

# Fascial Fitness

## Fascia oriented training for bodywork and movement therapies

Divo G. Müller, Robert Schleip

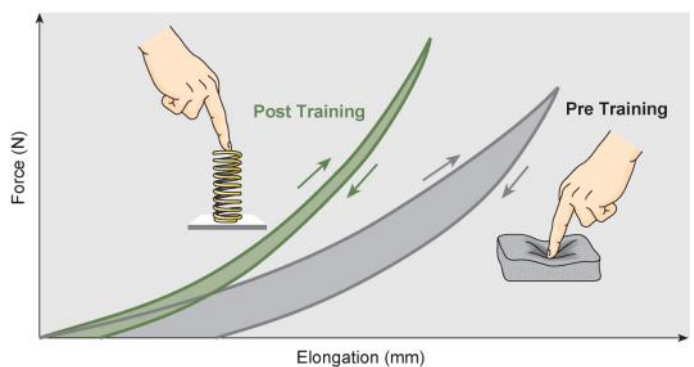
### Fascial Fitness

When a football player is not able to take the field because of a recurrent calf spasm, a tennis star gives up early on a match due to knee problems or a sprinter limps across the finish line with a torn Achilles tendon, the problem is most often neither in the musculature or the skeleton. Instead, it is the structure of the connective tissue – ligaments, tendons, joint capsules, etc. – which have been loaded beyond their present capacity (Renström & Johnson 1985, Counsel & Breidahl 2010). A focused training of the fascial network could be of great importance for athletes, dancers and other movement advocates. If one's fascial body is well trained, that is to say optimally elastic and resilient, then it can be relied on to perform effectively and at the same time to offer a high degree of injury prevention. Until now, most of the emphasis in sports training has been focused on the classical triad of muscular strength, cardiovascular conditioning, and neuromuscular coordination. Some alternative physical training activities - such as Pilates, yoga, Continuum Movement, Tai Chi, Qi Gong and martial arts – are already taking the connective tissue network into account.

The importance of fasciae is often specifically discussed; however the modern insights of fascia research have often not been specifically included in our work. In this article, we suggest that in order to build up an injury resistant and elastic fascial body network, it is essential to translate current insights of fascia research into a practical training program. Our intention is to encourage massage, bodywork, and movement therapists, as well as sports trainers to incorporate the basic principles presented in this article, and to apply them to their specific context.

### Fascial Remodelling

A unique characteristic of connective tissue is its impressive adaptability: when regularly put under increasing physiological strain, it changes its architectural properties to meet the demand. For example, through our everyday biped locomotion the fascia on the lateral side of the thigh develops a palpable firmness. If we were to instead spend that same amount of time with our legs straddling a horse, then the opposite would happen, i.e. after a few months the fascia on the inner side of the legs would become more developed and strong (El-Labban et al. 1993). The varied capacities of fibrous collagenous connective tissues make it possible for these materials to continuously adapt to the regularly occurring strain, particularly in relation to changes in length, strength and ability to shear. Not only the density of bone changes, as for example in astronauts who spend most time in zero gravity, their



**Figure 1. Increased elastic storage capacity.** Regular oscillatory exercise, such as daily rapid running, induces a higher storage capacity in the tendinous tissues of rats, compared with their non-running peers. This is expressed in a more spring-like recoil movement as shown on the left. The area between the respective loading versus unloading curves represents the amount of 'hysteresis': the smaller hysteresis of the trained animals (green) reveals their more 'elastic' tissue storage capacity; whereas the larger hysteresis of their peers signifies their more 'visco-elastic' tissue properties, also called inertia. Illustration modified after Reeves 2006.

bones become more porous; fascial tissues also reacts to their dominant loading patterns. With the help of the fibroblasts, they react to everyday strain as well as to specific training; steadily remodelling the arrangement of their collagenous fibre network. For example, with each passing year half the collagen fibrils are replaced in a healthy body.

The intention of fascial fitness is to influence this replacement via specific training activities which will, after 6 to 24 months, result in a 'silk-like bodysuit' which is not only strong but also allows for a smoothly gliding joint mobility over wide angular ranges.

Interestingly, the fascial tissues of young people show stronger undulations within their collagen fibres, reminiscent of elastic springs; whereas in older people the collagen fibres appear as rather flattened (Staubesand et al. 1997). Research has confirmed the previously optimistic assumption that proper exercise loading – if applied regularly - can induce a more youthful collagen architecture, which shows a more wavy fibre arrangement (Wood et al. 1988, Jarniven et al. 2002) and which also expresses a significant increased elastic storage capacity (Figure 1) (Reeves et al. 2006). However, it seems to matter which kind of exercise movements are applied: a controlled exercise study using slow velocity and low load contractions only demonstrated an increase in muscular strength and volume, however it failed to yield any change in the elastic storage capacity of the

collagenous structures (Kubo et al. 2003).

