PELVIC MECHANICS AND DYSFUNCTION

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When a person stands on one leg he doesn't fall down. The vertical poise against gravity is predicated on balance as the upper part of the body is broader than the base (foot). Our ability to maintain balance in one legged stance is an achievement which physicists have graced with the term *unstable equilibrium*. We all know that in this situation minor sways of the body are countered by muscle action bringing the center of gravity back over the narrow base. It is the brain which senses the balance and commands the muscles. The second factor which allows us to remain in balance is the stability of the leg, the stable strut should, one would think, be made best of a pillar of bone. However, as we inspect the anatomy of our legs we find that the foot is mounted through the hinge of the ankle by the tibia, the femur is mounted on top of it through another hinge. The ball and socket of the hip is superseded by the last joint in this chain, the sacroiliac joint. The (floppy) spine is mounted on top. How is it then, that this loose jointed collection of bones serves as a pillar, and why all the joints? It is plain that the joints facilitate locomotion. The great architect was confronted, then, with the need for stability and mobility in the same structure. This article will concentrate on pelvic dysfunction, but first, a brief review of the other section of the pillar. The foot is planted and the leg hinges over the ankle as we walk over the stance foot. During this phase the knee is locked in (hyper) extension which converts the hinge to a solid leg as long as the force of gravity maintains the slight hyper-extending pressure. The quadriceps muscle guards this position; but in a normal knee stability is maintained passively by the ligaments.

In the case of the ball and socket (hip joint), as long as the femur is upright, the acetabulum has nowhere to go. Try standing on one leg, you will find that whether you allow your pelvis to sag (in the Trendelenberg position) or whether you hoist your body over your standing femur, the righting reflex maintains your center of gravity right over the leg, so that only slight muscular action is needed.

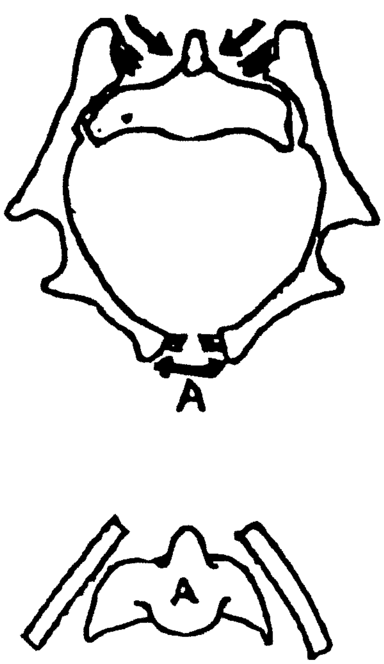
Stability at the sacroiliac joint is based on a more complex mechanism, which has recently been called *self bracing*[1]. This is an excellent term, but is conceptually little different from the ex-center stability maintained through the knee. First let us review some anatomic details of the sacroiliac joint. This synovial joint, in contrast to the other synovial joints of the body, has a rough surface. This has been demonstrated both microscopically and macroscopically[3]. When the auricular surface is inspected frontally it has, as the name indicates, the approximate appearance of an ear. As a simplified first approximation it is L shaped, open backwards. The major stabilizing ligament of this joint, which incidentally is the thickest ligament in the human frame, is located at the elbow of diagonally as they traverse the very short distance between the bones. The surfaces of the sacroiliac joints are not oriented in any of the primary body planes. As a first approximation one can see that the ilial surface faces medially, forward and superiorly. In adults the joint is not planar. The medial, superior and anterior facing applies to the upper (and larger) section of the joint. The inferior part is even more variable than the superior, but modally, usually faces medially, posteriorly and superiorly. It is helpful to think of the joint surface as similar to a propellor, or a corkscrew. The geometry of screws is best defined by the direction in which they tighten (for instance clockwise tightening, the familiar direction). Tightening between sacrum and ilium in the case of the sacroiliac joint is not dissimilar. In contrast to a wood screw, the tightening of the sacroiliac joint is controlled by the main central ligament (which you might think of as a rope). As torque is applied to it the fibers are squeezed together and the rope tightens. As it is a very short rope, the two surfaces it governs, namely the ilium and sacrum, are forced together. The rough surfaces between them maintain stable approximation, hence the stability when weight is borne on one leg.

