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FASCIA SCIENCE AND CLINICAL APPLICATIONS: PRACTICAL TRAINING EXERCISES

Training principles for fascial connective tissues: Scientific foundation and suggested practical applications

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Summary Conventional sports training emphasizes adequate training of muscle fibres, of cardiovascular conditioning and/or neuromuscular coordination. Most sports-associated overload injuries however occur within elements of the body wide fascial net, which are then loaded beyond their prepared capacity. This tensional network of fibrous tissues includes dense sheets such as muscle envelopes, aponeuroses, as well as specific local adaptations, such as ligaments or tendons. Fibroblasts continually but slowly adapt the morphology of these tissues to repeatedly applied challenging loading stimulations. Principles of a fascia oriented training approach are introduced. These include utilization of elastic recoil, preparatory counter movement, slow and dynamic stretching, as well as rehydration practices and proprioceptive refinement. Such training should be practiced once or twice a week in order to yield in a more resilient fascial body suit within a time frame of 6–24 months. Some practical examples of fascia oriented exercises are presented.

Introduction

Whenever a football player is not able to take the field because of a recurrent knee pain, a tennis star gives up early on a match due to shoulder problems, or a sprinter limps across the finish line with a torn Achilles tendon, the problem is most often neither in the musculature nor the skeleton. Instead, it is the structure of the connective tissue – ligaments, tendons, joint capsules, etc. – that may have been loaded beyond its prepared capacity (Renström and Johnson, 1985; Hyman and Rodeo, 2000; Counsel and Breidahl, 2010).

Fascia has been described as a body wide tensional network, which consists of all fibrous collagenous soft connective tissues, whose fibrous architecture is dominantly shaped by tensional strain rather than compression.

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This continuous network envelops and connects all muscles and organs. Elements of this fibrous network include muscle envelopes, joint capsules, septi, intramuscular connective tissues, retinaculae, aponeuroses, as well as more dense local specifications such as ligaments and tendons. While at some areas a local distinction of different tissue elements (such as aponeuroses, ligaments, etc.) is possible, many areas such as those in proximity to major joints consist of gradual transitions between different tissue architectures in which a clear distinction often appears as arbitrary and misleading (Schleip et al., 2012b).

Previous anatomical terminology often restricted the term fascia to dense sheets of connective tissues with lattice-like or seemingly irregular fibre architecture. In contrast, the more comprehensive and novel terminology proposed by the series of international fascia research congresses continues to honour that usage by referring to such tissues as 'proper fascia', but at the same time allows for a perceptual orientation in which also the other fibrous connective tissues mentioned above are included as elements of a body wide 'fascial net' for multi-articular tensional strain transmission (Findley et al., 2007; Huijing et al., 2009; Chaitow et al., 2012) (Fig. 1). It is important to understand, that the local architecture of this network adapts to the specific history of previous strain loading demands (Blechschmidt, 1978; Chaitow, 1988).

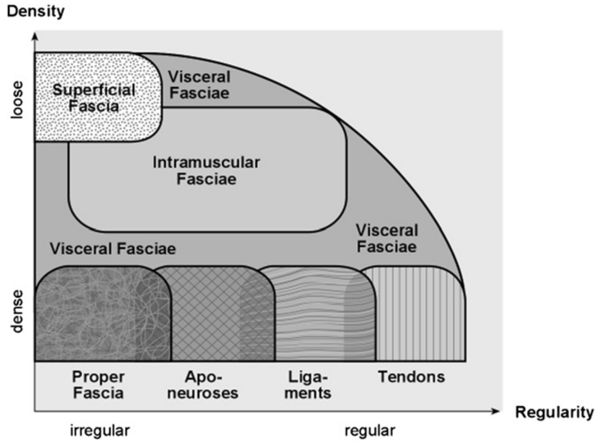

Figure 1 Different connective tissues considered here as fascial tissues. Fascial tissues differ in terms of their density and directional alignment of collagen fibers. E.g. superficial fascia is characterized by a loose density and mostly multidirectional or irregular fibre alignment; whereas in the denser tendons or ligaments the fibres are mostly unidirectional. Note that the intramuscular fasciae — septi, perimysium and endomysium — may express varying degrees of directionality and density. The same is true — although to a much larger degree — for the visceral fasciae (including soft tissues like the omentum majus and tougher sheets like the pericardium). Depending on local loading history, proper fasciae can express a two-directional or multi-directional arrangement. As indicated, there are substantial overlaps areas in which a clear tissue category will be difficult or arbitrary. Not shown here are retinaculae and joint capsules, whose local properties may vary between those of ligaments, aponeuroses and proper fasciae.

A focused training of this 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 may be relied on to perform effectively and at the same time to offer a high degree of injury prevention (Kjaer et al., 2009). Until recently, most of the emphasis in sports has been focused on the classic triad of muscular strength, cardiovascular conditioning, and neuromuscular coordination (Jenkins, 2005). Some alternative physical training activities — such as Pilates, yoga, Continuum Movement, and martial arts — are already taking the connective tissue network into account. Here the importance of the fasciae is often specifically discussed, though modern insights in the field of fascia research have often not been specifically included. It is therefore suggested that in order to build up an injury-resistant and elastic fascial body network it is essential to translate current insights from the dynamically developing field of fascia research into practical training programs. The intention is to encourage physical therapists, sports trainers and other movement teachers to incorporate the principles presented here and to apply them to their specific context.

