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Provider CPD 21418 (UK)
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Origins of Muscular Shortening: Integration of the Causal Systems

Introduction

In the previous chapters, we analysed how vector dominance in individual body regions determines specific skeletal configurations.
To understand the musculoskeletal system more fully, however, it is necessary to examine why muscles tend to shorten and which mechanisms trigger this process.

Muscular shortening is not a random phenomenon, but the result of precise physiological mechanisms leading to an increase in basal tone.
When this increase in tension persists over time, it progressively involves the connective tissue component of the muscle fibre, producing the permanent residual shortening observed in segmental analysis.

An increase in basal tone may be induced by three different systems that use the muscle as their final effector: the psychosomatic system, the neurophysiological system, and the biomechanical system.
Each of these systems may act independently or in synergy with the others, producing the complex clinical reality observed in daily practice.
This distinction guides therapeutic strategies, differentiating cases in which intervention should be directed mainly toward the muscular system from those in which primary action on other systems is required.

1. The Psychosomatic Model

The earliest formulations concerning the deep relationship between psyche and soma, between character structure and muscular structure, date back to the 1920s in the work of Wilhelm Reich and, later, Alexander Lowen. Reich's work on character analysis and Lowen's later development of bioenergetic analysis are central references in this line of thought.

In his early writings, Reich, a physician, psychoanalyst, and pupil of Freud, progressively affirmed a functional identity between psychic and somatic processes, relating character structure to the bodily structure of the person.
According to this view, tensions accumulated in the body and the adoption of attitudes aimed at blocking one's own emotions give rise to a dual armour.
This consists of character armour, understood as the set of psychic and behavioural attitudes characteristic of an individual, and a somatic counterpart in muscular armour.

These structures function as a defensive apparatus against both internal and external stimuli perceived as threatening, with the purpose of avoiding feelings of anguish.

Also described in orthopaedic language as a psychogenic myotensive state, chronic muscular tension represents perhaps the clearest process by which the ego expresses emotional experience in the body.

1.1 Developments in psychosomatic research

Alexander Lowen developed research in this field further and arrived at the formulation of a true therapeutic procedure known as Bioenergetic Analysis.
He focused on the relationship between the cognitive, emotional, and bodily levels of each person, with particular attention to skeletal functions and voluntary musculature.

At the psychophysiological level, muscular tensions represent the principal defensive tool of the ego as expressed in the body and, as such, may shape overall bodily attitude.
It can therefore be stated that muscular structure also reveals the personal history of an individual.

To represent each person in their psychosomatic unity, in addition to musculo-tensional aspects, it is essential to refer also to psycho-neuro-endocrine factors, understood as the system of mediation and modulation between psychic and emotional components on the one hand and organic and biological factors on the other.

1.2 Mechanism of muscular armour

The formation of bodily armour occurs through elevation of basal tone, that is, through excess tension in the contractile portion of the muscle fibre.
If this condition persists over time, the connective portion is also involved, giving rise to actual shortening of the muscular system, which in turn produces alteration of the correct articular sequence.
In this way, a myotensive state of emotional origin may evolve and become associated with a biomechanical problem.

2. The Neurophysiological Model

Muscle tone is the resultant of a complex series of psycho-neurophysiological processes within a cybernetic-type system, the tonic postural system.
This system has clearly defined inputs consisting of information arising from specific receptors, including the foot, the eye, the stomatognathic system, the skin, and the musculoskeletal apparatus.

Neurophysiological studies have paid close attention to receptor interference, since the output of the system, namely muscle tone, is conditioned by the incoming inputs.
Muscle tone, however, although dependent on incoming input, is also the product of what is processed by the central nervous system according to specific neuropsychological processes and experience.

2.1 Cortical and subcortical control

An imbalance does not necessarily indicate a problem originating at the level of sensory input, because it may be related to incorrect integration within the central system.

Cortical centres are involved in planning motor goals, while subcortical centres, using a mapping referred to as the body schema, modulate the execution of motor strategies.
In addition, subcortical centres modulate basal tone through gamma pathways. Standard physiology texts describe this integrated control of tone and movement planning at cortical and subcortical levels.

This does not involve "decisions" in the conscious sense: cortical centres process motor intentions, the "what" of action, while subcortical centres regulate motor implementation, the "how," through automated neural patterns.
When this text refers to nervous centres that "modulate," "process," or "regulate," it uses simplified language to describe complex neural processes.
These centres do not "decide" or "choose" consciously, but process information and generate motor outputs through interconnected neural networks and activation patterns shaped by evolution and modulated by experience.

