VASTUS MEDIALIS AND VASTUS MEDIALIS OBLIQUE – A NEW PERSPECTIVE

Introduction.

The human knee has been a subject of anatomic and clinical interest for more than 150 years. Few subjects in medicine – especially orthopaedic medicine – have had more written about it than the human knee. Early modern descriptions go as far back as 1836. Most of the early descriptions prior to 1917 were in the German-speaking world and difficult to access. After a quiet period between 1917 and 1941, a new surge in interest was started in the early 1970's by orthopaedic surgeons and bioengineers taking the place of anatomists. (Freeman; 2003) With the rise in interesting the knee from orthopaedic surgeons came a corresponding interest and need for rehabilitation of the knee after injury or surgery. Unfortunately, I doubt whether there is any other subject with more misinformation and anecdotal presentations than the muscular strengthening of the quadriceps and control of the patella.

In an excellent review by Terry Malone et al, many of the myths and misconceptions surrounding knee rehabilitation are addressed and discussed (Malone; 2002). Much of the confusion started with a statement by Smillie in 1962: "The extensor apparatus may be regarded as consisting of two components, the rectus femoris, vastus lateralis, and vastus intermedius, which extend the knee to within 10 – 15 degrees of full extension, and the vastus medialis which is selective in action and comes into force in producing the last 10-15 degrees of extension, although it may be used throughout the whole range in overcoming marked resistance." (Smillie; 1962)

It is also from his work that the vastus medialis got promoted to position of "the key to the knee." This concept was further addressed in the work of Lieb and Perry in 1968 and 1971. Since 1968 it has almost become the norm amongst clinicians to refer to these articles as being supportive of selective recruitment and strengthening in rehabilitation of a variety of knee problems. The term VMO (vastus medialis oblique) has become synonymous with patellofemoral exercise prescription. (Malone; 2002)

Background aspects of function.

 "The knee, more than any other single joint in the body, requires the normal functioning of all its parts to provide the harmony of motion, the security of stability, and protection against deterioration." (Larson; 1983) This was already recognized as long ago as 1938 when Palmer wrote in the Acta Chir. Scandinavica.: "Just as a flaw in any small part may upset the functioning of a machine and eventually impair the whole machinery, a lesion in any detail of the physiologic joint, may, through the imperfect working of the whole, result in injury of the entire joint."

I believe the two statements above to be profoundly important in that they both emphasize **ALL** the components that make up and contribute to a well functioning physiologic joint system.

Leading from this concept of balance between all the components being vital for normal functioning of the knee, two further views is getting more attention lately within a more holistic approach to treatment and rehabilitation of knee problems.

The first is the theory of the knee being a biologic transmission system with an envelope of function as put forward by Scott F Dye. (Dye; 1998)

The emphasis of his theory is that any loading beyond the safe functional range of any given joint may lead to loss of tissue homeostasis resulting in a painful, swollen, inflamed, dysfunctional joint system. (Homeostasis is a term used by physiologists to mean maintenance of constant conditions in the internal environment.) Loss of tissue homeostasis could be due to a single impact or load episode, or due to excessively repeated lower impacts or loading of the joint system over time, resulting in a breakdown of physiological function of the system. In his approach to the etiology of patellofemoral pain for instance, he moves the emphasis to the loss of tissue homeostasis of innervated musculoskeletal tissues as often being of greater importance than the presence of certain structural characteristics, such as chondromalacia of the patella. (Dye; 2005)

The second theory is a new look at the biomechanical and mathematical models upon which explanations of human movements are built. In January 1998 Donald Ingber, an associate professor of pathology at the Harvard Medical School, published an article, "The Architecture of Life" in The Scientific American, proposing a universal set of building principles behind the design of organic structure, from carbon compounds to complex systems. (Ingber; 1998)

This article has gone a long way in opening new ways in which structure is described and understood. Ingber goes on to state: *I discovered and explored an intriguing and seemingly fundamental aspect of self-assembly. An astoundingly wide variety of natural systems, including carbon atoms, water molecules, proteins, viruses, cells, tissues and even humans and other living creatures, are constructed using a common form of architecture known as* **tensegrity.** *The term refers to a system that stabilizes itself mechanically because of the way in which tensional and compressive forces are distributed and balanced within the structure.*

This new model of the underlying structure of organic tissue is opening new therapeutic possibilities as the underlying interrelationships of the building blocks of the human structure from microscopic to macroscopic is becoming clearer. This model – seeing the body as a tensegrity structure – explains the complex interrelationships of all the structural components of the body. It expands the view that only bones, muscles, ligaments, and joints are involved in movement, to include **all** structures of the body involved in movement and movement quality. (Levine; 1997) We are moving away from the simpler post-and–beam approach of biomechanics dominated by Newtonian based mathematics towards a more integrated model of movement.