The following presents some basic biomechanical and neurophysiological foundations for a fascia oriented training approach, followed by suggestions for some practical applications.

Basic foundations

Fascial remodelling

A recognized characteristic of connective tissue is its impressive adaptability: when regularly put under increasing yet physiological strain, the inherent fibroblasts adjust their matrix remodelling activity such that the tissue architecture better meets demand. For example, through our everyday biped locomotion the fascia on the lateral side of the thigh develops a more palpable firmness than on the medial side. This difference in tissue stiffness is hardly found in wheel chair patients. If we were instead to spend the majority of our locomotion 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 most challenging regular strains, particularly in relation to changes in length, strength and ability to shear. Not only the density of bone changes, for example, as happens with astronauts who spend time in zero gravity wherein the bones become more porous (Ingber, 2008); fascial tissues also react to their dominant loading patterns. With the help of the fibroblasts, they slowly but constantly react to everyday strain as well as to specific training, steadily remodelling the arrangement of their collagenous fibre network (Kjaer et al., 2009). For example, with each passing year half the collagen fibrils are replaced in a healthy body (Neuberger and Slack, 1953). Extrapolation of these roughly exponential renewal dynamics predicts an expected replacement of 30% of collagen fibres within 6 months and of 75% in two years.

Interestingly, the fascial tissues of young people show stronger undulations — called crimp -within their collagen fibres, reminiscent of elastic springs, whereas in older people the 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 (Fig. 2) (Reeves et al., 2006; Witvrouw et al., 2007).

However, it seems to matter which kind of exercise movements are applied: a controlled exercise study with a group of senior women 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). While the latter response could possibly be also related to age differences, more recent studies by Arampatzis et al. (2010) have confirmed that in order to yield adaptation effects in human tendons, the strain magnitude applied should exceed the value that occurs during habitual activities. These studies provide evidence of the existence of a threshold or set point at the applied strain magnitude at which the transduction of the mechanical stimulus influences the tensional homeostasis of the tendons (Arampatzis et al., 2007).

The catapult mechanism: elastic recoil of fascial tissues

Kangaroos can jump much farther 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 and Dawson, 1998). Here, the tendons and the fascia of the legs are tensioned like elastic rubber bands. The release of this stored energy is what makes the amazing jumps possible. The discovery soon thereafter that gazelles also utilize the same mechanism was hardly surprising. These animals are also capable of 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.

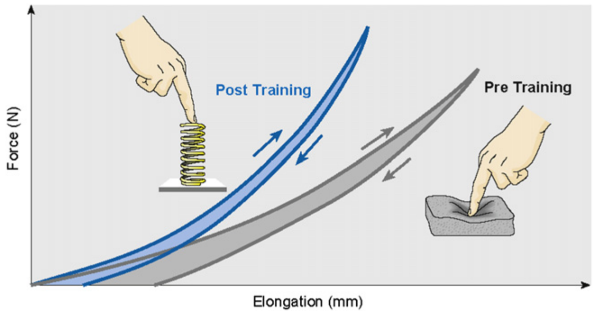

Figure 2 Increased elastic storage capacity. Regular oscillatory exercise, such as daily rapid running, induces a higher storage capacity in the tendinous tissues of rats, compared with their non-running peers. This is expressed in a more spring-like recoil movement as shown on the left. The area between the respective loading versus unloading curves represents the amount of 'hysteresis': the smaller hysteresis of the trained animals (yellow) 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 et al., 2006. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

The possibility of high-resolution ultrasound examination made it possible to discover similar orchestration of loading between muscle and fascia in human movement. Surprisingly, it has been found that the fasciae of humans 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. 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 classic form of energy transfer is still true — according to these recent measurements — for steady movements such as bicycling. Here, the muscle fibres actively change in length, while the tendons and aponeuroses scarcely grow longer. The fascial elements remain quite passive. This is in contrast to oscillatory movement with an elastic spring quality, in which the length of the muscle fibres changes little. Here, 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 swinging yo—yo (Fig. 3). It is this lengthening and shortening of the fascial elements that mostly 'produces' the actual movement (Fukunaga et al., 2002; Kawakami et al., 2002).

It is of interest that the elastic movement quality in young people is associated with a typical two-directional lattice arrangement of their fasciae, similar to a woman's stocking (Staubesand et al., 1997). In contrast, as we age and usually lose the springiness in our gait, the fascial architecture takes on a more haphazard and multidirectional fibre 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 (Fig. 4) (Jarvinen et al., 2002). The goal of the proposed fascia fascial training is therefore to stimulate fascial fibroblasts to lay down more youthful fibre architecture with a gazelle-like elastic storage capacity. This is done through movements that load the fascial tissues over multiple extension ranges while utilizing their elastic springiness (Fukashiro et al., 2006).

