Spinal Engine & Waist Power from Taijiquan Viewpoint

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Abstract

The myriad muscle actions of body segments have to be harmonized to produce motion of unified momentum underlying maximal waist power. This entails the harmony of the torques at the hip-joints of the pelvic movements and the spinal torsion. The practice solution to cultivate this harmony is forged by Taijiquan's principle of centrality that sorts out the multitudes of muscles in their functional roles of core-stabilization, postural control, and propulsion, as well as breathing, and allows them to balance and align accordingly. As it turns out, the centrality principle of yin-yang theory mirrors the SIJ hub in the transfer of forces between the upper and lower body through the three levers, the lumbar and the legs via the pelvic platform.

Introduction

The trunk's rotational motion is most crucial in the art of body motion. The body's core strength in sports and martial arts comes from the waist-groin, which relies critically on the trunk's rotation. And the role of the spinal engine is most critical in the trunk's rotation to generate waist power.

The spinal engine refers to the mechanism that introduces torsion in the spine by the lateral bending of the vertebral column due to the spinal curvatures. The pelvis is always tilting one way or another in body motion, causing the spinal column to flex, and thus inducing spinal torsion. The spinal engine is always running in body motion.

The trunk's rotation is primarily produced by the torques of muscle forces, which introduces torsion in the spine. This is independent of the spinal torsion produced by the spinal engine. The trunk is also riding on the pelvis platform, and the rotation at the waist involves the play of the pelvis, which links directly to the spinal engine. To produce the waist power necessary at high-level performances, the rotational motion of the trunk and the internal motion at the hip-joints, must harmonize with the spinal engine. Indeed, slight errors in managing the spinal engine and the pelvic platform can amplify to degrade waist-power output significantly, notably in the golf-range.

Developing waist power requires the discipline of the body's many segments, each powered by its own muscles, to move in unison to harmonize momentum. Unfortunately, the muscles do not respond to commands in such cooperation. The muscles underlying the movements of say a punch action, are not dedicated in their functions, but play multiple roles, which may be competing—the muscles have to attend to the stabilization, postural control, and balance of the body, as well as breathing. On top of that, the body is stubborn in its behavioral responses of muscles that can often undermine the intended actions. Unless these issues are addressed and resolved at the basic level, training cannot improve the waist-power output significantly. But the task is illusive. That is why it is not easy for weekend golfers to increase significantly their average drive.

This paper looks at how Taijiquan provides a practical solution that comprehensively resolves the complexity of the lever system of the many segments, the effects of the spinal engine and the responses of the neuromuscular system. The diverse factors are pulled together by a centrality principle of Taijiquan, which treats as paramount the core-stabilization role of muscles, thus keeping the integrity of the body structure intact under all situations.

The unorthodox slow-motion practice is directed at cultivating this centrality principle, which turns out to be an assertion of the hub principle of the sacral-iliac joint (SIJ): SIJ is the *'hub' of forces transferred from the trunk to the ground and vice versa.*

There is a larger pay-off. Studying how the Taijiquan deals with these issues in the context of generating strength, shines the light of physics and physiology on the esoteric yin-yang framework and Traditional Chinese Medicine (TCM), thus giving us a more concrete understanding of the traditional theories.

The Spinal Engine

Torsion is produced when a rod is twisted by applying torque. But not all torsion is born of a twist. We can produce torsion in a rod by bending only, without twisting. Bend a coat-hanger wire in one plane (without twisting), and then bend the curved wire in another plane. The second bending moves the wire out of its plane and introduces torsion in the wire. So whenever a curved rod is flexed laterally (bent transversely to its plane of curvature), an axial torsion is produced.

When we turn our torso, muscle actions produce a torque creating a torsion in the spine. However, because of our spinal curvatures (Fig. 1), a torsion is also produced whenever the spine bends out of the sagittal plane. The mechanism that produces the torsion in the spine by virtue of its curvatures and bending motions is called the *spinal engine*. This axial torsion of the spinal engine is often caused by the pelvis tilting, which results in the lateral bending of the spine.

This mode of conversion between linear bending motions and axial torsion does not appear in the designs of locomotive engineering, which rely on cogs, gears and shaft. However, these mechanical devices are not available to the skeletal structures of animals. Vertebrates develop some form of spinal curvatures, which coupled with bending motions, produce torsion that is a crucial factor in locomotion. This principle is very evident in the locomotion of lizards or reptiles in the lateral flexion and extension of the body.[1]

Gracovetsky (1985) who formalized the Spinal Engine Theory, credits Lovett (1898) and Farfan (1975) as having first observed the coupling between axial torsion (rotation) and lateral bending (linear) due to the spinal curvatures.[2] The Spinal Engine Theory has three components: curvature (curved rod or lordosis of the spine), lateral bending, and axial torsion or rotation. The coupling theory states that the combination of any two components produces the third.

Our gait relies on the axial torsion produced by the combination of lateral flexion and lordosis.

Lateral bending motions are often necessary to balance in juking and dodging in sports, which are produced by the combination of lordosis and axial torsion.

In the 1968 Mexico Olympics, Dick Fosbury approached the jump on the left side and propelled his body up on his right foot. His torso flexed laterally on the left as it powerfully rotated to the right. The combination of flexion and torsion increased his lordosis, enabling him to clear the bar on his back, with his center of mass below it. Dick took gold and set a world record in the showcase debut jump, which has come to be known as the Fosbury Flop.

We next review briefly the anatomy of the vertebral column to see better the spinal engine in our gait, dance, and sports to bring more awareness. At the same time, the review serves to point out the challenges posed by the spinal torsion in generating body strength, and thus its criticality in sports and martial arts training.

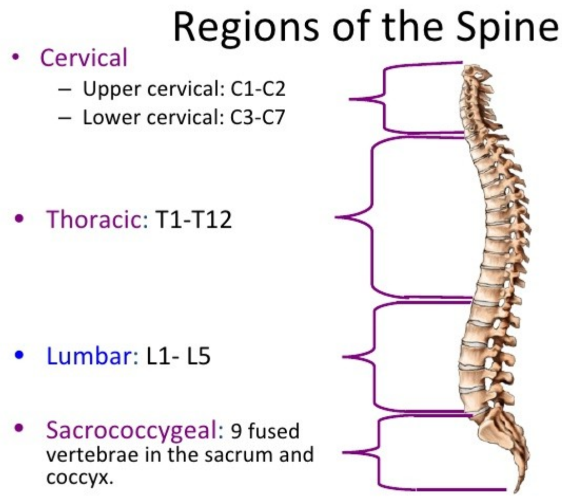


Fig. 1 Spinal Curvatures

The unsoundness of the skeletal structure

The most striking feature of the human skeletal frame is its structural unsoundness—the prominent ribcage hanging on the vertebral column supported precariously at the sacrum, which is joined onto the pelvic girdle (see Fig. 2). The design of the skeletal frame is very contrary to engineering principles heavily grounded on the stability of support structures. The spinal column consisting of vertebrae, one on top of another, and resting on the pelvic girdle at the bottom, cannot be more unsound and unstable—it requires a costly process of constant monitoring and muscle actions to maintain the integrity of the column and to keep it balanced.

To compound the challenge, the muscles that work the complex of bone levers are confined within the skin to stay close to the bones. This means that the muscles have to pull the bones at attachments close to the hinge with short moment arm. For example, the biceps are attached to the radius bone close to the elbow (see Fig. 3). Try raising a flag pole with the rope attached near the base, and you can imagine the enormous force the biceps have to exert to flex the arm, which add a huge burden to the muscles.

Such an engineering design, which requires continual computational and energy resources on demand to function, would seem unfeasible. Unwieldy as nature's engineering blueprints may be, dressed in muscles and equipped with the neural networks, they give us a human machine that is incomparable in the range of functionality and in the fineness and precision of control.

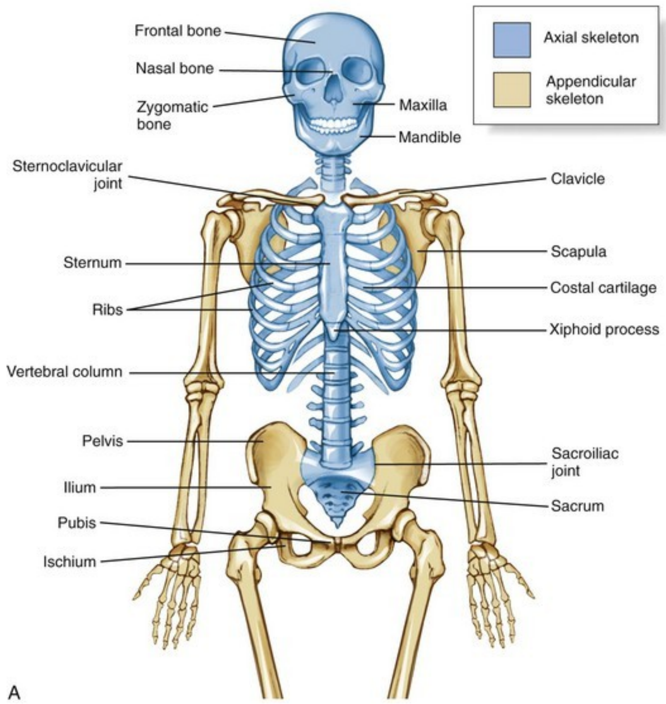


Fig. 2 Skeletal frame

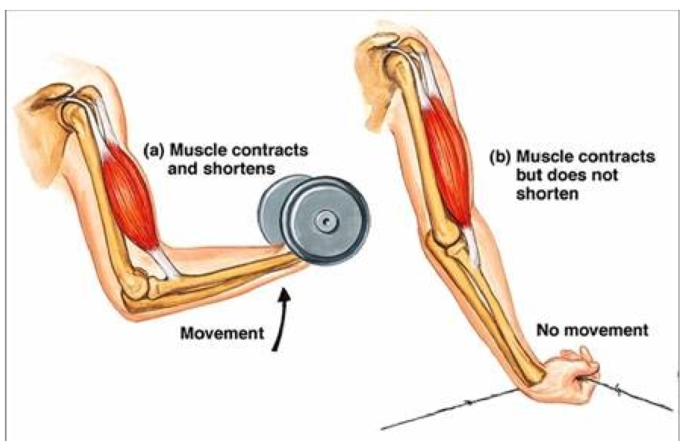


Fig. 3 The biceps attach to the radius bone close to the elbow

Enormous resources of muscles operate the complex of bone lever systems. The countless muscle fibers are organized into individual motor units, each ranging in numbers from tens to thousands, is innervated by a motor neuron. For instance, the biceps working the arm are served by about 774 motor units, each controlling an average of 750 muscle fibers.[3]

Amazingly, it is the unsound and unstable structure that is being exploited in bipedal functionality, with capabilities of fast response and agility. We think of stable structures as having a wide base or a low center of gravity, which can settle back to equilibrium under perturbation. However, imagine how unwieldy and cumbersome it would be to ambulate if our base were like a pyramid.