Ingber sums it up as follows: "*The principle of tensegrity apply at essentially every detectable scale in the human body. At macroscopic level, the 206 bones that constitute our skeleton are pulled up against the force of gravity and stabilized in a vertical form by the pull of tensile muscles, tendons, and ligaments (similar to the cables of Sneldon's sculptures.) In other words, in the complex tensegrity structure inside every one of us, bones are the compression struts, and muscles, tendons and ligaments are the tension-bearing members. (Ingber 1998)*

Both of the above theories move towards an integrated approach to anatomical structures surrounding any given joint. Both these theories also depend on the presence of an integrating tissue keeping all the individual anatomical structures together in a functional unit. The most likely, and best-suited tissue for this role is our extensive connective tissue system. As our understanding of the macroscopic role played by the connective tissue in both the biologic transmission systems within an envelope of function (Dye; 1998) and tensegrity (Levine; 1997, Ingber; 1998) become better understood, so our clinical reasoning in appropriate rehabilitation and treatment will improve. Connective tissue does not move bones or initiate movement, it merely controls the quality of the movement taking place while keeping the bony levers and spacers within a specific functional configuration.

General anatomical and biomechanical concepts.

It is with the above theories as background that I take a new look at vastus medialis and vastus medialis oblique within the functional knee joint.

Proper function of the knee requires maximal mobility while maintaining maximal stability during athletic and day-to-day activities. The knee is both a highly modified and an incongruent hinge joint. The incongruency of its poorly fitting articular surfaces is counteracted by a complex, highly perfected, and powerful capsular, ligamentous and muscular system. This means that the knee can behave like a solid and inseparable functional unit with a high degree of stability and mobility. Unfortunately, its high dependence upon soft tissue structures for stability also makes the knee very vulnerable to injury.

The knee is a combination of three separate joints within one capsule - each with its own specific movements prescribed by the bony and ligamentous configurations. In this way we can distinguish between a medial tibiofemoral joint, a lateral tibiofemoral joint, and a patellofemoral joint – all with their own distinct movements and its own unique soft tissue configurations. (Muller; 1982)

During flexion and extension of the knee, movement is a combination of rolling and gliding between the articular surfaces of the tibia and femur. The combinations of rolling and gliding differ between the medial tibiofemoral and lateral tibiofemoral joints because of their different bony architecture, ligamentous structures, and the mobility and design of the menisci. Automatic initial and terminal rotation as well as voluntary rotation is superimposed upon the basic flexion and extension movements in the sagittal plane. During extension of the knee, the tibia rotates laterally on the femur and medially during flexion. (Freeman; 2003)

The lateral tibiofemoral joint is more mobile in rolling because of two convex surfaces moving on each other and the greater amount of anteroposterior movement available because of the form of its ligaments. The much more mobile lateral meniscus helps to control the movements between the joint surfaces.

The medial tibiofemoral joint is between a convex femoral condyle and concave tibial plateau with a much less mobile meniscus between them. The triangular form of the medial collateral ligament also allows much less anteroposterior mobility. The much longer medial femoral condyle surface and its angle of about 22 degrees from the sagittal plane, forces the medial tibiofemoral joint to have much more gliding than rolling in its movements, especially in the last 20 degrees of extension.

During the final stage of extension, the lateral femoral condyle has already stopped moving, while the annular sector of the medial condyle is still gliding into place degree by degree. This mix of movements and individual functions of the two tibiofemoral joints in the last 20 degrees of terminal extension, combined with 15 degrees of automatic rotation and the screwing-home of the annular sector of the medial condyle, creates a situation where gliding of the femur greatly predominates over rolling.

Because of the awkward design of the bony elements of the knee, and the need for stability throughout its full range of motion, some of the ligament and capsular structures that become lax during movement, needs to by dynamically tightened to stabilize the knee joint throughout its full range of movement. Dynamic stability is made possible by the existence of "dynamized" (dynamically stabilized) fibres and structures passing from bone to tendon and muscle. (Muller; 1982)

The medial complex is strengthened dynamically by the longitudinal medial patellar retinaculum, radiating broadly into the fascia of vastus medialis, extensions from the adductor magnus tendon and fascia blending with the superficial layers of the medial collateral ligament, the pes anserinus complex, and the extensive "suction cup" attachment of the semimembranosis muscle

The lateral structures are strengthened by the biceps muscle tendon, the popliteus muscle, and the iliotibial tract dynamized from above by the tensor fascia latae, and gluteus maximus muscles. Many of the iliotibial tract's fibres also spread distally as a flat band to merge with the aponeurosis of tibialis anterior.

