

The importance of the pelvis and the consequences of its incorrect positioning

Anna Puchalska – Sarna¹, Michał Sarna², Victor Touma³

¹ University of Rzeszów, Collegium Medicum, Faculty of Health Sciences and Psychology, Institute of Physiotherapy, Poland

² University of Rzeszów, Faculty of Physical Culture Sciences, Study of Physical Education and Recreation, Rzeszów, Poland

³ ORTO Private Orthopedic Clinic, Poland

Pelvic anatomy

The pelvic bone consists of three main elements: the ilium, the ischium, and the pubis.

The ilium (os ilium) comprises a shaft and a plate, separated by an arcuate internal line.

The iliac body is attached to the obturator internus muscle (upper fibers) on the inner side, and to the rectus femoris muscle on the outer side. The iliac plate is characterized by the gluteal surface, the gluteal lines (posterior, anterior, and inferior), the sacropelvic surface, the iliac fossa, the auricular surface, the iliac tuberosity, and the iliac crest, which includes the anterior superior and posterior superior iliac spines, the outer and inner lips, and the intermedius linea. The following muscles attach to the outer lip:

The external oblique muscle of the abdomen, the latissimus dorsi, and the fascia lata of the thigh attach to the inner lip. The longissimus muscle, the iliocostalis lumborum, the quadratus lumborum, the transverse abdominis muscle, and the fascia ilialis attach to the inner lip. The internal oblique muscle of the abdomen attaches at the intermediate line, and the iliac tubercle, anterior inferior iliac spine, and iliopubic eminence are located nearby. On the external side of the anterior superior spine, the tensor fascia lata and the fascia lata of the thigh attach, while on the internal side, the iliac muscle, the inguinal ligament, and the sartorius muscle attach. The anterior inferior iliac spine is the site of attachment of the rectus femoris and the iliofemoral ligament. The posterior sacroiliac ligament attaches to the posterior iliac spine. The posterior inferior iliac spine and greater sciatic notch are also visible.

The ischium (os ischii) comprises a shaft with the posterior obturator tubercle, the ischial spine, the ischial tuberosity, and the lesser sciatic notch. Externally, muscles attach to the ischial spine, such as the superior gemini, while the internal surface contains the coccygeus muscle and the sacrosiatic ligament. The greater sciatic foramen, through which passes the piriformis muscle and the sciatic nerve. sciatic nerve, posterior cutaneous nerve of the thigh, upper and lower gluteal arteries, veins and nerves, internal pudendal artery and veins, pudendal nerve

The sacrospinous ligament limits the greater sciatic notch (greater sciatic foramen)

The lesser sciatic foramen contains the obturator internus tendon, the internal pudendal vessels, and the pudendal nerve. The lesser sciatic foramen is bounded by the sacrospinous ligament and the sacrotuberous ligament. Attached to the ischial tuberosity are the semitendinosus, semimembranosus, biceps femoris, inferior gemini, trapezius femoris, adductor magnus, and sacrotuberous ligament.

The pubic bone (os pubis) has a shaft with the pubic crest, linea limita, pubic tubercle, obturator sulcus, and obturator crest, as well as a symphyseal surface. The superior and inferior branches of the pubic bone form the pubic symphysis, which is strengthened by the superior pubic and arcuate ligaments. The pubic bones connect by the interpubic disc.

Pelvis – structure and connections.

The pelvis consists of the sacrum, two pelvic bones, and the coccyx. The bones are connected by ligaments: the superior pubic ligament, the arcuate ligament, the sacroiliac ligament (ventral, dorsal, interosseous), the iliolumbar ligament, the sacrosacral ligament (spinous, tuberosus), the inguinal ligament, and the obturator membrane. The pubic bones are connected by the interpubic disc [1, 2].

Pelvic Introduction and Functions

The upright human posture has widened and elevated the pelvis, which has influenced the shape of the spine and the muscular structures supporting it. Bipedalism is crucial for stability and motor function, and asymmetries in the body, including the pelvis, are common and can be morphological or functional, related to lateralization, lifestyle, athletic activity, and disease [3, 4]. Asymmetries can influence postural development, spinal deformities, and stability, especially in children and adolescents [5,6, 7, 8, 9].

The role of physicians, anthropologists, biomechanics, and physiotherapists is to assess these asymmetries, determine their causes, and determine their impact on the patient's health. If asymmetries can cause overloading and, consequently, degenerative changes and pain, it is important to develop preventive strategies and treatment methods. Particular attention is paid to asymmetries in the pelvis, as this part plays an important buffering role, transferring loads during movement and may contribute to back pain [5,7,10,11].