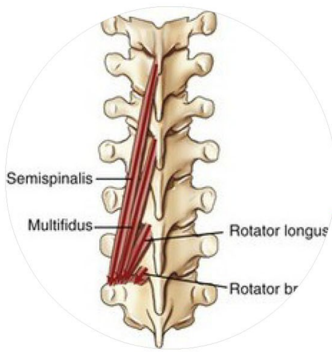
A stick standing on a table falls readily, but on a finger, the hand can move to follow its center of gravity to counter the falling moment and keep it in balance dynamically. Likewise, a stationary bike is unstable, but when it is riding, it stays balanced by the angular momentum of the wheels, without sophisticated control systems, just the steering hand bar. A slight turn changes the bike's direction, creating a torque that counters the gravitational moment, thus keeping it in dynamic balance. We learn to ride a bike by relying on the instinct to steer from the direction of fall, but without having to know the continually varying forces that keep it in balance.

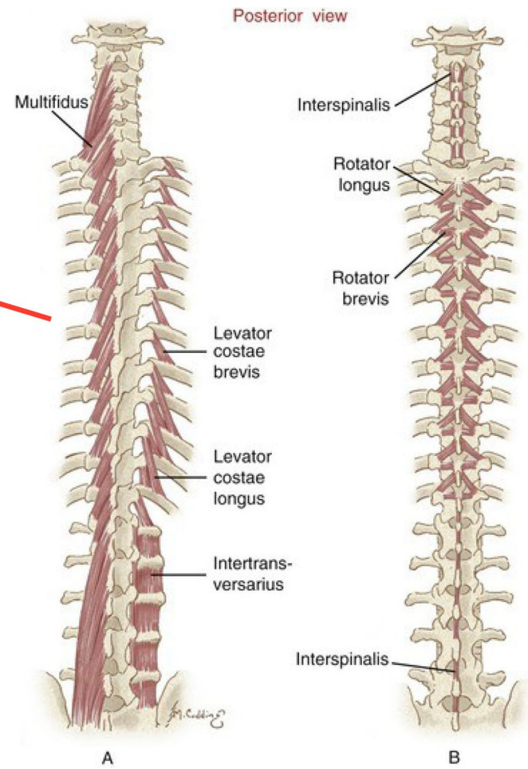
Not unlike an inverted pendulum, our skeletal frame falls readily. In our ambulation we are literally righting the body falling between states of unstable equilibria to keep balance. The mechanism of dynamic balance is preprogrammed in our neural circuitry and monitored by sensory inputs of our vision, inner ear, and proprioception, which occurs without our conscious effort. As we shall see, the spinal engine plays a primary role in our gait.

Anatomy of the vertebral column

The architecture of the skeletal column may be forbiddingly unsound, but its anatomy in details gives more comfort. The intervertebral discs (annulus fribrosus) which cushion between the vertebrae can withstand compression much better than the bones.[4] Ligaments securely bind the vertebrae individually to one another and crossing over to others as well, along the front and back of the column, making it robust and flexible. Likewise, deep muscles, which strap along the column, between and crossing over several vertebrae, further strengthen and stabilize the spine and allows for local movements (see Fig. 4). Also, the vertebrae increase in size gradually from the neck to the lumbar base, which enhances the structural strength of the column.

Critical to the soundness of the erect structure is the support of the column at the junction of the sacrum and pelvis (ilium), namely, at the **sacral-iliac joint** (**SIJ**). The plane surfaces of the SIJ interlock in their irregular grooves and ridges, which secure the lumbar-sacrum support. The ligamentous bindings and muscle strappings are even more elaborate and secure here—35 muscles attach the sacrum to the hip bones and the ligaments here are the strongest in the body. Thus buttressed at the base, the vertebral column, bound by deep axial muscles and ligaments, enjoys the integrity of strength and stability, and is equipped to withstand the compression, torsion and loads that the body may be subjected to.





Muscle group	Relative length and depth	Average number of crossed intervertebral junctions
Semispinalis	Long; superficial	6-8
Multifidi	Intermediate	2-4
Rotatores	Short; deep	1-2

The deep muscles secure, stabilize and maintain the integrity of the vertebral column.

Fig. 4. Deep muscles of the vertebral column

Besides the multifidus muscles immediate to the vertebrae and along the column that extend to the sacrum, three muscles secure and stabilize the lumbar spine to the pelvis (Fig 5). Attached at the lumbar vertebrae, the psoas muscles cross over the pelvis and the hip joint to insert at the femur head (the psoas minor inserts at the lower pelvic arc); the iliacus attaches at the pelvic crest and joins the psoas major to also insert at the femur head. (Together they are referred to as the iliopsoas, which appears often in the discussion of lower backaches). The quadratus lumborum, laying behind the psoas band, attaches at the lowest rib to secure the spine to the pelvic crest. The primary function of these muscles is to secure and stabilize the lumbar spine and to maintain the integrity of the erect structure. If in an action, this core integrity is violated, then its performance outcome would suffer significantly. Also, if the integrity is not maintained, chronic backaches would result due the persistent stress and strain on the muscles there.

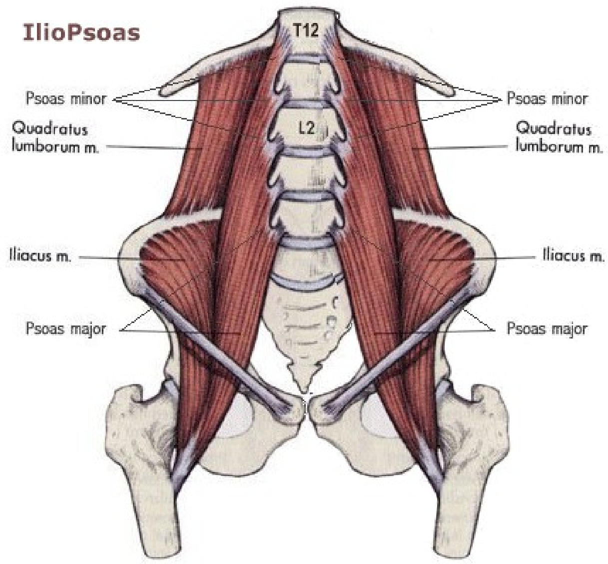


Fig. 5 The three muscles that secure the lower spine to the pelvis

The SIJ hub

The movements at synovial SIJ plane joint are very limited, in an average range of 2 to 4 degrees in each of the three planes. Of significance to spinal curvatures is the larger range of about 4 degrees in the rotational movement of the sacrum in the sagittal plane, “nodding” forward in nutation (tailbone turned backward), or rocking backwards in counter-nutation (tailbone forward), at the transverse axis through the second sacral segment (S2). Lordosis is increased by nutation and decreased by counter-nutation (Fig. 6). The rotation in the transverse plane is the axial rotation of the lumbar spine, which taken as a whole includes the incremental turn of each vertebra. The translational movement of the sacrum is limited to about 1.6 mm.[5]

The movement of the spine is linked to the movement of the pelvis at the SIJ. And the movement of the pelvis occurs at the ball-and-socket hip-joints. Thus, the pelvic platform provides not only support for the spinal column, but is also a conduit of motion and loads between the spine and the femurs, which are described as the three levers by Vleeming.[6]

Though the adjustments at the SIJ are small and internal, the SIJ plays a critical role in the transmission of motion and force between the spine and the femurs via the pelvic platform. In fact, *the SIJ form the ‘hub’ of forces transferred from the trunk to the ground and vice versa* (Lovejoy, 1988, Aiello & Dean, 1990).[7]

The principle of the SIJ hub strikes at the core of the art of body motion, which in many respects, is a play of load transfers between the trunk and the legs. The transfer occurs through two interlinked triangular conduits: the smaller lumbar-sacral joint (L5/S1) and sacral iliac joints at the base of the sacrum, and the larger SIJ and hip-joints of the pelvic platform.

In other words, the transmission of motion between the torso (spinal column) and the legs (femurs) through the pelvic platform is controlled at the SIJ and the pelvic joints. However, the control is complicated by the coupling between the axial torsion and the tilting of the pelvis due to the spinal curvatures—the effects of the spinal engine. Critical in sports, martial arts, or any performance arts is the control to align the sacral and pelvic movements, the precision of which is necessary to harness the full potential of the body. A slightest error at this basic level could amplify in costly degradation of output in performance.

This paper is about the pragmatics of cultivating the hub principle to transfer force and load at the pelvic platform through the methodology of Taijiquan. Taijiquan has long recognized the hub principle at the sacral triangle—the L5/S1 and the SIJ—by the principle of *the centrality of the dantian*, to be discussed. This turns out to be at the core of the training to harness what is generally called waist power, and here is where the spinal engine plays a critical role.