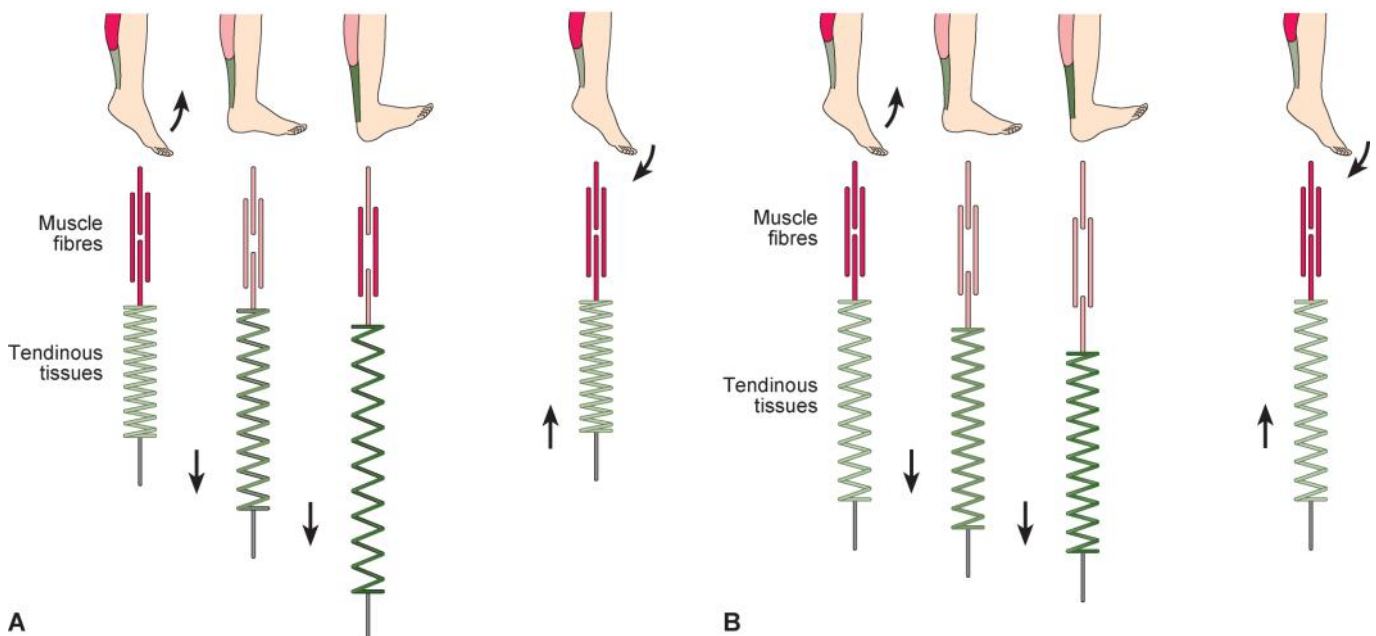


## The Catapult Mechanism: Elastic Recoil of Fascial Tissues

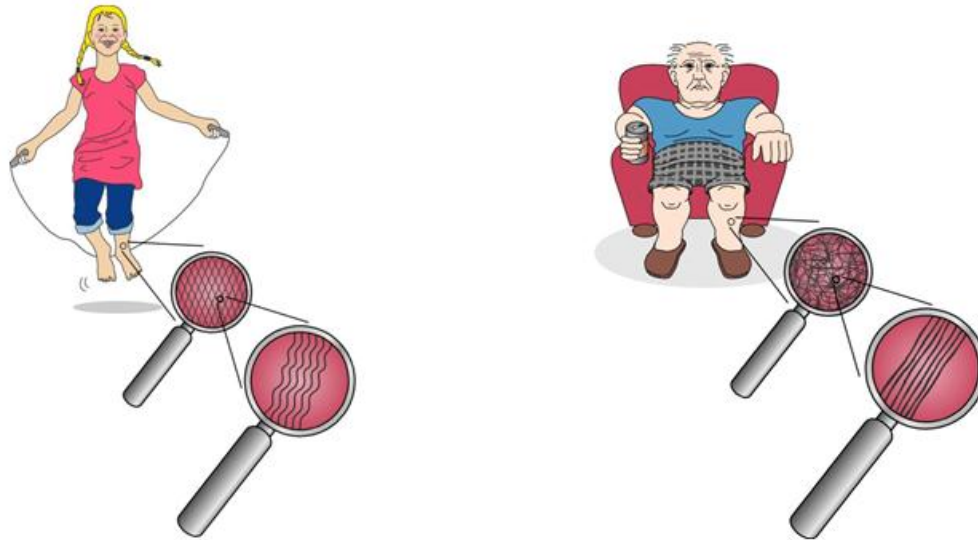
Kangaroos can hop much farther and faster than can be explained by the force of the contraction of their leg muscles.

Under closer scrutiny, scientists discovered that a spring-like action is behind the unique ability: the so-called *catapult mechanism* (Kram & Dawson 1998). Here the tendons and the fascia of the legs are tensioned like elastic bands. The release of this stored energy is what makes the amazing hops possible. Hardy surprising, scientist thereafter found the same mechanism is also used by gazelles. These animals are also capable of performing impressive leaping as well as running, though their musculature is not especially powerful. On the contrary, gazelles are generally considered to be rather delicate, making the springy ease of their incredible jumps all the more interesting.

Through high resolution ultrasound examination, it is now possible to discover similar orchestration of loading between muscle and fascia in human movement. Surprisingly it has been found that the fasciae of human have a similar kinetic storage capacity to that of kangaroos and gazelles (Sawicki et al. 2009). This is not only made use of when we jump or run but also with simple walking, as a significant part of the energy of the movement comes from the same springiness described above.