Since motor planning, the "what," is hierarchically prior to execution, the "how," the neural representation of the body schema influences the quality of muscular activation.
The less accurately the body schema is represented neurally, the more the muscular system will be activated with excess tension, through co-contraction of muscles not necessary for the action, eventually generating substitutive patterns in which muscles anatomically assigned to a given action are integrated by emergent coordinations involving other muscular groups.

2.2 Protective mechanisms of the subcortical centres

Subcortical centres are involved in protective mechanisms safeguarding physical integrity through modulation of muscle tone, which may be distinguished into "physiological" and "functional" responses.
Muscular contraction, as a function of the force-time relationship, produces residual shortening of the muscle itself: the lower the force and the shorter the duration, the smaller the shortening; the greater the force, and above all the longer the duration, the greater the residual shortening.

Muscular shortening and the resulting bodily asymmetry are found not only in people reporting orthopaedic pathology or symptoms, but in every human being, and may be induced by automatic muscular contractions neurally regulated in response to a given event.

Definition of the mechanisms
In the discussion that follows:

- **"Physiological"** refers to muscular contraction mechanisms that the nervous system activates automatically as a stereotyped response to a given event or stimulus.
- **"Functional"** refers to muscular contraction mechanisms that the nervous system modulates with individual variability according to perceived necessity, that is, "what is needed."

Both mechanisms are regulated by subcortical centres through evolutionarily ancient neural circuits.

2.3 Physiological mechanisms

These consist of muscular contraction maintained over time following an orthopaedic traumatic event.

Example: accidental event and ankle sprain
The subcortical centres send, via the gamma motor neuron, a contraction signal to all periarticular muscles in order to immobilize the joint.
This contraction will continue until the injured intra-articular structures have been repaired.
The duration of sustained contraction will be proportional to the damage; consequently, so too will the residual muscular shortening.

2.4 Functional mechanisms

These are muscular contractions maintained over time, consisting of a more or less significant increase in basal tone, again activated by subcortical centres through the gamma motor neuron, with the purpose of reducing or eliminating existing pain, that is, an a posteriori antalgic reflex, or of preventing latent pain from manifesting, that is, an a priori antalgic reflex, as described by Françoise Mézières.

Sustained muscular contraction, maintained for a given time until it causes structural conflicts, has an antalgic effect.
In their task of preserving life, the subcortical centres respond to a single temporal logic: "here and now."
Pain and/or functional incapacity are experienced as a threat, and strategies of avoidance are therefore adopted.

2.4.1 A posteriori antalgic reflex

From this perspective, the a posteriori antalgic reflex represents an extreme defence strategy in the attempt to preserve life as long as possible.
People in acute pain often adopt contorted bodily configurations but, as patients themselves commonly report, "it feels a little better like this."
This defensive strategy is useful in the immediate situation, but if it persists over time it becomes the cause of further mechanical conflicts.

2.4.2 A priori antalgic reflex

Physiological mechanisms and the a posteriori antalgic reflex intervene only at certain moments in life and, on their own, are insufficient to explain the accumulation of shortenings and asymmetries present in the body.
Their true cause lies mainly in the a priori antalgic reflex.

This is a permanently active reflex whose purpose is to avoid the manifestation of latent pain or latent mechanical conflicts.
Progressive muscular shortening, so long as it does not itself create conflict, prevents the de-latentization of musculoskeletal discomfort.
The subcortical centres use the muscular system by distributing shortenings in such a way as to alter all articular sequences systemically in order, as long as possible, to avoid local conflicts.

2.5 Behavioural manifestations

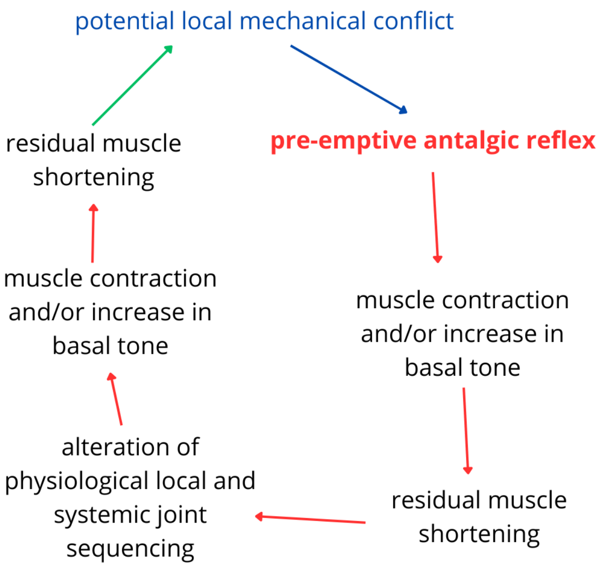
The a priori antalgic reflex also manifests itself through the adoption of specific bodily configurations or through movement itself, compelling the person toward non-random motor choices.
At first these constraints are unconscious: one "feels" the need or desire to move or position oneself

in a certain way.
If muscular shortening becomes more pronounced, motor constraints become consciously directed toward avoiding the onset of discomfort, for example: “I can’t sit for long otherwise…,” “I can’t walk slowly otherwise…,” and similar expressions.