Stretching variations for myofascial health

Usually slow static stretching methods are distinguished from rapid dynamic stretches. Dynamic stretching may be

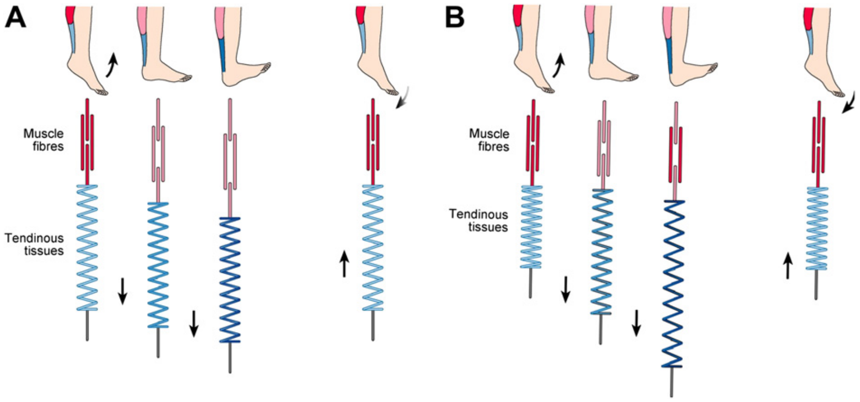

Figure 3 Length changes of fascial elements and muscle fibres in conventional muscle training (A) and in oscillatory movement with elastic recoil properties (B). The elastic tendinous (or fascial) elements are shown as springs, the myofibres as straight lines above. Note that during a conventional movement (A) 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).

familiar to many people as it was part of physical training in beginning and middle of the last century. During the last two or three decades, this 'bouncing' stretch was then assumed by most educators to be less beneficial, but the method's merits have been confirmed in recent 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 architecture of the connective tissue in that it becomes more elastic when correctly performed (Decoster et al., 2005). Indeed, when practiced regularly, static as well as dynamic stretching have shown to yield long term improvements in force, jump height, and speed (Shrier, 2004).

Different stretching styles seem to reach different fascial tissue components. Fig. 5 illustrates some of these different target tissues affected by various loading regimens. Classic 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 stretched and stimulated as well. However, little effect can be expected on extramuscular fasciae as well as on those intramuscular fascial fibres that are

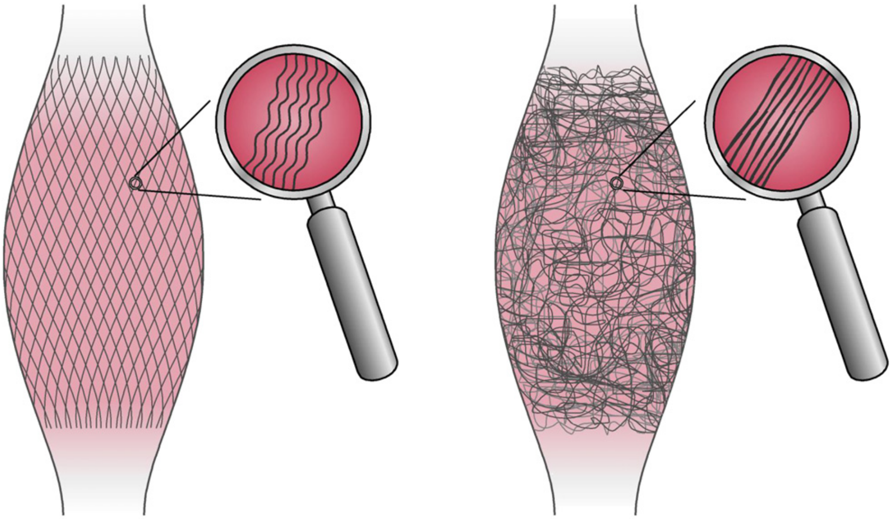

Figure 4 Collagen architecture responds to loading. Fasciae of young people (left image) express more often a clear two-directional (lattice) orientation of their collagen fibre network. In addition the individual collagen fibres show a stronger crimp formation. As evidenced by animal studies, application 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 (right image).