**Figure 2. Length changes of fascial elements and muscle fibres in an oscillatory movement with elastic recoil properties (A) and in conventional muscle training (B).** The elastic tendinous (or fascial) elements are shown as springs, the myo-fibres as straight lines above. Note that during a conventional movement (B) the fascial elements do not change their length significantly while the muscle fibres clearly change their length. During movements like hopping or jumping however the muscle fibres contract almost isometrically while the fascial elements lengthen and shorten like an elastic yoyo spring. Illustration adapted from Kawakami et al. 2002.



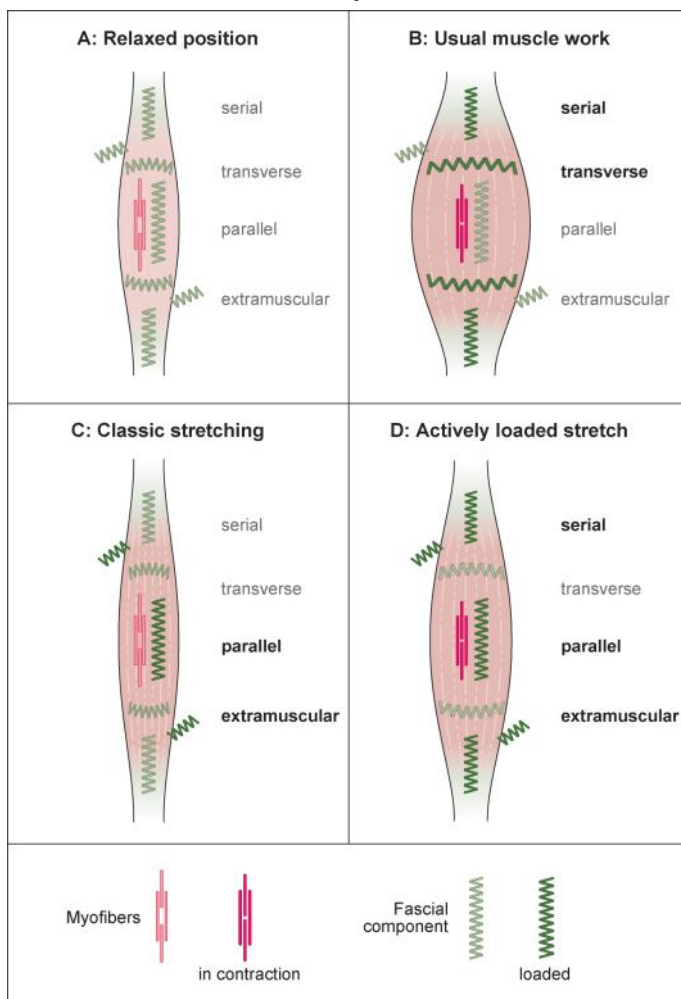
**Figure 3. Collagen architecture responds to loading.** Fasciae of young people express more often a clear two-directional (lattice) orientation of their collagen fibre network. In addition the individual collagen fibres show a stronger crimp formation. As evidenced by animal studies, application of proper exercise can induce an altered architecture with increased crimp-formation. Lack of exercise on the other hand, has been shown to induce a multidirectional fibre network and a decreased crimp formation.

This new discovery has led to an active revision of long accepted principles in the field of movement science.

In the past it was assumed that in a muscular joint movement, the skeletal muscles involved shorten and this energy passes through passive tendons which results in the movement of the joint. This classical form of

energy transfer is still true for steady movements such as cycling. Here the muscle fibres actively change in length, while the tendons and aponeuroses barely grow longer (Figure 2). The fascial elements remain quite passive. This is in contrast to oscillatory movements with an elastic spring quality in which the length of the muscle fibres changes slightly. Here, it is the muscle fibres contract in an almost isometric fashion (they stiffen temporarily without any significant change of their length) while the fascial elements function in an elastic way with a movement similar to that of a yoyo. Here, it is the lengthening and shortening of the fascial elements that ‘produces’ the actual movement (Fukunaga et al. 2002, Kawakami et al. 2002).

Work by Staubesand et al. (1997) suggested that the elastic movement quality in young people is associated with a typical bi-directional lattice arrangement of their fasciae, similar to a woman’s stocking. In contrast, as we



**Figure 4. Loading of different fascial components.**

**A) Relaxed position:** The myo-fibres are relaxed and the muscle is at normal length. None of the fascial elements is being stretched.

**B) Usual muscle work:** myo-fibres contracted and muscle at normal length range. Fascial tissues which are either arranged in series with the myo-fibres or transverse to them are loaded.

**C) Classical stretching:** myo-fibres relaxed and muscle elongated. Fascial tissues oriented parallel to the myo-fibres are loaded as well as extra-muscular connections. However, fascial tissues oriented in series with the myo-fibres are not sufficiently loaded, since most of the elongation in that serially arranged force chain is taken up by the relaxed myo-fibres.

**D) Actively loaded stretch:** muscle active and loaded at long end range. Most of the fascial components are being stretched and stimulated in that loading pattern. Note that various mixtures and combinations between the four different fascial components exist. This simplified abstraction serves as a basic orientation only.



