Generating Body Strength
Through Taiji Motion
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Abstract

The neural circuits work very well to match, functionally, between the command of an action, such as to swing a club, and the activation of muscles that result in the action. But the responses of neurobiology do not function well to meet a higher level of performance, which one may desire, such as a good long golf drive. The neural signals from the motor cortex do not activate the right sets of muscles to produce the drive that the body is capable of. Indeed, very often, much of the responses, conditioned by behavioral convenience, turn out to be obstacles, which form “barriers of neurobiology” to one's advancement in training. This paper examines the issues through the lens of Taijiquan, and explains how its unorthodox slow-motion methodology cultivates the body senses that elicit responses to overcome the barriers, and to activate the right balance of muscles to produce the ideal body motion of Taijiquan.

Introduction

We may be created equal in the design of the musculo-skeletal framework, which bequeaths our bipedal functionality, but we are not created equal in the use of our muscles, as evident in athletics and dance. While it is true that a person endowed with bigger muscles can lift heavier objects, physique alone is not a reliable predictor in the outcome of a contest of strength. We applaud with delight whenever a person of smaller build overcomes a larger in sports and martial arts. The factors in generating body strength are not just about developing muscles, but crucially, how they are recruited and how they align in coordination.

We are presumed to have control over our voluntary muscles, but much of the muscle activities of our physical actions operate under the radar of our consciousness. We may have command of the action, say to touch the nose, but we have no cognition of the complex of muscle activities that underlie the action. Between the command of action at the top hierarchy of the body's motor system and the final signal output to activate muscles at the bottom, there is a web of neural activities, which represents a huge gap that we are not conscious of. The communications from neuron to neuron may travel along the same neural pathway, but the signals are not the same. And we have no direct control over what occurs in the process, until the final outcome in terms of the action itself—the finger touching the nose.

We rely on training to improve on our actions, but we have to leave entirely to faith that neurobiology will make the right neural connections to recruit and align the right muscles. Yet, as hard as we train, we cannot produce the long drives of top golfers. Even for professional athletes, practice can sometimes hit a wall—stymied in progress. This points to some
responses of neurobiology that become obstacles in training. It evokes the question: Are elite athletes born or made?

This paper looks at these questions through the lens of Taijiquan. We stay guided by the quest of generating body strength to avoid being drawn into the esoteric nature of the subject. We navigate the terrain of neurobiology to find if there is a faculty in the brain that integrates the inflow of sense data to produce the maximal strength that the body is capable of.

We begin by looking at the mechanics of waist power, as it is the main source of power action in both sports and martial arts. The discussion provides a common ground on which to overlay the framework of physiology and physics, and that of Taiji yin-yang theory to study the factors of generating waist power. The approach forces one to evaluate the esoteric concepts of Taijiquan in terms of science.

Ironically, as it turns out, it is the so called mystique of Taijiquan that gives us a practical “link” in the huge gap of neural activities underlying the body motion of an action and thus a solution path to overcome the training obstacles that arise from the responses of neurobiology.

**Waist Power**

We use the waist to power almost all actions demanding of strength. Waist power is the key source to athletic and martial prowess—a 400-yard drive in golf, a 95 mph fast ball in baseball, an ace serve in tennis, or a knock-out punch. The force comes from the rotational motion at the waist, where the rotation of the upper body is supported by that of the lower body turning in the opposite direction, thus involving the whole body. A study in slow motion of the power action of professional athletes shows the mechanics of the waist—the postural balance between the left and right and the top and bottom. For example, in a right-hand swing, the torso turns at the axis of the spine in the left direction at the waist, but the lower body turns in the opposite direction².

The waist, more precisely, the junction at the hip joints, forms a division with the most proportional distribution of muscle masses between the upper and lower body, compared to other joints. Thus the physics and muscle physiology are easy to see in the use of the waist to generate optimal power. What is difficult is to get the body to synchronize the lineup the upper and lower muscles to produce the torque action and reaction, and work in mutual support and balance at the junction. That is why there is such a wide disparity of waist power output, for example, between the casual and professional athletes. How much can training do to narrow this disparity?

**Behavioral responses of muscles**

A novice associates a long drive with hitting the ball hard. In swinging the golf club hard, the muscles of the arm and shoulders would inadvertently dominate, depriving the drive action of the muscle power of the other parts of the body, particularly, of the legs. The body's demand of strength in the action draws a response of neurobiology that overrides the coordinating function of the waist. Thus, ironically, the very desire of a long drive elicits a response that
frustrates the mechanics of generating optimal waist power. That is why weekend golfers find it difficult and elusive to improve their long drives, despite many dollars and sessions spent at golf clinics.

Another example that illustrates behavioral responses of muscle that thwart the task at hand is that of picking up a box. For convenience, we bend forward to reach for the box, but keep the bad forward-leaning posture as we exert force to lift it, causing many a back sprain. We do not think of bending at the knees for a better posture of support to lift the box with a better use of waist power. We are mostly unaware of the debilitating effects of the posture on balance as they occur, until after the fact. The preferred response of neurobiology is for a convenient reach, less to weigh the postural effects on balance.

This behavioral response is actually quite typical of the muscles of the hand. We have remarkable control of the hands, the dexterity of which is unique to the human species. The map of the motor cortex, the part of the brain that sends signals to activate muscles of voluntary movements, shows a disproportionately high distribution of neurons allocated to the function of the hands (See Fig. 1).