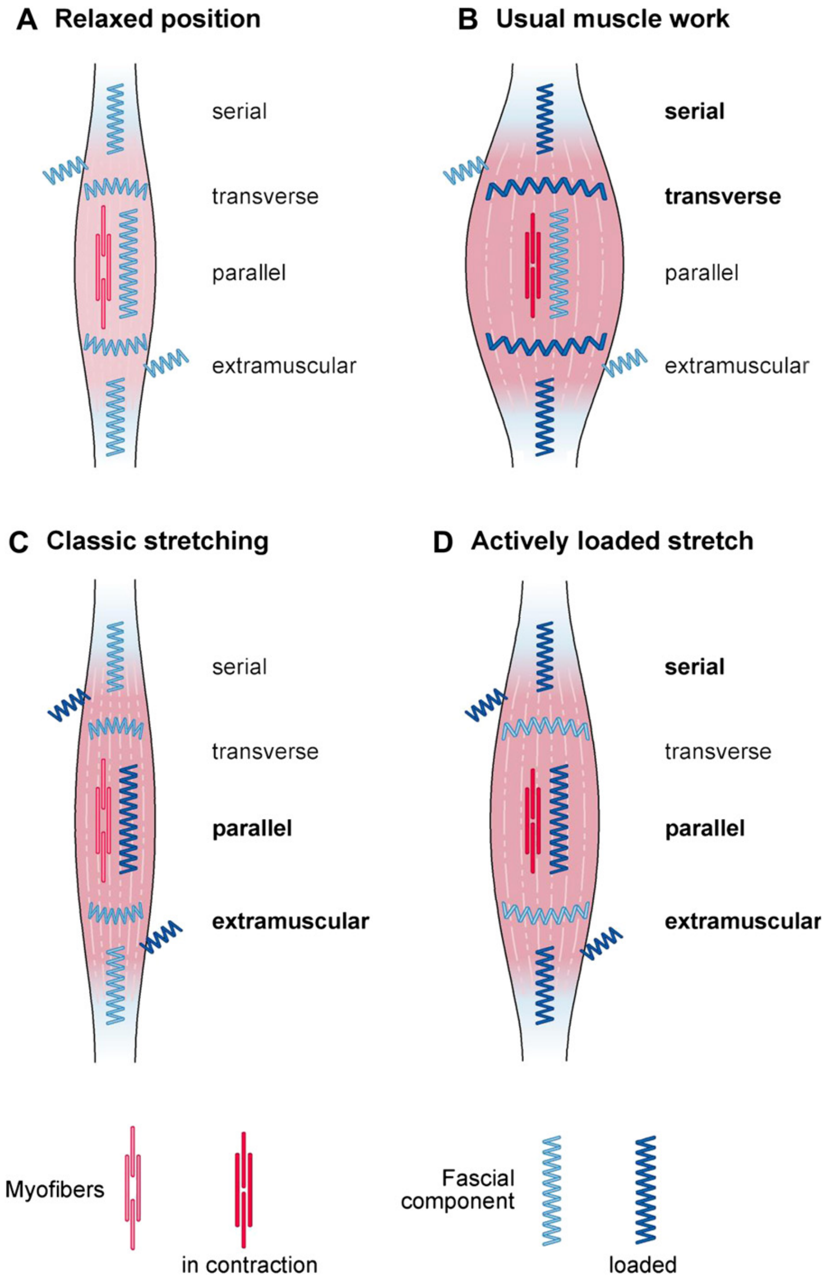

Figure 5 Loading of different fascial components. A) Relaxed position: The myofibers are relaxed and the muscle is at normal length. None of the fascial elements is being stretched. B) Usual muscle work: Myofibers contracted and muscle at normal length range. Fascial tissues are loaded which are either arranged in series with the myofibers or transverse to them. C) Classic stretching: Myofibers relaxed and muscle elongated. Fascial tissues are being stretched which are oriented parallel to the myofibers, as well as extramuscular connection. However, fascial tissues oriented in series with the myofibers are not sufficiently loaded, since most of the elongation in that serially arranged force chain is taken up by the relaxed myofibers. 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 therefore serves as a basic orientation only.

arranged in parallel to the active muscle fibres (Huijing, 1999).

On the other hand, classic Hatha yoga stretches, in which the extended muscle fibres are relaxed, will show little effect on those fascial tissues, which are arranged in series with the muscle fibres. The reason is that since the relaxed myofibers are much softer than their serially arranged tendinous extensions, they will 'swallow' most of the elongation (Jami, 1992). However, such slow and melting stretching promises to provide good stimulation for fascial tissues, which are hardly reached by classic muscle training, such as the extramuscular fasciae and the intramuscular fasciae oriented in parallel to the myofibers.

Finally, a dynamic muscular loading pattern in which the muscle is briefly activated in its lengthened position promises the most comprehensive stimulation of fascial tissues.

According to recent examinations of the collagen synthesis in cyclically loaded tendons, the resultant increase in collagen production tends to be largely independent of exercise volume (repetitions); meaning that only few repetitions are necessary to yield an optimum effect (Magnusson et al., 2010). The proposed fascia training therefore recommends soft elastic bounces in the end ranges of available motion.

In addition variation among different stretching styles is recommended, including slow passive stretches at different angles as well as more dynamic stretches, in order to foster easy shearing ability between physiologically distinct fascial layers and to prevent the tendency for limited movement range that usually goes along with aging (Beam et al., 2003). The reader is cordially invited to review the excellent study by Bertolucci (2011) of 'pandiculation'-like stretch behaviour in the animal kingdom, including his proposed practical recommendations for myofascial body self care of humans. While dynamic stretching may be a more effective warm-up practice before sports (McMillian et al., 2006), recent examinations suggests that slow static stretching can induce anti-inflammatory as well as analgesic effects in inflammatory tissue conditions (Corey at al., 2012).