The direction of closure and tightening of the surfaces of the sacroiliac joint is based on its geometry. Closure is achieved as the superior end of the sacrum moves backwards against the ilium. This has been defined as *counter nutation*. It is instinctual for us to think of rotation round an axis, but in fact the movement of most joints consists of a combination of rotation and gliding[2]. So, engineers, in order to maintain their terminology of rotation have coined the term *instantaneous axis of rotation* to define the minute fraction of the movement which has a theoretical axis at each degree of movement. This "point" moves with the glide, so they speak, of *a moving instantaneous axis of rotation*. The interrelationship of these axes are a physicist's Ptolemaic calculus. To the clinician the action is in the ligaments. Here tightening through a twist is achieved and the bony surfaces are approximated. There is an extraordinary degree of variation in the detailed bony anatomy between individuals and even between the two sides. In any case the geometry of the joint goes through changes in each of us with aging. It is the function which remains the same during the walking phase of life. So in walking, though counter nutation, with approximation of the bones and a variable glide of the auricular surfaces on each other, stability of the pillar is maintained through the stance phase. The pillar reverts to a flexible pendulum as the stride advances and the leg alternates into the swing phase; the knee unlocks, flexion occurs at the hip, and at the sacroiliac joint nutation occurs on that side; the sacroiliac ligament unwinds a little (incidentally restoring some elastic energy into the mechanism of locomotion) as the ilium moves slightly backwards and medially on the sacrum.

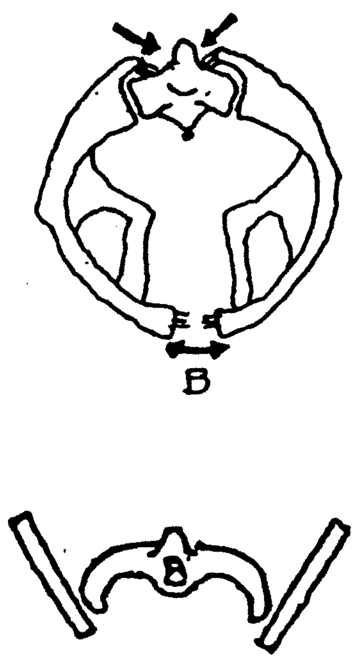
between the sides, locking on the stance side and unlocking on the swing side. Efficient walking is predicated on the mechanism being reliable. The fidelity consists of maintaining a stable strut in stance and unlocking on cue.

In the case of the movement of the peripheral joints, locking in stability, where it occurs is dependent on position and the forces surrounding the joint, but not dependent directly on the function of another joint. The sacroiliac joints are not so lucky because they share the sacrum. Even this versatile bone can move only in one direction at a time. Additionally, the ilia are united anteriorly at the syndesmosis of the symphasis. Herein lies the weakness of the human pelvis. In normal walking the sacroiliac joints lock and unlock on either sides alternately, so that counternutation (locking) and nutation (unlocking) define the cyclic sequence. The phases being opposite on the two sides. As locking consists of a backward movement of the upper portion of the sacrum[3] versus the ilium, if locking were to occur simultaneously on both sides, there would be extreme counter nutation of the sacrum versus both ilia. Because of the angle of the sacroiliac joint in the coronal plane, the pelvic circumference would tend to enlarge. The ligaments, will of course, allow so much stretch that as the the sacrum gets wedged, backwards, between the two ilia, the ligaments are finally tightened. Due to the locking mechanism, discussed earlier, it is possible for the sacrum to become *trapped* in this position. The inferior surfaces of the sacroiliac joints are such that for entrapment at the lower level of the pelvis to occur (as seen in the coronal plane) the inferior surface of the sacrum would need to move forward between the two ilia (this is also defined in the movement of counter nutation). As mentioned earlier, there is no distinct axis of rotation, so that this phenomenon of self bracing with entrapment of both sacroiliac joints (through counter nutation of the sacrum bilaterally) can occur in the upper portion of the pelvic ring, as well as at the level of the inferior portion of the sacroiliac joints, or at both simultaneously.

To make matters even more complicated entrapment can occur when the ilia are aligned symmetrically about each other, or when one is relatively more foreword than the other. The usual situation being an anterior right ilium in right handed individuals[4]. Ligaments are elastic. When stretched, the abducting forces contained in the elasticity of the ligaments of the pelvic ring, particularly the posterior sacroiliac ligaments, tend to maintain the entrapment. The self bracing mechanism of the sacroiliac joint through its propeller shape and rough surfaces partakes in this entrapment. And so it is that if both legs play the role of being in the stance phase of locomotion simultaneously this phenomenon of pelvic entrapment can occur. Conceptually this is no more complicated than driving a wedge into a tight space. The terminological definition of the various possible positions of the three pelvic bones in relation to each other has exercised the profession of osteopathy for a hundred years, and it has been systematized only recently[5]. It is estimated that the anterior rotation of the ilia, on one or both sides relative to the sacrum is common in a back pain population and is the root cause of most pelvic dysfunction, which in turn is responsible for many remote secondary soft tissue strains defined usually in osteopathic circles as local areas of *somatic dysfunction*. Manual correction, followed by self treatments of the anterior rotation and strengthening of the abdominal muscles relieves the problem in a large portion of the patients[6]. In most cases the first clinical observation is the loss of lordosis with pain in attempted extension at the lumbo-sacral level while standing. The usual range (for that patient) or rotation and side bending is also reduced, because the slack usually present in the ligaments which would ordinarily allow these movements is taken up by the abnormal (entrapped) position of the sacrum[7]. The importance of the slack in the soft tissues was described first in the case of cross referred pain from dysfunction in the sacroiliac joints in pain from attempted straight leg raising[8]. Pseudo-leg-length-discrepancy on lying supine is also usual, but can be found in individuals without pain as well. The presence of the asymmetry