![Fig 1 Motor map (motor homunculus) showing the disproportionate hand representation as mapped to the motor area by Dr. Penfield.](image)

The fineness and precision in the control of the hands come from a relatively large number of motor neurons, each innervating a relatively small number of muscle fibers, some in the tens. Anyone, young or old, can learn to use the chopsticks! By contrast, in the large muscles of the arms and thighs, a motor neuron innervates hundreds to thousands of muscle fibers.

Indeed, our mobility is hand-oriented! The hands dominate in our actions. The impetuous hands would always reach out first, say, to retrieve a cup of coffee, causing many a fried keyboard. The habit of the hands jumping ahead in action would offset postural balance requiring adjustments to right, and in so doing, it would compromise the muscles of the other parts of the body from coming into play. This habitual dominant behavior of the hands can
frustrate one's generation of waist power in sports and martial arts. In other words, the
exalted hands that give us the arts that define human civilization can also be the bane in
producing body strength.

In our mobility culture, the dominant behavior of the hands is a trait of response that poses a
great challenge to training in sports and martial arts. How much of the voluntary muscles can
be disciplined to restrain this behavior?

Control of voluntary muscles

The control we have of our voluntary muscles is only of the command of action, not of the
muscles directly. We do not decide what muscles are to be recruited, or how much or how fast
they should contract. The motor neurons that activate the contractile actions of the many
muscles underlying the motion are pre-programed in neural circuits that work under the
conscious radar like the operating system of a computer. How does training address this
opaqueness of neural signals and the discipline of muscles that we have no direct control of?

The brain processes a lot of sensory input for our bipedal functionality, but it does not always
get the right feedback with respect to actions. For instance, in the case of picking up the box,
the brain does not get feedback of the body's bad posture, but instead sends signals to
reinforce muscle actions to keep the poor leaning posture in balance! The body responds by
reflex to reinforce muscles locally to keep balance, not by making global postural
adjustments.

We can figure out the ill effects of bad postures and body mechanics from sensory inputs to
the brain, but we are not wired to be cognitive of the postural factors in generating maximal
strength in actions. The brain does not have a faculty that integrates sensory input of postures
and underlying muscle forces with regard to the body mechanics of power output of an action.

Indeed, very often, one develops behavioral responses of muscles that hinder the body
mechanics of generating waist power. This muscle behavior is compounded by the
opaqueness of the neural signals in producing body motion, and inadvertently it builds up
barriers of neurobiology to training in sports and martial arts. Let us review briefly the
activation of voluntary muscles in the nervous system.

Neural signals to voluntary muscles

The information flow between the brain and the body is a two-way traffic, descending and
ascending along columns of nerves in the spinal cord. Far more data flow in than out, typically
in the ratio of twenty to one. Outflow of command descends from the brain, carried by motor
neurons to activate muscles to produce motion, and sensory information collected from the
body flow up the spinal cord to the brain. The nerves are organized along where they leave
the vertebral location from the spinal cord: the cervical (neck), thoracic (chest), or lumbar-
sacral (lower back) vertebrae. The nerves branch out by this division to serve the different
regions of the body.

Muscles powering the hands, arms and upper body are innervated by nerves in the cervical
portion of the spinal cord and those powering the feet, legs, and buttocks, by nerves in the lumbar and sacral portions of the spinal cord, and they are distinguished between the left and right. We have volitional control of muscles in the sense that the command signal of the action originates at the conscious part of the brain—the cerebral cortex. A neuron cell in the motor cortex of brain literally traverses down the passage in the spinal cord, where it connects (synapses) with a motor neuron, which then physically exits from one of the vertebrae and wires to the muscle it innervates. In other words, the neural signal that activates a muscle of volitional movements is carried by only two neurons, making up a strand of the neural tract from the cortex descending along the spinal cord directly to the muscle (called the cortico-spinal pathway). The simplicity of this link in the neural network is deceptive—behind the signal output, there is an integration of a complex of signals from other parts of the body and brain to the motor cortex. Moreover, muscles of other parts of the body are also activated in concert with the single action.

The muscles powering the different segments of the body are activated separately by the motor neurons. Thus the neural wiring of our nervous system accords the independence of movements of the different parts of our body, between the left and the right, and the upper and the lower, as well as of the extremities. The independence endows us with the richness and versatility of the art of body motion that characterize the human species. But it can also frustrate demanding actions that require muscles to work together—the muscles become stubborn accustomed to their independence and habits, and so may not work the way we want them to. Indeed, it is often the development of this behavioral stubbornness that is hindering one from using the right body mechanics to generate strength.

To throw a punch, the output command is carried by motor neurons of the cervical cord to the arm and fist (in the cortico-spinal tract). We are conscious of the punching action. But the command also incorporates signals that travel further down the spinal cord to motor neurons of the lumbra-sacral cord to innervate muscles of the lower body to support the punch action and to maintain the integrity of the bipedal structure in balance. We are usually not aware of the muscles of the lower body supporting the action. Yet the power outcome of the punch action depends critically on the neural signals to the muscles of the groin and the legs, namely, the alignment of the muscles of the lower body to support the upper body action.

If we can summon the waist-groin muscles by command so that the rotational motion of the torso is in sync with that of the base in their mutual support, then we can achieve long drives in golf consistently! But there is no faculty in the cerebral cortex that integrates the coordination on the fly. Persons endowed with the facility of the waist-groin control of rotational motion enjoy an ease of movements at the pelvic joints, which gives them an advantage in generating waist power. A talented athlete is born with this advantage.