Hydration and renewal

It is essential to realize that approximately two thirds of the volume of fascial tissues is made up by water. During application of mechanical load - whether in a stretching manner or via local compression - a significant amount of water is pushed out of the more stressed zones, similar to squeezing a sponge (Schleip et al., 2012a). With the release that follows, this area is again filled with new fluid, which comes from surrounding tissue as well as the local vascular network. The sponge-like connective tissue can lack adequate hydration at neglected places. Application of external loading to fascial tissues can result in a refreshed hydration of such places in the body (Chaitow, 2009). In healthy fascia, a large percentage of the extracellular water is in a state of bound water (as opposed to bulk water) where its behaviour can be characterized as that of a liquid crystal (Pollack, 2001). Much pathology - such as inflammatory conditions, edemae, or the increased accumulation of free radicals and other waste products — tends to go along with a shift towards a higher percentage of bulk water within the ground substance. Recent indications by Sommer and Zhu (2008) suggest that when local connective tissue gets squeezed like a sponge and subsequently rehydrated, some of the previous bulk water zones may then be replaced by bound water molecules, which could lead to a more healthy water constitution within the ground substance.

Fascia as a sensory organ

Fascia contains a rich supply of sensory nerves, including proprioceptive receptors, multimodal receptors and nociceptive nerve endings. Some fascial tissues such as the retinaculae contain a richer sensory innervation than other ones. Those tissues that have been found to contain a richer supply seem to be able detect slight angular direction changes in mechanical loading, whereas the less densely innervated tissues, such as the lacertus fibrosus (bicipital aponeurosis), seem to be specialized for a more unidirectional passive biomechanical force transmissions only (Stecco et al., 2007, 2008). When including intramuscular connective tissues, periosteum and superficial fascia as part of the body wide fascial net as outlined above, fascia can then be seen as one of our richest sensory organs. It is certainly our most important organ for proprioception (Schleip, 2003).

It is interesting to note that during the last decade the classic '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., 2005; Proske and Gandevia, 2009; Ianuzzi et al., 2011). On the contrary, proprioceptive nerve endings located in the more superficial layers are more optimally situated, as here even small angular joint movements lead to relatively distinct stretch or shearing motions. Recent findings indicate that the superficial fascial layers of the body are, in fact, much more densely populated with sensory nerve endings than connective tissues situated more internally (Benetazzo et al., 2011; Tesarz et al., 2011). In particular the transition zone between the fascia profunda and the subdermal loose connective tissue seems to have the highest sensorial innervation (Tesarz et al. 2011). This seems to be also the zone at which large sliding or shearing motions between fascial layers seem to occur during multi-articular extensional movements, provided that no pathological adhesions are present within this transitional zone (Goats and Keir, 1991).

A mutually antagonistic relationship between myofascial pain and proprioception has frequently been described. Expressions of that are the significantly diminished local proprioception in low back pain (Taimela et al., 1999) or the decreased pain threshold when the proprioceptive nerves are experimentally blocked (Lambertz et al., 2006). In addition it has been shown by Moseley et al. (2008) that an increase in local proprioception can significantly lower myofascial pain. Most likely the mutually inhibiting relationship between soft tissue pain and fascial proprioception is facilitated through the wide-dynamic-pain (WDR) neurons in the dorsal horn of the spinal cord (Sandkuehler et al., 1997). Interestingly the research by Moseley et al. (2008) also indicated, that therapeutically induced peripheral afferent input needs to be accompanied by a conscious attention of the patient in order to yield a long term antinociceptive effect.

Training principles

The following practical guidelines are suggested applications based on these general biomechanical and neurophysiological considerations. Note that given basic limitations of human anatomy and the long and diverse history of human movement explorations, none of the suggested movements will be completely 'new'. In fact, it was found that many aspects of known movement practices - like rhythmic gymnastic, modern dance, plyometrics, gyrokinesis, chi running, yoga or martial arts, just to name a few — contain elements which are very congruent with the following suggestions. However, these practices have often been inspired by an intuitive search for elegance, pleasure and beauty, and/or they were often linked with non-fascia related theoretical explanation concepts. The novel aspect of the proposed approach is therefore to selectively develop training suggestions, which specifically target an optimal renewal of the fascial net (rather than e.g. muscular tissues or cardiovascular conditioning) and which are directly linked with the above outlined specific insights from the rapidly growing field of fascia research.

Preparatory counter movement

This movement principle utilizes the catapult effect of fascial tissues. Before the actual movement is performed, one starts 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. 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 (Fig. 6). 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 — one activates the catapult capacity of the fascia through an active pre-tensioning of the fascia of the back. When swinging backwards and up from a forward bending position, the flexor 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 kinetic energy which is stored on the posterior side of the fascial net 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 of their back muscles, but rather on dynamic recoil action of the fascia, requires a focus on timing — much the same as when playing with a yo—yo or a swinging elastic pendulum. It is necessary to determine the ideal swing, which is apparent when the action is perceived as fluid and pleasurable.