The mechanisms of asymmetry formation are not yet fully understood [12, 13]. People seeking the causes and treatments for pelvic asymmetry often assume that these asymmetries often coexist with myofascial dysfunctions [7, 11]. Changes in the orientation of skeletal landmarks can cause shifts in muscle attachments and the fascial system.

Various forms of asymmetry, both in terms of body structure and function, are much more common. This also applies to the pelvic girdle. Pelvic asymmetries can be observed in the alignment of the pelvic bones in various planes – frontal, sagittal, and transverse [5,14].

Asymmetries may be primary, i.e. related to the activities and functioning of the body, or secondary, resulting from diseases such as scoliosis or differences in the length of the lower limbs [6,7,11].

One symptom of pelvic asymmetry is pelvic rotation. Lewit [12] describes this as a situation where one side of the pelvis rises while the other falls. For example, the posterior superior iliac spines may rise on one side, while the anterior superior iliac spines may fall on the same side. Most often, the anterior superior iliac spines are lowered on the right side.

This mechanism causes the sacrum to become oblique, which in turn affects posture and the transfer of load from the lower limbs to the trunk. This can cause reflex muscle tension, sometimes leading to an apparent shortening of one leg. The precise mechanism by which pelvic rotation occurs has not yet been fully understood.

Studies have shown that individuals who participate in unilateral sports (e.g., sports in which the load is predominantly on one side) often have asymmetric changes in the tissues of the musculoskeletal system [15,16]. This suggests that directional asymmetries may be an anatomical adaptation that develops in response to repetitive stress.

Symmetry is one of the important criteria for correct posture in an upright position. In an ideal posture, viewed from the front or side, the pelvis should be symmetrical, the spine straight, and selected landmarks around the trunk should be evenly aligned. However, in reality, this is rarely the case. Instead, various signs of asymmetry can be observed. These may be functional asymmetries, resulting, for example, from the dominance of one side of the body (lateralization), asymmetric movements, or changes in the condition of muscles, tendons, and joint capsules. Another type is static asymmetries, which appear in response to developmental disorders or diseases. The position of the pelvic girdle in space plays a key role in the development of correct posture [17]. The pelvis is an important structure that connects the trunk with the lower limbs, supporting and transferring load during various movements. In a sitting position, it is part of the lower trunk, but during standing or walking, it becomes a functional element of the lower limb [18, 19].

Changes in pelvic alignment during standing have a significant impact on balance and body function [19,23]. Control of proper pelvic alignment is also essential for more efficient movement and walking [19,24]. If this control is impaired during walking, it can reduce gait speed, stability, and efficiency [25,26].

It is usually assumed that the pelvis should be positioned symmetrically, but asymmetries in its position can often be observed. These asymmetries result from various causes, such as anatomy (e.g. hip dysplasia; [27,28], degenerative processes, inflammation, fractures, or pelvic injuries [29,30,31].

The most common pelvic asymmetries encountered in clinical practice are those in the frontal plane, i.e., pelvic obliquity, often associated with unequal leg lengths [32,17]. Another type is asymmetry in the transverse plane, i.e., a rotated pelvis, or a combination of the two [14, 5, 33].

Lordotic posture – pelvic anteversion .

It is characterized by increased lumbar lordosis and pelvic anteversion , which leads to hip and knee flexion and also causes overloading of the spine and knee joints [34,35]. The abdominal muscles, gluteus maximus, posterior part of the gluteus medius, and hamstrings are lengthened, while the

quadratus lumborum, iliopsoas, and tensor fascia latae may be shortened. Functionally, weakening of stabilizing muscles is observed, which contributes to postural changes [36,37,38].

Lordotic posture is characterized by excessive curvature of the lumbar spine (excessive lordosis) and anterior pelvic tilt. Increased pelvic tilt causes the hip joints to be in flexion, which can lead to knee hyperextension and plantar flexion of the feet [42,43,44].

In this posture, the vertical line runs from the head down to the lumbar vertebrae, passing near the intervertebral joints, which causes excessive strain on these joints. This vertical line is also located in front of the knee joint axis, which contributes to overloading of the anterior compartment of the knee. In some cases, the projection of the center of gravity may coincide with the vertical line, or, with the head extended, may exceed it [43,44].

The abdominal muscles, gluteus maximus, posterior part of the gluteus medius, and hamstrings become elongated (hypoactive) [42]. The stabilizers, especially the gluteus maximus, show hypoactivity, which increases the activity of the hamstring tendons, which compensate for the gluteus muscle's function in stabilizing the pelvis and hips [45,46].