If one is not born with this talent, how can one train to overcome the behavioral stubbornness of the muscles set by habits and independence, to improve on one's golf drive for instance? To see what we are up against, let us review the major muscles that keep the structure of the spine and ribcage erect, particularly, the muscles of the midsection.

The axial muscles that keep the trunk erect
The architecture of the skeletal frame of the torso—the prominent ribcage hanging at the upper part of the spine—does not inspire confidence of a sound erect structure, even before it is loaded with internal organs. The vertebral column sits precariously with its tail sacrum that fuses onto the wings of hip bones (ilia). At the top, the first vertebra, euphemistically named atlas, holds the skull. Besides the support at the sacrum, there are no other skeletal props between the ribs and the pelvis. What gives functional integrity and stability to the trunk as a flexible, strong and erect structure are the many axial muscles—muscles close to the spinal axis—that bind the rib bones, the vertebrae and the hipbones, on the front and back.

Two muscle groups that work like straps keep the trunk erect: erectus abdominis (the two columns of “six-pack” muscles) on the front, and erector spinae, the muscles along the spine on the back. The six-pack muscles attach at the sternum above, and at the pubic bones below, so that when the muscles contract, the trunk is pulled forward.

The muscles of the second group—the erector spinae—are a collection of three major muscles that run along the spine, bulging as the two noticeable ridges on each side. They attach at the lower end of the spine—the sacral-lumbra vertebrae—and insert at the upper section of the spine—the cervical and thoracic vertebrae. Their contraction pulls the vertebral column back. They work with the erectus abdominis in antagonistic pairs to stabilize the erect structure of the trunk, and to provide the bending motion of the torso. As each left or right column of the erectus abdominis or erector spinae are innervated independently, the muscles contract in various combinations to give the versatile angular bending motions of the spine as well as the turning motion of the torso.

Two pairs of deep muscles further secure the vertebral column to the pelvis at the base. They attach at the lumbar vertebrae and sacrum and at the ilium (pelvic crest) to the femur thigh bone, just below the joint. Together they form the iliopsoas muscles (from iliacus and psoas). These are the inner muscles that keep the base of the trunk erect as well as provide support to the turning motion at the waist.

There is another group of major muscles that hold, support and protect the internal organs in the belly cavity—the abdominal muscles. These muscles consist of three sheets of muscles—the external abdominal oblique, the internal abdominal oblique, and the transverse abdominis—that wrap around the waist like a corset. They are made up of two halves, one around on each side, and are joined by a fascia of tendon tissues at the back, and “zipped” in a middle vertical sheath (called linea alba) on the front. The sheets attach variously at the lower ribs at the upper part, and to the pelvic crest on the lower part, to collectively provide a firm yet flexible support for the abdomen, which is expandable for pregnancies and beer bellies. The individual muscle sheets are innervated independently, and provide rotational movements as well as changes of intra-abdominal pressure that facilitates abdominal breathing—and belly dancing.

However, we are not cognitive of these groups of muscles in their primary function of stabilizing the trunk’s erect structure and balance. Their activation is triggered mostly in the brain stem and cerebellum, which we have no conscious control of. However, we can bend forward, backward or at any angle, as well as turn at the waist, but we cannot move the rib bones individually like we do the fingers and toes. The places where these muscles attach are...
designed less to produce torque power at the waist, but more to provide movements to support our bipedal functionality and balance. Nevertheless, these muscles work in their left-right pairings to generate the torso’s rotation on the spinal axis, and the balance of the muscle actions between the left and right, is critical to the output of torque power of the waist.

**Responses of neurobiology in generating waist power**

To harness fully the waist power, the torque action of the upper body must be supported by the torque reaction of the lower body. The muscles of the arms, shoulders, and torso must work in unison to produce the upper body rotation, and that of the groin and legs to support the lower body turning in the opposite direction. At the same time, the muscles between the left and right sides must also balance in their rotational actions. These refer to the major muscles of the limbs (appendicular muscles), together with the associated deep muscles.

More crucially, the actions of the appendicular muscles must also work in harmony with the inner axial muscles that maintain the balance and stability of the trunk’s erect structure. Not only must they work in tandem with the muscles of the paired columns of the erector abdominis, the erector spinae, and the iliopsoas, they must also align with the balance of the two halves of the abdominal muscles to keep the integrity of the turning motion.

While the inner muscles may be activated voluntarily in producing rotational motion, the function of maintaining the integrity of the erect structure in balance is involuntary. A good portion of the neural signals to the axial muscles of the abdomen do not travel along the cortico-spinal tract, that is, they do not originate from the conscious part of the brain—the cerebral cortex. In other words, the responses of neurobiology produce a mix of neural signals, of which only a portion are derived from the motor cortex of the brain.

The final output of neural signals that innervate the muscles is a function of a complex of sensory input from the body to the brain, but we have no cognition of the process, let alone direct conscious control of it. Whatever the mechanism of this function, it is not a design of neurobiology to produce optimal power output as the body wishes. That is why we cannot improve our golf drives at will; it is difficult to do so despite dedication of practice.

The training to cultivate waist power is not just about muscles and exertion of strength, but more importantly, it must first break the bad habitual responses of muscle behavior and then induce responses of neurobiology that would incorporate the factors of body mechanics in producing optimal power. The essence of training then should be to nurture responses from the sensory inputs of the effects of the muscle actions underlying body motion. The feedback then would cultivate responses of neurobiology that would activate muscle actions of better output of waist power. In short, the challenge is to develop the pragmatics of deciphering the effects of the right balance of muscle actions underlying body motion that corresponds to optimal waist power. As it turns out, one only needs to be concerned with “inner” balance!

