BIOTENSEGRITY,

A STRUCTURAL MODEL FOR THE HUMAN BODY AS A UNITY, BODY AND MIND

'What is so welcome is an evolving perspective such as biotensegrity that accounts for body, mind and being in a united, congruent whole, beyond the sum of the parts,'

(Joanne Avison)

LIEVE VAN RENTERGHEM

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ABSTRACT PAGE

Biotensegrity is a fairly recent and gradually more accepted biomechanical paradigm. It offers a holistic view on the growth, the 'continuously evolving form' and the mechanics of living entities. It is essentially about biological structure. This paper will focus on the human body and the way this model relates to the essence of the Pilates method.

In the case study I will use the perspective this model offers along with the BASI block system to work with Eva, a 21 year old female.

Tensegrity is a fusion of the words 'tension' and 'integrity'. The integrity of a tensegrity structure is the resulting balance of the interplay between two basic forces: (continuous) tension and (discontinuous) compression. The prefix 'Bio' refers to the application of this model to living entities.

The study of biotensegrity is closely linked to the research on the fascial web, the continuous tensioned web within the human body. A biotensegrity structure will always aim for equilibrium of the entire system, balance between tension and compression, trying to distribute external forces over its tensioned web, in order to keep its integrity. This overall perspective is very valuable for the Pilates teacher and at the same time very consistent with the Pilates principles.

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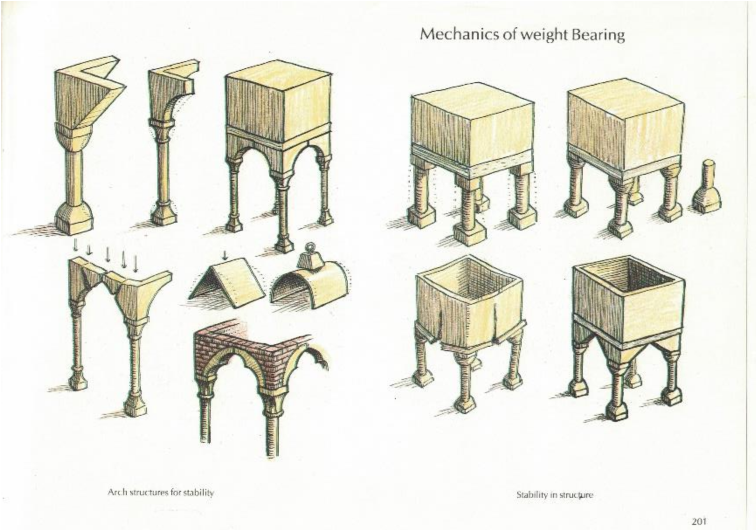

Fig. 1 Traditional biomechanics 'Mechanics of weight bearing' explaining the bony shape of the pelvis. Notice the 'architectural' approach

John Hull Grundy: 'Human structure and Shape'

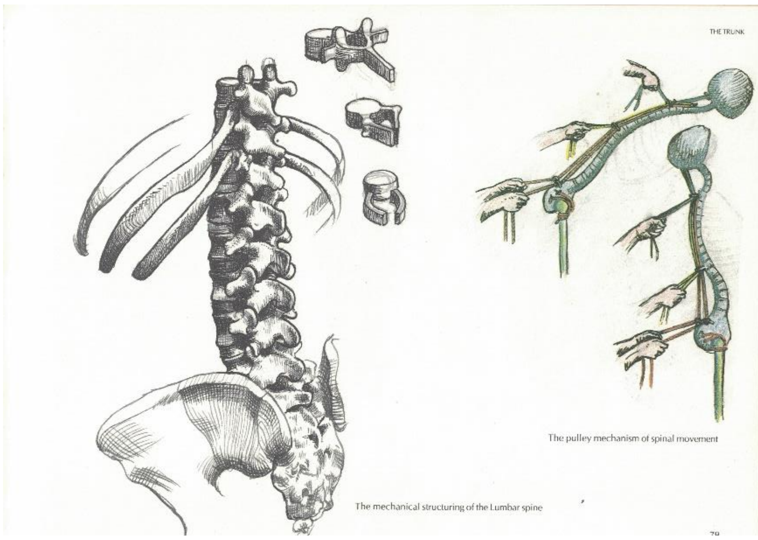

Fig. 2 Traditional biomechanics 'The muscles as a pulley mechanism moving the spine'