The angle of the sacroiliac joints in the coronal plane at the cephalic end allows entrapment with counter-nutation



The angle of the sacroiliac joints in the coronal plane at the caudal end allows entrapment in nutation.

in normals, while it becomes more pronounced in patients with entrapment has been called *asymlocation*[9]

In the frontal plane the sacrum is seen to be wider above. This has led to the time honored impression that it functions like a *keystone* in an arch. Seemingly this observation is correct only when it is in *dysfunction*. It is, however, an observation of this practitioner that patients with pelvic dysfunction lose up to 2cm in height when their pelvis is dysfunctional. Some height is regained after successful manipulation. This (unpublished) observation supports the notion that the sacrum descends between the ilia with wedging, at least in some instances, with entrapment.

The human pelvis in mechanically unique. The phenomenon of entrapment through the maintained adducting forces of the elastic ligaments, which hold the three pelvic bones together, can last for long periods. It may be fixed. If it is fixed the patient is dependent on an external force to unlock the dysfunction – manipulation. Sometimes the degree of entrapment is less severe and then certain maneuvers, which the patient can do himself, might suffice to restore optimal symmetry, or at least reduce the severity of the dysfunction. This phenomenon of entrapment, of *somatic dysfunction*, is characteristic of, but not confined to the human pelvis. Pelvic dysfunction is, however, usually present when the osteopath finds somatic dysfunction at any level of the axial skeleton. It is persistent or recurrent unless the pelvis is restored to normal. It is suggested here that the reason is the *unique quality of the human pelvis – entrapment*. The osteopaths' aphorism that *pain is a liar* is due to the fact that through the transfer of the tension in ligaments and fascia, the strain might be felt at a distant site.

Bipedality, by its inherent nature, necessitates alternating stance and swing phases of the legs. The transfer of weight from the central axial skeleton alternately to the legs is responsible for the inexorable mechanics of the human pelvis. These mechanics are quite different from those of all other creatures. The other bipedal animals, birds and dinosaurs, have different mechanics because they balance their tail and trunk like a see saw, in contrast to humans who balance the vertical torso over a point.

We find, then, that a mechanical analysis of the function of ligaments affords us an understanding of the dynamical forces active in locomotion and explains both the function and dysfunction of the *unique* human pelvis. Future textbooks of medicine should contain a section on ligaments with a subsection on disordered mechanics after a suitable analysis of normal mechanics. The chapter headings regarding the management of dysfunction should include manipulation because when there is entrapment only manipulation can release it. The altered strength and elasticity of ligaments should be addressed. The available modalities of treatment include 1) an adjustment in frequency of usage (rest and exercise), 2) metabolic support systemically (nutrition), 3) and locally (prolotherapy[10]). Preventative measures should include advice about maintaining satisfactory alignment of mechanics. Perhaps ligament weakness can be attributed to a sedentary lifestyle punctuated with acceleration deceleration forces on the axial skeleton. Does posture play a role? It is an unconfirmed observation that in primitive societies there is less back pain. It has been suggested that forces transferred via the hamstrings and the sacro-tuberous ligament to the infero-lateral angle of the sacrum, tending to bring on nutation are present during squatting while maintaining lordosis of the lumbar spine[11]. These forces might serve pelvic alignment and training better than sitting in a chair. Is it possible that the epidemic of back pain in Western civilization is a side effect of comfortable furniture and the toilet seat?

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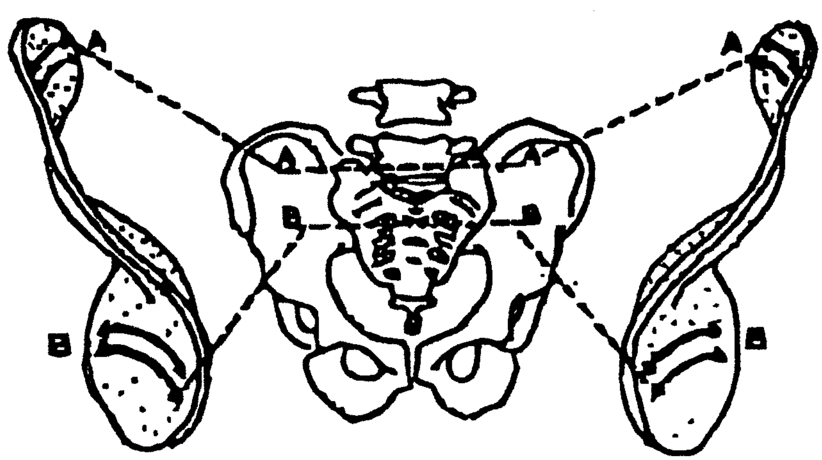