**Figure 5. Training example: The Flying Sword** **A)** Tension the bow: the preparatory counter movement (pre-stretch) initiates the elastic-dynamic spring in an anterior and inferior direction. Free weights can also be used. **B)** To return to an upright position, the 'catapulting back fascia' is loaded as the upper body is briefly bounced dynamically downwards followed by an elastic swing back up. The attention of the person doing the exercise should be on the optimal timing and calibration of the movement in order to create the smoothest movement possible.

age and usually lose the springiness in our gait, the fascial architecture takes on a more haphazard and multidirectional arrangement. Animal experiments have also shown that lack of movement quickly fosters the development of additional cross links in fascial tissues. The fibres lose their elasticity and do not glide against one another as they once did; instead they become stuck together and form tissue adhesions, and in the worst cases they actually become matted together (Figure 3) (Jarvinen et al. 2002).

The goal of the proposed fascial fitness training is to stimulate fascial fibroblasts to lay down a more youthful and *kangaroo-like* fibre architecture. This is done through movements that load the fascial tissues over multiple extension ranges while utilizing their elastic springiness.

Figure 4 illustrates different fascial elements affected by various loading regimes. Classical weight training loads the muscle in its normal range of motion, thereby strengthening the fascial tissues which are arranged in series with the active muscle fibres. In addition the

transverse fibres across the muscular envelope are stimulated as well. However, little effect can be expected on extra-muscular fasciae as well as on those intramuscular fascial fibres that are arranged in parallel to the active muscle fibres (Huijing 1999).

Classical Hatha yoga stretches on the other side will show little effect on those fascial tissues which are arranged in series with the muscle fibres, since the relaxed myo-fibres are much softer than their serially arranged tendinous extensions and will therefore 'swallow' most of the elongation (Jami 1992). However, such stretching provides good stimulation for fascial tissues which are hardly reached with classical muscle training, such as the extra-muscular fasciae and the intramuscular fasciae oriented in parallel to the myo-fibres. Finally, a dynamic muscular loading pattern in which the muscle is both activated and extended promises a more comprehensive stimulation of fascial tissues. This can be achieved by muscular activation (e.g. against resistance) in a lengthened position while requiring small or medium amounts of muscle force only. Soft elastic bounces in the end ranges of available motion can also be utilized



**Figure 6. Training example: Elastic Wall Bounces.** Imitating the elastic bounces of a kangaroo soft bouncing movements off a wall are explored in standing. Proper pre-tension in the whole body will avoid any collapsing into a 'banana posture'. Making the least sound and avoiding any abrupt movement qualities are imperative. Only with the mastery of these qualities a progression into further load increases – e.g. bouncing off a table or window sill instead of a wall – can eventually be explored by stronger individuals. E.g. this person should not yet be permitted to progress to higher loads, as his neck and shoulder region already show slight compression on the left picture.

for that purpose. The following guidelines are developed to make such training more efficient.

## Training Principles

### 1. Preparatory Counter-movement

Here we make use of the catapult effect as described above. Before performing the actual movement, we start with a slight pre-tensioning in the opposite direction. This is comparable with using a bow to shoot an arrow; just as the bow has to have sufficient tension in order for the arrow to reach its goal, the fascia becomes actively pre-tensioned in the opposite direction. Using one's muscle power to "push the arrow" would then rightfully be seen as foolish, in this extreme example of an elastic recoil movement. In a sample exercise called *the flying sword*, the pre-tensioning is achieved as the body's axis is slightly tilted backward for a brief moment; while at the same time there is an upward lengthening (Figure 5). This increases the elastic tension in the fascial body-suit and as a result allows the upper body and the arms to spring forward and down like a catapult as the weight

is shifted in this direction.

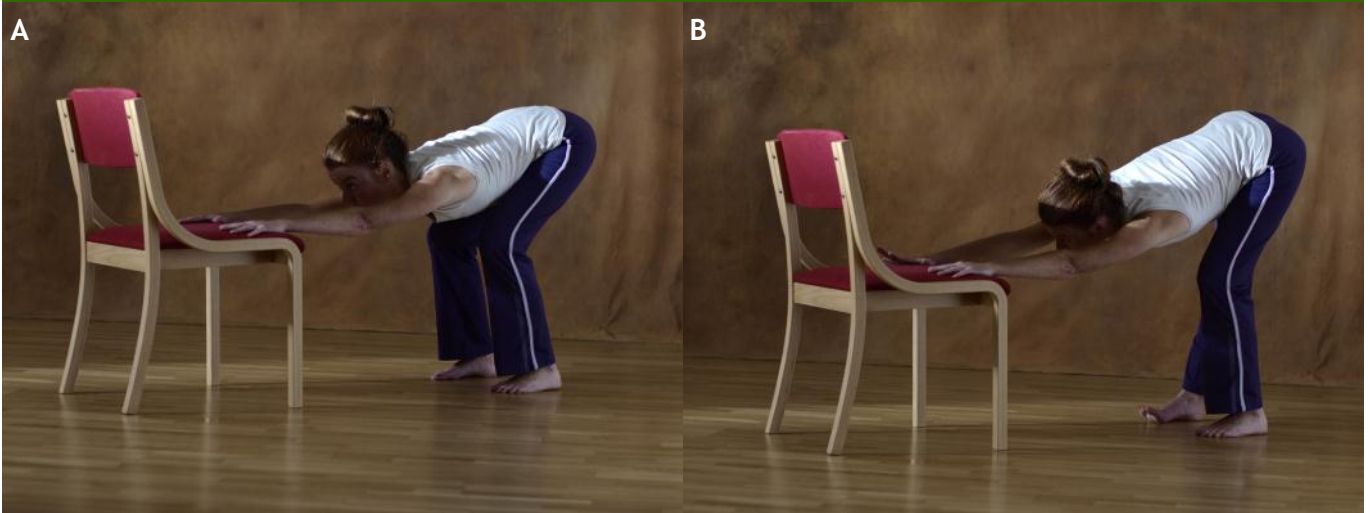
The opposite is true for straightening up – the mover activates the catapult capacity of the fascia through an active pre-tensioning of the fascia of the back. When standing up from a forward bending position, the muscles on the front of the body are first briefly activated. This momentarily pulls the body even further forward and down and at the same time the fascia on the posterior fascia is loaded with greater tension.