**Imbalance of muscle actions**

The action of picking up a box discussed earlier, illustrates a posture of physical balance that suffers from “inner imbalance.” Muscle actions of the back are reinforced by reflex to keep the
forward-leaning posture from falling over. The interplay of the muscle actions underlying the posture is burdened by keeping physical balance, which makes the body structure stiff and hard to respond in change. The body topples easily with a nudge. By bending at the knees, the body structure is adjusted to render a stronger posture, which not only provides a better balance but enables a better leverage to lift the box. The adjustment ameliorates the “internal imbalance” of the structure. More importantly, the body can learn to decipher the symptoms of stiffness and tightness of the structure, which impedes motion flow and the ease of change of movements, as internal imbalance of the underlying muscle actions.

We define \textit{internal imbalance} of muscle actions as a condition of excessive or deficient muscle actions underlying the structure of a posture or motion. Notwithstanding the external balance of the body in tasks mundane or demanding, the underlying muscle actions are invariably not in internal balance—some working too much, and some too lax. This imbalance is at the heart of the issues of generating body motion, which subsumes the generating of waist power.

What if we are not into competitive sports or martial arts, do we have to be concerned with internal balance? We function extremely well as bipedal beings and engage daily in all kinds of physical activities, without any concern of the harmony of the axial and appendicular muscles. For routine activities, there is sufficient muscle power to handle the task at hand, without us having to tap into the store of waist power. Indeed, important as it is, we are not aware of the interplay of muscle actions underlying body motion.

However, we do suffer from the effects of the imbalance of muscle actions. For instance, how long could one hold up a bad posture, such as that of a stooping posture? Stress would set in quickly—the muscles would burn and ache under the pressure resulting from internal imbalance. Imbalance is a source of stress, but its effects may be innocuous and negligible initially, except that it comes with sinister consequences.

In the modern workplace, the body is constantly subject to stress by imbalances of postures under repetitive work situations—sedentary, standing or crouching.Persisting over a prolonged period, the stress effects would accumulate without one knowing about it—there is no neural pathway to warn of the buildup of stress—until it manifests in chronic pains, with symptoms of feverish temperatures at the neck, shoulders, or lower back.

Resorting to pain killers, massage, or plaster therapies brings a temporary relief, but not cure. There is a common thread in these therapies—they induce a relaxation of the muscles, thus a temporary relief. The root cause—the imbalance of muscle actions—is exacerbated by a growing mismatch between the need of the muscles to work and the convenience of modern lifestyle, which is becoming less and less physically active.

Reducing imbalance of muscle actions would resolve a host of issues, from alleviating stress-related chronic pains to generating waist power. But there is no body sense-receptors for the imbalance of muscle actions. However, we can cultivate the senses of the effects of imbalance, such as the symptoms of stress and stiffness, to decipher and characterize imbalance. This will establish a link to the responses of neurobiology to provide a methodology to correct for imbalance. In other words, we reduce the problem of the body's
generation of strength or more generally, the art of body motion, to the core—the resolution of the internal imbalance of the underlying muscle actions.

The art of Taijiquan offers an uncanny solution to the discipline of body motion that builds on inner balance. It develops a comprehensive kind of strength, which is uncharacteristic of the physical strength that we are familiar with, hence it is dubbed “inner strength.” This inner strength incorporates waist power (includes golf of course), and is at the heart of Taijiquan's amazing kungfu prowess that one hears of. And most enticingly, it mellows with age!

This pronouncement usually evokes an immediate reaction of surprise and disbelief. The unorthodox slow-motion practice cannot be further from the speed and power of sport actions, both absent in Taijiquan. If anything, the exercise is opaque, and not geared towards developing any specific power action. However, once its rationale becomes clear, one can readily relate to the "soft" power.

The Taiji theory of yin and yang

The Taiji concepts of yin and yang are uniquely Chinese, and thus foreign to Western culture. Taiji philosophy has roots going back to the antiquities of time. The Chinese thinkers of old resorted to Taiji theory to expound everything of man between heaven and earth—it served as a “grand theory of everything.” Far from being relegated to history, the theory survives the millennia to the present.

The yin-yang lexicon still appears in common usage in Chinese culture: food, heath, medicine, music, calligraphy, art, fengshui geomancy, etc. and of course martial arts as in Taijiquan. Indeed, Taiji philosophy permeates Chinese thinking—the yin-yang duality serves as its organic logic, just as mathematical logic is the foundational language of science.

The theory posits that the essence of all things at the fundamental level is their yin and yang. Taiji theory is a study of the dynamics of yin and yang as governed by the yin-yang principles. The principles prescribe that yin and yang are not static, that the relative presence of one in the other is necessary in orderly change, and that the ideal state is Taiji balance, one where there is no excess of yin or yang. At the practical level, it is to identify the conditions of yin and yang and to seek solution-paths in the dynamics that lead to yin-yang balance. The reader is referred to the author's book (Chapter 3), where more of this is discussed.

Think of the art of Taijiquan as regulating motion to be in accord with the Taiji principles of yin and yang, where yin represents deficient muscle actions, and yang, excessive muscle actions. Taiji training then becomes a process of reducing the errors of excessive yin or yang, and developing a solution-path towards Taiji balance.