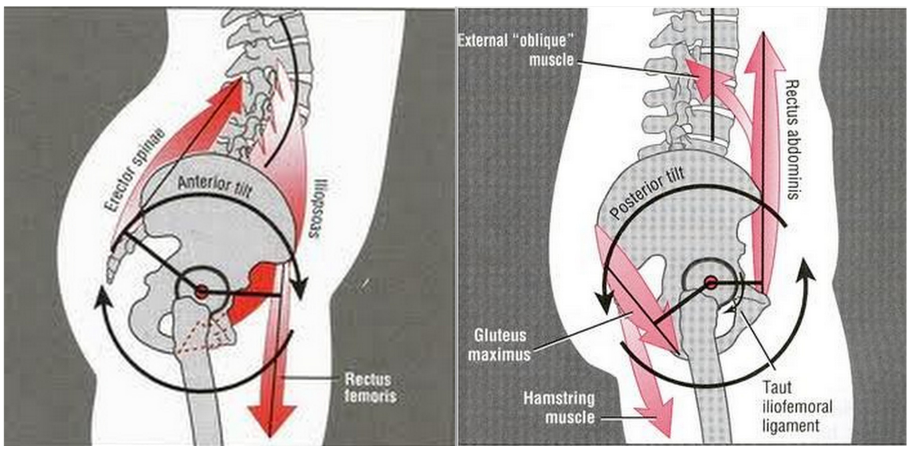


Fig. 6 Nutation Counter-nutation

The human gait and the spinal engine

This review is not intended to be comprehensive but to high-light the spinal engine in the human gait, so that we can appreciate its contrasting role in generating waist power discussed in a subsequent section.

We certainly would not argue that we use our legs to walk, but challenging conventional thinking, Gracovetsky argued that walking did not need legs. He put forth the proposition that the role of the spinal engine is primary in our gait. This is dramatically demonstrated by the ischia of the pelvis serving as legs in the ambulation of a subject born with no legs.[8]

We make use of the spinal curvatures and the pelvic platform to maintain dynamic balance in our gait, but we do not flex and extend our spine like a lizard in our locomotion. The lateral flexion, and thus torsion in our spine, is induced by the tilting of our pelvis.

Firstly, our head is kept stationary relative to our body in locomotion. When the pelvis tilts, the curved lumbar part of the spine (the lordosis) bends in the direction of the tilt while that of the thoracic spine in the opposite direction. In walking, as the left foot is raised to step forward, the right leg is bearing the weight and the pelvic platform tilts to the right, causing the lumbar spine to flex laterally to the right (Fig. 7c, 7d) and inducing the thoracic flexion to the left. Due to lordosis, the flexion to the right produces a torsion in lumbar part of the spine, rotating it to the right; and the flexion to the left of the thoracic spine, produces a torsion rotating it to the left, with the deep axial muscles aiding both the rotations—the mechanism of the spinal engine. The torque of the lumbar rotation and of the gravity would tend to fell the body-frame. But two factors kick in to prevent this: muscles activate to aid the thoracic torsion, which counter-rotates the shoulder and chest, and also the friction of the foot on the ground. The counter-rotation of the thoracic-spine occurs at around the thoracic-lumbar position (T12/L1), made conducive by the inflection change of the spinal curvatures. This is depicted by the right arm swinging in sync with the left leg striding forward (Fig. 7d, 7e). Gracovetsky describes the thoracic rotation as zeroing out the angular momentum of the lumbar rotation, which is the dynamic balance that keeps the body structure stable in motion. This balancing of the angular momenta characterizes the human gait, which is attributed to the spinal engine.

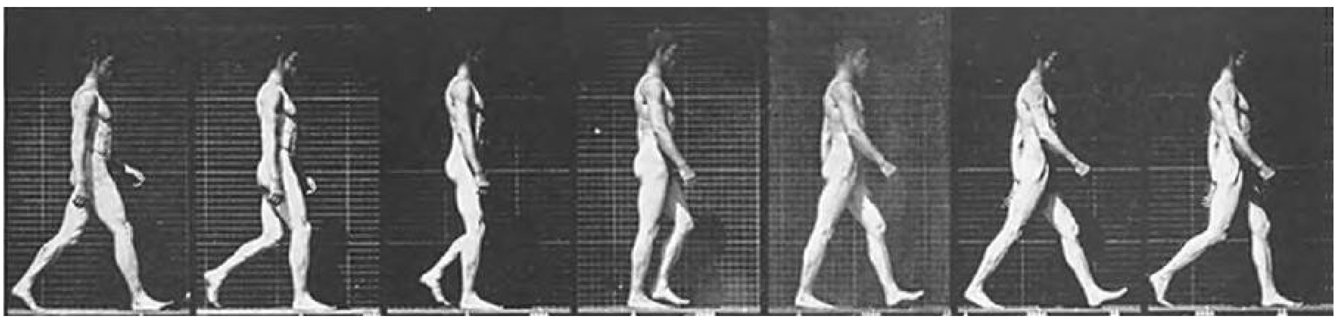


Fig. 7a 7b 7c 7d 7e 7f 7g

Gravitational force is ever ready to fell us. But the gravity field is also a resource—we store kinetic energy as potential energy for use in our ambulation. The center of gravity is at the lowest point when both feet are astride on the ground (Fig. 7a and 7f), and the highest when the legs are vertical together (Fig 7c). The body stores and uses potential energy following its center of gravity rising and falling in ambulation. At its highest point, the body is unstable and falls like an inverted pendulum, with the left leg stepping forward, converting potential energy to kinetic energy (Fig 7d and 7e).

As the right ankle is raised, and the left ankle rolls forward (Fig. 7f), the center of gravity drops back to the lowest point. Then, aided by hip extensors and friction, the rear right foot propels the body forward, raising the center of gravity (Fig. 7g), which reaches the highest point when the right leg closes in to the left leg, converting kinetic energy to potential energy. Then as in Fig. 7c and 7d, but with the legs transposed between left and right, the spinal engine kicks in again as the body falls forward, generating the angular momentum of the two curvatures, which balance dynamically to stabilize the forward stride of the right leg (Fig. 7a).

Thus walking is a cycle of converting potential and kinetic energies aided by hip extensors and the stabilization of the body by the dynamic balancing of the lumbar rotation and the counter-rotation of the chest and shoulder depicted by the arm swing in the same direction (thus counter to the stepping), aided by the friction of the foot on the ground. The dynamic zeroing out of the angular momentum reduces significantly the need to expend muscle energy to apply “brakes” and readjust to stabilize the body in motion. This is one reason why hunters of our primitive forbears could trail down and capture their wild prey by dogged pursuit, a measure of human durability and sustainability in locomotion over the animals.[9]

In other words, the spinal column is not a free-loader riding in the carriage of the torso, carried by the legs in locomotion. The spinal engine pays more than the torso's fare share—it is a primary factor in our gait. This is not to say that the legs are secondary. Integrated in locomotion, the legs are a quantum leap in ambulatory function. The legs provide the propulsive force in running and the support force for external loads. The movements of the pelvic platform ride on the ball-and-socket joints of the femur. Also, as we shall discuss in a subsequent section, *Waist-groin power*, the legs are instrumental in the maneuver of the rotational motion of the waist.

Spinal engine and dance

The spinal engine is very evident in the gait of a fashion model. The pelvic tilt is more pronounced as her steps are crossed in the catwalk. With an evocative look of coy indifference, the walk exudes sensual appeal as the spine sways in rhythm to her pelvis rocking side to side (Fig. 8).

Fig. 8 A fashion model's walk

Interestingly, the mechanics of the spinal engine is captured in x-ray vision in a Citracal TV commercial (Fig. 9).[10]

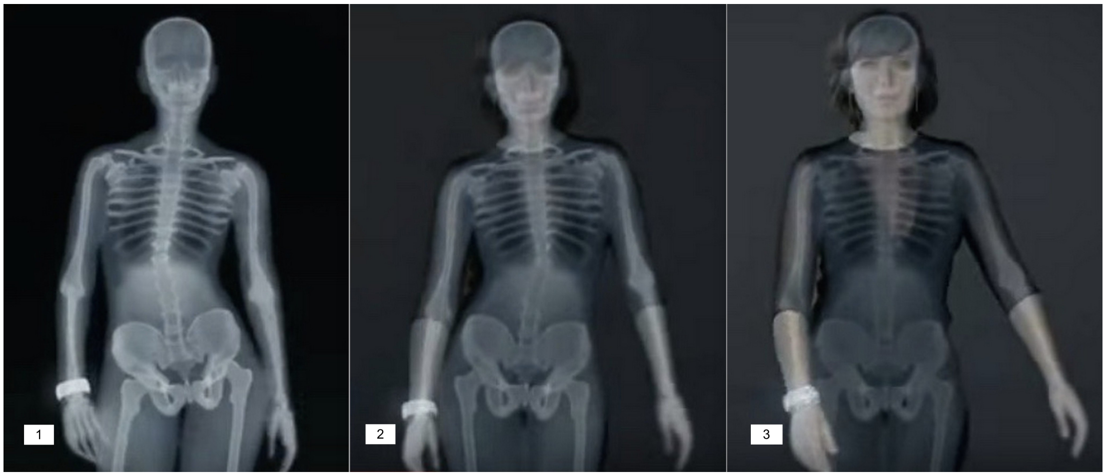


Fig. 9. X-ray vision of the spinal engine at work: frame 1 weight on right, stepping forward on left, thoracic rotation to left zeroing out lumbar rotation to right at about T12/L1; frame 2, steps changed; frame 3, spinal curvatures in about same sagittal plane in neutral.

Michael Jackson exploited the spinal engine fully when he rocked his pelvis in the defining moonwalk dance to his song, *Billie Jean.*[11] The 1982 release became an all-time worldwide sensation. The spinal engine hummed to the tune, which created a harmonious fusion of dance and music. Would the song be the same without the spinal engine running? This spawns the modern genre of robotic dance, as demonstrated by Fiskshun Stegall.[12]

The spinal engine is of course critical in all forms of dancing, not just in the pop culture. In classical Indian dancing, the head and neck dance movements (*shiro bheda* and *griva bheda*) are codified into nine *shiro* and four *griva*.[13] The movements require that the spinal engine works with precision. The dancer trains to move the neck side to side laterally, front to back, and also circularly.