The energy which is stored in the fascia is dynamically released via a passive recoil effect as the upper body 'swings' back to the original position. To be sure that the individual is not relying on muscle work, but rather on dynamic recoil action of the fascia, requires a focus on timing – much the same as when playing with a yoyo. It is necessary to determine the ideal swing, which is apparent when the action is fluid and pleasurable.

### 2. The Ninja Principle

This principle is inspired by the legendary Japanese warriors who reputedly moved as silent as cats and left

# Fascial Fitness



**Figure 7. Training example: The Big Cat Stretch. A)** This is a slow stretching movement of the long posterior chain, from the finger tips to the sit bones, from the coccyx to the top of the head and to the heels. The movement goes in opposing directions at the same time – think of a cat stretching its long body. By changing the angle slightly, different aspects of the fascial web are addressed with slow and steady movements. **B)** In the next step, we rotate and lengthen the pelvis or chest towards on side (here shown with the pelvis starting to rotate to the right). The intensity of the feeling of stretch on that entire side of the body is then gently reversed. Note the afterwards feeling of increased length.

no trace. When performing bouncy movements such as hopping, running and dancing, special attention needs to be paid to executing the movement as smoothly and softly as possible. A change in direction is preceded by a gradual deceleration of the movement before the turn and a gradual acceleration afterwards, each movement flowing from the last; any extraneous or jerky movements should therefore be avoided (see Figure 6).

Normal stairs become training equipment when they are used appropriately, employing gentle stepping. The production of ‘as little noise as possible’ provides the most useful feedback – the more the fascial spring effect is utilized, the quieter and gentler the process will be. It may be useful to reflect on the way a cat moves as it prepares to jump; the feline first sends a condensed impulse down through its paws in order to accelerate softly and quietly, landing with precision.

### 3. Dynamic Stretching

Rather than a motionless waiting in a static stretch position a more flowing stretch is suggested. In fascial fitness there is a differentiation between two kinds of dynamic stretching: fast and slow. The fast variation may be familiar to many people as it was part of the physical training in the past. For the past several decades this bouncing stretch was considered to be generally harmful to the tissue, but the method’s merits have been confirmed in contemporary research. Although stretching immediately before competition can be counterproductive, it seems that long-term and regular use of such dynamic stretching can positively influence the architec-

ture of the connective tissue in that it becomes more elastic when correctly performed (Decoster et al. 2005). Muscles and tissue should first be warmed up, and jerking or abrupt movements should be avoided. The motion should have a sinusoidal deceleration and acceleration shape each direction turn; this goes along with a smooth and ‘elegant’ movement quality perception. Dynamic, fast stretching has even more effect on the fascia when combined with a preparatory countermovement as was previously described by Fukashiro et al. (2006). For example, when stretching the hip flexors a brief backward movement should be introduced before dynamically lengthening and stretching forwards.

The long myofascial chains are the preferred focus when doing slow dynamic stretches. Instead of stretching isolated muscle groups, the aim is finding body movements that engage the longest possible myofascial chains (Myers 1997). This is not done by passively waiting as in a lengthening classical Hatha yoga pose, or in a conventional isolated muscle stretch. Multidirectional movements, with slight changes in angle are utilized; this might include sideways or diagonal movement variations as well as spiralling rotations. With this method, large areas of the fascial network are simultaneously involved (Figure 7).

### 4. Proprioceptive Refinement

The importance of proprioception for movement control is made clear by the case of Ian Waterman, a man repeatedly mentioned in scientific literature. This impressive man contracted a viral infection at the age of 19

## Fascial Fitness



**Figure 8. Training example: Octopus Tentacle.** With the image of an octopus tentacle in mind, a multitude of extensional movements through the whole leg are explored in slow motion. Through creative changes in muscular activations patterns the tensional fascial proprioception is activated. This goes along with a deep myofascial stimulation that aims to reach not only the fascial envelopes but also into the septa between muscles. While avoiding any jerky movement quality, the action of these tentacle-like micro-movements leads to a feeling of flowing strength in the leg.

which resulted in a so-called ‘sensory neuropathy’. In this rare pathology, the sensory peripheral nerves which provide the somato-motor cortex with information about the movements of the body are destroyed, while the motor nerves remain completely intact. This means that Mr. Waterman can move, but he can’t ‘feel’ his movements. After some time, this giant of a man became virtually lifeless. Only with an iron will and years of practice did he finally succeed in making up for these normal physical sensations, a capacity that is commonly taken for granted. He did so with conscious control that primarily relies on visual feedback. He is currently the only person known with this affliction that is able to stand unaided, as well as being able to walk (Cole 1995).