Taijiquan's methodology of relaxation

At the heart of Taijiquan practice is the cultivation of inner balance (Taiji balance), a state where the muscle actions underlying movements and support are neither excessive (yang) nor deficient (yin). It develops a comprehensive balance that is beyond physical balance. A stooping posture is a notable example of a structure in balance that lacks inner balance. The
following demonstrates another violation of inner balance.

When you take a deep breath, as when a doctor asks you to, the chest is heaved up and the abdomen is hollowed. The body becomes top heavy, and it topples easily with a gentle nudge. The inner balance is breached in bracing up the chest, but the physical balance in terms of the position of the center of gravity relative to posture and muscle mass, remains the same. Bracing up the chest uses more muscle actions than a posture at ease. The excessive muscle actions to keep the top-heavy posture come at the expense of the support at the base, which weakens the structure internally.

While there is no neural input of imbalance of muscle actions (yin-yang imbalance), we can develop a cognitive sense of top-heaviness, as we do in the sense of stress and stiffness, to decipher the imbalance. We can then mitigate the flaw of top-heaviness by relaxing the chest—letting the upper body “sink” with the breath so to speak.

Indeed, imbalance is very common in our body motion. This is illustrated by a simulation of the muscle actions of the arm. Hold out an arm to the side horizontally: You can stretch the arm out, tensing it (rendering it too yang), or you can let it droop (too yin). The physical balance is the same in both cases—the arm’s weight is balanced by muscle forces—but the underlying muscle actions are different in their relative exertion, giving rise to various states of internal or yin-yang imbalance.

Enlist a friend to hold the tip of a finger of the extended hand, and let the arm drop, so that it suspends like a cable between the shoulder and the held finger. The muscles become relaxed in a reset of the muscle actions holding up the arm. This reset reduces the yang-tenseness of the muscle actions, thus improves on the imbalance.

In the case where the arm is held loosely, and droops like a plant that has not been watered—the yin situation—extend the arm slightly. The extending strengthens and adds yang to the arm, and lessens the sense of slackness. This breathes yang-vitality to the laxity and reduces the yin imbalance.

In essence, what Taijiquan practice does is to relax whenever there is tenseness, and to extend whenever there is laxity. The Chinese terminology for this action is fangsong 放松, which transliterates as “let loose.” To conserve verbiage, we incorporate in the terminology of fangsong, the action of extending to strengthen the laxity as well. Thus the practice of Taijiquan then is one of fangsong—relaxing when there is tenseness, and extending when there is laxity.

The process of practice inculcates the pragmatic senses of imbalance—excessive muscle actions as yang-tenseness and deficient muscle actions as yin-laxity. At the same time, it also develops the fangsong tool of reducing the errors of yin-yang imbalance. The cultivation of the senses of imbalance and the responses to mitigate it establishes a link to the responses of neurobiology, thereby induces a discipline of muscle actions.

However, there is no neural barometer of inner balance. Taijiquan does not strive to cultivate inner balance directly. The key is that the training develops a discernment of a reduction of
yang-tenseness or yin-laxity. The practice simply applies the fangsong mechanism to put the body in the middle ground between the error of yang-tenseness and the error of yin-laxity. By reducing the errors, over time, the body converges towards the state of inner Taiji balance, ushered in by the narrowing margin of errors. This exemplifies the quintessence of the Tao of “doing without doing” (wei wu wei 为无为) — achieving Taiji balance without striving for it.

**The paramount status of the pelvic joints**

The tricky business is that the muscles binding the body frame defines a tensile integrity of the structure. This means that resolving imbalance at one joint affects the muscle actions, thus balance of the other joints. Such a process requires a constant feedback of muscle adjustments at multiple joints, clearly a daunting analytical task beyond the normal brain capability. Taijiquan offers an ingenious way of resolving it.

Taijiquan recognizes that of the major joints—hip, knee, and ankle of the legs; and shoulder, elbow, and wrist of the arm—the hip joints are preeminent. This is driven by bipedal functionality, which relies on the the hips as defining the line of division between the upper and lower body (discussed earlier). The Chinese has a specific term for the pelvic joints, called *kua* 胯, which refers to the inguinal fold to connote its functionality disposed to forward folding.

The methodology of Taijiquan is to resolve yin-yang imbalances relative to the *kua* (pelvic joints) as a base of reference. The reference centralizes the feedback issues of the other joints at the *kua*. This necessarily involves the application of fangsong to the muscle actions at the *kua* junction at each resolution. The upshot is that the muscles of the abdomen and the axial muscles are constantly disciplined to harmonize, which consolidates the rectitude of the trunk's erect structure in balance.

Significantly, the continual fangsong tempering of muscle actions relative to the *kua* builds a connectivity of motion between the different parts of the body and the *kua*. The tempering process in effect establishes a center of motion at the midpoint between the *kua*, which coincides functionally with a point called the *dantian* 丹田, described as three fingers below the navel, and about one-third the way inside. In short, the fangsong process nurtures the *dantian* as the control center of body motion. This is referred to in the Taijiquan literature as:

以丹田为核心 Yi dantian wei hexin.
Establishing the dantian as the nucleus.

The practical import of dantian centrality is that it not only imbues the body with comprehensive balance, but also provides a motion-connectivity of the different parts of the body to the dantian, thus developing a more precise perception of motion. The precision of perception is necessary in the finer discipline of the torque action and reaction at the kua junction in generating waist power.