On the other hand, diametrically opposite to the gyrations of the pop-culture genre, the spinal engine is subdued by restraining the pelvic tilts. In the Ryukyuan (Okinawan) Dance, the dancer moves by keeping the pelvis from tilting and the center of gravity level. The slow dance movements are stylized, calm and not strained—the spinal curvatures stay close in the sagittal plane, idling the spinal engine.[14] Taijiquan utilizes similar techniques to discipline the spinal engine.

Spinal engine in sport actions

Unlike dance movements, sports actions are not choreographed, but are characterized by bursts of enormous energy on demand, for instance, to interact timely with an externally directed source, such as a ball. The soccer player running after the ball does not stop but kicks it on the run, or heads the ball on the jump in the air. The basketball player ducking around the guard does not stop but shoots the ball over the block. The pictures of the actions in the air (Fig. 10) capture the dynamical balance with gravitational moments, and the unison of the body's rotational momenta, which require harmonization with the spinal engine.

These sport actions are very much focused on the ball—in the hoop or goal—and they require responses of the spinal mechanisms that are more endowed than trained. That is, a weekend warrior cannot hope to train to improve much the skills of juking or dodging like a professional player.

In golf, tennis and baseball, the explosive power behind a long drive, a forehand swing, or a fastball itself is of great fascination. What is the biomechanics of the swinging power and how can one train to improve on it significantly even if one is a recreational player not endowed with athletic talent? This brings us to the source of the body's core power, generated at the waist-groin region.

Fig. 10. L. Blocked in the air, Michael Jordan dunks the ball
R. Wesley Boyle heads the ball in the jump

Waist-groin power *dang-yao jin*

We admire the explosive power of a golf swing, but the golf ball at the tee sees only the momentum of the golf club. The force that sends the ball off is a consequence of the physics of collision between the ball and the club head. How long the drive will be depends on the momentum of the club transferred from the momentum of the body. The greater the momentum the body can generate, the greater the impact force of the club.

The different segments body must move in unison for the momenta to unify, and the most crucial component is the trunk's rotational motion. This is not about the body spinning in a pirouette, but harnessing the trunk's muscles to maximize its angular momentum with control of balance. In the rotational motion, the upper body turning in one direction must be balanced and supported by the momentum of the lower body turning in the opposite direction. Where should the division of rotation be between the upper and lower body?

The distribution of the body's mass between the upper and lower body is most proportionately balanced with the waist-groin junction as the division. This means that the greatest angular momentum will be generated if the rotation occurs at the waist-groin junction, hence the term *waist-groin power* or *dang-yao jin* 裆腰劲.

If the upper-body rotation occurred at the chest level, then the muscle mass of the midsection would not be contributing to the upper body's rotational momentum. If the upper body turned at the junction of the knees, there would not be enough muscle mass below to stably support the overloaded action, which would degrade power output and strain the knees and ankles, causing injury.

Thus, we see the rotation and counter rotation occurring at waist-groin junction in the sport actions captured in Fig. 11. In each of the right-handed action, the punch, downswing, forehand stroke, or fastball, the torso's rotation to the left above the waist-groin junction is mutually supported by the counter rotation to the right of the base below the junction. Note that "the groin is hooked inward" (*kou dang* 扣裆) on the left side in counter-rotation in support, and is aided by the friction on the ground.

The physics part is clear—the more the body's rotational motion is in unison, the greater the angular momentum, and thus the greater the torque-force that can be imparted. However, this would mean a departure from the customary mode of the torso's rotation in our gait, where the thorax turns one way and the lumbar the other way to cancel out their angular momenta in balance.

Therein lies the problem—we are habituated by our gait to turn the upper body at around the thoracic-lumbar vertebrae T12/L1. So we tend to do the same when we execute waist power, turning at the chest level, which would then deprive the action of the muscle power of the midsection, a flaw that could cost a drive a hundred yards. In other words, our torso's rotation is habituated not to occur at the waist-groin junction, a basic requirement of biomechanics for the waist power generated to be maximal. This requirement is for the thoracic rotation to follow the lumbar rotation in the same orientation to unify angular momentum. And this is where the spinal engine comes in—the spinal torsion must be harmonized with the torso's rotation.

Therefore, to produce maximal waist power, besides involving more muscle mass to generate greater momentum, the torso must turn at the waist-groin junction. This becomes a play of action and reaction of torque and counter-torque at the waist-groin junction that negotiates the mutual transfer of forces and loads between the torso (upper body) and the legs (lower body) at the triangle of joints—the SIJ and the hip-joints—through the pelvic platform.

Fig. 11 Waist-groin power

The pelvic platform—*kua*

The pelvic movements are directly linked to the spinal engine as the sacrum joins the two halves of the pelvic crest. Taijiquan refers to the pelvic platform as the *kua* 胯, which in common usage means "hip." *Kua* is not just a physical designation, but a specific term of the Taijiquan parlance used to refer to the play of the pelvic platform at the hip joints and the SIJ involving the three levers—the spine and the legs. Thus, spinal torsion, namely, the spinal engine, is inextricably linked to the play of the pelvic platform.

The kua is also commonly associated with the inguinal fold because in the horse or bow stances of martial arts, the internal play at the hip-joints is guided at the fold on the front. That is, the kua recognizes the functional predisposition of the body to fold or flex forward (in the sagittal plane) with the largest degree of freedom at the hip-joints, even though they are ball-and-socket. The motion of extension is markedly limited, being anatomically constrained. With larger degrees of motion are the abduction and adduction (in the frontal plane) and lesser, the rotation of the hips (in the transverse or horizontal plane). In combinations, they give us the versatility of our hip mobility.

In anatomy, the pelvis is considered a part of the appendicular skeleton (Fig. 3), but at times it fits more as an extension part of the axial skeleton. In actions where the legs can move freely at the hip-joints, like kicking or walking, the pelvis behaves more closely as a skeletal appendage, as demonstrated by the use of the ischia to walk by the individual born without legs (discussed earlier on the human gait). In the frame of appendicular skeleton, the torso's rotation commonly occurs at the thorax-lumbar inflection.

In waist-powered actions, the pelvis behaves more as part of the vertebral column—the hips function more as part of the column in the axial rotation. This is usually the case when both the feet are fixed on the ground, and the maneuvers of the upper body require enormous power from the waist. In the context of the waist-groin junction serving as the division between the upper and lower body, the pelvic platform behaves more as part of the upper body in the rotation. The power actions of sports and martial arts that require the feet solidly planted for stability and balance, rely on the pelvic platform to function more as part of the axial skeleton in rotational motions.

The triangle of joints: SIJ and the hip-joints

Pelvic motion occurs at the ball-and-socket hip-joints. The small internal movements at the hip-joints are guided at the SIJ in the triangle of joints to align the ground force through the femur heads via the pelvic platform to the lumbar. This action at the hip-joints initiates the torque of the upper body. Starting at the hip-joints, the rotational motion of the pelvic platform transmits through the SIJ, incrementally up the vertebral column, to sync with the trunk's rotation. In this way, driven at the femur heads, the kua-rotation coils up the torso in unified angular momentum to the shoulders. At the same time, the reaction force at the ball-and-socket joints pushes in counter-torque to spiral down the femurs through the knees to the lower legs, and through the ankles to the feet, to sync with the ground frictional force at the anchor. This powers the counter-rotation of the lower body below the kua junction.

This describes the biomechanics of the SIJ hub principle—the transfer of forces between the trunk and the ground via the pelvic platform at the triangle of joints. The force, initiated at the hub control, coils up the torso to power the action, such as a punch, and at the same time, the force reaction winds down to anchor the feet on the ground in full support.

The torque and counter-torque at the kua junction of the waist-groin power is a very precise hip rotation. To support the torque action of the torso maximally, the counter-torque must be driven by the reaction force at the hip-joints in conjunction with the ground friction, through the legs, aligned at the knees, ankles and feet. The common flaw in generating dang-yao jin (waist-groin power) is often due to a lack of clarity of this alignment of the ground path.

The discipline of force transmission is expounded in Taijiquan theory in the *Principle of Three Sections* (of Chen Changxin's *Ten Essential Principles*[15]), which divides the joints into three functional sections: “root” which serves to drive, “middle” to negotiate, and “extremity” to lead. With the feet, as the extremity, leading, to anchor on the ground, the driving force at the kua root negotiates through the knees (the middle section) with directional clarity.[16]

As we shall see, the cryptic slow-motion practice of Taijiquan is directed at cultivating the principle of the SIJ hub, which is featured in the art as the *Dantian Centrality.* As will be discussed, the hub control is an assertion of the centrality principle. The kua discipline is very challenging because in a fixed stance, the movements at the SIJ and hip-joints are internal, where minute errors can amplify as significant flaws in the transmission of load and force. And the trunk rotation is affected by the spinal engine. This is further exacerbated by the normal leg length discrepancies, which must be adjusted for in training.[17] Next we review the golf swing in the context of our discussion.

Waist-groin power in the golf swing

Let us review the torso's rotation in Rory McIlroy's downswing as captured in Fig. 12. In frame 1, the torso is wound up about 90 degrees to the right, coming to the end of the upswing phase. The weight is more substantial on the right. This rotation is a composition of the rotations of the pelvis, the SIJ, the lumbar and thoracic vertebrae, each turning a few degrees incrementally up the spine in the same orientation.

Fig. 12 The waist-torque is supported by the groin-torque in McIlroy's downswing

In frame 2, the weight is shifted to the left and the left foot is anchoring to begin the downswing phase, and the swing begins to "unwind." (This shift in weight is in conjunction with the "shoulder drop," as observed by Kelvin Miyahira.[18]) Where the torso is turning at the vertebra is critical in this phase. Note that the lumbar (SIJ) is leading the turn to the left in frames 2, 3, and 4, and the thoracic vertebrae following in sequence. If the lumbar lordosis were set off to the right of the sagittal plane as habituated in the walking gait, and remained so, then the torso would be forced to pivot at the lumbar-thoracic inflection, turning at the chest level, a basic flaw that would significantly impair the drive. (The pelvic tilt to the left helps to prevent this by the spinal engine.)