Observation of the way Waterman moves is similar to the way patients with chronic back pain move. When in a public place if the lights unexpectedly go out, he clumsily falls to the ground (see BBC documentary: The man who lost his body <http://video.google.com/videoplay?docid=-3032994272684681390#>). Springy, swinging movements are possible for him only with obvious and jerky changes in direction. If doing a classical stretching program with static or active stretches, he would appear normal. As for the dynamic stretching that is part of our fascial training, he is clearly not capable, as he lacks the proprioception needed for fine coordination.

It is interesting to note here that the classical ‘joint receptors’ – located in joint capsules and associated ligaments - have been shown to be of lesser importance for normal proprioception, since they are usually stimulated at extreme joint ranges only, and not during physiological motions (Lu et al 1985). On the contrary, propri-

ceptive nerve endings located in the more superficial layers are more optimally situated as here even small angular joint movements lead to relatively distinct shearing motions. Recent findings indicate that the superficial fascial layers of the body are in fact more densely populated with mechano-receptive nerve endings than tissue situated more internally (Stecco et al. 2008).

For this reason a perceptual refinement of shear, gliding and tensioning motions in superficial fascial membranes is encouraged. In doing this, it is important to limit the filtering function of the reticular formation as it can markedly restrict the transfer of sensations from movements which are repetitive and predictable. To prevent such a sensory dampening, the idea of varied and creative experiencing becomes important. In addition to the slow and fast dynamic stretches noted above as well as utilizing elastic recoil properties an inclusion of ‘fascial refinement’ training is recommended in which various qualities of movement are experimented with, e.g. extreme slow-motion and very quick, micro-movements which may not even be visible to an observer and large macro movements involving the whole body. Here it is common to place the body into unfamiliar positions while working with the awareness of gravity, or possibly through exploring the weight of a training partner.

The micro-movements are inspired by Emily Conrad’s *Continuum Movement* (Conrad 1997). Such movement is active and specific and can have effects which are not possible with larger movements. In doing these coordinated fascial movements, it appears possible to specifi-



**Figure 9. Training example: Fascial Release.** The use of particular foam rollers may allow the application of localized tissue stimulations with similar forces and possibly similar benefits as in a manual myofascial release session. However the stiffness of the roller and application of the body weight needs to be adjusted and monitored for each person. To foster a sponge-like tissue dehydration with subsequent renewed local hydration, only slow-motion like subtle changes in the applied forces and vectors are recommended.

cally address adhesions, for example between muscle septa deep in the body. In addition such tiny and specific movements can be used to illuminate and bring awareness to perceptually neglected areas of the body (Figure 8). Thomas Hanna uses the label ‘sensory-motor amnesia’ for such places in the body (Hanna 1998).

## 5. Hydration and Renewal

The video recordings of live fascia *Strolling Under the Skin* by Dr Jean-Claude Guimbertau have helped our understanding of the plasticity and changing elasticity of the water-filled fascia. This awareness has proven to be especially effective when incorporated into the slow dynamic stretching and the fascial refinement work. An essential basic principle of these exercises is the understanding that the fascial tissue is predominantly made up of free moving and bound water molecules. During the strain of stretching, the water is pushed out of the more stressed zones similarly to squeezing a sponge (Schleip & Klingler 2007). With the release that follows; this area is again filled with new fluid which comes from surrounding tissue as well as the lymphatic and vascular network. The sponge-like connective tissue can lack adequate hydration at neglected places. The goal of exercise is to refresh such places in the body with improved hydration through specific stretching to encourage fluid movement.

Here proper timing of the duration of individual loading and release phases is very important. As part of modern running training, it is often recommended to frequently intercept the running with short walking intervals (Galloway 2002). There is good reason for this: under strain the fluid is pressed out of the fascial tissues and

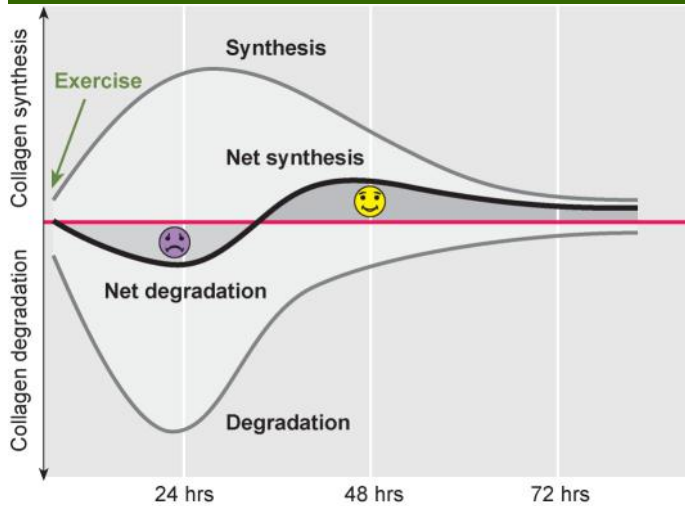
these begin to function less optimally as their elastic and springy resilience slowly decreases.