The spacial orientation of the surfaces of the sacroiliac joints is such that the superior aspects allow wedging with backwards displacement of the sacrum between the ilia. The anatomy of the inferior surfaces is more variable, but modally allows entrapment with forward movement of the sacrum at this level of the pelvis. Most cases of asymlocation involve a combination of these positional entrapments. When they are marked, they tend to be responsible both for local and remote symptoms through the transfer of forces through tensegrity

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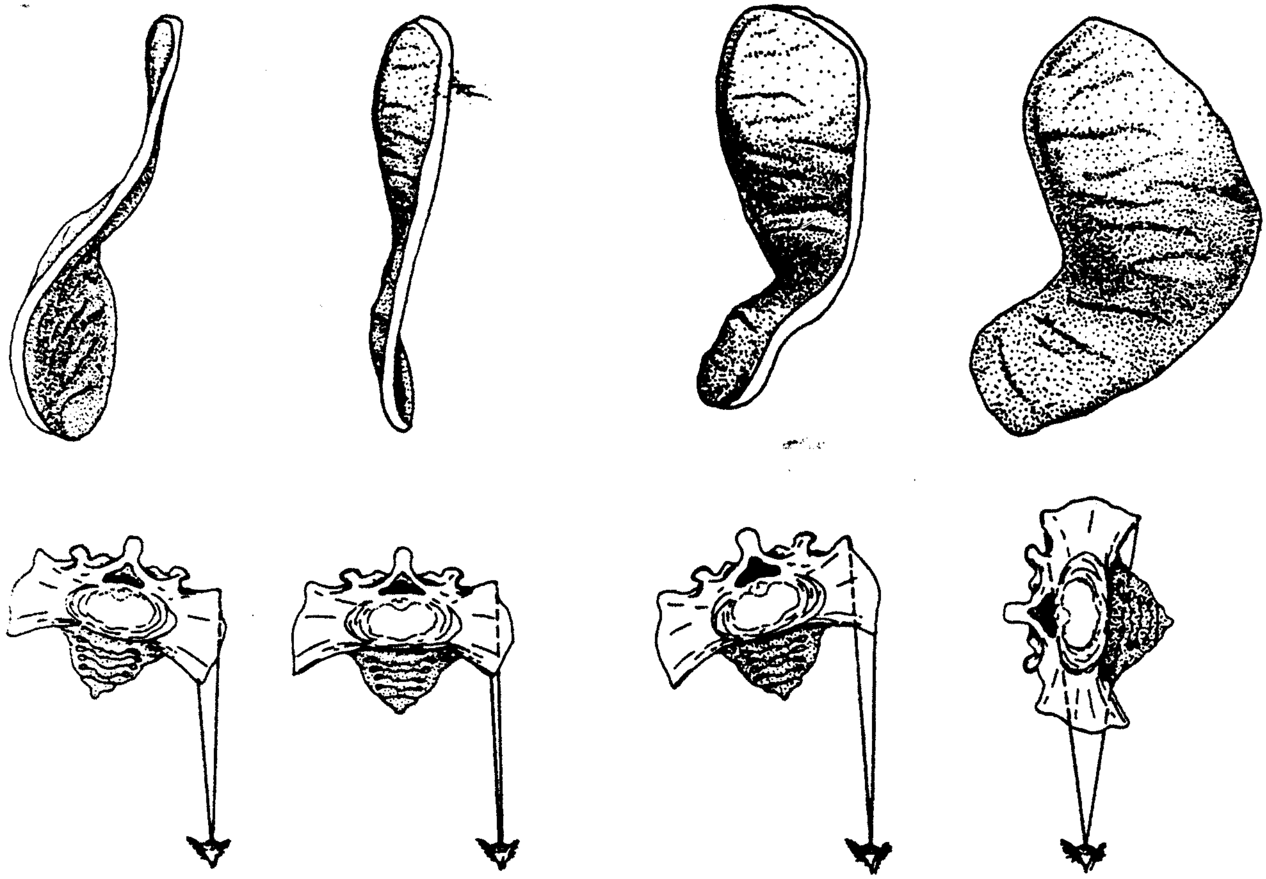

This is an artist's reproduction of the best known study of the anatomy of the sacroiliac joints, based on: Solonen KA The sacroiliac joint in the light of anatomical, roentgenological and clinical studies Acta Orthp Scand Suppl 1957;27