REVIEWING STRETCHING
AND
RECENT ADVANCES IN
SPORTS PHYSIOTHERAPY

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(In the early sixties, the author studied physiotherapy in Cologne (Germany). Resident in Sweden since 1969. From 1975 – 1995 he was sports physiotherapist for an elite football club in Hässleholm. Together with Dr Jan Ekstrand (at present Professor in Linköping), they introduced, for the first time in Sweden, stretching in a warming up programme.(31) As the validity of stretching is being questioned, the author looks forward to what comes next. He was even a former member of IMF (Swedish Society of Sports Medicine) from 1977 – 2006.)

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Abstract:

Sports physiotherapy is rather new in some European countries. Sport rehabilitation teams recruited physiotherapists, not only to treat, but also to actively take part in the research of injury preventions. The development has been rapid. Mid seventies, stretching was introduced as a preventive measure. Its popularity became immense and the application became random. Stretching programmes of that time emphasized in terms of a muscles origin and insertion. And yet, according to Bobath "the cortex knows nothing of muscles, it knows only of movement patterns" (59) so, stretching should be applied to several joints simultaneously. Several, German anatomists, in the 30's (32, 34), "described how chains of muscles that are linked together, often in loops, influence the quality of the entire movement."(90) In 1989, Bergmark (77) published his work, dividing the thoracocolumbar muscles into global and local groups. Based on it, Hodges et al (58) introduced trunk stability exercises. Their research also showed that trunk muscles are activated before any movement of the extremities."(90)
In the present day, emphasis is laid on functional stability training, which is based on the principles of the kinetic chain (15, 16) Proximal discrepancies can lead to distal deficiencies. Analysing athletic injuries require new ways of thinking.

“ The more we know about a muscle, the less we understand it and it looks as if we soon know everything and understand nothing” – Szent-Gyorgyi (Nobel laureate on Muscle Physiology) –Quoted by Prof. David Ottoson in Nervsystemets fysiologi. (35)

A variety of training methods, have been used by both physiotherapists and sports and PE- teachers. In the mid-seventies , almost simultaneously with the jogging mode, stretching became very popular. But, stretching as an intervention has been used by physiotherapists, in their day to day work since a long time. (1) Not to forget ancient cultures such as in India (Hatha-yoga) or the Chinese (cong fu) “used ritualistic positions and movements to relief pain.”(3) Both, Cong fu and Hatha Yoga develop supple joints.

Books on Therapeutic Exercises –old or new, have a chapter on stretching as a means to attain full Range of Motion. (1,2,3,4,5). And stretching as an intervention in day to day physiotherapy is well documented(6, 7, 8, 9, 10) But, of late, stretching as a mode to reduce soft tissue injuries in elite athletics has been questioned. (50,94) And quoting from a recent article, ”*Despite hamstring stretching being commonly advocated for injury prevention, the inclusion of a flexibility program has not been shown to reduce the incidence of hamstring strain injuries.”(78)*

Taking into account that stretching is primarily used to retain full range of motion, stretching one muscle at time, may not be sufficient. Just as in all athletic movements, muscles work in chains, and **“*No one muscle works alone” each movement is a sum of patterns and it is only movement patterns that are registered in the brain,*** further citing Bobath : **“the cortex knows nothing of muscles, it knows only of movement patterns.”(59)**

So, stretching programs should not emphasize single muscle stretching. Particularly not in sports. A muscles action does not start and finish with a muscle’s “origin and insertion.” Muscles are a part of a movement pattern. Research and hard work follow the trend, and we live in an ever changing world. “Change, alone is permanent.”(134) A method valid today, may not have the same enthusiastic appeal when it is overruled by a new method. But, stretching cannot be completely eliminated from a physiotherapist’s repertoire, as long as there is muscle length and joint range of motion deficiency, *stretching in one form or the other*, will be required to regain its physiological length. If a joint does not have its physiological length (range of motion), then it is apt to soft tissue injuries. (24, 60)

Regaining range of motion, in sports requires a new thinking. And recent research (53, 70,136) shows that eccentric training and stability training is sufficient to over come and prevent joint lesions and soft tissue injuries. Yet, patients with loss of range of motion will require stretching as a means of intervention in the day to day clinical physiotherapy.

Long before, stretching became popular to the sports world, dr. Janet Travell, who became famous because she was John F Kennedy personal doctor, introduced a method, in the late fifties, to treat “Myofascial Pain syndrome,” popularly known as “Referred Pain” which is

associated with “trigger points” that are localised in any skeletal muscle of the body, and that these lesions were treated with injections, cryotherapy and stretching. (99)

Throughout the last fifty years or more, wave after wave of training methods dominate for a time and then return to oblivion. Modern research requires quality and evidence, so methods come and go. Even if some training methods are particularly valid only to sports and some other methods only applicable to physiotherapy, many of the methods have been of value to both professions.

In the forties, Sweden had two world renowned runners, in Gunder Hägg and Arne Andersson,their trainings method was named as **“Fartlek”** (Broadly translated -“speed-play” (13, 20) in the fifties, Hettinger and Mueller (18) introduced a strength trainings method known as **“Isometric training”**. It was the short isometric contractions of six seconds, which even house wives could train at home. Today, it is widely used in physiotherapy. And, as everything new, it had a great appeal to the common people.” At one time, it appeared to challenge the popular methods of **progressive resistance exercises, (P.R.E.)** as introduced by Delorme & Watkins soon after the Second World War”. (3) “This method, which is called Progressive Resistance Exercises (P.R.E.), was adopted more rapidly and widely than any other gymnastic proposal in this century, except for early ambulation.”(3) Based on lifting very heavy load, **one rep max** is the amount of weight one can lift for a given one time only, previously known as one RM (Repetitive Maximum).Later, methods like Zinovieff (Oxford) and MacQueen have derived from P.R.E. (69)

Whereas another method which is only used in physiotherapy and particularly popular in Scandinavian is the Holten Method , also known as **Medical Exercise Therapy- (M.E.T)** or **Medical Training Therapy- (M.T.T.)** . Weight exercises are based on 60-80% of one RM, which are then used in a series of 7 to 9 stationary units (circuit training) using repetitions of 3 times 30 resulting in a total of 500 -1000 repetitions.(20), per session. The Holten method encourages patients to train independently and is progressive. From low repetitions to high repetitions and from unloaded, or with very little load to extreme load as in the “Holten pyramid” (25) All depending on the patients capacity and ability. The exercises are also closely related to the Norwegian Manuel Therapy methods as developed by Kaltenborn. (127,128).

The post war period also saw training methods like **circuit training** and **interval training**. And in the mid-seventies suddenly the world was engulfed in a **jogging** wave and with it **stretching** became an intervention module in the recreational world. (12)In the eighties, **aerobic** training and gyms became very popular, and they grew like mushrooms all over the country. The nineties saw a revival of **yoga-asana**, (an age old method of stretching exercises from India). But also **Pilates**. Using big balls, of 55 cm or more in diameter, the Swiss ball or physioball that was introduced by Susan Klein-Vogelbach (91, 92), now became popular. These balls were precided by the so called Bobathballs of 90 cm or more that were used in paediatric rehabilitation, to enhance **proximal stability** and **Postural** and M**otor Control**. (59).

The elite athletes found a new training method, which came from the Eastern Europe, and was called **plyometrics**, (118,119,120) which is based on “stretch-shortening cycle” or the rubber band effect. Plyometric, also found its way in the rehabilitation programs. This also led to **eccentric** muscle training became popular. Physiotherapists began to treat soft tissue injuries like, Tedinosis with heavy-load eccentric training (70, 71).

With the beginning of the new century**,** a new trend broke through, known as **Neuro-muscular training** and with it followed **Postural control and core stability** training.

Dominance and decline of stretching :

Research during the last fifty years or so, was not only for the benefit of the elite, but even the recreational sportsmen, who have profited from the advances made in sports medicine and

in particular sports physiotherapy. From the beginning of the seventies, to the contemporary day, there has been an explosion in the increase of the number of participants in various sports activities and physical fitness programs, which was simultaneously followed by an unavoidable increase in the number of soft tissue injuries. Interest in and research on developing methods to reduce sports related injuries and developing equipment and training methods have been the prime concerns of this era.