As the torso is rotating left (frames 2 through 4), the hips remain relatively fixed in order to support the torso's rotation—the ball-and-socket joints are providing the reaction force against the turn by the legs. By being fixed in position, the left groin is "hooked inward" (to the right) to support the swing-action to the left, by the friction of both feet anchoring on the ground. The *kou dang* (turning of the groin inwards) and the friction of the feet on the ground form the counter rotation (of the lower body) to support the swinging action. We see in the frames, the vertebrae are progressively turning in the same direction, one following the other along the spine, from the lumbar base to the thorax. This aligns the lumbar and thoracic rotations in angular momentum, which is aided by the trunk flexion and the tightening of the lumbodorsal fascia that reduces the lordosis.

Note that the pelvis remains cocked by the reaction force in the hip-joints to ensure the full transmission of power (rotational momentum) in the downswing, which represents the waist-groin junction. The role of the pelvis can be observed in the animation of Fig. 12 in the link: http://perfectgolfswingreview.net/McIlroyBackViewAnimation.gif.

After the downswing momentum of the trunk is transmitted maximally, the swing-pendulum changes sequentially, from the shoulder to the elbow and then to the wrist, as captured in the slow-motion video link.[19] Note that the swing-pendulum motions of the arms are themselves rotational motions that extend from the core rotation of the trunk.

Functional Roles of Muscles

From a functional perspective, the roles of the intervertebral muscles and the innermost muscles (of multifidus, rotares, levatores costae, and intertransversarii) are primarily to secure and maintain the structural integrity of the vertebral column (Fig. 4). The intermediate group of muscles, the semispinalis, also provides support for the cervical and the thoracic spine, but local movements as well. The outermost group of the erector spinae, which forms the two ridges at the back, adds strength to the back, and powers the trunk's flexion and extension together with the rectus abdominis on the front. The psoas and iliac muscles also secure and stabilize the lumbar support, but they also power the movements at the hip-joints (Fig, 5). Thus, the functions of the many skeletal muscles, unlike smooth muscles, are not dedicated in their roles.

The torque of the trunk rotation results from the composition of the horizontal moment component of the many muscles that strap the skeletal frame. The only sizable muscles that contract horizontally are the band of transverse abdominus of the abdominal muscles that runs around the midsection, and the torque it produces turns out to be relatively marginal. It is therefore not surprising that the body's familiarity of rotational motion is not as good as that of flexion and extension of the limbs. When pushed, we react instinctively by pushing back in the direction of push, even though such a response may often turn out to be a bad strategy. We lose the comfort of orientation when we perform the same task with the posture changed obliquely. We are predisposed to linear motion, and find it harder to produce waist power of performance grade.

Reviewing the muscles of the waist-groin junction, we find the long muscles that attach at the lower pelvic ischial base, running along the femur, to the heads of the tibia or fibula (the biceps femoris, semitendinous, semimembranous), and the longest one, the sartorius, which extends across obliquely from the iliac crest to the head of the fibula. Though these muscles power flexion and extension, and adduction and abduction, they also provide the torque in the rotation of the hip.[20] The frictional force at the feet, negotiated through movements at the knees and ankles, contributes to the torque to rotate the hips, as well as the torque by the internal movements at the hip-joints and SIJ.

All these torque actions from the long to small to deep muscles, particularly those at the SIJ and hip-joints, must align and balance to generate maximal waist-groin power. Together with the torque produced by the abdominal muscles and the other larger muscles, the lats and the glutes, which attach to the thoracolumbar fascia, they must also align and balance with the psoas, iliacus, and the quadratus lumborum (Fig. 5), and be in tune with the core axial muscles of the vertebral column. Any misalignment would cause resistance, impairing output of waist power.

Surely we are not equipped to navigate the complex of muscle actions. Generating maximal dang yao jin (waist-groin power) is indeed a very tall order. Our neurobiology does not provide an engineering solution of a right combination of muscle actions that produces body motion in unified momentum, thus of maximal strength with control. Interestingly, we find a pragmatic solution in Taijiquan training, which relies on the organic logic of yin and yang of Taiji theory.

The Taiji theory takes to the practicalities of training, and to that end, we divide the skeletal muscles into the following the functional groups:

1. Outer or prime-mover muscles that move the body segments, such as the arms and legs. These produce the body's translational as well as rotational motion.
2. Inner or core muscles that secure the joints and maintain the integrity of structure.
3. Since the rotational motion of the torso is so crucial, the muscles involved in producing the torque or moment are also highlighted as a functional group. Also, in conjunction, the inner muscles that secure and maintain the integrity of the spinal column, are grouped functionally as the core axial muscles.

The muscles are not exclusive in the groupings, neither are they in their functional roles. The muscles are not dedicated and indeed do compete in their functional roles.

As we shall see, the discipline to generate body motion with control and unified momentum is an interplay of the inner and outer muscles, and of the torso's torque muscles and the core axial muscles, to balance and align in accord—the principle of “inner balance.” The principle also sorts out the muscles competing in their functional roles. It should be noted that the interplay in training also includes the roles of the conventional synergists and agonist-antagonist muscle pairings. Next, we wade into the waters of Taijiquan in the study of “inner balance.”

Inner Balance

Taijiquan's slow-motion methodology does not just develop dang yao jin, but offers an uncanny solution to training strength, not just any strength, but extraordinary strength, called *neijin* 内劲 (“Internal Strength”). This pronouncement usually comes as a surprise as the slow-motion exercise cannot be more remote from the power crunching exercises of strength-building. To take a little of the mystery away, think of the quaint and unorthodox training as regulating one's motion to be in accord with the Taiji theory of yin and yang. Then imbued with the grandness of Taiji theory and a store of the core strength of neijin, the body's response in combat becomes both an offense that is unstoppable and a defense that is impenetrable. That is why kungfu peers have always regarded Taijiquan as a martial arts of the highest order.[21]

We take our balance for granted until we trip or slip. But a sportsperson or a martial artist knows well that balance is hard to maintain under unexpected load changes during play. Indeed, balance is easily compromised even in mundane circumstances. For instance, in taking a deep breath in a checkup as directed by a physician with a stethoscope on our chest, we inadvertently raise our ribcage and hollow our abdomen. In so doing we weaken the internal structure of the physical balance, rendering the body easy to topple.

The example also illustrates that there is a range of combinations of muscle actions interacting internally in the support of a given posture in balance. What should be a preferred combination of muscle actions? Taiji's answer is simple in metaphysics, namely, one of lesser yin-yang imbalance.

We define ***inner balance*** as a state where the muscle actions underlying body posture or motion are not excessive (referred to as too yang) or deficient (too yin), subject to the the loads on the body. This is a manifestation of yin-yang balance in the musculoskeletal framework.

The definition covers all aspects of physical balance—statics of structure and support, dynamics of muscle actions, and importantly, the balance of moments or torques in rotational motion. Cast in yin and yang, it includes the functional balances of physiology (homeostasis) and of the mind (equanimity). The comprehensiveness of balance means that no muscle energy would be diverted from force output to correct for imbalances. Therefore, imbued with inner balance, the force that ensues is consummate.

The formulation provides a pragmatic test of yin-yang imbalance in terms of an excess (too yang) or a deficiency (too yin) of muscle actions, which the body can learn to access without the burden of having to know the complex of muscle activations. The practice is to discern what is excessive or deficient in muscle actions and then to resolve them towards inner balance. This entails cultivating the senses to discern imbalances and developing the tools to resolve them. That is, the training is applying the conscious movements of kinesthesia to enhance the proprioception factors of balance.

In the above example of taking a deep breath, the muscles inadvertently activated to raise the ribcage, become excessive-yang relative to combinations that support the postural balance, thus flawed in inner balance. In learning new movements or doing heavy physical tasks, we often experience tenseness of muscles and are tired out by excessive muscle actions.

Taijiquan presumes that the manifestation of yin-yang balance is not perfect, namely, the underlying muscle actions of any posture or movement suffer some flaws of yin-yang imbalance—they are to some degree too yang (excessive) or too yin (deficient). That is, there is always room to improve in practice.

The errors of yin-yang imbalance are discerned at different skill levels. At the beginning, the errors are associated with tenseness from bad postures or poor execution of movements. Going past the initial phase one can see better the errors of muscle actions and be more attentive to the inner and outer muscles aligning in balance at the joints, and to the torque muscles of the torso and the core axial muscles harmonizing. In time, the body learns to associate the ease of transmission of motion through the joints and the agility of rotational motions with the underlying muscles actions that are not too yang (excessive) or too yin (deficient) in their functional roles.

At deeper levels, the errors of the imbalances of muscle actions are at the SIJ and the hip-joints, which involve the spinal engine. The errors are nevertheless registered as too yin or too yang, regardless of where they are sourced, muscle torque or spinal engine; they require more precision to discern and finer tools to resolve. The errors impact the force transmission between the upper and lower body via the pelvic platform, through the three levers of the spine and the legs, critical to producing maximal strength by the body.

However, we cannot regulate the movements to comply with inner balance by allocating so much muscle actions here and so much there, as we do in adjusting weights in a balance scale. The muscle activations are just too complex and the neural processes are not wired to do that. Interestingly, we find a practical, albeit, unorthodox solution in the slow-motion methodology of Taijiquan. The rest of the paper gives a scientific rationale of Taijiquan's traditional training to infuse the body with the principle of inner balance.

The practical insight of inner balance is that it places emphasis on the inner and core muscles in their functional role to secure, balance and maintain integrity, but without impinging on breathing. With this priority, the training operationally sorts out the competing demands of the multitudes of muscles in their functional roles of core-stabilization, postural control, and propulsion, as well as breathing, and allows them to balance and align accordingly. As we shall see, inner balance serves as a mirror to the SIJ hub principle in the pragmatics of generating dang yao jin.