John Hull Grundy: 'Human structure and Shape'

Fig. 3 Snelsons Needle tower, from below (Kröller Müller museum, Otterlo, the Netherlands) Picture: Lieve Van Renterghem

Fig. 4 Snelsons Needle tower, (Kröller Müller museum, Otterlo, the Netherlands) Picture: Lieve Van Renterghem

Fig. 5 X-piece: the first visualisation of tensegrity by Kenneth Snelson (1949)

Picture: www.tensegriteit.nl

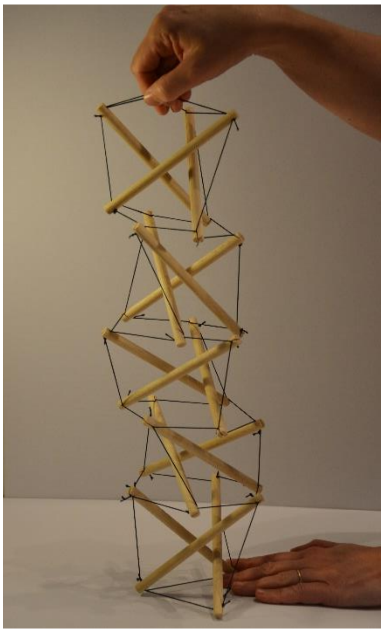

Fig. 6 Basic tensegrity mast,

Notice the similarity with the segmented spine

(Self-build model)

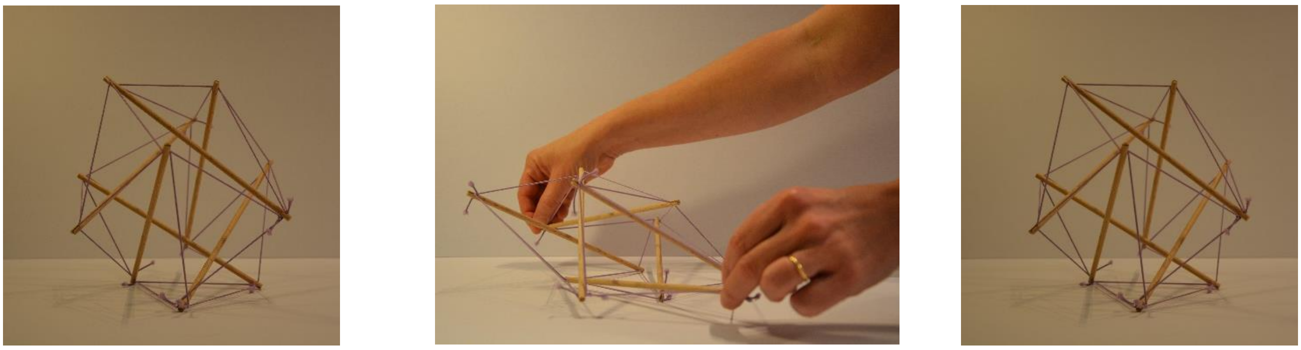

Fig. 7 Tensegrity icosahedron: Full - External force applies – resilience (Self-build model)

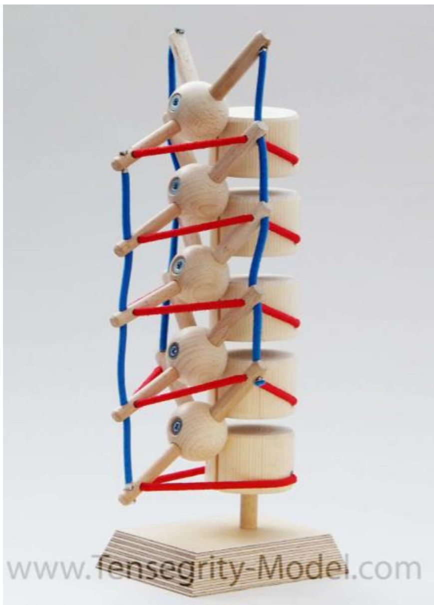

Fig. 8 Tensegrity model of the spine:

The vertebrae are ‘spaced’ by the tensioned elastics representing the deep spinal myofascial. None of the bony elements touch, the joint space is held by tension in the surrounding myofascial

Picture: www.Tensegrity-Model.com

Fig. 9 Any external applied force, is divided over the whole tensional system

Picture: www.jerichophysio.com/tensegrityand-your-fascia-a-whole-body-approach-to-treatment/

THE TRADITIONAL BIOMECHANICAL VIEW

Traditional anatomy looks at the (human) body as an assembly of easy-to-differentiate parts. This view has artificially evolved since the first dissections ages ago. Mechanics of movement (biomechanics), formulated by Borelli in the 17th century, are based on Newtonian mechanics and transfer the mechanical rules of inert materials and machines to living entities. The traditional biomechanical view of the human body is that of a skeleton, consisting of bones, stacked one on the other. The bones of the skeleton transfer the forces of gravity downwards, so the joints are under enormous compressive load (Fig. 1). Intra-articular space is considered to be held through hydrostatic pressure of the joint fluid. Articular cartilage transfers the loads from gravity and its opposite ground reaction force. Gravity is seen as an important (compressive) factor that holds everything together, in the same way as it is essential to hold the bricks of a wall. Gravity is literally seen as a compressing factor, fundamental to the integrity of the human shape. When buildings have their main volume at the base and get thinner towards the top, according to the logics of these laws, how can this system explain how a flamingo can hold its weight on one tiny leg? Or how a flower can 'carry' its own heavy head? Traditional mechanics are not consistent with the behaviour of moving biological structures.

When we consider the traditional view of the myofascial system, the muscles are defined, one separate from the other, and attached, through tendons, on the passive system. The fascia, surrounding and deeply interwoven in the muscular system, are traditionally considered of little importance. By contracting the muscles, the skeleton moves. Movement is explained by an artificially set up system of masses (the bones), fulcra (the joints) force vectors (exerted by the muscles) and levers, which respond to the same laws engineers use to build and manipulate machines (Fig. 2). Forces are calculated locally, problems are identified locally and are treated locally. For instance, a shoulder problem is diagnosed, treated at and around the shoulder joint. The muscles, especially in medical textbooks, are well defined, with clear origins and insertions, one clearly separated from its neighbours. The Greek 'anatamnein', literally means 'to cut open'. The way corpses (inert material, the basic tone of living material has disappeared) are cut and analysed determines the view of the medical student. [1]Add to that the fact that muscles pull and thereby move long levers, the joints cannot but compress. The result is therefore compression, shear and bending forces. How can this view explain the wholeness, the elongation, the support from within we want to develop and refine in teaching in Pilates?

[1] John Sharkey 'Biotensegrity blog'

BIOTENSEGRITY

Living entities behave differently, they have a basic coherency and tonus. We definitely move in the gravitational field but our shape has developed structurally from inside out, from the embryonic mesoderm to a complete human being. And the resilience of the 'whole' determines the way we are able to withstand gravity and external forces. Biotensegrity offers a more consistent explanation for the mechanical behaviour of biological structures. It sheds a different light on growth, integrity of the form as well as how everything is interdependent within the structure itself from micro to macro level. It explains the appearance of patterns and the self-organisation of natural shape on every level, from cell to outer form. Although the research on this model still leaves many blind spots, the recent evolutions are very promising and offer a consistent fundamental theoretical base for the way in which humans exist as a unity, body and mind.

The concept of 'tensegrity' was first formulated by an American architect. Buckminster Fuller (1895-1983), architect, engineer, philosopher and visionary, fundamentally disagreed with the traditional mechanics developed by Newton. As a theorist and not quite well understood in his time, he developed a system of holistic thinking in his main work: 'Synergetics'. In this work he studies the formation and self-organisation of patterns in systems. Fuller recognised an omnipresent principle, namely the interplay between tension and compression as a driving form and pattern generating principle in nature. Both forces are always present at the same time, balancing each other out. He had a vision of a new kind of architecture, based on these two forces, but was not able to fully materialise his idea.