As mentioned earlier, the application of **stretching in its various forms (passive, active, ballistic, static and PNF)** is to attain full Range of Motion (ROM) In sports, ballistic stretching was more common, which later was replaced by static stretching.

The measurement of a particular joint from the flexed to the extended position is known as the Range of Motion for that particular joint. If the physiological Range of Motion is decreased then it will require either passive or active stretching to regain its physiological range of motion. For example after removal of a cast, that particular joint will lack full range of motion. Therefore, stretching has long been an asset for physiotherapists.

Text-books on posture and body alignment, (1) which was first printed in the late fifties, advocated the use of stretching;"*when range of motion is limited*."(1) Almost during the same time, in the early fifties, Dr.Kabat, a neurophysiologist, and together with a physiotherapist, Margaret Knott, developed a treatment method known today as "Proprioceptive Neuromuscular Facilitation,"(3, 12,13,), popularly known as PNF. Stretching techniques like"Hold-relax; Contract-relax; Hold relax and contract relax with antagonist contraction" (3, 12, 13, 14, 17, 23, 90) are derived from this method, and is popularly used by physiotherapists.

In the recreational sports world stretching became popular in the mid-seventies simultaneously as the general population began with jogging. With it came the wear and tear syndromes of the soft tissues and using routinely stretching became more and more an answer to "all problems." Women's magazines led by health prophets, who without any medical backgrounds took to stretching, irrespective of whether they required or not. Movie stars produced videos and DVDs and suddenly "stretching was solving all health problems."

But for the clinicians a new method was introduced. In the mid-seventies, Professor Vladimir Janda, of Charles university, Prague (22,23,**90**), left his home town, and toured Europe to hold lectures, on his theory that there is an imbalance in certain muscle groups, one group is prone to tightness and the other group prone to inhibition. The causes for muscle imbalance were myriad, and reasons can vary from sedentary life to one sided work –as in sports or as in industry. Quoting Janda,"Muscles prone to weakness are predominantly phasic in function; they atrophy readily, they are primarily *single jointed muscles*, and they associated with extensor reflexes. Muscles prone to tightness have a predominantly postural function, resist atrophy, are primarily *double-jointed muscles*, and are associated with flexor reflexes."(7)

"Stretching is a general term used to describe any therapeutic manoeuvre designed to increase mobility of soft tissues and subsequently improve ROM (Range of Motion) by elongating (lengthening) structures that have become hypomobile over time.(2)

What is then hypomobility?

Hypomobility: is decreased range of motion to a joint or body part either due to dysfunction, disease, injury, or extreme load, which will result in abnormal shortening of that joint. Factors that may cause such an adaptive shortening of the soft tissues include (2):

1 – Prolonged immobilization of a body segment.
2 – Sedentary lifestyle.
3 – Postural malalignment and muscle imbalances.
4 – Impaired muscle performance (weakness) associated with an array of Musculoskeletal or neuromuscular disorders.
5 – Tissue trauma resulting in inflammation and pain.

6 – Congenital or acquired deformities.
"Any factor that impairs mobility, that is, causes restrictions of soft tissues, can also impair muscular performance" (2)
Thus, any of the above criteria will show a decreased range of motion. When motion is restricted or the mobility of a joint is decreased, we refer to it as hypomobility (2) "There are many factors that can contribute to hypomobility and stiffness of soft tissue."(2) An altered range of motion can vary from "mild muscle shortening to irreversible contractures" (2)
There are several contributing factors to restricted motion to one or several joints.
Prolonged immobilization, like in" fractures, osteotomy, soft tissue trauma or repair" (2) belong to the extrinsic form, and require cast or splints or even skeletal traction. (2)
The intrinsic factors may be due to "micro and macrotrauma as also degenerative diseases. Joint trauma or disease. Myositis, tendonitis, fasciitis, burns and skin grafts, scleroderma, Osteophytes, ankylosis, surgical fusion and peripheral lymphedema. (2)
Postural malalignment either congenital or acquired can result in Scoliosis or Kyphosis. (2)
Paralysis, tonal abnormalities and muscle imbalances acquired through Neuromuscular disorders and diseases.(2) CNS or PNS dysfunction leading to spasticity, rigidity, faccidity, weakness, or muscle guarding spasm. (2) Is also known as "defence musculaire," can lead to muscle imbalance. Last, but not the least." Sedentary lifestyle and habitual faulty or asymmetric postures (2), which are acquired due to "confinement to bed or a wheel chair; prolonged positioning associated with occupation or work environment."(2) (See fig.4) As also seen in, overuse syndromes of wear and tear in sports.

When is stretching indicated?

1 - When Range of Motion is limited because of soft tissue lesion as in scar tissue, adhesions and contractures.
2 – When a muscle is required to be lengthened. Or as Janda (22, 23,24 and 90) proposes single joint muscles, are phasic muscles and tend to atrophy and requires *strengthening*, whereas the postural muscles are generally two joints muscles and tend to tightness and require *stretching*.
3 –The use of stretching before and after a vigorous trainings program, as also in fitness programs. (2)
The different types of Stretching are dividing into five groups
.a) - Passive stretching as applied by the therapist to the patient.
b) - Continuous mechanical movement to treat contractures
c) Hold and Relax, a PNF Proprioceptive Neuromuscular Facilitation technique (3, 4, 14)
d) Static stretching, originally used in Hatha Yoga (19) and perhaps the most popular method applied today.
e) Ballistic, stretching, a form used previously in athletics. and comparing it with the static stretching, found that neither form was superior to the other, but that the static form was less prone to injuries. (19)
f) With the advent of elastic rubber bands a new and popular form of stretching was developed. Using multi joints and in combination eccentric strength and stretch with elastic resistance to increase range of motion (7)
As such, most hypomobile joints require stretching. But what is then hypermobility?
Hypermobility is "**easy to spot and easy to miss" (Fig.1) .**When, hypermobility is manifest on several joints; it can be a cause of illness and requires further investigation. Hypermobility in one joint is not uncommon, and is popularly called joint laxity, and can lead to that joints pathology. In athletics, particular joints used frequently and requiring excessively rotation as in the tennis serve, swimming or the cricket bowler will develop hypermobility of that joint.
Very often in spinal pain, one joint may be more mobile than another (Kaltenborn). Carter and Wilkinson first described joint laxity in 1964, in congenital hip dislocations. (74) But it

was Beighton and later his co-workers, Grahame and Kerr that established hypermobility as a syndrome. (73)

Common ranges of motion (ROM) tests used in the clinics are sufficient to provide information about the status of hyper mobility in a patient. Simple tests, like the high arm cross or touching the hands behind the back are sufficient to evaluate the shoulder joint, as suggested by Landa. (90) But for a complete test on hypermobility we prefer to use the Beighton test (fig 1) as described here below.

. **Hypermobility** is **"easy to spot and easy to miss"**. One of the first rules of stretching is never to prescribe stretching to a hypermobile person. **Hypermobility is not an illness. Up to 10 to 15% of normal children can have one or more hypermobile joints without having any other pathological symptoms.** "If excessive range of movement is controlled adequately by muscles – as in ballet dancers (gymnasts or circus acrobatics) – the joint will be symptomless"

But, joint laxity or hypermobility can be symptom in various disorders like Ehler-Danlos syndrome* or Loeys-Dietz syndrome (73) only to name a few. To screen hypermobility, one should use the nine point **Beighton** Score..(73).

"The ability to:

	Right	Left
1 Actively hands flat on the floor Without bending the knees	1 (one point)	
2 Passively hyperextend the elbow To more than 10 degrees	1	1
3. Passively hyperextend the knee to To more than 10 degrees.	1	1
4 Passively appose the thumb to the Volar aspect of the forearm	1	1
5 Passively dorsiflex the fifth Metacarpalphalangeal joint to 90deg	1	1

One point may be gained for each side for manoeuvres 2-5 so that the hypermobility score will have a maximum of 9 points if all are positive.