**The medium of qi energy**

The fangsong methodology has an inner dimension that complements the physical tempering
of the body—it resorts to the so-called life-force qi energy. The concept of qi, circulating in a system of passageways or meridians in the body is fundamental in Traditional Chinese Medicine. However, qi has eluded definition in terms of basic science, but the body relates to qi readily in its practical usage. Indeed, the age-old Chinese system of medicine has yet to be reconciled with physiology.

We take qi as given in Traditional Chinese Medicine, but we develop it as guided by its pragmatic function of disciplining body movements. This renders a representation of qi that ties it to the mechanism of fangsong, and thus provides a comprehension of qi that relates to physiology and kinetics.

We treat qi as a bio-energy and study its association with movements. The practice of Taijiquan or any exercise of qi energetics, commonly called qigong, develops a sensation of qi bio-energy. For the present, we can think of the body's qi sensation as encompassing stimuli picked up by receptors in the joints, ligaments, tendons and muscles, such as of proprioception, as well as of touch. In other words, we approach qi by cultivating a body sense of qi, rather than defining it.

At the beginning, the fangsong mechanism relies primarily on the senses of yang-tenseness and yin-laxity of muscle actions. Upon sensing tenseness, the practitioner relaxes to reduce excessive muscle actions; and upon sensing slackness, he extends to reinforce deficient muscle actions. As the fangsong reduces the errors of tenseness and laxity, the body registers an easier flow of motion, as current with less resistance, and with it a sense of energy flow, which is attributed to qi. These rudiments of qi energy usually manifest as a warm or tingling sensation in the hands. In the early phase of practice, the sensation of qi is intermittent but gradually firms up over time—the more the errors of imbalance are reduced, the stronger the sensation of qi. In other words, the practice cultivates the perception of qi as a product of the fangsong process.

The modus operandi is the deliberative and slow-motion nature of the exercise—it induces attentiveness and nurtures a calm state of mind to be perceptive. In time, with fangsong reducing more of the errors of yin-yang imbalance, the sensation of qi gains strength and clarity. Then when the qi development reaches a certain maturity, the practice transforms to the internal phase: The body learns to resort to the qi medium to discern and resolve the errors of imbalance.

Qi and inner balance

Using qi to discern and resolve the errors of imbalance represents a game-changer in the physical training—qi adds another dimension to refine one's art. Refinement delves in the discipline of the deeper layers of muscles. All our physical actions are stabilized and supported by the deep muscles, which work in synergy with the appendicular muscles. The problem remains—we have no cognition of muscles in general, let alone the deep muscles.

The fangsong mechanism applies to all the muscles involved in the motion. In time, the resolution of imbalance penetrates the deeper layers of the muscles together with the sharpening of the perception of the associated qi. The sharper perception of qi enables the
finer discipline of the deep muscles to align with the external muscles in their actions.

From another perspective, in the continual pragmatic use of qi in fangsong, the sensation of qi flow becomes infused with motion flow. In the unification of qi and motion, one learns to direct motion through qi. Then the discipline of motion—the elusive task of disciplining the underlying muscle actions—is functionally reduced to a manipulation of qi. With this development, the practitioner realizes the yi-qi-motion paradigm of Taijiquan: The mind, yi 意, issues the command and activates qi as signal; then qi arrives and drives the motion.

This ushers the practice into the internal phase and the fangsong process grows more and more into one of nurturing qi. However, it remains driven by the rationale of reducing imbalance, except that it relies primarily on the sensation of qi, and less on tenseness or laxity, to discern and resolve errors. In other words, the qi energetics of Taijiquan is grounded in inner balance.

Grounding qi in inner balance builds a qi comprehension of the principle of dantian centrality—the motion connectivity centered at the dantian. The qi nurtured by the fangsong tempering at the kua collects in the pelvic bowl. The constant reference to the kua induces a buildup of qi that concentrates in the dantian, referred to as dantian qi. The maturing dantian qi accords the discipline of the deep muscles of the trunk, abdomen, and the pelvic girdle (kua-groin region), that critically harmonizes with the appendicular muscles in bipedal functionality.

The development of inner balance is the development of dantian qi. It is measured by the motion-qi connectivity of the different parts of the body to the dantian—the formation of the central status of the dantian. In the fusion of motion and qi dynamics—the realization of the yi-qi-motion paradigm—dantian qi becomes vested with the authority to direct motion, under the command of the mind yi. This investiture of the central status of the dantian is earned through years of practice! The practitioner is said to have acquired kungfu mastery—attained only in a process of time and effort of zhiku “eating bitterness!"

From the perspective of health, the imbalance of the deep muscles is a deeper source of stress. The affliction of chronic pain due to this kind of stress is more tricky to alleviate—it cannot be reached by simple physical therapy, being more deeply rooted. It requires the cultivation of qi that penetrates the deeper layers of muscles. That is why Taijiquan and some qi energetics exercises, as well yoga, have proven to be of such efficacy as a health therapy for stress.

**Inner Strength**

How does inner balance translate to the “soft” strength that overcomes the stronger or the faster? Does it deliver a long drive in golf? Is it different from the force of a knock-out punch? More to the point, what is the force generated by the body? We are usually muddled over the force generated by the body.

The body produces two kinds of force. The first is the force of the contractile actions of muscles, which generates motion. The second is the force created when body motion is resisted. The force of a punch that inflicts damage to the nose is the force generated when
the nose stands in the way of the punch; the muscles only produce the motion of the punch. While bigger muscles produce greater contractile force, muscle bulk does not determine the outcome of the punch.