It was his pupil Kenneth Snelson (1927-2016), a sculptor, who was the first to materialize a structure based on these forces (X-piece, 1949) (Fig. 5), visualising the balance between compression and tension. Snelson preferred the name 'floating compression' instead of Tensegrity. Snelson's 'Needle tower' (Fig. 3 & 4) visualises the strength and adaptability of a tensegrity structure made with distinct compressive elements floating in a tensional net. None of the compressive elements touch, they 'float' in a tensional web.

But it was not until the mid-seventies that orthopaedic surgeon Stephen Levin had the fundamental insight, watching Snelson's Needle tower, that this model could be the base of a new biomechanical approach. (Dr. Levin noticed that Snelson's needle tower shows a lot of similarities with the mechanical behaviour of the spine)(Fig. 8). Around the same period, cell biologist Donald Ingber recognised the tensegrity icosahedron as the base of cell structure and behaviour. Dr. Levin coined the term 'biotensegrity' and has been researching this topic ever since.[2]

[2] Dr. Steven Levin's website: www.biotensegrity.com provides a wealth of material

THE TENSEGRAL BODY & PILATES

Let us consider the basic properties of tensegrity structures and then apply these to the body and the Pilates approach. Tensegrity structures exist in many shapes, but all of them share the same fundamental properties. Tensegrity as a structural principle differs so much from our traditional stacking based mechanical thinking (the spinal 'column') that it is not an easy-to-grasp concept. By building and manipulating basic tensegrity models, the structural qualities become clearer. They should be explored by 'feeling' and 'moving' a model.

The tensegrity icosahedron (Fig. 7) is an interesting model to start with, as it is the one most closely resembling a sphere. It is fully triangulated and through manipulation it reveals all fundamental qualities of tensegrity structures: from a Pilates point of view some of these qualities are very familiar.

The tensegrity icosahedron is constructed with compression members of the same length. None of these touch, they are held apart by the tensioned network. On a macro scale the model abstractly allows us to understand how the bones in the body, as compression struts, float in the myofascial continuum and are at the same time kept apart by this web. The same interplay of these forces is found on different scales in the body; even at the smallest scale, the living cell behaves structurally as a tensegrity[3]. So this model offers a fractal

[3] Work of Donald Ingber

view on the body. It is an 'inside out' model, connecting top to bottom, the deep with the superficial.

Properties (fig.7):

1) The integrity of a tensegrity structure is based on the balance between discontinuous compression elements and a continuous tension network.

2) The model has form-integrity in itself, independent of external forces, including gravity.

3) The tensional web is pre-stressed. This pre-stress gives the structure its resilience as a whole. Forces are internally locked (Fig. 7). This makes the shape omnidirectional, meaning its integrity is independent of its orientation towards gravity. Consider this in contrast to a traditional 'building' were the walls depend on gravity for their stability.

4) When external forces apply, they are divided over the whole structure. (fig. 9) In contrast to traditional structures, the structure behaves in a non-lineal manner, i.e. it becomes stronger with loading. When reaching a certain point, it collapses.

Indeed, looking at a healthy body, bones do not touch, joint space stays intact by a balanced myofascial tonus around the joint (Fig. 8). The deep musculature, whose function is fundamentally different from the superficial, plays such an important role, stabilising the joints from different angles, preserving a healthy joint space. Manipulating this model gives us a visual and tactile base to explain the importance of lengthening and creating space in the body and to stress the importance of developing deep and balanced muscular force. The model also explains, on an abstract level, the importance of looking at the body as a whole. Any 'misalignment' is distributed over the entire structure. Whatever misalignment, trauma in the body, the eventual reaction/stress/pain can be at quite a distant location from the original cause (Fig. 8). The biotensegrity model offers a frame to look at relationships in the body. As Pilates teachers we are constantly looking for relationships in the body and are trying to make our clients aware of how relationships of the different parts determine good posture and movement. We are constantly looking for the most balanced, symmetrical, deeply supported outcome possible. The behaviour of the structure as a unity, the importance of balance in the myofascial web, the resilience of the whole are grounded by looking at the body as a tensegrity structure.

