ADAPTIVE ALIGNMENT, TENSEGRITY, FROZEN SHOULDERS AND PROBLEM THUMBS

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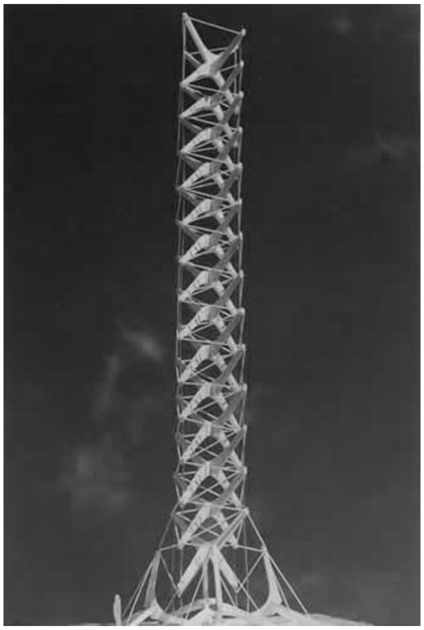
Adaptive alignment describes the positioning of segments of the body in response to conditions internal and external. For example: we adapt the alignment of many segments of our body in the process of climbing stairs. Also, whether moving or standing still, we adapt many segments our body if we have a foot fixed in eversion. The adaptive alignment of the body is limited by the adaptive capacity of the joints between segments. Each joint is inherently limited by the shape of segmental surfaces and the tensional capacities of cartilage, ligaments, tendons, fascial sheaths and muscles. But within these limits each joint has a ready capacity for adaptive alignment. The adaptive alignment of every joint in the body is at the service of spatial orientation and balance, i.e. equilibrium. In static and dynamic function the joints between segments must adapt their alignment to maintain equilibrium. This allows the vestibular system to function so that the organism can continue on in the most biologically economical manner possible. (Mann 2007)

The connections between segments are the joints. If we see the joints as the connective points in a tensegrity[1] system, adaptability becomes a constant function of alignment not just a factor of movement sequences. Tensegrity systems use tension to hold segments together, while at the same time, holding them apart. This preserves the adaptability of the joint. The transfer of weight and support is then, not a factor of direct compression through the joints. Stephen Levin, an Orthopedic Surgeon and leading theorist in the field of tensegrity, points out that because of tensegrity mechanics, the joints "float", rather than compress, in a state of "continuous tension, discontinuous compression". Saying further,

> *"Although some of the rigid components of a tensegrity system 'kiss', it does not mean that they are in compressive opposition to one another." (Levin 1982, page 33)*



In dynamic (moving) tensegrity structures the adaptive alignment between joints remains a matter of flexion, extensions, rotations and side bends. There are some other very interesting aspects of tensegrity mechanics for biomechanics and Structural Integration. There are aspects of tensegrity mechanics that involve triangulations for transmission of tension, 60° rather than 90° alignments, and, perhaps more close to this articles heart, counter rotational weavings. However interesting these factors could be to speculate upon, for this discussion, the important understanding we need to take from tensegrity mechanics is that the joints are not sites of compression.

Throughout the body there are some joints which have a great capacity for adaptation and other joints that have a miniscule capacity to adapt. (See the lists below). The inherent capacity for adaptation is prescribed by the shape of the joint surfaces and the organization and tensile capacities (which includes both contraction and stretch) of the soft tissue components of cartilage, ligament, tendon, fascial sheaths and muscles. In normal function the joints need to have varying degrees of adaptability to maintain the best use of the body's resources, while creating the most stable, adroit and resilient positions possible. As the body moves different areas of the matrix tense and let go in a process that produces sequences of alignment for the joints.

This multidimensional capacity for integrated sequences of movement is created by the varying alignments of the fascial components associated with a joint. Significant among these but often ignored, are the fascial sheaths which surround the joints creating the joint capsules. This fascia, known as the crura, is composed of layers of connective tissue that cross the joint connecting the body's segments. The layers are continuous with the connective tissue pervading and wrapping the muscles and tendons. Research demonstrates that the orientation of fibers in the crura changes from layer to layer.