How strong a punch is also depends on what is hit. A karate chop that breaks a brick does not produce the same force when it strikes a pillow. Force is created in the impact collision between the fist and the target—a consequence of a change in motion. The force that arises from a change in motion, more specifically, a change of momentum, is just an observation of Newton's Second Law of Motion:

\[
\text{Average Force} = \frac{\text{Change in momentum}}{\text{Time duration}}.
\]

Therefore, in building body strength, we should be talking about regulating body motion to involve the different parts of the body to move in unison, not just about building muscle bulk. The more unified body mass produces greater momentum, thus greater force when called upon in use.

Taijiquan's training tempers the body (and mind) so that its motion is in compliant with Taiji principles. In pragmatic terms, resolving the imbalance of yin and yang in the musculo-skeletal framework—of deficiency and excess of the underlying muscle actions—imbues the body with inner balance through the qi medium. This leads to the development of full dantian qi, which establishes the central status of the dantian. The practical import of dantian centrality is that the body moves in unison as directed by dantian qi; it undergoes change with ease; and it can speed up the motion at will.

Inculcated thus, the body moves and responds in accord with Taiji principles, and the force that arises from the change in motion (momentum) is the consummate force of inner strength or neijin 内劲. The term neijin is also commonly referred to simply as jin 劲. The qualification of nei 内 (inner) merely points to the non-physical characteristics of jin. Neijin is defined by its dual character—the “soft” (rou 柔) of yin and the “hard” (gang 刚) of yang. This gives us the rou jin and the gang jin, which manifest the yin and the yang of jin.

It seems that the concept of neijin belongs more to the realm of metaphysics than the physics of force, but the body relates to the rou and gang readily, which in usage, brings out effectively the vector of force in direction and magnitude. The brain output signal to the muscles is not a force vector. For example, in moving a heavy furniture, we play to find its center of gravity by a feedback of trial and error, and adjust our body posture to use leverage to move the object along. In other words, the brain does not analyze the force vector to be used, but responds to the maneuverability of the object in rou jin or gang jin, which translates to the appropriate force vector. The body uses rou to adjust the right posture (direction) for leverage, and gang to unify body mass in exerting force (magnitude).

**The physics of the prowess of neijin**

The phenomenon of martial prowess ascribed to neijin seems to defy the laws of physics: the weaker overcoming the stronger or the slower beating the faster, as seen, for example, in an elderly man of ordinary physique disposing of a hefty younger person with seemingly little
effort and ease. However, much of the feat's wonderment appears only to be so, being set against an expectation that visible strength and speed should triumph.

A punch may be blazingly fast, but the rest of the body does not move at the same speed. One can catch and block the punch at lesser speed by intercepting the attack at the upper arm. Also, at close range, the fist that relies on the extension of the arm loses its advantage of speed.

The Taiji body—one infused with the yin-yang principles—responds in \textit{gang jin} (the hard mode of neijin) when the need arises to exert strength by aligning muscle mass through dantian qi in generating motion. This would unify the body mass in motion, producing greater momentum, thus greater force in the encounter. In the \textit{rou} (soft) mode, the body responds with agility, by undergoing change within the body frame at the joints, but continuing to maintain inner balance. That is, the rou-gang interchange enlivens the body to respond accordingly to the changing situation in combat while inner balance—control—remains intact.

Very often, in a tussle, one pushes back hard against the opponent as a natural reaction, believing that doing so would save one from being pushed over. Also, the body is predisposed to linear motion, so it responds in action along the same straight line. The outcome in the encounter would then be predictable—the stronger person would prevail. In the scuffle, the body cannot maneuver under pressure, being trapped and locked in the position.

Taijiquan offers a “yielding” game plan. Instead of fighting back force with force, the body's inner balance responds by settling into the kua (pelvic joints), thus directing the opponent's force to the feet and ground. This is effected by the response of \textit{rou jin}—the soft jin receives and absorbs the push by adjusting internally at the joints, thereby staying put without resisting in the realignment. Then at will with the control accorded by dantian centrality, he can turn at the waist to redirect the push to the side, causing the opponent to falter. In this way, the opponent's force is “guided into emptiness” (\textit{yin jin luo kong} 引劲落空). It should be noted that there must be sufficient \textit{gang} (hardness) force of neijin to support the soft maneuver or else one would be shoved off before the skill could come into play.

Upon sensing the opponent's loss of balance, the Taiji expert immediately follows through with a short burst of hard (\textit{gang}) jin to propel him off. Aided by his own faltering momentum, the opponent is impressively sent off several meters away with ease. This is the skill of “borrowing the opponent’s force against himself” (\textit{jie li lai da ren} 借力来打人). The effectiveness of these techniques is predicated on the Taiji player's development of neijin that provides the lively interchange between the \textit{rou} and \textit{gang} in the response that manifests in the changing force vector used to one's favor.

The martial skills of Taijiquan fascinate because its kungfu maneuver appears to be almost effortless. This skill is touted as “four ounces repelling a thousand pounds” (\textit{si liang bo qian jin} 四两拨千斤), and it points to some tremendous leverage that can be tapped to one’s advantage. In order for a small effort of four ounces to move a thousand pounds placed at six inches from the fulcrum, the lever would have to be over an unmanageable length of 2000 feet! Clearly, it would be impossible for the musculo-skeletal structure to effect a lever system to provide such a leverage.
Taijiquan gains its remarkable advantage by simulating the leverage of a screwdriver. That is the advantage of controlling the handle of the screwdriver against the opponent holding the tip. The waist-\textit{kua} turning the body acts as the handle turning a screwdriver. For instance, if the arm is seized in a grip, the kua turns as the handle of a screwdriver, against the part of the arm held by the opponent as the tip. With the overwhelming advantage of screwing leverage, no matter how big or strong the opponent is, the grip is broken. Thus, with seemingly a little force of “four ounces,” one overcomes “a thousand pounds.”