The Ninja principle

The legendary Japanese warriors who reputedly moved as silently as cats and left no trace inspire this principle. 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 (Fig. 7). This goes along with the perception of a smooth and 'elegant' quality of movement. As an

Figure 6 Training example: The Flying Sword A) Tension the bow: The preparatory countermovement (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.

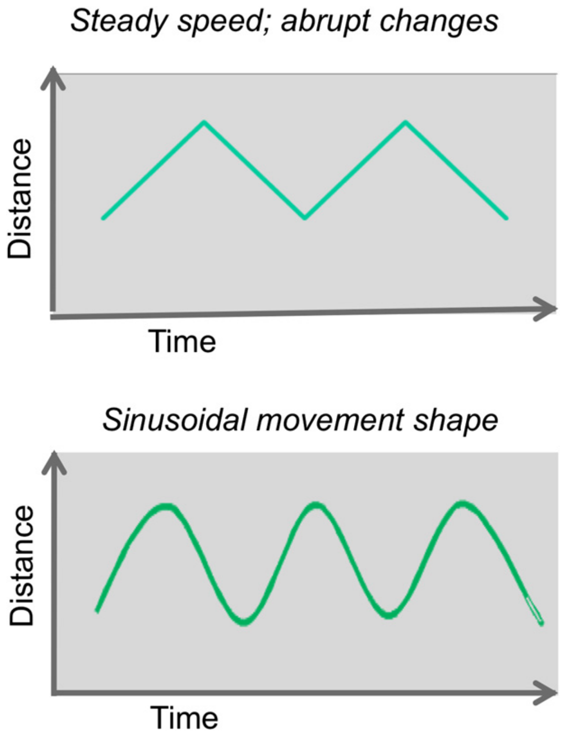

Figure 7 Movement shapes during jerky versus elegant direction turns. When directional turns (like moving a limb forward and back) are performed without proprioceptive refinement, they tend to include sudden turns at which tissues are frequently prone to injury due to the abrupt loading pattern (above). In contrast, when the same movements are conducted with an internal search for elegance, then a more sinusoidal movement change can be observed, characterized by gradual deceleration before the turning point and a subsequent gradual acceleration. In this pattern the loaded tissues are less prone to injuries, the movements appear as more graceful, and also less acoustic noise is created (e.g. during bouncing movements).

inspirational analogy for the more embodied' patient, one can refer to 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 (Fig. 8).

For more technically oriented patients future development of small accelerometer based feedback devices may be useful. Direction changes which are based on the Ninja principle will then be characterized by a more sinusoidal movement shape, rather than the sudden and jerky direction changes in a person who moves with less fluid elegance and who will be more likely to induce overload strain injuries during these exercises (Fig. 7).

Normal stairs become training equipment when they are used appropriately, employing gentle stepping. The suggested 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. Of course use of barefoot or barefoot-like plantar foot contact with the ground will be of advantage for this kind of 'stair dancing'.

Figure 8 Training example: Elastic Wall Bounces. Imitating the elastic bounces of a gazelle's soft bouncing movements is explored in standing and bouncing off a wall. Proper pretension in the whole body will avoid any collapsing into a 'banana posture'. It's imperative to make the least amount of sound and avoid any abrupt movement. A progression into further load increases can occur only with the mastery of these qualities. Stronger individuals can eventually explore e.g. bouncing off a table or windowsill instead of a wall. The person shown should not yet be permitted to progress to higher loads, as his neck and shoulder region already show slight compression.

Slow and dynamic stretching

Rather than a motionless waiting in a static stretch position, a more flowing stretch is suggested. It is recommended that both fast as well as more rapid but fluid stretching modalities be utilized. Before any rapid movements are used, the myofascial tissues should first be warmed up, and jerking or abrupt movements should be avoided.

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 classic 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 (Fig. 9).

In order to stimulate the more serially arranged tendinous and aponeurotic tissues, more dynamically swinging stretch movements are recommended, similar to the elegant and fluid extensional movements of rhythmic gymnasts. The same tissues can also be targeted by muscular activation (e.g. against resistance) in a lengthened position, similar to how a cat sometimes enjoys pulling his front claws towards the trunk when stretching. And finally so-called 'mini-bounces' can be employed as soft and playful explorations in the lengthened stretch position.

Dynamic, fast stretching can be combined with a preparatory countermovement, as was previously described. For example, when stretching the hip flexors, a brief backward movement could be introduced before dynamically lengthening and stretching forwards.