Compromised movement on the fascial and myofascial level anywhere in this entire system of dynamic support, be it due to adhesion, thickening or scarring has a potentially damaging effect on the smooth functioning of the knee joint, and may lead to disruption of homeostasis within the envelope of function of this delicately balanced joint complex. Loss of homeostasis is seen as chronically painful conditions or premature degeneration of the joint surfaces.

Dissection observations.

All pictures, drawings or dissections shown of the quadriceps muscles in textbooks are always without its supporting and interconnecting connective tissue, myofascia, fasciae and fat pads. They are normally dissected away for better clarity in studying and visualizing all the "more important" anatomical structures. These descriptions are usually with the surgeon in mind. The distribution of these interconnecting connective tissue structures is what my dissection investigations attempts to clarify.

The fascia lata (deep fascia of the thigh) forms a complete tubular sheath around the muscles. It is thicker in the proximal and lateral parts of the thigh. Over the flattened lateral surface of the thigh the fascia lata is specially thickened as a strong band, the iliotibial tract. Over the medial aspect the fascia lata is thin. (Warwick 1973). Textbooks give a very poor and incomplete description at best of the fascial and muscular relationships as seen in dissection. These textbook description are of little help in full understanding of knee function as every single structure from fascia, myofascia, areolar tissue and fat deposits has functional relevance in maintaining homeostasis within our envelope of function and tensegrity models for the knee joint.

They all contribute equally in guiding muscle contractions and influencing the quality of functional joint movement.

A brief description of some of the dissection findings I believe to be relevant in function of the knee joint will follow.

Splitting the fascia lata (deep fascia of the thigh) down the middle (median line) from inguinal ligament to patella, I made the following superficial observations:

1. A well-defined fat layer over the upper third of rectus femoris (between tensor fascia latae and sartorius).
2. The fascia is easily stripped off vastus lateralis by blunt dissection to the level of the lateral intermuscular septum. A well defined fat layer is visible between fascia and the vastus lateralis myofascia (epimysium)
3. The fascia thins considerably over the lower half of rectus femoris and is easily stripped from the muscle by blunt dissection, revealing a well-developed fat layer between fascia and the rectus femoris aponeurosis.
4. The fascia lata is very thin medially and can only be separated from vastus medialis by sharp dissection. Medially fascia lata is the epimysium of vastus medialis, and crosses into the muscle by well-defined intramuscular septa (perimysium) giving the muscle a striated appearance through the fascia lata.
5. Vastus lateralis, vastus medialis, and rectus femoris are strongly attached to each other in the midline down the entire length of the thigh.

As dissections continued into the deeper layers of the anterior thigh, another few observations need to be pointed out – especially in the distal third of the thigh.

1. Vastus lateralis, vastus medialis and vastus intermedius, share attachments centrally and superiorly and are so strongly interrelated that they can almost be seen as a single muscle proximally. Distally they are more clearly separated and split into a medial, central and lateral functional unit to control the three divisions of the knee joint.
2. Vastus lateralis under its distal quarter has a thick fat pad separating it from the distal femur, lateral to the articularis genu muscle and suprapatellar pouch.
3. Centrally, the three muscles unite into a tendon attached to the superior patella.
4. The deep surfaces of vastus medialis and vastus medialis oblique are loosely attached to the distal femur by loose areolar tissue.
5. The oblique part of vastus medialis attaches strongly to the tendon and fascia of adductor magnus.
6. Superior to the adductor miatus, vastus medialis continue to have a strong fascial relationship with the entire adductor canal and its neurovascular contents.
7. Medially, the fascia/epimysium of vastus medialis splits to invest sartorius within its own sheath, and then continues further medially as a thin fascia over the adductors and gracilis.
8. Distally, vastus medialis oblique fibres attach strongly into, and become the longitudinal medial patellar retinaculum, attaching to the proximal tibia and joining the corresponding fascial layer from the lateral patellar retinaculum over the patellar tendon and infrapatellar fat pad.
9. The underside of this vastus medialis oblique tendon and longitudinal patellar retinacular system has a well-defined fat layer separating it from the medial

collateral ligament and joint capsule. The position of this fat layer reduces friction between the vastus medialis tendon and its expansion and the underlying ligamentous and capsular structures.