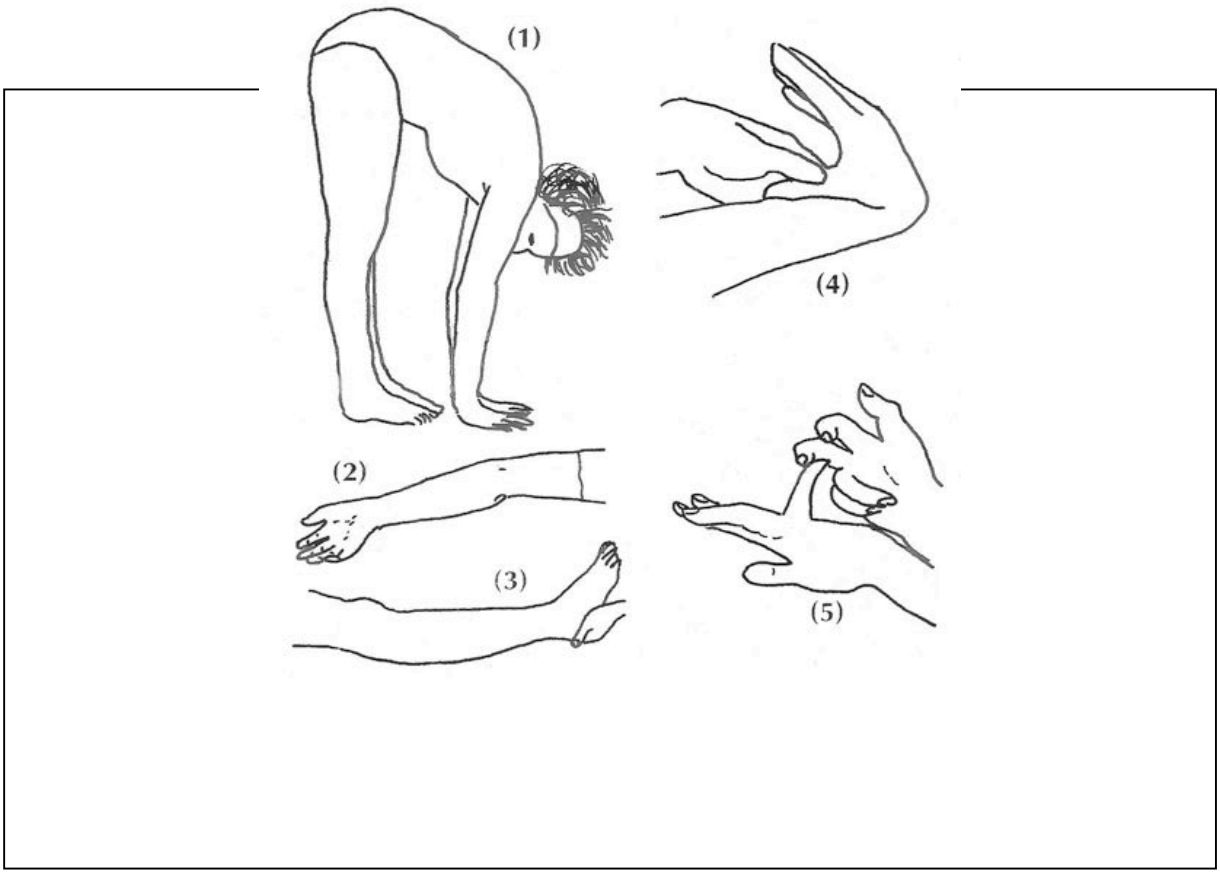

Fig.1 - Illustrating the Breighton score of the Hypermobile syndrome.
(Kind permission from "FYSIO", Nyhetsbrevet för sjukgymnaster, www.fysio.us)

Inadequate results of muscle stretching; to stretch or not to stretch, with special references to Hamstrings and calf muscles.

A-**Hamstring Muscles**

According to Sahrmann, (60) numerous articles have been written describing the best methods of stretching muscles. Most of these studies are on the hamstring muscles. Such research on the hamstrings can be found in the following articles (37, 40, 43, 44, and 47). Sahrmann also points out that if synergies to one muscle are dominant, that muscle will tend to overuse and strain, as is the case with the hamstring muscles. "*The hamstring muscles, acting as hip extensors and knee flexors, are particularly active during sports that involve running. The hamstring muscles are extremely susceptible to an overuse syndrome when they are dominant because of inadequate participation of the abdominal, gluteus maximus, or even rectus femoris muscles, as well as the lateral rotators of the hip."(60)* A weak synergists will result in excessive demand on other synergists resulting in muscle strain. *"The non-dominant synergist should be tested for weakness, and movement pattern should be carefully observed."(60)*

Donatelli, (15) on the other hand writes: **"***hamstrings strains result from weakness of the CORE hip abductors, extensors and rotators and CORE trunk muscles". "Dysfunction of any one of the joints within the lower kinetic chain linkage system may result from muscle imbalances, joint restrictions and inadequate rehabilitation of previous injuries***."**

Individuals sitting long periods in an extreme rounding of the lower back, (Fig.4) will acquire a pathological kyphosis of the lumbar spine, which evidently will over-stretch the thoraco-lumbar fascia and the gluteal muscles, resulting in weakening of these muscles. (90) The hamstrings with its origin in the pelvis will also be affected. An earlier method of just stretching one muscle at a time is not sufficient. Muscles working in a chain require more attention. Many of the hamstring stretch that was popular did not necessarily

stretch both ends of that muscle. Putting a foot on a stool or block and leaning forward, would surely stretch the distal parts of the hamstrings, but not the area around the insertion into the pelvis.(40,43,55) Stretching the Quadriceps (Rectus femoris), by just bending the lower leg backwards is insufficient. Both the Hamstrings and the Rectus femoris have their origins attached to the pelvis, together with several other muscles of the hip. Proximal pelvis stabilisation is a prerequisite to stretch the muscles of the upper leg. That is why, such stretching is inadequate. One of the most disabling injuries to the hamstrings is the avulsion fractures to the proximal insertion into os pubis. (37) Hamstrings stretching should incorporate the muscles around the pelvis. These muscles, around the hip have an inhibitory effect on the upper leg muscles (17) The hamstrings testing in the usual straight leg position is inadequate. Therefore testing the hamstrings, and its synergists, by moving the *straight leg in an arch* from hip abduction in a full pathway to hip adduction while the knee is kept straight. (25) Likewise the Rectus femoris muscle should be tested in the prone position, together with the hip flexors (Iliopsoas) as Evjenth et al recommended. (17) Using the "Thomas test"; the patient lying at the end of a treatment table, one leg flexed towards the chest. "A tight iliopsoas will restrict extension of the femur. A tight rectus will restrict knee flexion" (25) in the same position, the muscle lengths of two joint hip adductors and tensor fascia lata can be tested. (25)

B-**Calf muscles**

Another, muscle group, researchers have concentrated upon, are the calf muscles. (38, 39, 46, 56) This muscle group, previously known as "Triceps Surae", consists of the three muscles: Gastrocnemius, Soleus and Plantaris. Recent American books on physical therapy literature, (15, 16, and 90) substitute it with the name "**gastrcoc-soleus muscle**." The gastroc-soleus muscle, has a common tendon known as Achilles tendon and has long been a scourse of clinical investigation. Way back in the thirties, Benninghoff -1890-1953, found that (see page 298 in 34) afro-American athletes had "anatomical differences to be the reason of "black" dominance in jumping and short distance running (speed) events. (Fig.2).

Fig. 2 – Observe calf muscle length between the first two athletes. In the 1930's Benninghoff (34) wrote about "anatomical differences" in the "Black" athletes for their dominance in jumping and short distance running. Photo kind permission Bildbyrå – Hässleholm.