Shortened muscles include the quadratus lumborum and the single- and double-joint hip flexors: the iliopsoas, rectus femoris, and tensor fascia lata. The iliopsoas can be considered as two functionally distinct muscles: the iliacus (usually hypoactive) and the iliopsoas (usually hyperactive). Similarly, the quadratus lumborum consists of a medial (spine stabilization, usually hypoactive) and a lateral (motor, usually hyperactive) portion [45,46,47,48].

The spinal erectors often show shortening in the lumbar spine, although in practice they are rarely shortened, which may be due to a long-term sedentary lifestyle, which causes stretching of these muscles [42, 49,50]. In turn, the hip flexors are most often shortened and hyperactive.

Additionally, as a result of excessive knee extension and plantar flexion of the feet, shortening of the triceps calf muscle, including the soleus muscle (underactive) and the gastrocnemius muscle (overactive) may occur [42, 45, 47].

Flat back posture – posterior pelvic tilt.

Characterized by flattened lumbar lordosis and reduced thoracic kyphosis, with possible increased upper kyphosis [39]. The pelvis remains in a neutral position or with limited forward tilt [40,41].

Pelvic tilt is a functional condition in which the muscles responsible for maintaining correct posture are improperly trained.

The gluteus maximus is shortened and hypoactive, while the hamstrings are shortened and hyperactive [42,45,47].

The muscles stretched in this posture are:

- spine extensors (lumbar section),
- single-joint hip flexors (iliac muscle, iliopsoas),

- two-joint flexors (rectus femoris, tensor fascia lata).

The iliopsoas muscle is usually hypoactive, while the iliopsoas and biflexors are hyperactive. The gluteus maximus is shortened and hypoactive, and the hamstrings are shortened but hyperactive [42,51,52,53].

Trunk deviation and lateral pelvic tilt

During lateral pelvic tilt, one side of the pelvis elevates, resulting in asymmetry of the back, shoulders, and head. The left iliac crest is seen to be higher than the right, and the spine takes on a slight leftward curvature. The head may be slightly tilted to compensate for balance. Symptoms include muscle tightness on the elevated side, limb asymmetry, unequal leg length, and difficulty maintaining an upright posture.

Lateral pelvic tilt can be distinguished from other conditions such as:

- anterior pelvic tilt (forward shift),
- limb length disproportion,
- scoliosis, which may be a result of compensation or a cause of asymmetry [54].

The Lateral Subsystem and Functional Patterns: The lateral subsystem (LSS) includes the gluteus medius, the tensor latissimus fascia, the adductor complex, and the contralateral quadratus lumborum. Its proper function is crucial for pelvic stability during gait and unilateral activities. Disturbances in this system manifest as recurrent knee, hip, and patella pain, as well as symptoms such as Trendelenburg gait.

Side subsystem

In single-leg movement, the (LSS) complex controls the femur at both the proximal and distal ends, thanks to the origins and insertions of the gluteus medius and gracilis muscles (related to the adductor complexes).

During single-leg activities, pelvic and spine stabilization is largely dependent on LSS function. Stair climbing and descending generates significant external loads on the central axis, increasing the transmitted forces to peripheral joints, which may engage for stability. If subsystem recruitment is impaired, joints and soft tissues are more susceptible to injury and overload.

Dysfunctional movement patterns can be assessed in dynamic conditions, such as single-leg stance, overhead mini-squats, lunges, or gait analysis. It is recommended to begin with lower-intensity tests to observe compensations and increase load. Before dynamic assessment, it is recommended to perform open-chain table testing, adjusting for the patient's pain tolerance and range of motion.

Manual testing of muscles such as the quadratus lumborum, gluteus medius, TFL, and functional adductors is important. Often, one muscle may be inhibited (weaker) compared to another, which may be more efficient (stronger). The location of pain, tightness, spasm, and stiffness aids in diagnosis but is not the only criterion.

The next stage is a more dynamic analysis, including:

- gait (observation of foot strike, leg swing, chest rotation, hip range of motion)
- Trendelenburg position (standing on one leg – hip drop on the unloaded leg indicates weakness of the gluteus medius muscle)
- overhead mini-squat (shoulder width, arms above head, assessment of knee valgus, foot pronation, hip rotation)
- mini pistol squat (standing on one leg, squatting to 20-30°, checking balance and hips)
- dynamic forward lunge (test of advanced functional patterns, assessment of control, knee valgus, rotation, pain) [55].