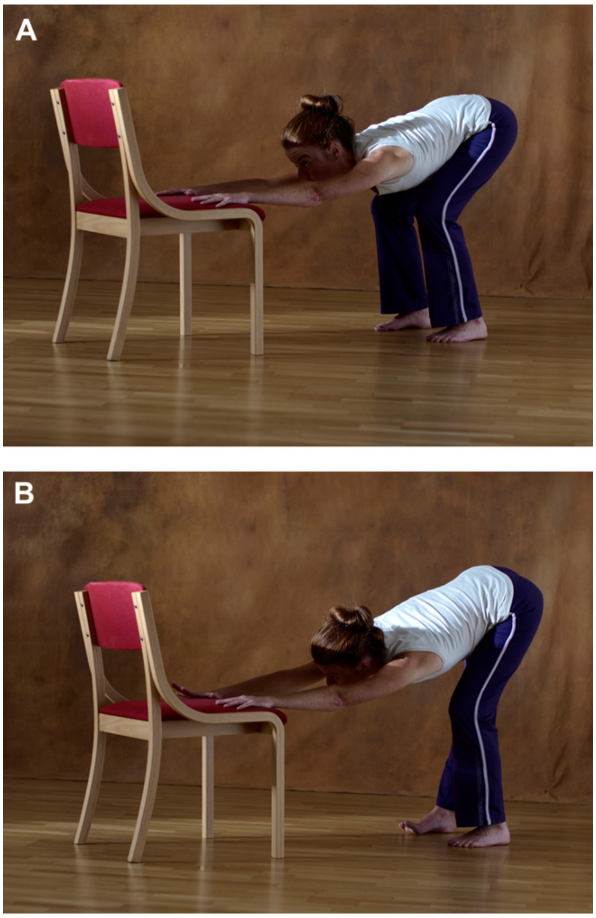

Figure 9 Training example: The Big Cat Stretch. A) This is a slow stretching movement of the long posterior chain, from the finger tips to the sit bones, from the coccyx to the top of the head and to the heels. The movement goes in opposing directions at the same time — think of a cat stretching its 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 one rotates and lengthens the pelvis or chest towards one 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. Afterwards, note the feeling of increased length.

Proprioceptive refinement

It is essential that the importance of fascial proprioception is clearly explained and repeatedly emphasized during the training process. For proper motivation both rational explanations as well as limbic-affective components should be utilized. As an example the case of Ian Waterman can be used, a man repeatedly mentioned in scientific literature. This impressive man contracted a viral infection at the age of 19, which resulted in a so-called 'sensory neuropathy' below his neck. In this rare pathology, the sensory peripheral nerves, which provide the somatomotor cortex with information about the movements of the body, are destroyed, while the motor nerves remain completely intact. This meant that Mr. Waterman could move, but he could not 'feel' his movements. After some time he 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, which is able to stand unaided, as well as being able to walk (Cole, 1995).

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://bbc-horizon-1998-the-man-who-lost-his-7812922.cooga.net). Springy, swinging movements are possible for him only with obvious and jerky changes in direction.

If doing a 'classic' 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.

Congruently, in the proposed fascia training 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 cortical transfer of sensations from movements which are repetitive and which the cerebellum can predict via feed-forward anticipation (Schleip, 2003). To prevent such a sensorial 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, the inclusion of 'fascial refinement' elements are recommended, in which varying 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, as well as large macro-movements involving the whole body. To this end, it may then be not uncommon to place the body into unfamiliar positions while working with the awareness of gravity, or possibly through exploring the weight of a training partner.

Exploratory 'micro-movements' with an amplitude below an inch (~2.5 cms.) can be incorporated as described in the Continuum Movement work of Conrad (2007). Using interoceptive stretch sensations as a guideline, it may be possible that postoperative or other fascial adhesions could be partly loosened by the careful utilization of such micro-movements when performed close to the available end-range positions (Bove and Chapelle, 2012). In addition, such tiny and specific local movements can be used to bring proprioceptive attention and refinement to perceptually neglected areas of the body whose condition Hanna (1998) had described with the term 'sensory-motor amnesia' (Fig. 10).

Squeezing and rehydrating the sponge

The use of special foam rollers or similar materials can be useful for inducing localized sponge-like temporary tissue dehydration with resultant renewed hydration. However, the firmness of the roller and application of the body weight needs to be individually monitored. If properly applied and including very slow and finely tuned directional changes only, the tissue forces and potential benefits could be similar to those of manual myofascial release treatments (Chaudhry et al., 2008). In addition, the localized tissue stimulation can serve to stimulate and fine-tune possibly inhibited or desensitized fascial proprioceptors in more hidden tissue locations (Fig. 11).

For motivational and explanatory purposes the excellent video material of Guimbertau et al. (2010) has proven helpful for fostering an understanding of the viscous plasticity and adaptive elasticity of the water-filled fascia. The resulting perception of the liquid architecture of the fascial net has proven to be especially effective when incorporated into the slow dynamic stretching and fascial refinement work.

Figure 10 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. The tensional fascial proprioception is activated through creative changes in muscular activations patterns. This function 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.