The physics is the easy part. The hard part is getting the body to emulate the action of a screwdriver to effect the leverage in application. It requires the development of dantian centrality. The skill flows from the dantian as the control center and the discipline of the body’s rotational motion. Taijiquan’s training of regulating motion by the yin and yang principles also incorporates the rotational movements of the body segments, described as “silk-reeling training” (\textit{chansi gong} 缠丝功). This essential component is discussed in chapter 8 of the author’s book.

\textbf{Reflex response of inner balance}

Taijiquan’s defining feature is that inner balance is kept intact at all times—the fruit of the formation of the central status of the dantian. The Taiji expert responds to the myriad changes in combat without losing inner balance. Thus he would not be disadvantaged for failing to keep balance.

In practice, the Taiji expert responds spontaneously with a varying combination of \textit{rou} and \textit{gang} of neijin, which produces the appropriate force vector to effectively counter any given offense or defense at hand. That is to say, the Taiji body’s response of \textit{rou} and \textit{gang} is a highly cultured reflex action.

As noted, we are not aware of the many muscle actions in our movements. For instance, when we wave our hands, we are not attentive of the elbow nor of the wrist. We are not aware of the legs being raised against gravity and landing forward as we walk, nor of the movements at the knees and ankles. Indeed, we are not aware of many movements that are activated by neural circuitry that forms the central pattern generators of motion, which includes walking, running, swimming, and so on. And we are certainly not aware of the many deep muscles working to support these actions.

We do become aware of the underlying muscle actions only when there is a failure, such as when we slip. Then the body responds by reflex to keep it from falling. The response comes after the balance is lost, which more often than not, proves to be too late. The body’s self-adjusting mechanism to keep balance works fine in routine activities, not when suddenly pushed from behind or in an accidental slip.

Inner balance extends significantly the parameters within which the body can self-adjust to keep balance. For instance, when accidentally stepping on a banana peel, the body, infused with dantian centrality, responds by reflex to settle in the kua to keep balance, thus mitigating a fall that could be catastrophic in old age.
How does Taijiquan develop the reflex response of dantian centrality? Taijiquan's slow-motion methodology painstakingly cultivates awareness of the body mechanics of inner balance. The deliberative slow motion induces attentiveness of the movements, which provides feedback as to the state of imbalances of the underlying muscle actions, and thus its resolution. In other words, during training one is consciously mindful of the effects of the input and outflow of signals primarily through the pyramidal pathway to discern and resolve the imbalances. This process of mindful meditation builds and heightens one's perception, which is essential, as the practice requires ever increasing precision.

The cultivation of mindful perception is necessary to breakthrough the thicket of muscle actions underlying the multitudes of movements associated with our volitional acts in the qi medium. The process of cultivation is consciously volitional and relies primarily on the pyramidal pathway to carry the neural signals, but the development of dantian centrality occurs in the restfulness of meditative observation—of the extrapyramidal pathway.

While the cultivation of the Taiji body is consciously volitional (activated through the cortico-spinal tract), the response in usage of inner balance is by reflex, primarily through the extrapyramidal pathway. This represents a crossover between the pyramidal and extrapyramidal pathways that consolidates the strategies to keep inner balance. In this way, the Taiji expert is not burdened with inner balance, just as one is not concerned with balance in normal routine activities. With inner balance intact in his martial exploits, the expert thus is free to dispose of his opponents at will! It is no wonder that kungfu peers have long regarded Taijiquan's martial skills as of the highest order.

The reflex response of inner balance renders the Taiji expert stable and unmovable as a mountain, since his balance remains solidly intact. This is dramatically demonstrated by Grandmaster Chen Xiaowang who stayed unmovable by Longwu, a two-time Asian strongman champion. The strongman, hailed an Asian Hercules, could move an eighteen-wheeler truck and nudge a car into a tight parallel parking spot between two cars, but he failed to move the older and smaller master an inch, in an open challenge of three one-minute rounds. The master merely stood there, attending to his dantian centrality to keep inner balance without fighting back, as the strongman pushed and shoved at him with all his Herculean strength to no effect.  

This is the fruit of the process of time and effort in practice—which is what the familiar term, kungfu (or gongfu 功夫) implies. That is, a Taijiquan master is trained not born. Indeed, one often reads in the biographies of Taijiquan masters that many were once sickly, and were prescribed the Taiji exercise therapy to nurture their health and constitution.
1 Coursera Series: *Understanding the Brain*, taught by Prof. Peggy Mason, University of Chicago, 4/29/14 The discussion on neurobiology is guided by the 10-week online course.

2 The mechanical and physiological basis of the role of the waist is discussed in author's book.

3 Bruno Dubuc, *The Brain from Top to Bottom*  
   [http://thebrain.mcgill.ca/flash/d/d_06/d_06_cr/d_06_cr_mou/d_06_cr_mou.html](http://thebrain.mcgill.ca/flash/d/d_06/d_06_cr/d_06_cr_mou/d_06_cr_mou.html)

4 CCTV Oct 2012  [https://www.youtube.com/watch?v=nALIDi5Ni64](https://www.youtube.com/watch?v=nALIDi5Ni64)