Running is the basis of most sports events. As such, the gastroc-soleus group is put to enormous overuse strain. Here are some examples from the same source: (112)

*"A 70kg runner at 1175 steps per mile absorbs at least 220 tons of force on each foot per mile."(112)
* "A long distance runner who runs 100 miles per week plants each foot about 3 million times a year."(112)
* "Monotonous, asymmetric and specialized, such as running only, is a great factor for chronic tendon injuries."(112)
* "Fatigued muscles have a decreased ability to absorb repetitive shock or stress and may result in overuse injuries" (112).
Similar overuse strain can also be seen in elite athletes. In the Swedish football league (soccer), players are absorbing 2, 5 millions steps per season, and run around 3000 km per season! (Page 121 in100). And in countries like Germany, England, Italy or Spain, the number of football matches per season is much higher. Such overload and overuse will certainly lead to wear and tear injuries to the soft tissues, which definitely lead to an imbalance of length and strength of these muscles. As running is the basis of most athletic events, the calf muscles and its tendon are put to extreme load. Research from Finland demonstrates the amount of load on this particular muscles group. Komi, Fukashiro and Järvinen (93), measured in vivo, the load on the Achilles tendon, while running at a pace of 6m/s, to be equivalent to 12, 5 times body weight. Thus a person weighing 80kg could have a tonne load on this tendon! Repetitive motion will lead muscle length and strength disbalance. Detecting muscle weakness is a prerequisite. It has been shown that dynamic functional training is superior to static stretching, especially when it comes to the calf muscle group. Quoting Donatelli (15)
"Improving gastrosoleus (calf muscles) flexibility is particularly difficult due to the shortening influence of the muscle tendon unit during sleeping hours when the foot is in end range of plantar flexion." *(pp 149 in 15).* No wonder patients suffering from plantar fasciitis or Achilles tendinopathies have difficulties to take the first few steps after sleep.
Youdas et al (61) reported on the effects of a 6-week program of static calf musculature stretching with 101 adults. A 6-week once-per-day static stretching regimen for up to 2 minutes was not sufficient to increase active dorsiflexion range of motion in this group. Functional gastrosoleus stretching exercises include dynamic movement and neuromuscular training into the direction of desired motion. Ryerson and Levit (62) describe movement reeducation training to stimulate firing patterns of the foot and the ankle with weight shift and foot posturing strategies for neuromuscular reeducation."(15)
Post injury rehabilitation that does not take into account range of motion is poor rehabilitation. Especially minor, successive ankle sprain injuries can be a latent factor for loss of range of motion, and indirectly affecting the tendon of the calf muscle. The gastrocnemius muscle is a typical two-joint muscle. Its prime function is the plantarflexion of the foot, but plays a vital role as synergist to the quadriceps muscle in the full extension of the knee. So loss of rage of motion to one joint can have negative effect to the knee joint. Citing, Janda et al (7) "Muscles prone to tightness have a predominant postural function, resist atrophy, are primarily double-joint muscles and are associated with flexor reflexes." Postural muscles are generally older in the phylogenies. (23)
The usual standing calf muscle stretching is inadequate, because of inadequate range of motion. To stretch the calf muscles adequately, one must stands on toes on a block and the heels should permitted to go under the level of the forefoot. As advocated in eccentric training of the calf muscles. It has been noted that "heavy load eccentric training" to be superior, particularly in the treatment of tendinopathies (80) of the Achilles tendon. (70) Yet, calf muscle stretching to relief persons suffering from nocturnal leg cramps is not new. (56).

In a very recent report, published in the Scandinavian Journal of Medicine and Science in Sports (vol 20; Nr.2; 2010), McHugh & Cosgrave (121) reported that,"*there is evidence that pre-participation stretching reduces the incidence of muscle strains:"* and further *"stretching does not reduce the risk of sustaining overuse injuries."(121)* They also wrote :*"Optimal stretching prescription with respect to* **intensity,frequency and duration** *for reducing passive muscle stiffness, has received little attention in literature pertaining to effects of stretching on injury prevention and performance."*(121)
Further more, modern researchers have recently shown developing muscle strength with eccentric training is superior to concentric training. (15) This was reported, among others, by Farthing & Chillibeck in 2003 and earlier by Hartobagyi et al in 1997. Very recent research,(135) suggest that an eccentric loading program be used to improve function and decrease pain in patients with midportion Achilles tendinopathy.(135)and that "stretching exercises can be used to reduce pain and improve function in patients who exhibit limited dorsiflexion range of motion with Achilles tendinopathy"(135)
But eccentric training can also cause damages to muscles and tendons (118,120,126).
"Typically, eccentric contractions can generate two to three times more force than concentric contractions"(15) Especially using intensive periods of plyometric or *stretch-shorten reflex* exercises require periods of rest and recovery periods.(118,119)

Reciprocal innervations

Rene Descartes (1596-1650) was first to conceive a model of **Reciprocal innervation** in 1626,but ,up to this day, the same law is popularly ascribed to Sherrington's (1858 – 1957) and is known as Sherrington's law II of **Reciprocal Innervations** and is the basis of all muscle physiology. That is to say, when one muscle contracts (agonist), the opposite muscle will relax (antagonists). But because no one muscle works alone. It will be accompanied by a *chain of muscles* (synergists) that help it to accomplish a complicated movement pattern. (14, 59). This is well depicted in the following lines ,by Wood Jones, – "*to do an act of precision with the fingers, we call into play the prime movers of the action: the antagonists exert their regulating control to the utmost: the synergists prevent undesired actions of the prime movers. But as the business becomes more exacting fixation of the hand becomes necessary, fixation of the elbow may also be demanded and when all our attention is concentrated upon the performance of some very delicate act, which may require only one tiny muscle for its active performance, we may in fact have to employ a host of muscles for the immobilisation of parts, the movement of which would hinder the desired act."(6)*

The Kinetic Chain:

Way back in 1932, E.Payr (86) wrote in a Scandinavian Journal, about the action of the muscles working in a "kinetic chain" (Die kinetische kette). Subsequently, German Anatomists like Hoepke(32) and above all Benninghoff(34), in his classical book "Lehrbuch der Anatomie", described the functioning of athletic movements as muscles joining each other to form a "movement chains"(34). Later, in the post-war period authors like K. Tittle (33) and V.Janda (23) re-introduced and wrote on movements working in "chains or coils" (ketten oder schlingen-33). Lately, several authors on sports rehabilitation, (15, 16, 25 and 90) use the musculo-fascial connections to describe functional movements.
Analysing and describing movement patterns as synergies may not apply when describing in kinetic link. For example the Rhomboids and the Serratus Anterior are considered antagonists, but in the Serratus fascia they work together in the kinetic chain. (34)
The concept of kinetic chain is based on the works of Reuleaux (1875) a German engineer. (101). Later, Steindler, published in 1955 in a book on normal and pathological kinesiology, analysed human movements, under different conditions and dividing them into ***open and closed kinetic chain***. A few decades later, exercises and sport-specific activities were being

described in open and kinetic patterns. (101) when researchers found that post traumatic patients, especially ACL injuries, had deficiency in Proprioception and kinaesthesia. (These two words are often used interchangeably with Proprioception, is the ability to discriminate and perceive posture and joint position, where as kinaesthesia is a similar term with emphasis on motion.)These patients were treated in closed kinetic chain which enhances Proprioception.

Different Movement Patterns:

In the world of sports, the muscles and movements require not only coordination, but also flexibility, strength, power, precision and rhythm. And movements can be in the open or closed kinetic chain all depending on the action to be undertaken.

1. Open Kinetic Chain. (OKC) A dominant method in physiotherapy used in the sixties and the seventies. Example like biceps curl or stationary quadriceps table.

Characteristics in the Open Kinetic Chain are: as stated below (pp 291 in 28)

* The distal end is free.
* Isolated angular joints
* Muscle recruitment limited to the single joint movers
* Stable joint axis during movement pattern
* Non-weight-bearing movement pattern
* Production of joint shear forces dependent on placement of resistance
* Usually limited to a single plane of movement
* Use of equipment provides artificial means of stabilisation.

Simple examples of open kinetic chain are exercises like the biceps curl or the stationary knee extension. When one single joint is in movement. Where "the distal aspect of the extremity is not fixed to an object and terminates free in space."(25)

In this era saw the advent of different Isokinetic apparatus like Cybex and Orthotron. Their popularity decreased soon. Today, these equipments are used more to evaluate progressions in rehabilitation and in measuring strength in research works.