The short walking pauses then serve to re-hydrate the tissue as it is given a chance to take up nourishing fluid. For an average beginning runner for example, the authors recommend walking pauses of one to three minutes every 10 minutes. More advanced runners with more developed body awareness can adjust the optimal timing and duration of those breaks based on the presence (or lack) of that youthful and dynamic rebound: if the running movement begins to feel and look more dampened and less springy, it is likely time for a short pause. Similarly, if after a brief walking break there is a noticeable return of that gazelle-like rebound, then the rest period was adequate.

This cyclic training, with periods of more intense effort interspersed with purposeful breaks, is recommended in all facets of fascia training. The person training then learns to pay attention to the dynamic properties of their fascial “bodysuit” while exercising, and to adjust the exercises based on this new body awareness. This also carries over to an increased ‘fascial embodiment’ in everyday life. Preliminary anecdotal reports also indicate a preventative effect of a fascia oriented training in relation to connective tissue overuse injuries.

The use of special foam rollers can be useful tools for inducing a localized ‘sponge-like’ temporary tissue dehydration with resultant renewed hydration. However firmness of the roller and application of the bodyweight needs to be individually monitored. If properly applied and including very slow and finely-tuned directional changes only, the tissue forces and potential benefits





**Figure 10: Collagen turnover after exercise.** The upper curve shows collagen synthesis in tendons is increasing after exercise. However, the stimulated fibroblasts also increase their rate of collagen degradation. Interestingly, during the first 1-2 days following exercise, collagen degradation outweighs the collagen synthesis; whereas afterwards this situation is reversed. To increase tendon strength, the proposed fascial fitness training therefore suggests an appropriate tissue stimulation 1 to 2 times per week only. While the increased tendon strength is not achieved by an increase in tendon diameter, recent examinations by Kjaer et al. (2009) indicated that it is probably the result of altered cross-link formations between collagen fibres. Illustration modified after Magnusson et al. 2010.

could be similar to those of manual myofascial release treatments (Chaudhry et al. 2008). In addition, the localized tissue stimulation may serve to stimulate and fine-tune possibly inhibited or de-sensitized fascial proprioceptors in more hidden tissue locations (Figure 9).

## 6. Sustainability: The Power of a Thousand Tiny Steps

An additional and important aspect is the concept of the slow and long-term renewal of the fascial network. In contrast to muscular strength training in which big gains occur early on and then a plateau is quickly reached wherein only very small gains are possible, fascia changes more slowly and the results are more lasting. It is possible to work without a great deal of strain – so that consistent and regular training pays off. When training the fascia, improvements in the first few weeks may be small and less obvious on the outside. However, improvements have a lasting cumulative effect which after years can be expected to result in marked improvements in the strength and elasticity of the global fascial net (Figure 10) (Kjaer et al. 2009). Improved coordination as the fascial proprioception becomes refined is probable.

A bit of Eastern philosophy might help in the motivation of impatient Westerners looking for quick gains: to be

supple and resilient like a bamboo requires the devotion and regular care of the bamboo gardener. He nurtures his seeds over a long period of time without any visible positive result. Only after enduring care does the first bamboo seedling become visible as it pushes its way toward the sky. From then on it grows steadily upwards until it dwarfs its neighbours in height, flexibility and resistance to damage. It is therefore suggested that training should be consistent, and that only a few minutes of appropriate exercises, performed once or twice per week is sufficient for collagen remodelling. The related renewal process will take between six months and two years and will yield a lithe, flexible and resilient collagenous matrix.

For those who do yoga or martial arts, such a focus on a long-term goal is nothing new. For the person who is new to physical training, such analogies when combined with a little knowledge of modern fascia research can go a long way in convincing them to train their connective tissues. Of course fascial fitness training should not replace muscular strength work, cardiovascular training and coordination exercises; instead it should be thought of as an important addition to a comprehensive training program.

For more information on fascial fitness see: [www.fascialfitness.de](http://www.fascialfitness.de)

This article is adapted from: *Fascia in Manual and Movement Therapies*, Schleip et al., Elsevier Science 2011.

## References

- Chaudhry H, Schleip R, Ji Z, Bukiet B, Maney M, Findley T (2008). Three-dimensional mathematical model for deformation of human fasciae in manual therapy. *J Am Osteopath Assoc* 108(8): 379-90.
- Cole J (1995) *Pride and a Daily Marathon*. MIT Press, London.
- Conrad E (2007) *Life on Land*. North Atlantic Books, Berkeley.
- Counsel P, Bredahl W (2010) Muscle injuries of the lower leg. *Semin Musculoskelet Radiol* 14(2): 162-75.
- Decoster LC, Cleland J, Altieri C, Russell P (2005) The effects of hamstring stretching on range of motion: a systematic literature review. *J Orthop Sports Phys Ther* 35(6): 377-87.
- EI-Labban NG, Hopper C, Barber P (1993) Ultrastructural finding of vascular degeneration in myositis ossificans circumscripta (fibrodysplasia ossificans). *J Oral Pathol Med* 22 (9): 428-431