Inspired by the principle of Inner balance the body is in an ever-ready mode of balance, lively and agile in the interchange between yin and yang in response. The different parts of the body move in coherence of mutual support and balance, and with unified momenta. And the payoff is that the force that ensues from motion regulated by the principle inner balance is consummate, and by definition, is that of *neijin*.

Neural Wiring and Responses

A basic issue is that our neuromuscular system does not pay heed to the principle of inner balance. If it did, then fastballs, long-range drives, and neijin would be common place. Quite to the contrary, the neural responses to a command often elicit muscle activations that can be far from ideal for the task at hand.

For example, in the mundane task of picking up a box, we bend forward, out of convenience, to reach for it. The back muscles fire up by reflex to keep the leaning posture from falling over. In lifting the box, the weight pulls the body further down, triggering more muscle activations to keep balance, and even more to raise the load, resulting in much reduced muscle energy to do the task at hand.

By stepping closer to the box and bending at the knees, the posture is more balanced internally and the task can be performed with better leverage and the help of leg muscles, thus less effort. The second posture is in a better state of inner balance. But the neural responses do not attend to postural factors of balance. Not only that, the neuronal firings of back muscles exacerbate the poor leaning structure, the cause of many a lower back ache.

We are presumed to have control over our voluntary movements, but the control we have is limited at the top hierarchy of the motor chain, in the command, say to touch the nose. The simple command triggers a complex of neural activities and a flow of signals and information data between the brain and muscles, which are completely opaque to us. We only know that the muscle activations result in the movement-output of the hand touching the nose.

The limited control we have of our somatosensory muscle system—the volitional part—is very limited indeed. We cannot execute a plan of muscle allocation according to an engineering solution to comply with inner balance even if one can be devised. We cannot tell which muscles are wanting in a golf drive or a punch. That being said, the neural wirings of our musculoskeletal system give us a remarkable range of versatility in dance and sports and the finest of control of our hands, as attested to by human artistic endeavors.

The problem is that we have no sensory feedback of the overall structure of the body on the fly with regard to the relative state of muscle actions as to which combination is better or preferred. The issue may or may not be pressing for routine activities, but still relevant to health—to prevent chronic back aches. However, the issue is critical for generating strength needed in performance. This is the source of frustration in training—we cannot summon the body to execute the movements with the accuracy and power we wish, even with dedication of practice, as weekend golfers know well.

The neural responses for a given action or posture do not activate the same but many different combinations of muscles underlying it. The activations are influenced by habits of convenience and formed and evolved by preprogrammed elementary pattern motion-generators. The neural responses do not attend to inner balance, and often undermine the principle. In other words, often, the “natural” responses turn out to be barriers of neurobiology to training in sports and martial arts. Unless addressed, they persist as inhibiting factors that stymie training—the syndrome of practice hitting-the-wall.

Between the command of action at the top hierarchy to the motor neurons activating the muscles at the bottom, there is a huge gap of neural activities that we have no cognition of. There is no feedback of the execution as it is occurring. By the time the result can be gauged as good or bad, it would be too late to bring about any corrections, especially, in a combat situation where the target is moving. How do we bridge this gap, which is critical to the discipline of muscle actions?

How can we resolve the muscle activations that we only have limited or no cognition of, and often are themselves the result of the responses of neurobiology? Taijiquan's solution to this conundrum is the prescription of the practice process of *fangsong* (relaxation), which cultivates a body comprehension of what is too yin or too yang in the muscle actions, and develops tools to resolve them. The methodology develops the “life-force energy qi” in the process, which in time leads to the establishment of the yi-qi-motion paradigm. (For the present, think of qi as a bioenergy, and as given in Traditional Chinese Medicine).

The yi-qi-motion paradigm is the Taijiquan bridge of the neural gap. The command of *yi* 意 (mind-intent) activates qi, and qi serves as a conduit of signals to innervate muscles, and hence the movements. Qi disciplines motion so to speak. To be sure, the yi-qi concepts are foreign to the musculoskeletal structure, but in practice, the body takes to them readily, and in that, we find their scientific basis.

Fangsong **relaxation**

To illustrate the concept of *fangsong*, hold an arm out to the side; it is in physical balance between its weight and the muscle forces supporting it. To discern the quality of balance, stretch the hand out as much as you can. The stretching increases the muscle activations, which is sensed as a tensing up of the arm, and is changing the internal dynamics of the muscle actions in support of the balance. Holding it in position for a duration, discomfort of stiffness would set in, a consequence of tenseness of the muscle actions—a discerning of inner imbalance. Upon sensing the discomfort, the reflex is to relax or let go to lessen the tenseness. The reflex response has the effect of resettling the muscle actions to one of lesser discomfort in the physical balance—a better quality of internal balance structure. This response represents the rudiments of the tool of *fangsong* 放松 which translates as “relax and let go.”

However, the muscle interactions in the motion of an action cannot be readily sensed as in the stationary case. This is where the slow-motion methodology comes in—it acts to moderate the muscle actions that tend to dominate. Taijiquan has another tool to induce balance in the constant admonishment of the mantra of “using mind-intent, not force” (*yong yi bu yong li* 用意不用力) as a guiding principle in practice. The mantra is baffling as “not to use force” is often loosely translated as “not to use muscle-force,” which makes no sense as movements are produced by the contractile forces of muscles. Nevertheless, the training exhortation offers a new mode of doing exercise where the execution of movements is not driven by an external directive, such as to kick a ball. The cryptic mantra turns out to be an ingenious accompaniment to “fangsong-relaxation” in the slow-motion discipline to induce balance.

In time, the fangsong and the mantra in the slow-motion practice improve the quality of balance of the interplay of muscle actions, and the fangsong tool becomes more robust. The process leads to an awareness of the joints, and a sensation of bioenergy associated with an ease of motion flow at the joints. This bioenergy is identified as *qi* 气.

In other words, qi energy serves as a biomarker—a sensation associated with fangsong to resolve muscle actions to improve the quality of balance and the ease of motion. In this sense, fangsong by operation cultivates a dynamics of qi through the joints, which is internal, in contrast to motion which is external. And importantly, the cultivated qi is viewed as qi dynamics regulating the motion.

In time, with the development of qi, imbalance is deciphered as an impedance of qi. The body thus builds the association: the more robust the qi, the better the quality of balance structure. As the practice progresses, the fangsong tool grows organically in sophistication and the practitioner uses the qi energy as a medium to decipher and resolve imbalances, that is, to regulate muscle actions. This means that the development of qi energy in practice is gradually but crucially bridging the gap of neural activities, leading to the formation of the yi-qi-motion paradigm: The yi-mind commands at the top hierarchy, activates the qi, and the qi "activates" the movements. Since qi energy is cultivated, we are conscious of it. Thus, the body induces a sensation and feedback of movements at the joints through the qi medium. In this sense, the qi medium bridges the gap of neural activities.

At the deeper levels of practice, fangsong becomes more precise, going beyond tenseness, to work on the balance and alignment of inner and outer muscles and of the axial and torque muscles of the trunk, and as well as of the muscle actions at the SIJ and hip-joints at deeper levels still, in the nurturing of the principle of inner balance.

The fangsong mechanism remains simple. Fangsong works with two prongs in the resettling of the muscle actions. The first is the mantra's urging of "not using force," which in the deliberative slow motion, imposes a discipline that forestalls and subdues the outer muscles from dominating in the action. The second part of the mantra of "using mind-intent" gives time in the slow motion for the deeper and inner muscles to activate to stabilize the structure at the core. Both work to prevent the appendicular muscles and the torque muscles from jumping ahead of the axial muscles, and thus for them to align and balance. The practice mantra in slow motion is persistently tempering the outer and prime-moving muscles, and pumping the inner and axial muscles in their crucial roles to secure, stabilize and balance support at the joints and the vertebral column, especially at the SIJ. An increase in the activations of the inner muscles produces a surge of warmth, which is attributed to as qi.

There is another dimension to the fangsong tool, which incorporates a complementary function to strengthen support that is languid. Stretching a droopy arm may add strength to the support, but it also tenses up the arm. To do this without tensing, the fangsong stretch is "internal," described as "stretching the tendons and bone" (*shen jin ba gu* 伸筋拔骨). The internal stretching gives the lax support a connectivity of energy and motion, analogous to giving tautness to a slack string, which is discussed more in the author's paper, *Generating Body Strength Through Taijiquan Motion*.[22]

Thus the fangsong tool resolves the errors of imbalance by relaxing when it senses tenseness and stretching internally when it feels laxness. This keeps the support in the goldilocks zone —neither too tense (yang) nor too lax (yin), and with it, the sensation of qi associated.

The Taiji strategy is to stay in between the excesses or deficiencies of yin and yang—in the middle ground so to speak, and to work on reducing the margin of errors. The margin of errors tapers by the sharpening of the organic fangsong tools, and the heightening of the discernment, which ushers the practice path in convergence towards inner balance. And this is induced by the discipline of meditation—the mind part of the practice, which develops by constant attentiveness to the process. In this sense, one is not specifically striving for inner balance, only resolving the errors of imbalance, a sort of “doing without doing” (*wei wu wei* 为无为). The path of staying in the middle ground exemplifies the quintessential way of the ancient philosophy of *Dao* 道.

A Basis of Qi energy in Taijiquan

The “life-force energy” qi is viewed as a bioenergy sensed in association with fangsong resolution. The experience of qi as a somatosensation serves the purpose of this paper in terms of cultivating inner balance and generating strength. It relies on the sensory data from the muscle spindles (of muscle stretch and speed of stretch), and the golgi tendon organs (of muscle-tendon tension). In composite, the senses stimulated by tension and movements of muscles and tendons at the joints (kinesthesia), of position and space (proprioception), of balance (vision and inner ear), of pressure, pain and temperature, and light, as well as of blood flow, are viewed as qi-sensation.