> *"Since the spatial orientation of the collagen fibers differs from layer to layer, the crural fascia assumes anisotropic[2] characteristics. In particular, the mechanical response of a single layer differs if the layer is loaded along the direction of the collagen fibers or along another direction. The presence of loose connective tissue interposed between adjacent layers permits local sliding, allowing the single layers to respond more effectively to different traction. If this interlayer sliding is altered by trauma or overuse syndromes then all of the force distribution within the fascia changes." (Stecco, et all, 2009, page 1)*

Injuries produced by trauma and repetitive motions alter the adaptive function of joints by fixating various components of the fascial matrix. Because the body is an integrated system, an altered capacity to adapt in one joint will require a congruent diminished adaptive capacity from, or place increased demands for adaptation upon, other joints. When the adaptive capacity of any joint in the system is diminished or exaggerated the transference of tensions throughout the tensegrity structure will be skewed, such that, to maintain orientation and balance, other joints will have to compensate. Compensations are adaptations. When joints have to adapt to fixations in the matrix they do so by diminishing the usual range of function and/or by taking the joint to, and possibly beyond, the limits of normal adaptive range.

It is easy to see how, when there are fixated areas in the fascial matrix the alignment of one or more joints will produce functional anomalies that will immediately alter the alignment and function of the entire matrix. Ultimately this will reduce the potential for the entire system to adapt and could produce acute damage in several joints of the body. Most often the body, by means of compensation, can maintain functional alignment and movement that causes only minor realignments stacking on upon the other until the body looses much of its adaptive capacity. However, it can be that the compensations required will violate the inherent boundaries of the joint surfaces and soft tissues will become traumatized by the process of adaptive alignment itself. The joint surfaces of the body will not be protected by "float" when exaggerated alignments create irregular compressions. And, if joint and soft tissue injuries are not enough, research also demonstrates that failure to access the full movement potential of the fascial matrix, as would be increasing the case with compensatory patterns, has immediate and ongoing consequences for cellular function and system vitality. [3] (Ingber, 2008)

For professionals familiar with assessing posture and movement, many adaptive anomalies seem very common place. For example, in the action of pivoting on one leg, the knee and hip are required to express an extreme range of motion because the ankle, for some reason, is expressing too little of its possible range. Or, in the contra-lateral motion of walking, when one shoulder joint has a diminished capacity to swing then the opposing hip joint will also express a decreased range of motion. In these two examples there are many other possible compensatory responses that could be described. The process of understanding the nature of potential compensatory responses is best guided by a set of principles. The list below is an introductory attempt at creating such a set. Further on in this article, the principles suggested below will be put to use in assessing two areas of joint dysfunction.

Principles of Adaptive Alignment

Orientation is the primary drive in alignment:

For the body to maintain balance and orientation, the alignment of the vestibular apparatus is primary. The need to keep the eyes forward and the ears to the sides requires that the rotation, flexion or extension and side-bending of a segment be corrected by an opposite tending position of a succeeding segment or opposite side segment. In this way balance and orientation will be maintained even if it requires exaggerated alignments that would damage joints or diminished function that would reduce vitality.

Adaptive alignment is a compensatory response:

Changes in position of any segment will be adaptively responded to with changes in position of successive or opposite side segments.

Tension is always a condition of adaptation:

When any segment deviates from static neutral there will be an increase in tension in the fascial components of the joints associated with that segment.

If one then, potentially, all:

Because of the holistic nature of the fascial matrix and of tensegrity systems, adaptation in any one joint will have the potential to alter the alignment of all of the other joints via a process of compensatory response.

Inherent limitations to adaptive capacity:

The capacity of a segmental joint to adapt is prescribed by the shape of the boney surfaces and the organization of the soft tissue components of cartilage, ligament, tendon, fascial sheaths and muscles associated with the joint.

Degree of compensatory response:

The exact nature and degree of a compensatory response by a joint will be prescribed by:

1. The primary need to preserve equilibrium.
2. The positions the body must take to interact with the external environment.
3. The inherent limitations of the joints structure.
4. All existing fixations in the fascial matrix.

Compensatory response to dysfunctional joints:

The inability of any joint to access its full range of adaptive capacity will produce either or both of the following compensatory responses.