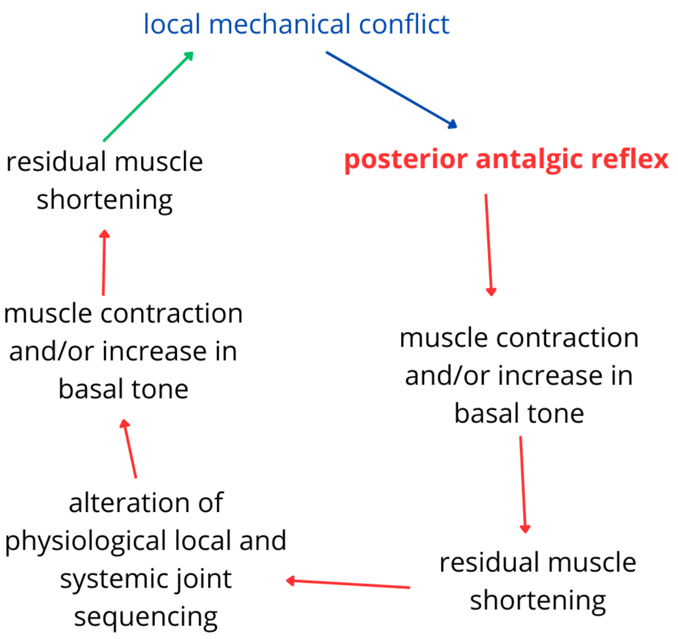
2.6 Self-reinforcing circuits

If the mechanism of systemic muscular shortening persists over time, local conflicts may develop, giving rise to a self-reinforcing circuit in which both antalgic reflexes coexist.

Circuit 1: a priori reflex dominant



Circuit 2: a posteriori reflex dominant



3. The Biomechanical Model

3.1 Organization of the musculoskeletal system

In the biomechanical model, the ways in which the musculoskeletal system organizes itself in statics and dynamics are analysed.
This organization follows precise physical laws governing force equilibrium and the distribution of body loads.

In statics, postural imbalances manifest as loss of the physiological articular sequence of the various skeletal segments in the three planes of space.
In dynamics, these imbalances are expressed as the inability to perform movement while making the best use of the muscular forces available.

3.2 Principle of vector equilibrium

To guarantee both the axial alignment of skeletal segments and harmonious articular movement, muscular forces must be balanced.
When this balance is lost, articular mechanics are altered: the points of application of muscular vector forces change, as do their moments and the distribution of loads on skeletal segments.

Regardless of the primary disturbing elements and the type of initial perturbation, alteration of physiological axes is always the resultant of the interaction between the muscular “complex system” and the skeletal “complex system.”
This interaction gives rise to a functional interrelationship definable as the **musculoskeletal complex system**.

3.2.1 The compensation mechanism

Every time a skeletal segment loses its physiological alignment, the muscular system must intervene to re-establish equilibrium.
This is a physical law: the skeleton cannot maintain proper configuration unless muscular tensions are balanced.
The principle demonstrates concretely how muscles guide skeletal organization, never the reverse, except in the case of congenital or acquired structural alterations.

3.3 The system “at the edge of chaos”

Low-intensity equilibrium of muscular vectors guarantees the coexistence of good stability and good articular mobility.
This optimal condition creates the premises for the musculoskeletal system to position itself “at the edge of chaos,” the area in which the elements of staticity and dynamicity are expressed at the best level structurally possible. The concept is consistent with complex systems theory as developed in nonlinear dynamics.

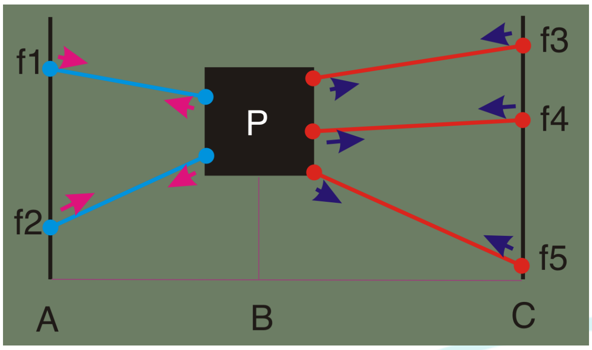


Fig. 01 - The position of body P is ensured by co-contraction of all the forces represented by their vectors, acting at low intensity. Body P is subjected to the minimum traction necessary for stabilization. Static and dynamic elements are balanced with minimal energy expenditure; the system is "at the edge of chaos."