Research does give us an experimental basis for qi-sensation. In the kua play of the pelvic platform in Taijiquan, the activation level of the quadricep muscles is raised 2 to 4 times more than in walking.[23] The higher activation levels are registered as a qi sensation. Muscle activations in walking rely primarily on neural pattern generators, but fangsong in slow motion induces the muscles to settle more into the kua, thus are fired at higher levels. Also, in the deliberative slow-motion fangsong, the outer and prime-moving muscles that tend to dominate are restrained so that the inner muscles get to fire more. The higher activation level of the inner muscles is often sensed as a surge of heat, which is sensed as a development of qi.

Changes of physiology and bioenergy elicited by fangsong practice have been studied at the Laboratory for Mind-Body Signaling & Energy Research and Susan Samueli Center for Integrative Medicine, University of California, Irvine. The research team headed by Shin Lin has quantified increases in the following physiological and bioenergetic changes due to Taijiquan or qi-energetic exercises: a) blood flow (perfusion), b) state of relaxation as indicated by heart-rate variability and brain-wave analysis, and c) bioenergy emission in the form of heat, light (photon counts), electrical charge, and conductance at acupuncture points.[24]

These changes of bioenergy as qi surrogates are sensed differently. Blood perfusion, experienced as tingling sensation in the hands, is most prevalent in qigong practice, while photon count is not sensed as it is small, though the increase is significant,. Much of the cultivated qi-sensations in Taijiquan are changes in bioenergy that stimulate the sensory receptors in the tendons, muscles, bones, and fascia, most notably, by higher activation levels of muscles. Together, they offer an experimental basis to the experiential knowledge of qi dynamics in Taijiquan.

Taijiquan of course has long validated the basis of qi in the time-honored wondrous kungfu of neijin. In the context of qi, neijin arises from motion that is harmonized with qi dynamics, namely, motion (external) is regulated by qi dynamics (internal), which represents the “unity of the internal and external" (*nei wai jie he* 内外结合). This is a representation of Taijiquan using qi dynamics to direct motion, thus providing the qi-bridge in the gap of neural activities to discipline muscle actions.

In traditional Taijiquan theory, the fruition of the unification of qi dynamics and motion is borne of the three internal unities of: heart (*xin* 心) and mind (*yi* 意); *qi* 气 and force (*li* 力); and tendons-muscles (*jin* 筋) and bones (*gu* 骨).

Meditation nurtures the conditions for the heart and mind to be one. The practice requires attentiveness, but the mind cannot be attentive if one is beset with worries and distracting thoughts. The slow-motion practice inculcates awareness that moderates thoughts flitting in and out, quiets the mind and clears the murkiness. The unity of the heart and mind sharpens perceptiveness and deepens awareness to gain insight.

With heightened perceptivity, the fangsong resolution can better activate the deep and inner muscles, as well as the axial muscles, to secure and stabilize the joints and the spinal column. This is the discipline of "uniting" the tendons-muscles and bones. The unities of the "heart and mind" and "muscles and bones" are conditions for qi and motion (force) to unify to give rise to neijin.

Dantian Centrality and SIJ Hub

Dantian centrality is the piece de resistance in the theory of Taijiquan. The theory of centrality reduces the quest of inner balance, which involves the gargantuan task of resolving muscle actions at the myriad joints, to the elegance of the dantian achieving the central status. Grandmaster Chen Xiaowang, a 19th generation descendant of Chen Family Taijiquan, has been instrumental in the articulation and propagation of this principle.

Checking balances at the joints one by one is clearly a daunting task. But what makes it more daunting is that resolving imbalance at one joint may affect that of the other joints because of the body's tensile integrity. This means that the resolution at one joint requires a recalibration at the other joints each time, which would make the undertaking impossible if not impractical.

To compound the task even more, each of the many segments of the body linked at the joints, has its own power plant of muscles. This makes the problem of resolving the imbalances and of aligning the muscle actions of the segments, analytically intractable. Amazingly, by following the actual task of the undertaking guided by *The Essential Principles*,[25] one is led onto a solution path via a principle of centrality.

The eminent status of the kua in generating waist power makes the kua a natural junction of reference for the movements of body. Picking the midpoint of the kua junction to serve as the point of reference refines the fangsong to work on the left and right hip-joints. Built on this foundational balance, the fangsong can then be extended to work on the corresponding pair of the shoulder and kua, then to the elbows-knees and the hands-feet pairs, and then further extended to any of the other joints of the body. Referencing the resolution to the same point nurtures a centrality of motion at the point. This point is functionally represented by the *dantian*, a point of qi-energy in the theory of Traditional Chinese Medicine (TCM).

The *dantian* 丹田 ("field of elixir") is located at the position, the width of three fingers below the navel and about a third of the way inside. The navel is positioned at about the vertebral level of L3/L4 with slight variations.[26] The relative measure of the width of three fingers puts the dantian at the approximate level of the SIJ.[27]

The centrality of the dantian is not just a reference point in name. In referencing to the dantian, the fangsong resolution is actually tempering and working each time on the imbalances of the muscle actions at the triangle of joints—the SIJ and the hip-joints—thus developing the centrality of the dantian. Also, crucially, the qi cultivated in the fangsong resolution at each joint relative to the dantian is nurturing a connectivity between the joint and the dantian, forged by inner balance. This builds a web of qi-connectivity of the joints centered at the dantian, which forms the basis of the principle of dantian centrality that alleviates the sticky problem of the matrix of joints.

The body relates to the centrality principle via qi cultivated in the systematic fangsong resolution at the joints relative to the dantian. The constant attentiveness to the dantian and particularly, the fangsong at the SIJ and hip-joints, induce the qi-energy to collect in the lower abdominal region, concentrating at the dantian. In time, the nurtured concentration of qi culminates as the "fullness of dantian qi" (*dantian qi baoman* 丹田气饱满). The fullness of dantian qi gives the body a deepest experiential appreciation of the centrality principle.

The dantian qi may seem esoteric, but it works indispensably to resolve imbalances at the deepest vestiges, cutting the Gordian knot of inner imbalances, that leads to its maturing fullness. With this achievement, the body is said to be invested with the principle of centrality.

The significance of the investiture of the central status on the dantian (*yi dantian wei hexin* 以丹田为核心) is that in the yi-qi-motion paradigm, motion is directed and regulated by dantian qi. The corollary is that the motion directed by dantian qi is regulated by yin-yang balance and forged by inner balance. Therefore, the motion (thus momentum) transmits between upper and lower body through the dantian center in balance and alignment with ease, without obstruction. This means that the dantian is serving as *the hub of forces transferred from the trunk to the ground and vice versa* without loss of energy due to flaws of inner imbalance. Dantian centrality is a realization of the hub principle of the SIJ.

To sum up, the attainment of dantian centrality represents the maturity of inner balance and the mastery of the art. Infused with the principle, the body becomes very conversant with the movements at the joints, so can undergo change spontaneously in response with ease and at will according to the loads. Thus, Taijiquan's kungfu maneuvers appear "soft," opposite to the strenuous exertion of strength associated with brute force. Taiji kungfu is the stuff of neijin born of inner balance.[28]

It should be emphasized that the investiture of dantian centrality can only be earned through the long and arduous process of fangsong practice. It cannot be endowed. True Taijiquan masters are made not born.

Harmonizing the Spinal Engine Redux

Rotational motion is always present to some degree in body motion, but in the art of body motion it is not only prevalent, it is a crucial component. Indeed, Taijiquan regards rotational motion, studied as “silk-reeling motion,” as forming the basis of Taiji motion.[29]

We have noted that the role of the spinal engine is critical in harmonizing angular momentum of the trunk's rotation, but it can have different applications. In walking, harmonization refers to the angular momentum of the chest (thoracic) rotation being balanced by that of the lumbar's counter-rotation, namely, they balance by zeroing out in their opposite orientations. But in generating maximal waist power (dang-yao jin), harmonization means that the two must be in sync and be in the same orientation to unify. The thoracic rotation must follow the lumbar rotation in sequence and not jump ahead. In plainer terms, the shoulder and kua (defining the torso) must turn as one piece in rotation. That is, the thoracic and lumbar curvatures remain close to the sagittal plane in the trunk's rotation.

The trunk's rotation is powered mainly by the torque actions of the prime-mover muscles. But the trunk's rotation also rides on the rotation of the pelvic platform, which occurs at the ball-and-socket hip-joints, and the movements at the hip-joints are powered by the muscles of the legs and the ground frictional force. And axial rotation is affected by the spinal torsion of the spinal engine, which is produced by flexion and spinal curvatures, not by torque action of muscles. This makes the harmonization of spinal torsion, hip-rotation and trunk rotation to align and balance very tricky, but the fangsong tool is well equipped to handle it.

We have discussed how the fangsong practice restrains the prime-mover and outer muscles from dominating the axial rotation in their torque actions. This allows the fangsong tool to work at the deeper core axial rotation due to the hip-rotation and spinal engine. In the context of generating waist-groin power, this is governed by movements at the triangle of joints, the SIJ and the hip-joints, which represents control at the subtlest level.

Very often, the spinal torsion caused by flexion from the tilting of the pelvis, sets the lordosis off the sagittal plane, which induces the thoracic curvature to turn in the opposite orientation, and the torque actions between the left and right to be uneven. These impinge on the harmonization of trunk's rotation and the transmission of angular momentum up the spinal column, thus inhibiting the strength output of the waist power. These issues are mitigated by keeping the pelvic platform level, and by abdominal breathing pushing on the lumbar to reduce lordosis by counter-nutation (See Fig. 6).

In Taijiquan practice, we decipher the disharmony of the axial rotation as yin-yang imbalances impeding qi flow at the SIJ and hip-joints. The triangle of joints represents the last frontier of the musculoskeletal structure in the fangsong resolution. The deepest vestiges of resistance to the unity of motion and qi reside in the imbalances at the triangle of joints, the fangsong resolution of which, sets the qi flowing unimpeded in developing full dantian qi. That is to say, the fullness of dantian qi encompasses the harmonizing of the spinal engine to be in compliance with yin-yang balance.