PNF pelvic patterns

- Anterior pelvic elevation: active abdominal oblique muscles, lateral flexion of the spine on the side of the pattern, reduced lordosis, rotation in the direction of movement.
- Posterior pelvic elevation: active quadratus lumborum, latissimus dorsi, iliocostalis, longissimus – on the same side lateral flexion, increased lordosis, rotation.
- Anterior pelvic depression : active abdominal oblique muscles, lateral flexion, extension on the pattern side, decreased lordosis.
- Posterior pelvic depression: active quadratus lumborum, latissimus, iliocostalis, longissimus – on the opposite side, lengthening, increased lordosis, rotation.

In summary, proper functioning of the pelvis and its patterns is the basis for stable posture and effective movement, and any asymmetries and dysfunctions require detailed assessment and appropriate corrective exercises. [56]

Gluteus medius (GM) weakness and pelvic prolapse

The gluteus medius (GM) serves a crucial role as the primary hip abductor, which is essential for maintaining pelvic stability in the frontal plane during gait and other daily activities. Weakness or insufficiency of the GM is associated with many lower extremity injuries and gait cycle abnormalities. Therefore, there is a need to develop detailed guidelines for GM conditioning programs that can be used by rehabilitation specialists and strength and conditioning coaches, regardless of the patient's skill level. Such a program should gradually increase the load on the GM muscle, incorporating active mobilization, strengthening, and proprioception exercises , before progressing to more functional or sport-specific exercises.

Gottschalk and colleagues described the GM as "a broad, thick, radiating muscle on the outer surface of the pelvis." This muscle has anterior, middle, and posterior fibers, is curved and fan-shaped, and terminates in a strong tendon. The origin of the GM is on the outer surface of the ilium, between the mid and posterior gluteal lines, and inserts on the lateral surface of the greater trochanter of the femur. Functions of the GM include hip abduction, with the anterior fibers contributing to flexion and internal rotation of the hip, while the posterior fibers participate in extension and external rotation of the hip. This muscle plays a significant role in preventing the pelvis from falling to the opposite side during the

stance phase of gait, which is called the Trendelenburg gait . Furthermore, the GM is crucial for providing frontal stability to the pelvis during walking and other functional activities.[57,58,59]

Lateral Pelvic Tilt: Causes, Symptoms, and Consequences

Lateral pelvic tilt is one of the most common postural disorders that can lead to serious health problems if not properly diagnosed and treated. When describing this dysfunction, it's important to consider its impact on the entire musculoskeletal system, from the pelvis, through the spine, and finally the lower extremities. Below, we provide a detailed description of what happens during lateral pelvic tilt, along with a discussion of the symptoms and possible consequences.

Description of changes during lateral pelvic tilt

1. Deviations in pelvic position

During lateral pelvic tilt, one hip is observed to be higher than the other. The iliac crest (the top of the hip bone) on the side of the tilted pelvis is higher than the opposite side. This condition causes uneven body weight distribution, which affects the stability and function of the musculoskeletal system [61].

2. Changes in the spine

A slight curvature appears in the spine, convex to the left, which may indicate functional scoliosis or adaptation to a pelvic tilt. This curvature often results from the body compensating for an uneven pelvic posture [62]. On the side of the elevated hip, the muscles above the pelvis, such as the quadratus lumborum and abdominal muscles, are shortened, while on the lower side of the pelvis, these muscles are lengthened. Simultaneously, the adductor muscles are shortened on the side of the elevated pelvis, while the abductors are lengthened, further exacerbating the asymmetry [63].

3. Asymmetry of the shoulders and head

As a result of lateral pelvic tilt, we also observe an uneven shoulder line – the left shoulder may be higher than the right. This condition may be caused by tight chest muscles pulling the left shoulder upward [64]. The head may be slightly tilted to the left as a compensatory mechanism to maintain balance, further exacerbating postural imbalance [65].

4. Impact on the functioning of the musculoskeletal system

Lateral pelvic tilt causes serious dysfunction in the musculoskeletal system. These disorders include:

- uneven weight distribution, which can lead to overloading of the hip and knee joints [66],
- limited range of motion, especially when bending forward or twisting the torso [67],
- visible asymmetry of the hips and lower limbs [68],
- uneven wear of the soles of shoes, which is an indicator of overloading one side of the body [69],
- difficulties in maintaining correct posture and stability [70].

5. Clinical symptoms and signs

Common symptoms of lateral pelvic tilt include:

- uneven distribution of body weight,
- tilting the trunk and head in the direction opposite to the raised side of the pelvis,
- uneven shoulders and asymmetrical posture,
- tension in the hip flexors or buttocks on the side of the lifted pelvis [71],
- limited flexibility and difficulty in performing certain movements,
- visible asymmetry of the hips and lower limbs when standing or walking [72].

