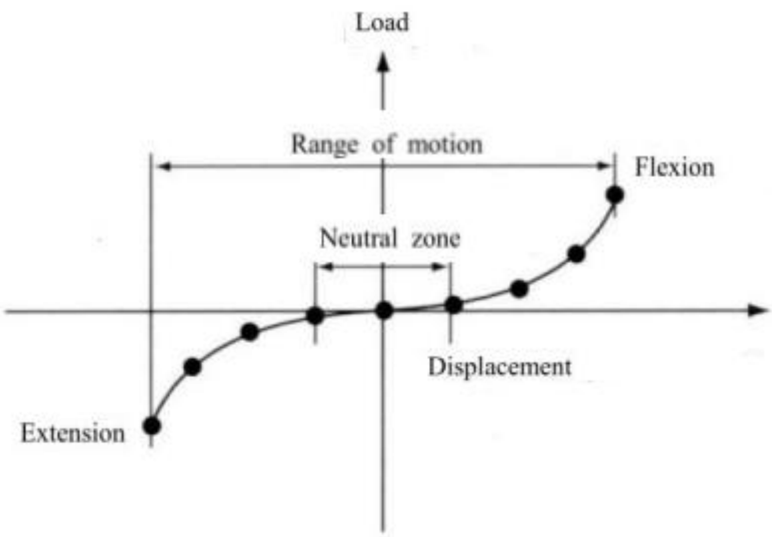

Fig. 2. Neutral region model according to Panjabi [20,21]

Increasing the range of motion of the neutral zone is detrimental to the joint - it can lead to its damage. Delayed proprioceptive information about the current joint position that reaches the central system will give a muscle tone response, but it may turn out to be incompatible with external force acting on the joint. The reduced range of motion of the neutral zone is also unfavorable. If the stimulation of proprioreceptors is too early it will result in an increased muscle tension around the joint. The neutral zone is disturbed by traumas, degenerative processes, and muscle stabilization weakness [20].

The Panjabi's model shows the stabilization of human body as a dynamic phenomenon which depends on many factors:

- external factors: gravity acting on the body which causes the occurrence of shear forces (vertical and horizontal);

– internal factors: interaction of nervous system, myofascial system; skeletal system and articular-ligamentous system.

Hoffman and Gabel [22] proposed a new, extended theoretical model in which the new mobility system is placed beside the existing stability system and subsystems [Fig.3].

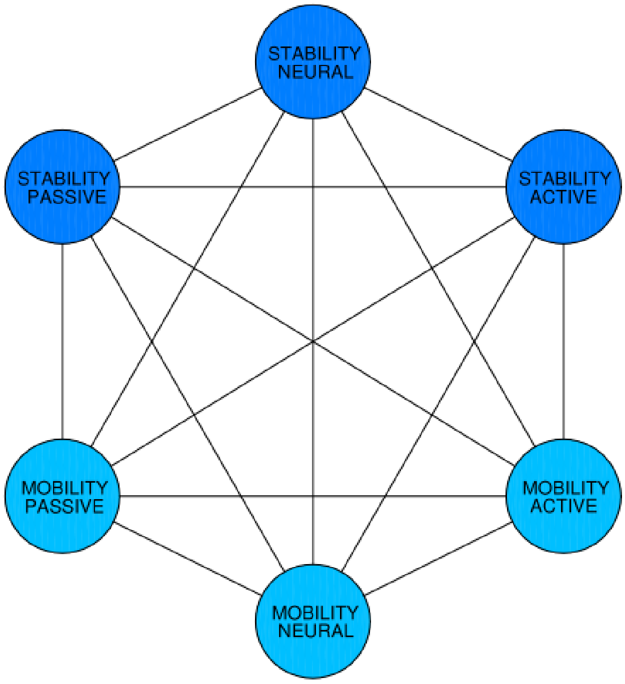

Fig. 3. The six subsystems of movement according to Hoffman and Gabel [22]

Harmonious work of stability and mobility systems determines the quality of movement, but the malfunction of these systems affects other subsystems and thereby the quality of movement. The authors of this theoretical model suggest that both rehabilitation and mobility systems should be involved in rehabilitation exercises, with the movement being at a possible level but without pain and discomfort. According to Hofman and Gabel, the use of this model can be a universal motion analysis system, as well as allow understanding of musculoskeletal disorders. At the same time, the authors point out that during the rehabilitation exercises it is not always possible to involve all six subsystems, and the level of interaction between them determines the level of functionality. This holistic model, in which the movement functions as a continuum, can help clinicians develop therapeutic programs covering six subsystems, so there is a need for further research into this theoretical model.

It should also be stressed that the dysfunction of the LPH complex, resulting from the lack of stabilization, can give distant responses, such as [1,2]:

– peripheral nerve compression syndromes of the upper limb;

- headache, nausea, vomiting;
- the increase of muscle tone of the latissimus dorsi muscle, which may cause limitation of mobility of the shoulder-arm complex;
- scapula-arm rhythm disorder;
- hipo - and hypertonia of peroneus longus muscle resulting in club foot position of the ankle;
- motor dysfunction of the proximal and distal Tibiofibular syndesmosis
- tendillopathy of Achilles tendon;
- patellar tendonitis (jumper's knee);
- chondromolacia patellae (runner's knee);
- piriformis muscle syndrome, which can mimic enterological or gynecological problems;
- respiratory disorders and oxygen usage disturbances resulting from abnormal tension of transversus abdominis muscle and diaphragm (muscles in the deep stabilizing system responsible for respiratory movements);
- incontinence - a pelvic or lumbar spine pain can affect the tonus of the pelvic floor muscles.

Stabilization exercises for the LPH complex are used in physiotherapeutic procedures in patients with pain and spinal injuries, with stress urinary incontinence as well as in pregnant women [23-28]. The effectiveness of central balance exercises was confirmed by a meta-analysis by Wang et al. [29]. The review included randomized studies published between 1970 and 2011 comparing central balance exercises with general-purpose exercises in patients with pain in the lower back of the spine. 28 studies with 414 participants were specified. Central stabilization exercises were assessed as more effective in reducing pain and increasing the mobility of the participants tested. However, there were no statistically significant differences between groups for long-term therapeutic effects.

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