Taijiquan training program in sports

Training regimens may differ in sports, but two basic elements are essential, without which performance cannot excel. The first is the body's core strength, the basis of waist power, and the second, is the body awareness and knowledge of the motion at the joints, which is the basis of maneuverability and fine control.

In the power actions, the core power of the waist is transmitted up the torso to the shoulder, then through the elbow, wrist and fingers in the kinetic sequential order. For example, at the beginning of the golf downswing, the L-shaped arms remain unwound to follow the waist's rotation (in the four images of Fig. 12); the swing motion of the arms at the shoulder fulcrum follows after, in the downswing, then followed by the motion of the forearms at the elbows, then with the unhinging at the wrists, the power is transmitted to the golf club (as the second pendulum) with the release directed by the fingers in the grip.

The principle of sequential kinetics is captured in the collage of pictures of the pitching action (Fig. 13). The pure power of the pitch that delivers a 90 plus mph fastball comes from the waist-groin, which transmits through the body segments in sequential kinetics. The torque action at the waist turning to the left (above the kua junction) is balanced and supported by the torque reaction at the groin turning to the right (below the kua). The main picture shows the torque winding up the torso to the shoulders, ready to transfer to the arm. The other pictures show the transmission through the elbow to the forearm, to the wrist and fingers to the release of the ball in the sequential order.

The two basic elements of sports, the core strength of waist power and the fine control of maneuverability at the joints, are at the heart of Taijiquan training of inner balance. This is good reason enough to port the fangsong methodology to sports training. The greater benefit would be to break the barriers of neurobiology due to the neural responses of habits that stymie progress in training, and greatest still, would be the development of qi pathways to bridge the gap of neural activities to better discipline muscle actions.

The gentle unorthodox slow-motion practice may seem incompatible with the vigor of sports training, but individuals have reported that their golf or tennis swings have greatly improved with Taijiquan practice.

While it is well known and acknowledged in Chinese Martial Arts that neijin is the stuff that delivers the mesmerizing kungfu feats of Taijiquan, little of it is applied outside of combat. Infused with the principle of inner balance that inspires solidity of balance and the spontaneity in the interchange between yin and yang, the body is rendered soft and hard as needed to meet the unpredictable situations in any physical interactions. Sports, such as football or rugby, can certainly draw on such a lively response of strength, versatility and balance. Imagine a running back dodging his way, unstoppable, against a line of burly defenders, to the end zone with Taijiquan skills! That scene might seem far-fetched, but so would the adoption of the ancient Chinese therapy of cupping to condition muscles in modern sports. Indeed, in the recent Rio Olympics 2016, handsome cupping marks were conspicuous on the bare back of Michael Phelps.

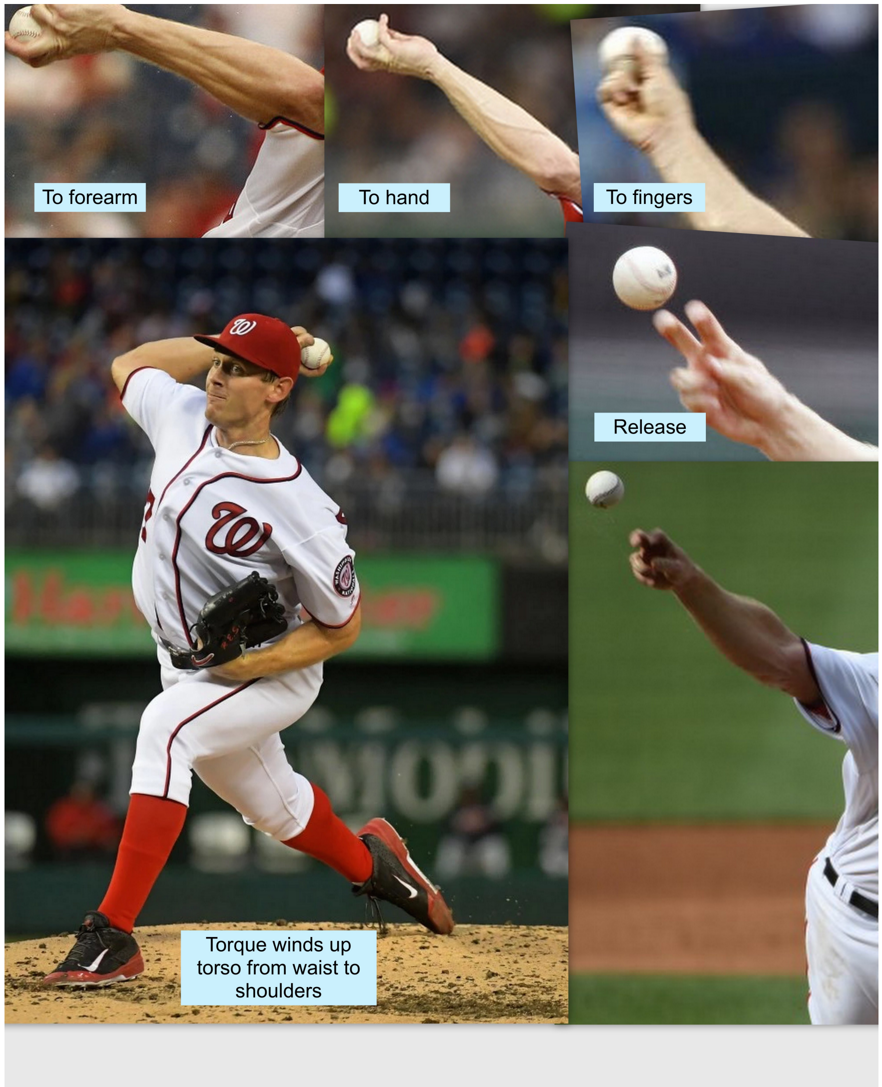


Fig. 13 Stephen Strasburg of Washington Nationals
by Katherine Frey/Washington Post July 14, 2016

Conclusion

Even though the paper does not tout the health benefits of Taijiquan practice, the message of its efficacy in health is ever present in the thrust of inner balance. TCM views an excess of yin or yang or a blockage of qi flow as a marker that portends ill health. Thus, the fangsong practice of resolving yin-yang imbalances and developing qi represents the very tenet of health, thus, preventive medicine in TCM.

Taijiquan's inner balance, as a product of yin-yang balance, also promotes the functional harmony of the internal organs, which are classified under the Five Elements (in parenthesis): liver (Wood), heart (Fire), spleen (Earth), lungs (Metal), and kidneys (Water). The theory refers to the practice as nurturing the internal unities between the organs under the involuntary control of the autonomic nervous system and the skeletal and body parts under the voluntary control of the somatic nervous system: between heart and eyes, spleen and flesh, lungs and body-form, kidneys and bones, and liver and tendons-muscles. The practice of inner balance covers the unities of the correspondences to attain the oneness of the body:

Zong zhi 总之
Yi dong er wu bu dong 一动而无不动
Yi he er wu bu he 一合而无不合
Wu zang bai gu xi zai ji zhong yi 五脏百骸悉在其中矣

In summary,
Once in motion, no part is not in motion
Once in unity, no part is not in unity
The five organs and hundred bones are together in harmony.

In this regard, the principle of inner balance asserts the functional harmony of the “five organs and hundred bones” through qi and blood. Thus, the achievement of dantian centrality is also a TCM passport in the passage to longevity.

This is saying that inner balance is maintaining a stable environment for the functional harmony of the internal organs, namely, the homeostasis of the biological and physiological environment of the body, on which health rides.

The feature of Taiji practice that arguably provides the greatest impact on health and wellbeing comes from the meditation component. Although the practice may begin as a physical activity, the modus operandi of deliberative slow motion entails attentiveness, which grows into meditation that complements the training. The attentiveness keeps the mind from wandering and acts to restrain the “monkey mind” of restless thoughts darting in and out incessantly. Taijiquan resorts to meditation to calm and quiet the mind so that it becomes more perceptive of the practice. Meditation sharpens the mind, which is necessary at the higher levels of practice where the errors of imbalance are more subtle, requiring more refined tools to resolve.[30] With awareness and tranquility, equanimity takes root, leading to the insight of the art—and along with the development, the tremendous health benefits that inure.[31]

To sum up, the achievement of inner balance bears three gems:

1) Neijin. Body is always in balance, and in response is ever ready to change at will under pressure or load, and the force that ensues is that of neijin and is consummate.
2) Equanimity. The keen awareness of the mind keeps unwholesome and negative responses driven by greed, hatred, jealousy, anger, or more generally, delusions, at bay, thus tranquility and blissfulness are nurtured.
3) Homeostasis. The oneness of the “five organs and hundred bones” is the maintenance of a stable environment for the functional harmony of the internal organs.

1 Locomotion of monitor lizard: http://giphy.com/gifs/ZIuyq5yzyvfRC, from original video link: https://www.youtube.com/watch?v=H0l847bhvNI
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3 Mary Key Floeter, *Disorders of voluntary muscles*. Table 1.1 http://assets.cambridge.org/97805218/76292/excerpt/9780521876292_excerpt.pdf
4 Gracovetsky cited the 1960s experiments conducted at the biomechanics laboratory of the Wright Patterson Air Force Base in Ohio, which subjected monkeys strapped to a chair to impact forces of 120g's. The monkeys shrank by about half as their vertebras were crushed, but their annulus fibrosus remained essentially intact.
5 These movements are studied and utilized in childbirth, and are illustrated in the video graphics: https://www.youtube.com/watch?v=-ZKgzMvWXVM.
6 A Vleeming, et al. *The sacroiliac joint: an overview of its anatomy, function and potential clinical implications* J Anat. 2012 Dec; 221(6): 537–567. Most of the discussion here on SIJ are based on this paper. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3512279/
7 Ibid 7.
8 Serge Gracovestsky: http://www.tubechop.com/watch/8212331. The longer original version in the link: https://www.youtube.com/watch?v=EAMK7yR9RgI
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