1. Succeeding and/or opposite side segments and joints will more greatly express their adaptive range.
2. Succeeding and/or opposite side segments and joints will under express their adaptive range.

Destructive compensations:

Unnatural compression of a joint and damage to the soft tissues and boney surfaces can result in any of three ways:

1. Exaggeration - there is a response of counter positioning beyond the capacities of the joint.
2. Suppression - there is prolonged diminished use of the full adaptive range of the joint.
3. Congruence - there is a failure of a normally counter-positioning joint to respond with counter positioning. (This could be a result of suppression or conflicting demands for compensation.)

Destructive compensations differ depending on inherent adaptive capacity:

1. Joints with a greater range of adaptive capacity are more likely to be traumatized from compressions resulting from suppression and congruence.
2. Joints with a lesser range of adaptive capacity are more likely to be traumatized by compressions resulting from exaggeration.

Stated in the opposite – greater adaptive capacity joints are more functional in counter-rotation; lesser adaptive capacity joints are more functional in congruence and by their inherent nature they are naturally suppressed.

Categories of adaptive capacity:

1. Joints with a greater range of adaptive capacity:

Sphenoid joints
Temporomandibular joints
Atlanto-occipital joint
Cervical joints
Vertebral joints
Intercostal joints
Sternoclavicular joints
Glenohumeral joints
Elbow
Radiocarpal joints
Ulneocarpal joints
Carpometacarpal
Metacarpalphalangeal joints
Interphalangeal joints of the hand
Hip joints
Pubic symphysis
Knees
Distal tibiofibular joints
Tibiotalar joints
Tibiocalcanial joints
Talarnavicular joints
Calcaneonavicular joints
Calcaneocuboid joints
Cuneometatarsal joints
Metatarsalphalangeal joints
Interphalangeal joints of the foot

1. Joints with a lesser capacity range of adaptive capacity:

All joints of the cranium excepting
    a. Sphenobasilar joint
    b. Temporomandibular joints
Acromeoclavicular joints
Radioulnar joints
Intercarpal joints
Intermetacarpal joints
Costovertebral joints
Lumbosacral joint
Sacroiliac joints
Proximal tibiofibular joints
Talarfibular joints
Calcaneofibular joints
Talarcalcanial joints
Intertarsal joints
Intermetatarsal joints

Frozen Shoulder

Frozen shoulder is a combination of two types of destructive compensatory patterns. There is a suppression of the glenohumeral joint's adaptive range and a failure of the natural counter positioning between the humerus and scapula, in other words, a congruency. In planer language: For the shoulder joint to be fully functional, the scapula and the humerus need to be able to rotate in opposite directions. If this is not possible, and the joint becomes fixed with the humerus and shoulder blade rotating in the same directions, extreme compression results and the joint becomes unable to express a normal adaptive range.

Rotation for the scapula happens around its vertical axis, meaning that:
1. In medial rotation the lateral edge of the scapula positions anterior, toward the axilla and the medial edge positions posterior;[4]
2. In lateral rotation the lateral edge of the scapula positions posterior, away from the axilla, and the medial edge positions forward.[5]

Rotation of the humerus happens around its vertical axis, as well, so that:
1. In medial rotation the lateral side will be rotating anterior;
2. In lateral rotation the lateral edge will be rotating posterior.

With medial rotation of the scapula the most functional response will be a counter-rotation of the humerus toward the lateral. With lateral rotation of the scapula the humerus should medially rotate. These counter-rotations will create the least compression and most adaptive freedom for the glenohumeral joint.

The design of the glenohumeral joint explains why this is the case. The glenoid fossa is a concave surface on the superior, lateral edge of the scapula. Medial rotation takes this concave surface forward. Lateral rotation takes the surface backward. The head of the humerus is an egg shaped convex protrusion on the superior, medial side of the humerus. The greater length of the egg shape runs horizontally toward the concavity of the glenoid fossa on the scapula. When the humerus laterally rotates the surface of the egg shaped protrusion will swing anterior. With medial rotation the surface of the egg swings posterior. Counter-rotation will keep the joint surfaces travelling together.