2. Closed Kinetic Chain (CKC) Examples like "standing squat, lunge, step up" and dips on the floor are: Characterics in the Open kinetic Chain are, as stated below (pp294 in28)

* Fixed distal end segment
* Motion at multiple joints
* Muscle recruitment at each moving joint
* Moving joint axis relative to external room coordinates
* Weight-bearing movement pattern
* Joint compression
* Multiple planes of movement

In the closed kinetic chain, the entire extremity is involved which adds to muscular co-contraction thereby increasing the kinaesthesia but also proprioceptive and afferent stimulation .Therefore, closed kinetic exercises are preferred in the rehabilitation after joint injury. This was based on the unsatisfactory results and incomplete rehabilitation that was reported in the eighties. In post operative high performance athletes. (25)

"After joint injury, Proprioception and kinaesthesia are diminished. It is therefore necessary to use functional exercises that will help to restore normal neuromuscular control. Stimulation of joint mechanoreceptors during CKC exercises improves the coordinated neuromuscular controlling mechanism required for joint stability. (28)

3. Core Stability: Based on the works of Bergmark (116), who described the local and global systems of stability of the lumbar spine. Richardson, Hodges & Hides (58,87) not only introduced a series of exercises to stabilise the lumbopelvic area, but were also the pioneers to recognise and treat, "the deep muscles close to the lumbar spine and pelvis, their possible

function in protecting the joints from injury and their dysfunction in low back pain"(58) . This led to the foundation of new thoughts of how the thoracolumbar fascia runs into each other to work in chains. And yet the idea of muscles working in chains, was not new, it introduced by German anatomists in the 1930's (32, 34).
Recent researchers prefer to call the lumbar-pelvic-hip area as"**the hub",** or CORE. For the muscles of the lower CORE are required both as weight bearing and even in active functional kinetic chain movements. It not only initiates but controls movement and transfers forces as seen by the heel strike but also when upper extremity trunk forces are transmitted inferiorly.(87) "The lumbar-pelvic-hip complex stability and mobility are dependent on several musculo-fascial systems: thoracocolumbar fascia, abdominal fascia, fascia of the thigh (fascia lata), and tranversalis fascial system"(25)
"CORE is defined as a clinical manifestation in which delicate balance of movement and stability occurs simultaneously" (15)
The upper CORE consists of the glenohumeral joint and the scapulothoracic joint. The lower CORE consists of the hip and trunk. Thirty-five muscles attach directly to the hip and trunk. The trunk muscles include the abdominals, thoracolumbar, lumbar and lateral thoracolumbar muscles. (15).
"A combination of power, strength, and endurance is critical for the muscles of the CORE to allow the athlete to perform at his or her maximum capabilities. (15)
"Any muscular imbalances, joint restrictions or pain will restrict and thus prevent the athlete to perform at his or her maximum abilities. (15)
One such intervention is speed. "**Speed is allegedly an innate talent and cannot be changed with training**."(15) However, a combination of strength, power and endurance which is critical for the muscles of the CORE will allow the athlete perform at its maximal capabilities. (15)
"CORE stability describes the ability of the trunk to support force production, and withstand the forces acting upon it."(10) "But it is important to note that CORE stability contributes to but cannot fully account for overall functional **Stability."(10)**

4. Stability Training

What is then functional stability?
"The term stability, describes how the human body effectively manages forces."(10)
"A useful definition for stability is,"the ability to utilise the body's structures in the safest, most efficient positional relationships for the functional demands imposed upon them."(10)
Often "loosely referred to as core stability of the trunk, it actually encompasses much more than that as it combines elements of strength training, endurance training, coordination development, and ultimately motor learning."(15)
"Training programs for nearly every professional sport now include attention to optimizing neuromotor function of the trunk. Thus high-level athletes as diverse as professional golfers, football players, baseball pitchers, soccer players, and swimmers have all come to realise that optimal functioning of the trunk is the necessary keystone to precise functioning and explosive motion of the extremities for many of the complex and coordinated activities seen in sport."(15)
"Functional stability can influence technical performance by increasing biomechanical efficiency. By increasing biomechanical efficiency, we can achieve better results for our effort. In certain circumstances, this may influence physiological efficiency, although the precise relationship is yet to be clearly defined" (Andersson T, 1996; Jung A.P. 2003) (10)
The pillars of Functional Stability, according to Elphinston (10) is as follows:
1 – **Functional mobility**: the ability to move through the full necessary range of motion required by the sport under dynamic conditions.
2 – **Balance:** the ability to organise the body over its support point and accurately.

3 – **Posture:** the neuro-musculo-skeletal relationship which optimise joint motion and muscular action, trigger automatic stabilising activity and minimise structural stress on the body.
4 – **Optimal functional motor pattern**: the timing, proportion and sequencing of muscle activation.
5 – **Neuromuscular control**: the unconscious, automatic activation of joint stabilising muscles to prepare for the impulse to move, or respond to rapid, sudden and unexpected body control challenges or loading (Loow,2006)
6 – **Movement symmetry**: the balance of movement around a controlled central axis in the body
The above criteria "can help you to structure a programme in a way that ensures that you have the motion and control to move well." These foundations will prepare help you to effectively develop: Speed, Power, Strength, Agility, Flexibility and Injury resistance. (10)
"The entire training programme is therefore influenced by **functional stability**."(10)
And functional stability is obtained by training in a closed kinetic chain and the flow of movements of the muscles run into each other like chains or coils. (32, 33, 34)
In order to understand how chain and coils of muscle work elaborately, it is important to understand how the fascial system functions. Several recent authors in Sports rehabilitation have chapters on the fascial systems. (15, 16, 25, 90). An elaborate description of Myofascial evaluation and dysfunction is found in Hertling & Kessler's book (25)

The Fascial system or the muscle-fascial chain (MFC):

"Fascia is more or less continuous over the entire body but it is commonly named according to regions."(25) "MFC (muscle-fascial chain) is a group of muscles that are connected through the fasciae and are longitudinally (and diagonally) positioned in the human body. They run in the same direction and overlap in a continuous chain, like tiles of a roof, which efficiently conducts tension. All of the muscles in the chain are mutually dependent and behave as if they were a single muscle."(88)
"The fascia is an interpenetrated web of tissue that surrounds muscles, bones, organs nerves, and other structures. It is responsible for maintaining structural integrity; for providing support and protection and acts as shock absorber."
"Fasciae are dense, fibrous connective tissue that interpenetrate and surround the human body to protect, nourish and hold organs in place" (88)
Three layers fasciae exist:
1 - Superficial fascia lies under the skin and is enveloped by a thin layer, and is found in the subcutis in most regions blending with the reticular layer of the dermis. Acts as the body's second line of defence against pathogenic agents and infections after the skin. It is the fascia that after a trauma creates an environment for tissue repair.
2-Visceral fascia in which the organs are suspended, within their cavities and wrap them in layers of connective tissue.
3-Deep fascia surround muscles, bones, nerves and blood vessels and are densely populated with myofibroblasts and several types of receptors (nociceptors, proprioceptors, mechanoreceptors, chemoreceptors, thermoreceptors). Myofibroblasts are fascial cells that are created as a response to mechanical stress and actively contract in a smooth, muscle-like manner"(88)
The deep fascia is a dense, tough bluish white fibrous tissue that surrounds **each muscle in a fascial sheath and is continuous with that of the neighbouring muscle bundles. It also facilitates the gliding of adjacent structures freely upon each other."**(88)
"The fascial system is important not only because it can passively distribute tension in the body muscles when mechanically stimulated, but also because it contains mechanoreceptors

and possesses an autonomous contractile ability that influences the tension of the fasciae. The stimulation of intrafascial mechanoreceptors (mostly interstitial and Ruffini endings) cause the vegetative nervous system and the CNS to change the tension in intrafascial myofibroblast and regulate fascial pre-tension. These tensions are transmitted along the muscle-fascial chain (MFC) thereby influencing the posture of the entire body."(88)

One of the biggest problems of intensive training is that certain muscles tend to become tight, especially when training is one sided. According to a new book on"the Janda Approach" (90), one inhibited muscle will compensate by activating another muscle in that chain.

As mentioned earlier, the idea of muscles working in chains is not new. **"Muscle slings have been recognized in European anatomy and medicine since the 1930s**" (90) among others Benninghoff (34) described "how chains of muscles that are linked together, often in loops influence the quality of the entire movement."(90) Adding, **"In contrast to synergists that work together locally for isolated joint motion, muscle slings are global, providing movement and stabilisation across multiple joints."(90)**

Based on the earlier works ,fascias of the different muscles acted together forming groups like the thoraco lumbar and the abdominal fascia, gluteus- lattissimus fascia, rhomboid-serratus fascia only to name a few, and which are described in detail later on.

Janda, "recognised both fascial and functional factors in muscular chains" (90).and continued to work on the same lines, and divided muscles into two groups depending on "muscular predisposition to imbalances" (24). "Certain muscle groups are predisposed to inhibition or weakness, whereas others are prone to facilitation or tightness". (24)"Muscles prone to weakness are predominantly phasic in function; they atrophy readily, they are primarily single-jointed muscles. The other group of muscles prone to tightness and have a predominantly postural function, they resist atrophy and are primarily double jointed muscles. (24) .More recently in 1989, Bergmark, (77) subdivided the muscles around the trunk into two groups of Local and Global stabilizing systems. (See chart below.)