The study of biotensegrity is closely linked and evolves with the research on fascia. The fascial web, for a very long time ignored as a serious study domain, connects and contains everything within the body. Lines of fascial pull are recognised in the work of for example, Thomas Myers, who speaks of myofascial meridians, connecting top to bottom, left to right, recognising the body as a tensegrity[4]. But as important is the kinaesthetic factor, the link to our awareness. The fascial web is densely innervated and highly responsible for our proprioceptive awareness. It is, as Joanne Avison[5] calls it, the 'organ of organisation'. The myofascial web is immensely important in developing the

[4] Thomas Myers 'Anatomy Trains'
[5] Joanne Avison 'Yoga fascia anatomy and movement'

mind-body factor, in developing kinaesthetic awareness, an ongoing process in Pilates.

The pre-stressed tensioned web (fascia on macro-scale) compresses the struts (the bones on a macro-scale), at the same time the struts act as spacers and tensors for the tensional web. This polarity is felt in the deep centring, versus the expanding out, lengthening against gravity. Danièle-Claude Martin, an expert on biotensegrity speaks of 'restrained expansion'[6], Marie-José Blom, Pilates teacher, speaks of 'Oppositional length tension'[7].

In Pilates it is our goal to make our clients, as a unity of body and mind, more resilient towards external forces. Using either gravity on the mat or the spring tension in the machine. With this model in mind, we can see if the client is resilient enough to withstand the external forces applied. The springs of our equipment have an elastic-like quality with endless possibilities of training the myofascial web in 'oppositional length tension'. With the springs we can either assist in the direction of the myofascial pull, or at the appropriate time, we can challenge the resilience of our myofascial web by working against the resistance. An example: Roll-up, top loaded on the Cadillac, assists, roll-up bottom loaded, challenges the inner resilience by adding extra compression, just by reversing the direction of the resistance. Many more examples can be found. Looking at the body of the client as a biotensegrity structure gives us a tool to evaluate the quality of the performance in terms of being able to keep

[6] Danièle-Claude Martin 'Biotensegrität oder die Kunst der Wohlspannung'
[7] Maria-José Blom 'Pilates and Fascia: The art of working in'

the length vs. buckling under compression. If the resilience of the client's myofascial web is not enough to withstand the force applied, we need to re-evaluate the force applied.

CASE STUDY

I worked with Eva, my 21-year old daughter, keeping this model in mind. She has hypermobile joints and has little natural muscle strength. She is tall, but has a shortened posture, too kyphotic for her age. She has a distinct scoliosis (idiopathic), and is in fact not a moving person at all. Her main hobby is horse riding, but after a session she complains of back pain. The superficial mid-back muscles are clearly in a spasm. Her (deep) abdominals are very weak, she clearly has difficulties to withstand gravity.

Desired results:

Short to mid-term: developing her awareness of deep abdominal support, upper back extensor support, organisation of her body around the midline.

Mid to long-term: developing overall strength to support a good posture

With the tensegrity model of the spine in mind and using it as an abstract visualisation of what happens in the body, I teach her a greater awareness of the role of the deep myofascia in supporting a good, lengthened posture.

We have worked once a week for approximately 6 months.

BLOCK	EXERCISES	AIM
WARM UP	Breathing and aligning	Creating awareness/ focus and a sense of organising the body/spine around the plumb line. Feeling the expansion of the ribcage, extremely important for scoliotic people, while maintaining length in the spine.