3.3.1 Progression toward rigidity

If the balancing of forces occurs at high intensity, skeletal axiality remains possible, but movement requires more energy and becomes disharmonious.
Skeletal components are subjected to greater stress, static elements prevail over dynamic ones, and the system, moving away from the edge of chaos, becomes rigid.

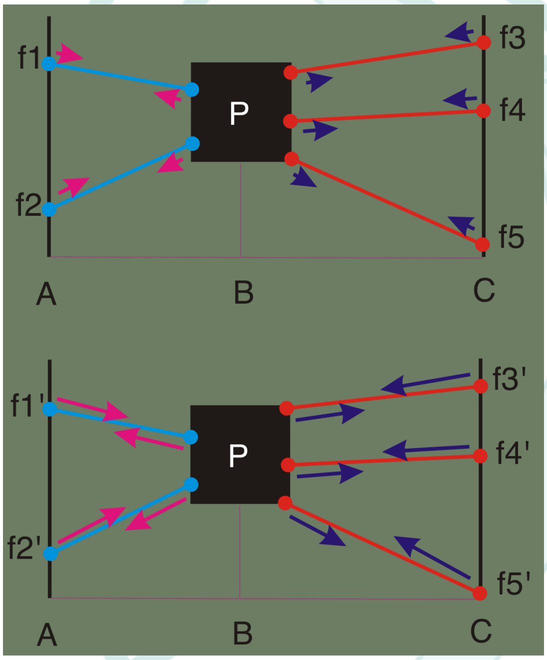


Fig. 02 - If forces f increase in intensity and the vectors of f1 and f2 are able to balance those of f3, f4, and f5, body P remains in the initial position but is subjected to greater traction. Static elements prevail over dynamic ones and the system becomes rigid.

3.4 The self-reinforcing circuit

High-intensity vector equilibrium, maintained over time through increased basal tone, produces vector imbalance in favour of the dominant muscular forces.
The system adapts and reorganizes a new equilibrium at the price of segmental skeletal misalignments, while movement becomes limited or replaced by intervention of other joints: a clear example of priority protection of function.

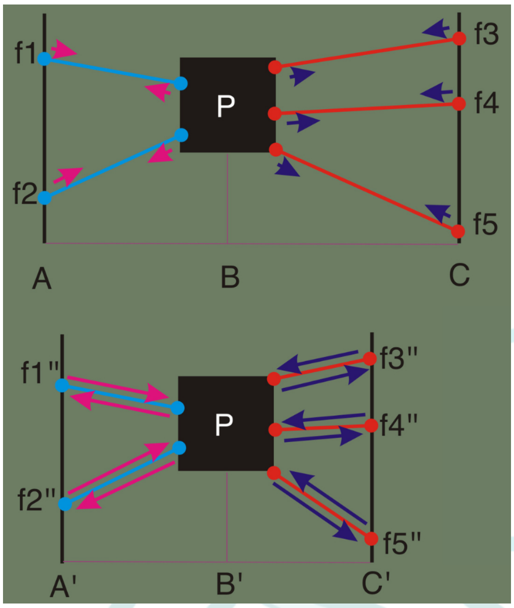


Fig. 03 - If the increase in intensity of the forces is systemic and maintained over time, body P is pulled in the direction of the dominant vectors. The opposing forces attempt to resist the displacement by increasing the vector intensity of their action. Since in the skeleton there are no absolutely fixed points, all the forces acquire shorter length and greater intensity. They therefore increase traction and resistant force but lose working capacity, that is, force through displacement. Skeletal relations are altered, static elements prevail over dynamic ones, and the system becomes misaligned and rigid.

3.4.1 Biomechanical consequences

This situation produces a transformation: all the acting forces acquire shorter length and greater intensity, increase their traction and resistant capacity, but lose working capacity.
Skeletal relations are altered, static elements prevail over dynamic elements, and the system loses the physiological articular sequence, becoming rigid.

3.5 Clinical example: the scapulo-humeral joint

To understand these principles concretely, consider the muscles producing anterior and posterior flexion of the humerus.
Vector dominance, both in terms of potentially expressible force and the arrangement of force lines, favours the posterior flexors.
The consequences of this asymmetry are both static, concerning the position of the humeral head within the glenoid cavity, and dynamic, concerning movement execution.