- Fukunaga T, Kawakami Y, Kubo K, Kanehisa H (2002) Muscle and tendon interaction during human movements. *Exerc Sport Sci Rev* 30(3): 106-10
- Fukashiro S, Hay DC, Nagano A (2006) Biomechanical behavior of muscle-tendon complex during dynamic human movements. *J Appl Biomech* 22(2): 131-47.
- Galloway J (2002) *Galloway's Book on Running*. Shelter Publications, Bolinas, CA, USA.
- Hanna T (1998) *Somatics: Reawakening the Mind's Control of Movement, Flexibility, and Health*. Da Capo Press, Cambridge MA, USA.
- Huijing PA (1999) Muscle as a collagen fiber reinforced composite: a review of force transmission in muscle and whole limb. *J Biomech* 32(4): 329-45.
- Jami A (1992) Golgi tendon organs in mammalian skeletal muscles: functional properties and central actions. *Physiol Rev* 72(3): 623-666.
- Jarvinen TA, Jozsa L, Kannus P, Jarvinen TL, Jarvinen M (2002) Organization and distribution of intramuscular connective tissue in normal and immobilized skeletal muscles. An immunohistochemical, polarization and scanning electron microscopic study. *J Muscle Res Cell Motil* 23(3): 245-54.
- Kawakami Y, Muraoka T, Ito S, Kanehisa H, Fukunaga T (2002) In vivo muscle fibre behaviour during countermovement exercise in humans reveals a significant role for tendon elasticity. *J Physiol* 540 (2): 635-646.
- Kjaer M, Langberg H, Heinemeier K, Bayer ML, Hansen M, Holm L, Doessing S, Kongsgaard M, Kroegsgaard MR, Magnusson SP (2009). From mechanical loading to collagen synthesis, structural changes and function in human tendon. *Scand J Med Sci Sports* 19(4): 500-510.
- Kram R, Dawson TJ (1998) Energetics and biomechanics of locomotion by red kangaroos (*Macropus rufus*). *Comp Biochem Physiol B* 120(1): 41-9. <http://stripe.colorado.edu/~kram/kangaroo.pdf>
- Kubo K, Kanehisa H, Miyatani M, Tachi M, Fukunaga T (2003). Effect of low-load resistance training on the tendon properties in middle-aged and elderly women. *Acta Physiol Scand* 178(1): 25-32.
- Lu Y, Chen C, Kallakuri S, Patwardhan A, Cavanaugh JM (2005) Neural response of cervical facet joint capsule to stretch: a study of whiplash pain mechanism. *Stapp Car Crash J* 49: 49-65.
- Mackey AL, Heinemeier KM, Koskinen SO, Kjaer M (2008) Dynamic adaptation of tendon and muscle connective tissue to mechanical loading. *Connect Tissue Res* 49(3): 165-168.
- Magnusson SP, Langberg H, Kjaer M (2010) The pathogenesis of tendinopathy: balancing the response to loading. *Nat Rev Rheumatol* 6(5): 262-268.
- Myers TW (1997) The 'anatomy trains'. *J Bodyw Mov Ther* 1 (2): 91-101.
- Reeves ND, Narici MV, Maganaris CN (2006) Myotendinous plasticity to ageing and resistance exercise in humans. *Exp Physiol* 91(3): 483-498.
- Renström P, Johnson RJ (1985) Overuse injuries in sports. A review. *Sports Med* 2(5): 316-333.
- Sawicki GS, Lewis CL, Ferris DP (2009) It pays to have a spring in your step. *Exerc Sport Sci Rev* 37(3): 130-138.
- Schleip R, Klingler W (2007) Fascial strain hardening correlates with matrix hydration changes. In: Findley TW, Schleip R (eds.) *Fascia Research – Basic science and implications to conventional and complementary health care*. Elsevier GmbH, Munich, p.51.
- Staubesand J, Baumbach KUK, Li Y (1997) La structure fine de l'aponévrose jambière. *Phlebologie* 50: 105-113.
- Stecco C, Porzionato A, Lancerotto L, Stecco A, Macchi V, Day JA, De Caro R 2008. Histological study of the deep fasciae of the limbs. *J Bodyw Mov Ther* 12(3): 225-230.
- Wood TO, Cooke PH, Goodship AE (1988) The effect of exercise and anabolic steroids on the mechanical properties and crimp morphology of the rat tendon. *Am J Sports Med* 16 (2) 153-158.

## About the authors



*Divo Müller is one of the first internationally authorized Continuum teachers in Europe since 1992. She is a Somatic Experience practitioner, author of a book, numerous articles and DVDs, all of which teach a specially designed movement approach for women, based on Continuum. Divo teaches regularly all over Europe as well as in Brazil and in New Zealand. She offers a unique movement program in her Studio Bodybliss in Munich [www.bodybliss.de](http://www.bodybliss.de)*



*Robert Schleip PhD, is an International Rolfing Instructor and Fascial Anatomy Teacher. Robert has been an enthusiastic certified Rolfer since 1978. He holds on M.A. degree in psychology and is a Certified Feldenkrais Teacher since 1988. He earned his PhD with honours in 2006 at the age of 52, and shortly thereafter established the Fascia Research Project at Ulm University and has a lab of his own. He was the co-initiator and organizer of the first Fascia Research Congress at the Harvard Medical School in Boston, USA in 2007. See Robert's website [www.somatics.de](http://www.somatics.de)*

***www.terrarosa.com.au***

***Your Source for Massage Information***

***We offer the best service for your continuing education:***

- Over 200 DVD titles and 150 book titles on massage and bodywork in stock.***
- Free monthly Massage Newsletter highlighting the latest research and news in massage and bodywork.***
- Free electronic magazine featuring articles on research and techniques by the finest authors in massage and bodywork.***