	Standing roll-down Pelvic curl	Creating awareness of the central axis of the body, and the support of the deep abdominal/spinal muscles while articulating and lengthening the spine
	Spine twist supine	Creating rotation with the support of the oblique layers, which are very weak in her body
	Leg lifts, changes	Lumbo-pelvic stabilisation from the deep layers, with the sensation of keeping the length, space in the spine.
	Chest lifts, chest with rotation	We work on the pure movement without compensations
FOOT WORK	REF Footwork	All, with special emphasis on single leg work.
	WCH Footwork	The sitting posture is an extra challenge for controlling the length in her mobile spine. We integrate the footwork in a tensegral approach of the spine and body. I notice focus is all important. Whenever she loses focus, her spine collapses.
ABDOMINAL WORK	CAD Roll-up with RU bar	Assisted articulation for movement control. The springs assist in creating more space between the vertebrae.
	REF Hundreds prep	
	MAT Hundred, double leg stretch, single leg stretch, criss-cross	
HIP WORK	REF supine leg series	Main focus on disassociation of the hip joint, while keeping the length and stability in the lumbo-pelvic area and a well-organised upper thoracic region
	CAD supine leg series	
	CAD supine single leg series	Particularly interesting for organising the asymmetries in her spine
SPINAL ARTICULATION	REF Bottom lift	The emphasis is on control and deep support of the segmental work
	MAT Spine stretch	

STRETCHES	LB Gluteals, hamstrings, adductors and hip flexors	
FULL BODY INTEGRATION	REF Scooter, Knee stretch round back and flat back, reverse knee stretch, elephant	Due to her overall weakness, for the moment we limit this block to the most supported exercises.
ARM WORK	REF Arm supine series, Arm sitting series, shoulder push WCH Shrugs, triceps	We work on the relationship/awareness of the scapula and the thoracic area. Correct execution for the moment is more important than strength at this point
LEG WORK	WCH Leg press standing	Integrating the leg work with an overall awareness of posture. This exercise is interesting because it requires a functional relationship with gravity. Again, this requires her focus, whenever she loses it, she goes back to the usual compensations.
Lateral flexion/rotation	MAT Spine twist WCH Side stretch	This requires a lot of organisation in her trunk: the feeling of axis, and rotating the ribcage, while stabilising the pelvis.
Back extension	MAT Back extension REF Breaststroke prep WCH Swan basic	Despite her kyphotic posture, her thoracic area is still very mobile. With this basic exercise, we try to strengthen the thoracic extensors, to gain more support

Since we started working she has evolved towards a greater awareness. One of the major results at this stage is that she herself asks to practice. She has gained muscular strength and is able to support her posture for a short period. She is a visual learner, so the tensegrity models offered her a very accessible visualisation of the importance of deep support in creating length and good posture. However, when she is tired, she is not able to support her posture for a longer period. We will continue our work on the same path.

CONCLUSION

I chose Georgia O'Keeffe's 'winter road' on the front page, because of its expressive energy in a 'simple' line, its expressive tension. This expressive tension is what, in my opinion, makes Pilates aesthetical. Rael Isacowitz refers to the C-shape of the spine as 'a shape as (made by) the brush of an artist'.[8] Tension, in an expressive way, as a shape with an innate expansion, lines with expressive opposition, direction of energy. The tensegrity model offers a frame for understanding the forces creating this energy. Biotensegrity is first of all the principle of living architecture!

Practically, I use the frame tensegrity offers me in two ways while teaching:

For my clients as a model to visualise the floating compression/bone concept in a continuum of myofascial, densely innervated. It offers them a simple structural model for understanding the interwoven nature of our bones, myofascia and nervous system and for the expanding from inside out while centring, creating opposition. Balance in the myofascia is vitally important to secure the integrity of the different joint spaces, but balance in the myofascial lines as a whole is very important for posture and efficient and even graceful movement. It helps them understand the concept of the body as a whole, while working on the never-ending process of refining their kinaesthetic awareness.

For me, as a teacher, biotensegrity offers a frame through which I can observe the bodies of my clients. How the different body parts are related in terms of

[8] Rael Isacowitz on Pilates Anytime # 2281

alignment and whether my clients are able to withstand the external forces I apply with my program, do they 'elongate' or do they look compressed, even observing the smallest joints.

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