The essential elements of this counter rotation are:

Humerus medial rotation = humeral head swings posterior
Scapula lateral rotation = glenoid fossa swings posterior

Humerus lateral rotation = humeral head swings anterior
Scapula medial rotation = glenoid fossa swings anterior

When the humeral head and the glenoid fossa can adapt with a counter-rotated alignment there is less strain put on the core structural fascia of ligament, tendons and the fascial sheaths. There will also be less demand on the voluntary muscles to act as stabilizers, which, if active would narrow the joint space. If a counter-rotation alignment is not maintained, then strains on the core fascia and the narrowing of the joint space from recruitment of voluntary muscles as stabilizers will create a condition of frozen shoulder. If these strains and demands persist, more permanent fixations can become established in the fascial matrix and the condition will become chronic creating damage for the surfaces of the glenohumeral joint. Further, with chronic fixations such at a frozen shoulder, successive and opposite side segments and joint surfaces will be negatively affected.

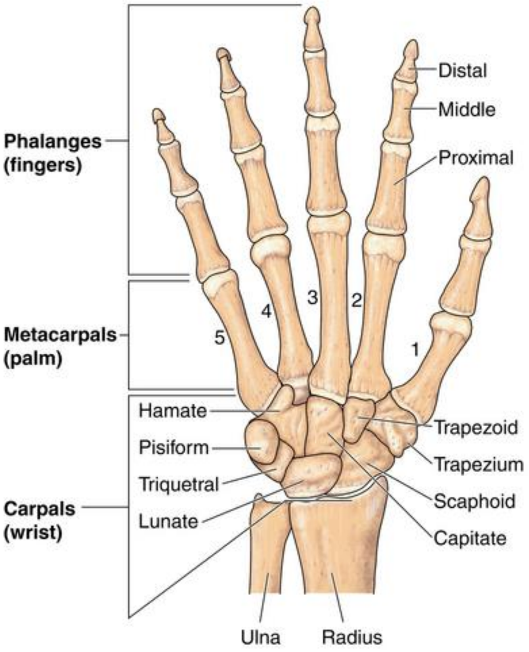
Intervening to correct the misalignment of a frozen shoulder would involve working with the extrinsic and intrinsic fascia to release the fixations holding the two bones in congruent rotations so that the joint can return to a functional counter-rotational alignment. Further assessment for compensatory fixations throughout the body will point to the areas where compensatory fixations will need to be released.

Problem Thumbs

Problems with the thumb generally arise from exaggerated compensations at the intermetacarpal joint between the first and second metacarpals (the thumb and index finger). The 1st metacarpal will be rotated opposite to the direction of the other four metacarpals. This places an adaptive demand on the carpal bones of the wrist. The joints between the 1st metacarpal and the trapezium, between the trapezium and scaphoid and between the scaphoid and radius can be forced to express an exaggerated counter positioning much beyond their inherent capacities to adapt.

For the wrist and hand the functional adaptive responses are:

1. The radius and ulna, as a pair, congruently rotate around the vertical axis of the lower arm (their respective long axes);
2. The carpal bones, as a group, congruently rotate in the opposite direction of the radius and ulna around the vertical axis of the wrist;
3. The five metacarpals rotate, as a group around the vertical axis of the hand (which are their respective long axes) in the opposite direction of the carpal bones and in the same direction as the radius and ulna;
4. The 1st phalanges rotate around the vertical axis of the hand, which is the long axis of the phalange) in counter rotation to the metacarpals;
5. The 2nd phalanges will rotate opposite of the 1st phalange and the 3rd phalange will rotate opposite the 2nd.



It can be a little difficult to keep clear about the functional and dysfunctional congruencies in the regions of the body with so many different components. To make it simpler, for the joints associated with the 1st metacarpal, here is how they sort out.