3.5.1 The three phases of compensation

First phase – Physiological tone: balancing of forces ensures a good articular relationship and harmonious movement.
Second phase – Compensation still possible: increased tone still allows the anterior flexors to balance the system. The position of the humeral head remains unchanged, but the joint structures undergo greater stress and movement requires more energy, losing harmony.
Third phase – Decompensation: tone is further increased and contractures and shortening of the connective portion of the muscle fibre are present. Balancing becomes impossible and the arm is flexed posteriorly, causing the humeral head to project anteriorly and into internal rotation within the glenoid cavity.
The consequences are joint rigidity, potential intra-articular mechanical conflicts, and, dynamically, limitation of anterior arm flexion with triggering of compensatory strategies such as elevation of the shoulder girdle.

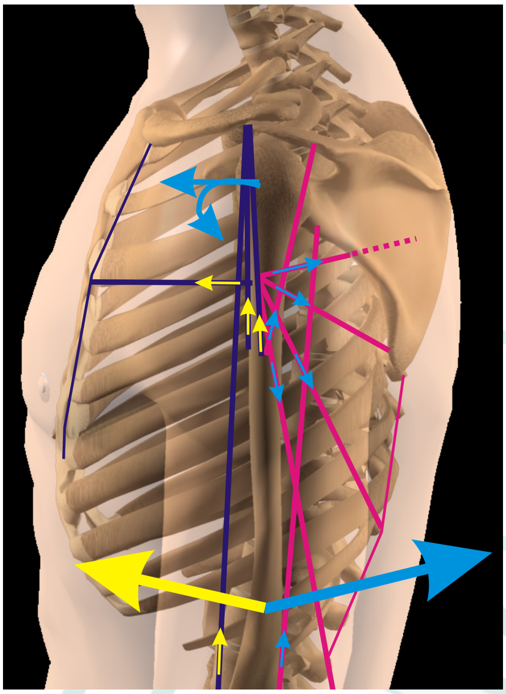


Fig. 04 - Anterior humeral flexors: biceps brachii, coracobrachialis, pectoralis major, anterior deltoid: dark blue and yellow arrows. Posterior humeral flexors: latissimus dorsi, teres major, subscapularis, triceps brachii, posterior deltoid: magenta and light blue arrows.

The posterior humeral flexors, having greater vector potential than the anterior flexors, are dominant.
If the muscular tone of the posterior flexors increases, the anterior flexors can balance it only up to a certain limit.
Initially, the skeletal relationship remains unchanged, but movement requires a greater quantity of energy and becomes disharmonious.
If the increase in posterior flexor tone becomes such that balancing is no longer possible, physiological articular relationships are altered, with posterior flexion of the humerus and anterior projection in internal rotation of the humeral head within the glenoid cavity, and movement becomes limited or impossible.
Anterior arm flexion then occurs through use of other joints, for example through posterior flexion of the trunk.

3.6 Adaptation of the body schema

When skeletal segments lose their physiological alignment, the body must completely reorganize its movement schema.
Because it can no longer use the original motor patterns, since bodily geometry has changed, the central nervous system must elaborate alternative strategies.
The primary goal nevertheless remains the effectiveness of the gesture: the body must be able to perform the required functions, even if by means different from the physiological ones.

This process of adaptation can be interpreted as a demonstration of the intelligence of the biological system in finding alternative solutions when optimal ones are no longer available.
These adaptations do not represent dysfunctions of the nervous system, but strategies of functional optimization.
The neuromuscular system develops creative solutions that transcend conventional motor patterns in order to guarantee movement effectiveness under altered conditions.

3.7 Analysis of centres of gravity: frontal plane

To allow maintenance of upright stance, the tonic postural system activates itself so as to keep the body centres of gravity and the ground reaction force within the support polygon described by the surface of the feet.
In dynamics, by contrast, the gravity-ground reaction force couple is exploited in order to economize the Work necessary for gait.
The overall centre of gravity is given by the resultant of the individual skeletal centres of gravity. To make calculation easier on the frontal plane, the human skeleton can be simplified and transformed into a summation of geometric figures.

3.7.1 Optimal condition: alignment of centres of gravity

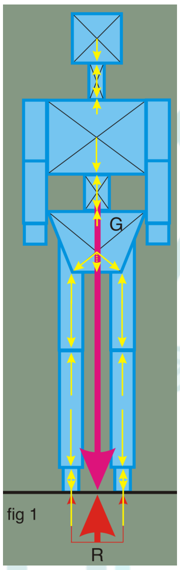


Fig. 05 - If the individual skeletal centres of gravity are aligned, the energy necessary to balance the automatic movements required to maintain the G and R forces applied to each single bodily centre of gravity, as well as the overall G and R forces, on the same vertical line, is of low intensity. The individual g and r components are distributed over all joint surfaces. The system is mathematically "at the edge of chaos" because it can pursue the objective of maintaining upright stance through small variations in energy.