Differentiation from other postural deviations

It is important to distinguish lateral pelvic tilt from other conditions and postural deviations:

- anterior pelvic tilt, characterized by a forward tilt and curvature of the lumbar spine [73],
- leg length disproportion, which may cause similar symptoms, although it results from different bone lengths [74],
- scoliosis, i.e. curvature of the spine, which is often associated with an uneven pelvis, but has a different basis [75].

Pelvic bone displacement, such as a shifted or deformed pelvis, can affect leg length.

After external trauma or sudden overload, the pelvic bone can twist clockwise or counterclockwise. As a result, one of the legs on that side becomes seemingly shortened or lengthened. Torsion of the pelvic bone causes tension in the muscles that lift the pelvis upward, which exacerbates the apparent leg shortening. With unilateral primary pelvic torsion, the other pelvic bone must perform a compensatory movement consisting of twisting and sliding in the opposite direction. Tension also occurs in the pubic symphysis. Forces acting in opposite directions cause sacral inclination. At the transition to the fifth lumbar vertebra, unfavorable loads on the spine occur. It should be noted that some deep muscles respond to nerve irritation caused by bone displacement with contractures, particularly the psoas major and the iliacus. When the right leg appears to shorten, the lumbar spine performs a counterflexion movement to equalize the length of the limbs. Pelvic displacement, especially with a misaligned sacrum, leads to an oblique positioning of the lumbar vertebrae under load. The vertebral bodies may twist, performing a sliding movement, which can result in lumbago (lower back pain). In radiological examinations of the pelvis, it is important to establish a reference line, or baseline, as a reference point for the floor.

Pelvic bone torsion mechanism:

1. The right iliac crest rotates backward, causing it to appear higher and further down on the x-ray.
2. The left iliac crest moves forward.
3. The sacrum slides behind the posteriorly rotated right iliac crest, shifting its right side posteriorly. On x-ray, the right side of the sacrum appears wider and higher than the left.

4. The fifth lumbar vertebra rotates in the same direction as the sacrum.
5. The fourth lumbar vertebra rotates in the opposite direction to the rotation of this vertebra.

Effects of apparent leg shortening:

Radiographic changes show that a correctly posteriorly rotated ilium causes the femoral head on that side to point forward and outward, while the left femur is positioned closer to the sacrum and the midline of the body. Factors that exacerbate apparent leg shortening include knee and ankle joint displacements [78].

Movements of the sacrum:

- **Nutation** : The pubic mons moves anteriorly and inferiorly, and the apex of the sacrum moves posteriorly and superiorly. Gliding movements occur at the sacroiliac joints in a posteroinferior direction. Nutation is limited by the sacrotuberous, spinotuberous, and sacroiliac ligaments (positive and dorsal).
- **Counternutation** : The colliculus moves posteriorly and superiorly, and the apex of the sacrum moves anteriorly and inferiorly. Gliding movements occur in the sacroiliac joints in an anterosuperior direction. This movement corresponds to pelvic flexion at the hip joints and is limited by the posterior and anterior sacroiliac ligaments [76,77].

The influence of the quadratus lumborum on the position of the pelvis

Quadratus lumborum muscle (musculus quadratus The lumborum is a significant deep muscle located in the lumbar region and lateral abdomen. It plays a key role in stabilizing the spine and in lateral movements and lifting the lower torso. One of its important functions is to elevate the iliac crest, which is important in lower limb movements and pelvic stabilization.

The quadratus lumborum originates from the lower end of the 12th rib and from the upper lumbar vertebrae (L1–L4 or L5). It attaches to the iliac crest, lateral part of the crista iliaca), and to the iliopsoas ligament. This muscle is deep and located in the lateral part of the lower abdominal wall, lying beneath the latissimus dorsi muscle.

The quadratus lumborum muscle has several functions:

- Stabilizes the lumbar spine
- Allows lateral bending of the torso
- Helps in lifting the iliac crest (pelvic lift)
- Supports breathing by stabilizing the lower chest

A shortened form of this muscle, resulting from overuse or poor posture, can lead to limited pelvic and spine mobility. However, its primary function is to enable the hip joint to lift, which is crucial during movements such as hip lifts or gait.

The elevation of the iliac crest by the quadratus lumborum muscle is particularly important in processes such as standing on tiptoes, climbing stairs, or lifting the limb upwards during walking [79,80,81,82].

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