Functionally congruent joints:
1. Radioulnar joint
2. Intercarpal joints

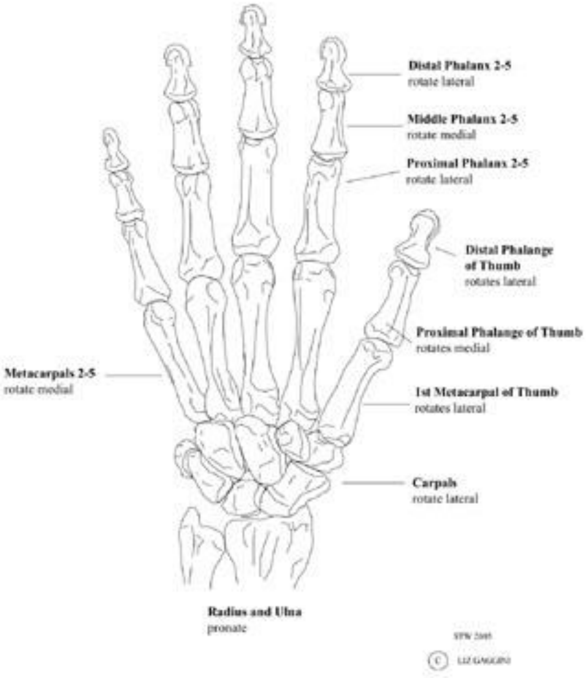
Functionally counter-rotating joints:
1. Radiocarpal joints
2. Carpometacarpal joint
3. Intermetacarpal joint

3. Metacarpalphalangeal joint
4. Interphalangeal joint

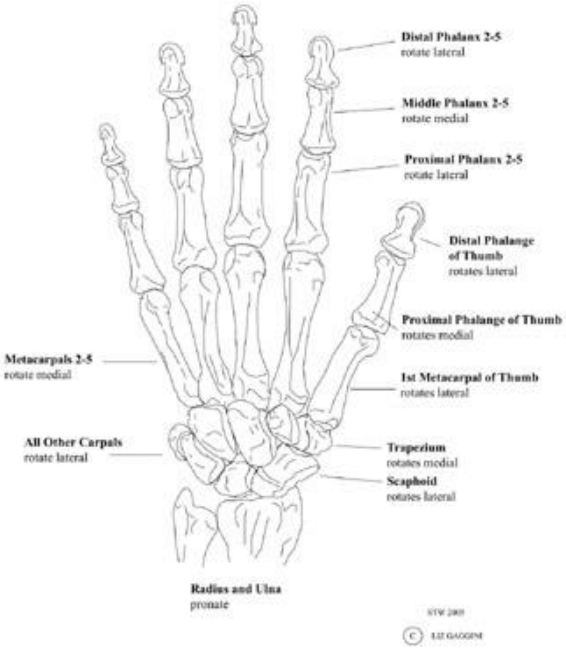
When the thumb counter-rotates to the index finger, the carpometacarpal joint at the head of the metacarpals is forced to move outside its normal range of adaptability. This exaggeration dislocates a joint that is designed to allow only a minor amount of adaptability. Further, this counter-rotation puts the 1st metacarpal and the trapezium into a dysfunctional congruency. This also creates a suppression of the normal adaptability of this carpometacarpal joint. The same dysfunctional congruency would occur at the metacarpalphalangeal joint.

With dysfunctional congruencies there is usually also a suppression of the joint. Suppression in these joints normally cannot hold for long because of the constant demands for adaptive motion put on the joints of the hands. Often the metacarpalphalangeal and interphalangeal joints will switch their rotations making the thumb somewhat more functional. This adaptation is illustrated in the figure labeled, “Variation One”.

Variation One



Variation Two



A further compensation is illustrated in “Variation Two” The compensation further includes the trapezium counter-rotating to the misaligned metacarpal and to the scaphoid. While this creates a functional relationship for the joint between the trapezium and the 1st metacarpal it creates a dysfunctional exaggeration for the joint between the scaphoid and trapezium as well as for the joint between the trapezium and the trapezoid. And now there is a dysfunctional congruency between the trapezium and the 2nd metacarpal. So what started out as a problem with symptoms related to the thumb becomes a problem with symptoms instead for the wrist and index finger.