In this ideal condition, basal tone, that is, the force expressed by the muscles in maintaining the individual centres of mass, is the minimum necessary to counterbalance the shifts in centres of gravity induced by automatic bodily movements such as respiration.
Force R, the ground reaction force, is equal and opposite to force G, the weight force. Since the individual skeletal centres of gravity are aligned, the g and r components are distributed uniformly over the whole support surface.
The joints function at the best of their structural potential, without compressive moments concentrated in restricted areas.

3.7.2 Loss of equilibrium

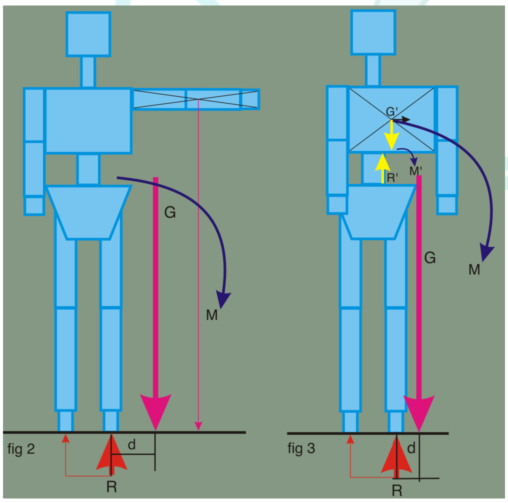


Fig. 06 - Lateral displacement of one body segment determines projection of the overall G force outside the support polygon. The overall R force is applied at the edge of the support polygon. The overall G and R forces determine a destabilizing force moment M. To balance moment M, the muscular system must raise muscular tone both globally and asymmetrically.

3.7.3 Skeletal compensation strategy

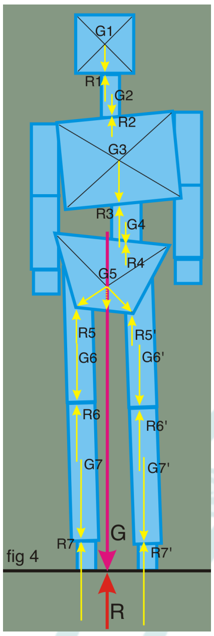


Fig. 07 - Increased tone and shortening of the connective portions of the muscle fibre determine systemic misalignment of skeletal segments. The system organizes this misalignment so that the overall G force falls within the support polygon, making equilibrium possible. The energy required, however, is greater than would be necessary if the individual centres of gravity were aligned, and the system moves away from the edge of chaos, becoming rigid

Since the individual skeletal centres of gravity are misaligned, the individual G and R forces have their g and r components concentrated in restricted areas of the joint surfaces, creating the premises for potential mechanical conflicts.
In order to recover equilibrium when it is lost, the muscular system, by misaligning the body segments, can bring the G-R pair back within the support polygon: equilibrium is thus possible, but at the price of losing the physiological articular sequence, which, if prolonged over time, may lead to compressive articular conflicts.

3.8 Analysis of centres of gravity: sagittal plane

Using a similar geometrization of the body in the sagittal plane, one can show how, in the optimal condition, the individual centres of mass determine an overall resultant G situated on the same vertical line as the resultant of reaction force R.

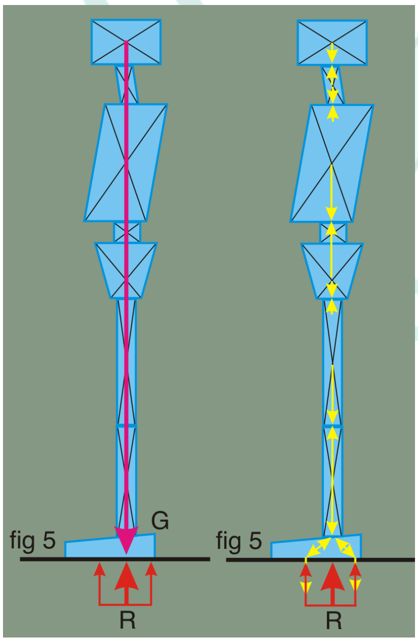


Fig. 08 - The overall G and R forces lie on the same vertical line and at the centre of the support polygon. Decomposition of G and R applied to each body segment shows how their g and r components can be distributed uniformly over the articular surfaces. Equilibrium is ensured by muscle tone balancing automatic movements at low intensity.