GLOBAL STABILIZING SYSTEM	LOCAL STABILIZING SYSTEM
§ Longissimus thoracis par thoracis	§ Intertransversarii
§ Iliocostalis lumborum pars thoracis	§ Interspinalis
§ Quadratus lumborum, lateral fibers	§ MULTIFIDUS
§ Rectus abdominis	§ Longissimus thoracis pars lumborum
§ Obliquus externus abdominis	§ Iliocostalis lumborum pars lumborum
§ Obliquus internus abdominis	§ Quadratus lumborum, medial fibers
	§ TRANSVERSUS ABDOMINIS
	§ Obliquus internus abdominis
	(Fibre insertion into thoracocolumbar fascia)

Adopted from A.Bergmark (1989): Stability of the lumbar spine. A study in mechanical engineering. Acta Orthopaedica Scandinavica 230 (suppl):20-24

Based, among others, on the works of Bergmark, (77) Paul Hodges et al (58), described muscles working as in an orchestra "*The coordination between the local and global muscles of the trunk is analogous to the coordination of musical instruments in an orchestra. Like the trunk muscles, all instruments contribute to the final output, but the contribution of each is specialised all are needed for optimal function"(58)* Moreover, layers of fascia which surround individual muscles and divide group of muscles into compartments which hold the muscles to form a coil or chain. Hides, Hodge et al. based their work on lumbar stability by using the "Thoraco-lumbar fascia" (58) and Donatelli (15) and Ellenbecker et al (16) described, rather extensively the CORE muscles and its **fascial** link to the lower and upper

extremity. Many more recent publications deal extensively with myofascial dysfunction (25, 58, and 90)

"It seems to indicate that, because of the connections within the fascial system, change in any part of the body may create a disorder in another. (88)

"*The muscle-fascia chain (MFC) may also explain why an anterior cruciate injury influences muscular activity of masseter, anterior temporalis, posterior cervicals, sternocleidomastoid, and upper and lower trapezius."(89 cited in 88)*

The above declarative sentence cannot be taken as affirmative until more research has been undertaken .We believe, that this type of reaction may occur on other planes, like the reaction from autonomic nervous system. According to, Fulkerson and Hungerford : *"The autonomic nervous system is involved in any injury no matter how slight"* (pp399 in 28). All reactions cannot be due to the fascial chains. As all new discoveries, there is an excessive believe that all bodily reactions are connected to the fascias. This sounds as absurd as when stretching was extremely popular as in the eighties, the author was asked if stretching could be applied, as a means of reducing weight in children!

Let us instead look into four important muscle group that work in"chains and coils."(33) And the result of the researches done during the last decades, on kinetic chains. (15, 16, 58, 68, 77, 81, 90)

a-**The thoraco-lumbar fascia**, is plays a very important role in the stabilisation of the lumbo-pelvic region. (76)

The thoracolumbar or the lumbodorsal fascia" is an extensive fascial system in the back that consists of several layers.

*It surrounds the erector spinae and quadratus lumborum, thus providing support to these muscles when they contract.

*The aponeurosis of the latissimus dorsi and fibers from the serratus posterior inferior, internal obliques, and transverse abdominis muscles blend together at the lateral raphe of the thoracolumbar fascia so that contraction of these muscles increases tension through the angled fascia, causing stabilising forces for the lumbar spine."(2)

In the dynamic stabilisation of the thoracolumbar region, both the superficial and the deep muscles of the spinal region act to stabilise the spine under varying conditions." The more superficial muscles, the erector spinae (ES), rectus abdominis (RA), the external oblique (EO) function as prime movers with secondary function in stabilisation. The deeper (core) muscles, the multifidus, rotatores, tranversus abdominis (TrA), internal oblique (IO), and quadratus lumborum (QL), are closer to the axis and primarily function to stabilise."(2)

Interesting to note is that, according to Benninghoff, (34) muscles like serratus posterior superior (SPS) and serratus posterior inferior (SPI) are linked together by a thin fascial scheath. And in certain animals these two muscles are formally one muscle. The fasciaes of these two posterior muscles are attached to the thoracolumbalis fascia. (34)

b- **The Abdominal Fascial system** connects on the posterior aspect of the trunk and the fascia lata system of the lower extremity."Contraction of the external oblique, internal oblique and the transversus abdominis increases tension of the abdominal aspect to the abdominal fascia, much the same as how the latissimus dorsi and gluteus maximus increase tension to the thora-columbar fascia."

"Hodges and Richardson found that **transverse abdominis is the first muscle that is active during movement of the lower limb following contralateral weight shifting**. (87) They provide evidence that the central nervous system initiates of abdominal muscles in a feed-forward manner in advance of lower limb motion, hence the interdependency and linkage between the trunk and the lower limb in the control of postural stability."(15, 87)

The linkage between the thoracocolumbar fascia and its connections to the gluteus maximus exerts a tension that follows to the lower extremity. Similarly latissimus dorsi exerts a similar

tension from the erector spinae and multifidus connecting to fascial systems of the upper extremity. The muscle coils of the gluteus maximus connects latissimus dorsi with deltoideus muscle of the upper, thus connecting lower extremity to the upper extremity. (32)
"Muscle slings in the trunk are necessary for facilitating reciprocal gait patterns between the upper and the lower extremity as well as for rotational trunk stabilization. Three slings have been identified: the anterior, spiral, and posterior slings. The biceps, pectoralis major, internal oblique, contralateral hip abductors, and Sartorius comprise the anterior sling. Wrapping from the posterior to the anterior, the rhomboids, serratus anterior, external oblique, contralateral internal oblique and the contralateral hip adductors create a spiral sling. (90) See below sketch.

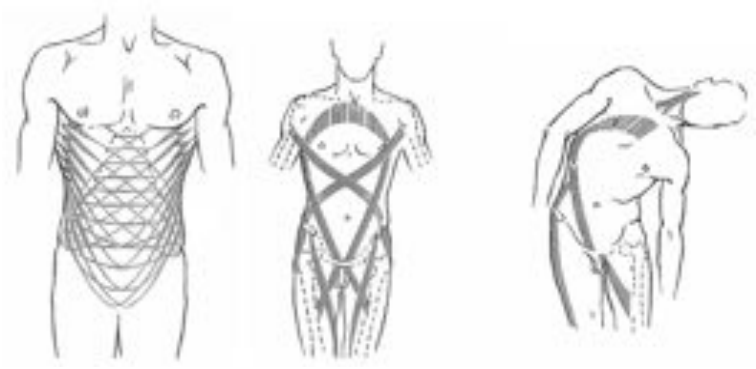

Fig3 - The figure to the left shows the anterior trunk muscle slings, in the middle, the spiral trunk muscle slings, and to the right, the interaction of the anterior abdominals with the serratus-rhomboid fascia and its connections with the fascias of the lower extremity. (Reproduced with the kind permission of the present publishers (for Benninghoff et al (34) and for Tittle's Book (33) Elsevier GmbH & Urban Fischer Verlag –Munich).

c- "The hip muscles, even called the CORE or hub (because the interaction of the trunk muscles to the extremities, particularly the link between Gluteus maximus and latissimus dorsi), include psoas, iliacus, gluteus maximus. gluteus medius (anterior and posterior fibers), rectus femoris and the hamstring muscle group. The external and internal rotators of the hip include a large group of muscles. These muscles are important to the hip and trunk for movement and stability. Lack of strength and power of the muscles noted as follows can contribute to injury of the lower extremity or reduced performance, or both. "(15) Hoepke, (32) among others (25) describes the connection of the gluteal muscles to the Tensor Fascia Lata and forms the lateral iliotibial tract and merges to the lateral patellar retinaculum and projecting from there to form the crural fascias of the anterior lower leg to the top of the foot. Thus, the inter-action "of posture and movement patterns allow us to access the locomotor system in a global way to identify chains of disturbances that can have an impact on the myofascial and skeletal system as a whole and can help identify localised dysfunction.. The locomotor system works as a functional whole and *all movements occur as a result of a chain of muscle activity*, with each muscle involved serving its own particular role in carrying out smooth, efficient, and stable *movement pattern*."(25)

d- The rhomboidus-serratus coil (32): is formed with the interrelationship of the fascias of the following muscles, "the rhomboids, serratus anterior, external oblique and internal oblique. These muscles form like a "wrap" around the body much like a shawl draped over the trunk, hence the name"serape" effect. Understanding this line of muscle force helps the clinician appreciate the linkage between the shoulder girdle and the abdominal mechanism."(16)