It can also happen that the joint between the trapezium and scaphoid does not counter-rotate and instead, the two bones stay congruent with one another but counter-rotate to their neighbor carpals, the trapezoid, lunate and capitates. This creates several destructive exaggeration compensations within the carpals as well as congruent compensations for the joints with the radius and 2nd metacarpal. So, trouble spreads. Thumb problems becoming carpal tunnel problems or radial joint problems at the elbow, as so on.

Restoration of order here requires assessing which joints are not expressing their functional alignments and working with the associated fascia to restore the segments to their natural positions. It is quite easy to alter the fascia once the directions of rotation have been assessed and the proper rotations are understood. In the case of the thumb you can be guided by the facts that:

1. The radius and ulna should have the capacity to rotate in the same direction.
2. All the carpals should have the capacity to rotate in the same direction and opposite the direction of the radius and ulna.
3. All of the metacarpals should have the capacity to rotate in the same direction and opposite the direction of all of the carpals.

Conclusions

Inherently the joints do not have a proclivity within their natural range toward one direction or another of rotation, flexion, extension or side-bending. Adaptive function allows for whatever range is inherently possible to happen. If there are not demands for adaptation coming from the environment or from within the fascial matrix itself, then the joints should be in neutral positions. Though this can easily be achieved in terms of demands from the external environment, there is likely nil prospect that the fascial matrix would not be placing demands for adaptation away from neutral. Trauma and repetitive patterns are too common for the joints of the body to not be perpetually in the compensatory response of counter positioning from tensions in the matrix alone. Femurs are going to be fixed in counter-rotation to tibias, carpal groups are going to be counter-rotated to radii and ulnae, occiputs are going to be counter side-bent to sphenoids. The elegance of a tensegrity system is that it adapts to a myriad of deforming fixations and still finds equilibrium in the most efficient and economical way possible. As we know, when we go to fool around with this elegance, it can be hard to predict what will happen next. Its best for us to continually to try to understand the details of the structure and to always work from a point of view that contains the whole .... as best we can. I hope these ideas will contribute to that.

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[1] TENSEGRITY pronunciation [ten-seg-ri-tee] noun; the property of skeletal structures that employ continuous tension members and discontinuous compression members in such a way that each member operates with the maximum efficiency and economy.

[2] ANISOTROPIC pronunciation [an-ī-sə-träp-ik] adj.; Exhibiting properties with different values when measured in different directions.

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[3] Donald E Ingber, M.D., PhD, Wyss Institute at Harvard: "*Anyone who is skilled in the art of physical therapy knows that the mechanical properties, behavior and movement of our bodies are as important for human health as chemicals and genes. However, only recently have scientists and physicians begun to appreciate the key role which mechanical forces play in biological control at the molecular and cellular levels. This article provides a brief overview of a lecture presented at the First International Fascia Research Congress that convened at Harvard Medical School in Boston, MA on October 4, 2007. In this lecture, I described what we have learned over the past 30 years as a result of our research focused on the molecular mechanisms by which cells sense mechanical forces and convert them into changes in intracellular biochemistry and gene expression—a process called "mechanotransduction". This work has revealed that molecules, cells, tissues, organs, and our entire bodies use "tensegrity" architecture to mechanically stabilize their shape, and to seamlessly integrate structure and function at all size scales. Through the use of this tension-dependent building system, mechanical forces applied at the macro scale produce changes in biochemistry and gene expression within individual living cells. This structure-based system provides a mechanistic basis to explain how application of physical therapies might influence cell and tissue physiology*". (Ingber 2008, page 198)

[4] In kinesiology medial rotation is assumed but not frequently delineated as factor in the action known as shoulder protraction, also, sometimes termed, shoulder abduction. However, shoulder protraction/abduction includes the additional action of the scapula moving away from the posterior midline while the humerus moves toward the anterior midline. As neither of these additional motions are essential or necessarily present in glenohumeral counter-rotation or congruency, I have chosen to not use the terms protraction or abduction to.

[5] The action of lateral rotation would be a factor in the action retraction or adduction of the shoulder. However protraction/adduction includes the motions of the scapula moving toward the posterior midline while the elbow moves posterior. As with medial rotation of the scapula in note 4 above, these additional motions are not essential or necessarily present in glenohumeral counter-rotation or congruency therefore, I have chosen to not use the terms protraction or abduction.