3.8.1 Mechanism of destabilization

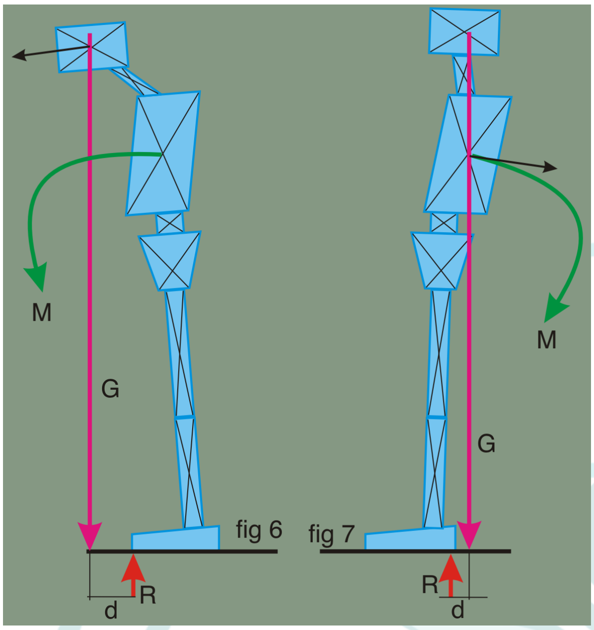


Fig. 09 - Anterior or posterior displacement of the projection of force G on the ground beyond the support polygon determines a destabilizing moment M. To avoid loss of equilibrium, the muscular system must activate itself at high intensity.

3.8.2 Reorganization strategy

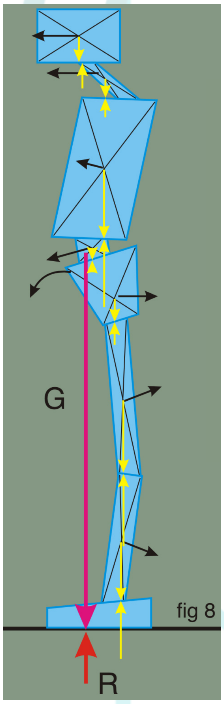


Fig. 10 - Increased tone and shortening of the connective portion of muscle fibres determine misalignment of skeletal segments. In order to maintain equilibrium, the muscular system organizes these misalignments so that the overall G force is projected within the support polygon. To do so, it uses more energy than would be required if the individual centres of gravity were aligned. The system loses dynamicity, gains staticity, and becomes rigid.

The individual G and R forces applied to the skeletal centres of gravity have their g and r components concentrated in restricted portions of joint surfaces, creating the premises for potential mechanical conflicts.
One example of a muscular "strategy" to bring G back into the support polygon is projection of all skeletal elements anteriorly or posteriorly.
This displacement occurs through muscular action and, since no muscle can lengthen itself actively, muscular action occurs in compression.
Compression, if maintained over time, involves the connective portion of the muscle fibre, producing permanent residual shortening.

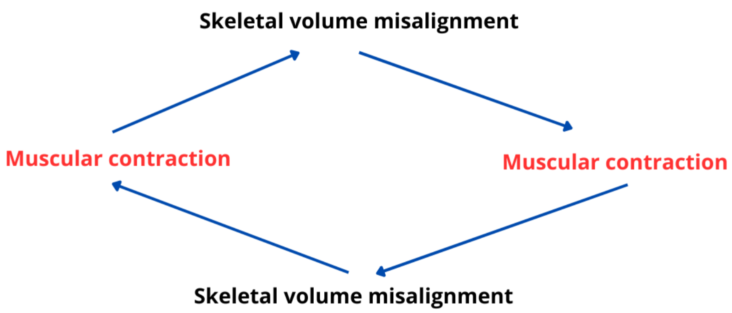
3.9 The self-reinforcing circuit

The transition from the optimal condition to the dynamic phase requires only minimal muscular activation to create the gravity-ground reaction force couple facilitating gait.
Under these conditions, elements of staticity and dynamicity are organized at the best level structurally possible and the system is at the edge of chaos: it can use small quantities of energy to pass from one state to another.

When shortenings are present in the muscular system, the individual body centres of gravity are no longer aligned.
The basal muscular force necessary to maintain equilibrium must therefore increase in intensity.

3.9.1 Mechanism of perpetuation

Increase in basal tone produces shortening of the connective portion, giving rise to a self-reinforcing circuit: misaligned centres of gravity compel an increase in basal tone, which produces muscular shortening, which further misaligns the centres of gravity.