The rhomboid-serratus coil links the trunk and extremities is of interest for overhead sports: "**Kibler provided an objective analysis of force generation during a tennis serve. 54% of the force development during the tennis serve comes from the legs and trunk, with only 25% coming from the elbow and the wrist. Nonoptimal performance and increased risk for injury occur in tennis and other sports activities when an individual attempts to use the smaller muscles and distal arm segments as primary source of power generation "(page 21 in 21)**

Muscles like pectoralis major, latissimus dorsi and teres major as also the muscles of the rotator cuff (Supraspinatus, infraspinatus, teres minor and subscapularis) link the torso to the upper arm. But up to now, little has been written about the musculo-fascial coils and slings of the upper extremity. (16)

Likewise, it is interesting to note the connections of the torso to the muscle coils of the neck. The upper trapezius and pectoralis minor and again the lower and upper trapezius with levator scapulae. (32)

Beginning with the intrinsic muscles of the foot, chains and coils from the anterior and posterior sides of the limb to connect fascial system of the gluteus maximus and anteriorly the adductor muscles is connected to the abdominals throuth the obliquus ext, which in turn connects to the serratus anterior (the rhomboideus-serratus coil).(34)

The abdominal muscles, linking together latissimus dorsi and gluteus maximus are primarily responsible for the standing posture. (32)

As we have seen earlier, "several **slings have been identified**. **Muscles within these slings work together to produce functional movement rather than isolated muscle contraction; therefore, we cannot think of muscle strength solely in terms of origin and insertion."(Pp31 in 90)**

As for the stretching of the calf muscles (gastroc-soleus), Youdas et al (15) recalled how difficult it was to stretch this particular muscle group, because of our noctural habits of sleeping, around eight hours with the foot in plantar flexion. No wonder patients with plantar facsitis or Achilles tendonitis have difficulty in taking the first after after sleep. Just calf muscles are better trained with eccentric training.

Most books of anatomy and kinesiology refer to muscle action as agonist and antagonists and some synergists, all influenced by Sherrington's law. Even if the idea of muscles working in "chains and coils" (ketten oder schlingen), is not new. (33). But the newer trend of stability training bring to us new terms of global and local muscle action. (15, 16, 77)

Thus, if we begin to see the entire body is interpenetrated by the deep fascia system. It is worthwhile questioning if stretching a single muscle at a time has any value. But stretching as an intervention to treat loss of range of motion, in day to day physiotherapy remains an asset. Particularly if stretching is administered in combination of length and strength of that particular muscle and as advocated Among others, like Sahrmann (60) and Janda. (22, 23, 24, 90) or as the newer version of stretching by Southward (68, 69)

From France comes this very new form of stretching, in which multiple joints are stretched simultaneously, and is called"Le Stretching Global" (68)-introduced by Suchard and seems even to be very popular in the Latin American countries, above all Brazil. (57) This has led to the introduction of a training method known as –Global Postural Re-education (GPR).

It is too early to say, if the GPR is superior to the other forms of stretching. In time and after research will show if this method has a chance to prevail.

The core to floor -interrelationship (15)

And finally, a too often forgotten part is the distal part of the lower extremity. As if the body started above the knee. And yet," the foot and the ankle provide shock absorption, contact

balance, and spontaneous propulsion in all motion planes."(15) Notable is, that "foot and ankle injured athletes demonstrated significant weakness of the hip abductors and adductors when compared with the uninvolved side." (Pp146 in 15) This indicates there is an interrelationship between the trunk and hip core and the distal foot and up again.
Neuromuscular Control: "neuromuscular control involves the subconscious integration of sensory information that is processed by the central nervous system, resulting in controlled movement through coordinated muscle activity." (Pp247 in 15) Further, "Dynamic joint stability and postural control are the result of coordinated muscle activity achieved through neuromuscular control. Any injury that disrupts the mechanoreceptors, alters normal sensory input or interferes with the processing of sensory information may result in altered neuromuscular control. (Snyder-Mackler et al in 15)
In the human body, the skin, muscles, bones, joints and even the surrounding fascias have small receptors, commonly known as **proprioceptors**, which when stimulated, react and send messages as sensory input, to the central nervous system and react to the given stimulus accordingly. A great deal has been lately written on neuromuscular control and joint stability(30) The results of a retreat on non-contact knee injuries was published in 2007.(29) A similar concept of the International Olympic committee was published in 2008 (97)
This research led to new training methods to prevent and to treat according to these methods. Several recent books, (9, 10, 15, 16) and still more articles on the subject (52, 53, 54, 96, 97), only to mention a few, which provide us with ample necessary knowledge.
Way back in the eighties, Zätterström et al, (122, 123) were one of the first to rehabilitate young athletes following ACL injuries, without open surgery and a training based on neuromuscular postural control and balance. Reconstruction ACL operations are costly; not operating was a means of cost reduction. Later this type of neuromuscular training was also applied to post operative patients, with remarkable results. Research from the same clinic, had also shown that former players developed osteoarthritis as a result of early trauma to the knee. (100)

Have we reached the optimum?

Sports injuries are unavoidable in direct contact sports. But it is encouraging to read how proper warm up programs have led to the reduction of non-contact knee injuries.(52,53,54,82,96,97,105,111) In spite of all these new research, what is the reason to recent lower leg injuries to leading Swedish track and field stars on one hand, and on the other, the large amount of metatarsal fractures in English football? Is there any intrinsic or extrinsic cause for these injuries? Can it be that tight fitting shoes hamper movement of the intrinsic muscles and indirectly cause atrophy and weaken the athlete's feet? Or is it the inadequate training of the intrinsic muscles of the feet, the real cause? Definitely research is required. Interesting to note, is that at least eight Premier league players have in the last decade suffered from "metatarsal fractures". The usual rehabilitation time is between six to eight weeks. The panorama of players returning to play has varied from 6 weeks to 34 weeks. With one player returning after just six weeks. "His own remedy! Drink plenty of milk" (104).
Modern athletic footwear are not only costly, but also cause leg stiffness and altered running kinematics *(131) Altered position of the heels will have a negative effect on posture, will shorten the calf muscles and place increased pressure on back and knees.* With the exceptions of the calf muscles. Not many athletic programmes include flexibility and strengthening of the anterior muscles of the lower legs and especially the intrinsic muscles of the feet.
And yet the feet carry enormous burden. According to Janda (24, 90) "a strong and inflexible gastroc-soleus muscle will result in a weak and flexible tibialis anterior." According to Wolff*s law (90), *bones of a healthy person will adapt to the load placed on it. It will remodel and become stronger to resist that sort of loading. For example the one handed*

tennis player is more developed and stronger in that arm. The opposite is also valid; Astronauts spending a long time in space (without load) will have weaker bones! (23).

The question that arises is, whether we are putting enough loads to the anterior lower leg and the intrinsic muscles of the feet, should it not be necessary to return back to the fifties and sixties when general "foot gymnastics" was in mode? (Pages 40, 41 in103) The authors of a book, from 2006, on Therapeutic exercises (76) recommend not only exercises with a rubber band,to train the tibialis posterior, which, when weakened causes the navicular drop or flat foot, but also train the "short foot," in a bid to avoid foot malalignment.

It has been wrongly claimed that Janda first introduced the short foot, (90). In the early fifties, Daniels and Worthingam (1) used the short foot to train the tibialis posterior muscle. But Janda, much later, reintroduced the short foot,**" as a posture of the foot in which the medial and longitudinal arches are raised to improve the foot's biomechanical position. This posture relatively shortens the length of the foot."** And continuing adds**: "The goal of the short foot is to activate the intrinsic muscles of the feet in a tonic manner; specifically, a sustained low-level activity is desired to increase afferent sensitivity and place the foot in a more neutral and less- pronated position in which the longitudinal and transverse arches are actively maintained. The short foot should be firm but not fixed or rigid."(90**)

"The small (short) foot improves the position of the body segments and the stability of the body in the upright position. The small foot also helps to increase the afferent input, mainly from the sole and helps to improve the required springing movement of the foot during walking."(25)

These simple exercises help to keep the foot in trim. Awareness and special care should be given to the feet, which not only carry the entire body, but is also essential in keeping the upright position, as also, in preserving the necessary balance act through out ones life.