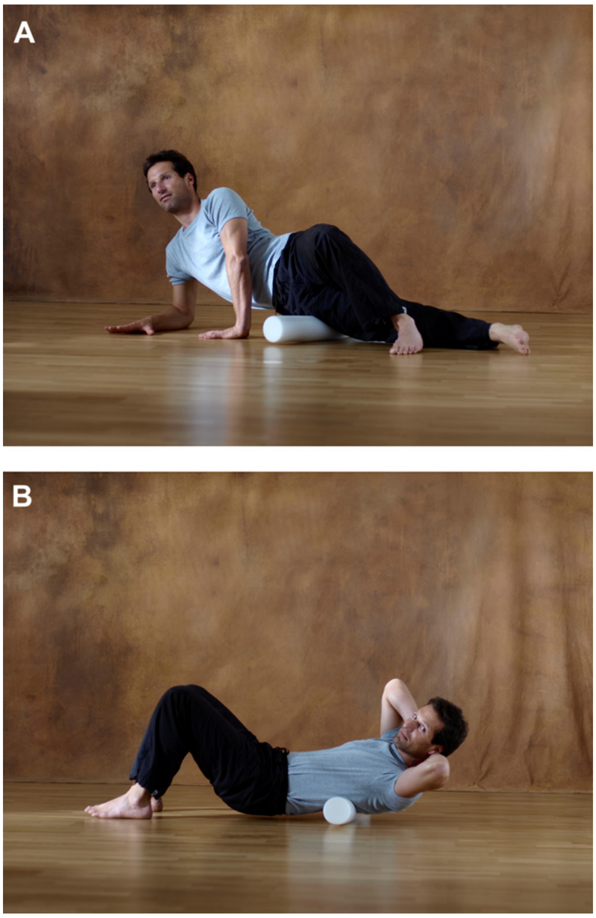

Figure 11 Training example: Fascial Release. The use of particular foam rollers may allow the application of localized tissue stimulations with similar forces and possibly similar benefits as in a manual myofascial release session. However the stiffness of the roller and application of the body weight needs to be adjusted and monitored for each person. To foster sponge-like tissue dehydration with subsequent renewed local hydration, only slow motion like subtle changes in the applied forces and vectors are recommended.

Proper timing of the duration of individual loading and release phases is very important. As part of modern running training, it is now often recommended to frequently interrupt 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 and their elastic and springy resilience slowly decreases. Short walking pauses — with a recommended duration between one and 3 min - then serve to partly rehydrate the tissue, as it is given a chance to take up nourishing fluid. For an average beginning runner such rehydration breaks may be best every 10 min, while more advanced runners with a 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. For well trained runners with a less refined sensuous kinaesthetic proprioception the additional use of accelerometer driven feedback devices (as described in the first section of this paper) may be useful indicators for the appropriate timing of such walking breaks.

This cyclic training, with periods of more intense effort interspersed with purposeful breaks, can subsequently be 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. The resulting understanding of fascial renewal dynamics together with the refined proprioception should then carry over to an increased 'fascial embodiment' in everyday life.

Sustainability: the power of a thousand tiny steps

An additional and important aspect that needs to be understood by the trainee is the concept of the slow and long-term renewal of the fascial network. It is explained that 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 therefore 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 (Fig. 12) (Kjaer et al., 2009).

The intention of the proposed fascia oriented training is to influence the matrix renewal via specific training activities which may, after 6—24 months, result in a more injury-resistant and resilient 'silk-like body suit' which is not only strong but also allows for a smoothly gliding joint mobility over wide angular ranges. Proper nutrition and life style that fosters an anti-inflammatory matrix milieu with sufficient presence of growth hormones — such as are expressed during deep sleep and after appropriately challenging muscular or cardiovascular exercise — are additional factors that influence the positive matrix renewal in response to.

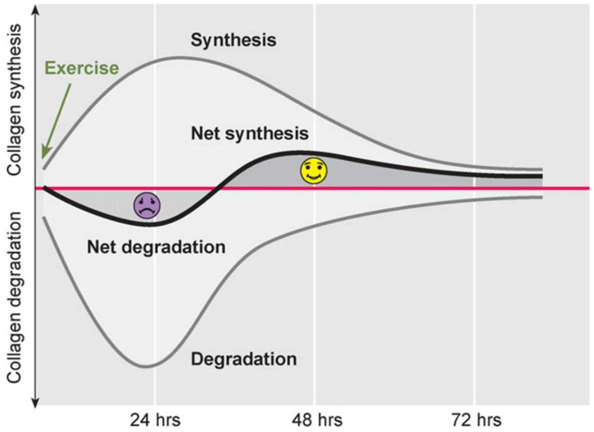

Figure 12 Collagen turnover after exercise. The upper curve shows collagen synthesis in tendons is increasing after exercise. However, the stimulated fibroblasts also increase their rate of collagen degradation. Interestingly, during the first 1—2 days following exercise, collagen degradation over- weights the collagen synthesis; whereas afterwards this situation is reversed. To increase tendon strength, the proposed fascial fitness training therefore suggests appropriate tissue stimulation 1—2 times per week only. Illustration modified after Magnusson et al., 2010.

It is 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 6 months and 2 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 knowledge of fascial properties can go a long way in convincing them to train their connective tissues.

Of course, these fascia oriented training suggestions should not replace muscular strength work, cardiovascular training and coordination exercises; instead, they should be thought of as useful addition to a comprehensive training program.

Conflicts of interest

There were no identified conflicts of interest.

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