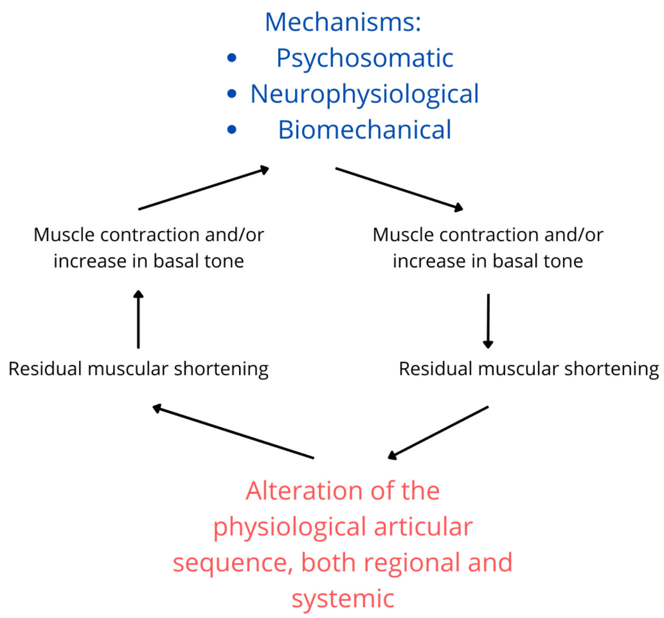
In this way, the vertebral sinusoid is modified and the overall bodily centre of gravity moves closer to the ground.
To pass from the static phase to the dynamic phase, greater muscular action becomes necessary: the system loses dynamicity but gains staticity, moving away from the edge of chaos and becoming rigid.

4. Conclusions: integration of the systems

The three systems, neuromuscular, psychosomatic, and biomechanical, all use the muscular system in achieving their own aims.
By the first characteristic of complex systems, they too are interacting and interdependent: whichever system is primarily implicated in the imbalance, the others must implement adaptive strategies in order to preserve function as effectively as possible.

They therefore behave as an integrated system, which reacts by raising basal tone and activating regional and systemic muscular contractions.
If muscular contraction and/or increased basal tone persist for sufficient time, the connective portion of the muscle fibre becomes involved, producing residual shortening and loss of the physiological articular sequence.

This misalignment then becomes in turn a cause of muscular contraction and elevation of basal tone, giving rise to the self-reinforcing circuit that perpetuates and amplifies the initial imbalance.



The general self-reinforcing circuit of the systems can therefore be described as follows: whatever the system primarily implicated in the imbalance, neuromuscular, psychosomatic, or biomechanical, the final action always converges on the muscular system through increased basal tone and muscular contraction, producing shortening of the connective portion and perpetuating the imbalance.

Understanding these physical mechanisms provides the scientific basis for interpreting alterations of physiological skeletal axes, independently of the therapeutic approach used for their correction. Physical analysis of muscular shortening shows that, regardless of the primary causal system involved, the final result always follows the same mechanical laws.
Increased basal tone and the consequent connective shortening modify vector relationships, alter distribution of G and R forces, and move the system from optimal equilibrium at the edge of chaos toward rigidity.

5. Key concepts of the chapter

Three causal systems of muscular shortening
Psychosomatic system, with character-muscular armour; neurophysiological system, with protective reflexes; biomechanical system, with vector equilibrium. All converge on increased basal tone, which determines connective shortening.

Psychosomatic model: functional identity of psyche and soma
Muscular armour corresponds to character armour. Emotional states are translated into chronic muscular tensions which, if maintained over time, involve the connective component and create structural alterations.

A priori and a posteriori antalgic reflexes
A posteriori: contraction to alleviate existing pain. A priori: permanent contraction to avoid manifestation of latent conflicts. The system distributes shortenings in order to avoid local conflicts.

System at the edge of chaos
Optimal equilibrium occurs when muscular forces act at low intensity. Static and dynamic elements are balanced with minimum energy expenditure. High intensity leads to rigidity and movement away from the edge of chaos.

Postural self-reinforcing circuit
Misaligned centres of gravity lead to increased basal tone, which leads to connective shortening, which leads to further misalignment. The circuit perpetuates and amplifies the initial imbalance.

Vector dominance and obligatory compensations
When dominant muscles increase tone beyond the balancing capacity of antagonists, articular relationships are altered. The system must reorganize the motor schema through substitutive strategies.

Distribution of G and R forces
When centres of gravity are aligned, g and r components are distributed uniformly. With misalignment, they become concentrated in restricted areas of the articular surfaces, creating the premises for mechanical conflict.

Cortical and subcortical control of tone
Cortical centres process motor goals, the “what,” whereas subcortical centres regulate execution, the “how,” through automated patterns. An imprecise body schema generates excess tension and substitutive patterns.

Systemic integration of the three models
The systems are interdependent: whatever the origin, the final effect always converges on the muscular system through increased basal tone, creating a unified circuit of perpetuation.

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