Still more recently(2008) authors like Elphinston (10) advices to "listen to the foot", and have an "aim for a supple, adaptable foot in all weight bearing exercises. Remember to check your foot to ensure it is not rigid during the movements."(Pages 70 to 72 in 10) Emphasis should also be lead on special training of the Tibialis Posterior (pp146 in 16). A muscle that has a tendency to drop into pronation in overuse, causing a flat foot! (pp 90 in 1)

Perhaps, the future conception of all round training will also include not only strength and flexibility of the lower extremity, but also special gymnastics for the intrinsic muscles of the feet. Another, rather neglected problem are the athletic shoes. If orthotics is used, they should be tested individually. Proper fitting shoes are of utmost importance to the athlete. Robert Deppen's chapter on "From CORE to floor –interrelationship" not only gives us a variety of suggestions on orthotics, but also advice on"Athletic footwear Characteristics for Injury Prevention." I quote a few of characteristics below (15)

"***Athletes should shop for shoes after a training session when their feet are at their largest.**

***Toe box length should be 1 fingerbreadth from the end of the box to the end of the longest toe. "(15)**

The question arises, are the methods used in sports rehabilitation optimal? Today's rehabilitation is no longer" a joint or muscle specific treatment."(15) The modern approach is to follow "the total kinetic chain approach, with attention given from above and below the injured area."(15) Not forgetting total functional stability and mobility. A large number of publications regarding neuromuscular training claim to have reduced the number non-contact ACL injuries in females. (52, 53, 54, 97, 105) These programmes include balance and coordination, strength and flexibility, power and condition, and postural control and alignment. If there should any criticism, why so little thought is given to the lower leg and the feet? Could this acquired knowledge, be of value to the school children? In this sophisticated

modern world, children are growing “watching television and working on computers” with increased faulty flexed postures which could lead to impairment of the lumbo-pelvic region.(Fig. 4) An early habit of proper neuromuscular postural control, could perhaps lead to better habits later on in life **.**

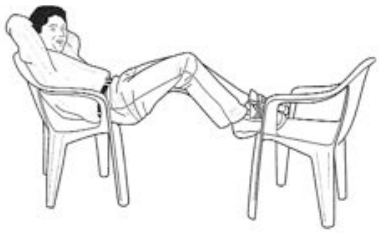

Figure 7.1 Relaxed lifestyle in the sitting position.

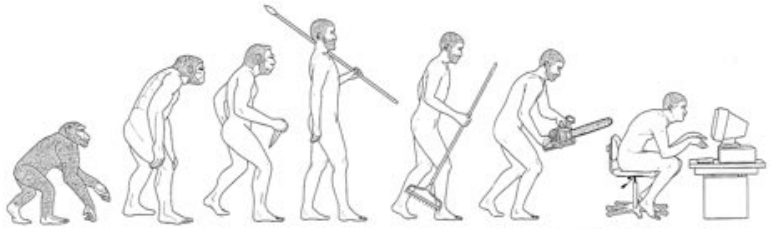

Figure 7.2 The evolutionary development of an antigravity erect posture and the gradual lifestyle changes that are reversing these postures.

Fig.4 Reprinted with kind permission- < Churchill Livingstone-(Elsevier-Oxford)> (58)

And finally, static stretching is and remains a clinical asset in the day to day treatment of joint pathology. Whereas dynamic stretching requires a greater ability to perform coordinated movements patterns mimicking sport related activities. Among the advantages of dynamic stretching is the engagement of several joints simultaneously thus increasing joint mobility, neuromuscular coordination, endurance, power and balance. (138) **Dynamic stretching, being active movements has a positive effect on blood circulation and is therefore recommendable as a warming up procedure.(138)**

Physical perfection of athletic movements as seen below, requires enormous practice such as a musician attains his or hers virtuosity. Richardson et al (58) make an analogous description of “the coordination between local and global muscles” which can be compared “to the coordination of musical instruments in an orchestra.” “..All instruments contribute to the final output, but the contribution of each is specialised and all are needed for optimal function” (58)

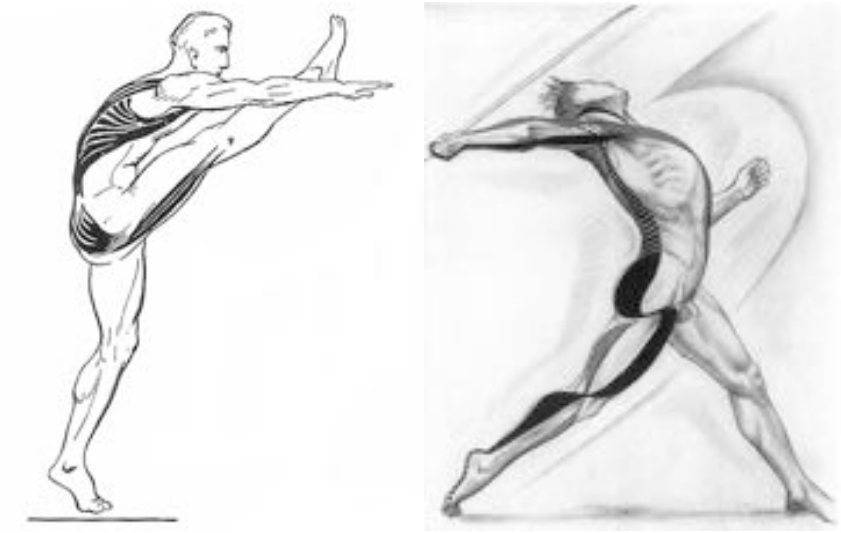

Fig.5 these two figures show how the muscle-fascias work in a continuous chains or coils. (Reproduced with kind permission of the present publishers: for the picture to the left from Benningoffs (34) and for the picture to the right – Tittle (33) permission obtained from Elsevier GmbH & Urban Fischer Verlag - Munich)

Conclusions

Whenever there is a loss of range of motion to a joint, stretching in its various forms will be required to maintain full range of motion.(2) Among others, Janda,(23,90), Sahrmann (60) and Donatelli (15) have all critically reviewed stretching as it is performed today.
All movements follow a certain pattern working in "chains and coils" (33) to perform a movement in harmony will require following them in a certain pattern. **The cortex registers only movement patterns; it knows nothing of a single muscle**. (59) No, one muscle works alone. All movements occur in synergies.
According to Bahr et al (132) : "the clinical studies on athletic injuries has increased by 43% over the last 7 years," and during the same period "clinical studies and randomised controlled trials related to sports injury prevention has increased by 200 – 300% (132) New training methods develop, due to modern research and gradually replace the older forms. And **"Only change is constant" (134)**
The causes and risk factors in sport injuries are not only intrinsic or extrinsic. Behavioural conditions such as attitude (focus and concentration), motivation, alertness, and conscious readiness are important factors in preparing an athlete. Most injuries happen when they are least expected.

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review of the literature, concluded that. using neuromuscular electrical stimula-. tion combined with exercise was more.Â Methods: Fifty-four patients undergoing physiotherapy completed the Persian versions of KOOS and Tegner scales at weeks 6 and 10 post ACL-R. The 7-point global rating of change was also completed at week 10. Responsiveness was calculated via receiver operating characteristic curve and correlation analysis.Â Therefore, these scales should be used to evaluate the effects of physiotherapy treatment and the changes in activity levels in this population. The MCIC scores of the KOOS and Tegner scale can be used to detect changes significant to the patient while avoiding limitations of other methods. View. Stretches for Back Pain - Stretches the hip flexor muscles, which run from the lower back to the front of the thigh bone. Sit on the edge of a table, bench or bed. Lie down on your back and grasp your knees; your entire lower back should be in contact with the surface. Grab left knee with both hands and extend right leg so it hangs freely. Hold for 10 seconds, then tense the muscles being stretched.Â Use a chair for balance and eliminate the squat for simplicity, if needed. Pendulum: A more advanced exercise to strengthen the core and hips. Start with smaller movement and increase your range of motion as you become stronger. Tight Hip Flexors.