I believe vastus medialis oblique therefore not to be so strongly attached to the patella, but rather to be part of the retinaculum medially, as well as a separate intermediate fascial layer over the anterior patella as described by Scott Dye recently (Dye 2003).

The distribution and placement of fat pads, fatty tissue layers, and loose areolar tissue layers between anatomical structures has clinical relevance in that they function as "functional bursae" to reduce friction between moving parts, thus contributing to the quality and ease of movement within a kinetic chain of joints (like the lower limb).

Nerve supply.

Before we can look at the different roles played by the four heads of the Quadriceps, a few comments on the afferent nerve supply of the area.

Free nerve endings are found in all types of connective tissue, including the dermis, fasciae, ligaments, tendons, joint capsules, and the endomysial spaces of all types of muscles. These nerve fibres are both myelenated and non-myelenated, but always of small diameter and low conduction speeds (group III and IV sensory afferent types) (Warwick 1973). In muscle, free nerve endings of the groups II, III and IV types lie in association with intra- and extrafusal muscle fibres, the capsules of muscle spindles and tendon organs, tendon tissue, at musculotendinous junctions, the adventitia of arterioles and venules, fat cells and connective tissue (epi-, peri-, and endomysium of muscle) (Stacey; 1969).

Type IVa free nerve endings detect crude touch, pressure, pain, heat and cold. Primarily they constitute the articular (and muscular) nociceptive system. They remain inactive during normal circumstances but become active when they are subjected to abnormal mechanical deformation (Biedert 2002). Biedert et.al. also investigated the density of these nerve endings in 18 structures around the knee joint. They found the highest counts of free nerve endings in the medial and lateral patellar retinaculae, the patellar ligament, and the pes anserinus. Most of the medial structures had higher free nerve ending counts than structures on the lateral side of the knee joint. (Biedert 1992)

Although no studies have been found to clarify the true afferent nerve supply of the myofascia other than what Stacey mentioned about free nerve endings in the fascia of muscles in 1969, I am of the opinion that muscle must have an abundant supply of free nerve endings within its connective tissue and fascial structures. If this is true, not only joint afferents are responsible for proprioceptive feedback to the central nervous system, but also all myofascial and connective tissue structures contribute to the total proprioceptive and sensory picture of an area.

Discussion

If we start looking away from the individuality of the various anatomical structures making up the complex mechanical transmission systems of the lower limb, to focus on functional integration of all the parts, understanding the role connective tissue, fascial and myofascial relationships take on a new meaning. As stated earlier, connective tissue does not move bones or initiate movement - it merely controls the

quality of the movements taking place, while keeping the bony levers and spacers within specific functional configurations.

The clinical importance of the above anatomical observations and neural findings, coupled with the observations of the differences in the fascial and myofascial arrangements over vastus lateralis and lateral structures, as opposed to the different design medially and over vastus medialis, leads me to believe that the four heads of the quadriceps may each have its own additional role within the quadriceps, over and above knee extension and patellar control.

The connective tissue and fascia surrounding and integrating the four heads of quadriceps into the rest of the lower limb, guides me to describe the four heads in a different way from most texts.

Rectus femoris, being kept separate from the other heads within a fascial sheath, well padded by adipose and areolar tissue, controls the relationships between lower back, pelvis, hip, and the knee. Changes due to scarring or thickening that may interfere with the freedom of the muscle belly to slide and glide within this fascial sheath, will influence hip – knee relationships during walking and running.

Vastus lateralis, with its well defined fat layer/areolar tissue separating the muscle from the fascia lata (deep fascia of the thigh) anteriorly and laterally, and the extensive fat pad under the distal portion of the muscle reducing friction between muscle and femur - seems to be designed as the workhorse of the quadriceps. Vastus lateralis is well positioned for strong extension of the especially the lateral tibiofemoral joint in the sagittal plane. With the fat layer arrangement helping to produce friction free sliding of the muscle under the fascia lata, more of the muscle's contraction power is available for knee extension and shock absorption.

Vastus intermedius cannot be separated from both of the other two vasti, and can therefore only be seen as another workhorse for knee extension, deceleration and shock absorption within the quadriceps group.

The **vastus medialis** muscle is often split into the more longitudinally oriented vastus medialis, and the distal part of the muscle more acutely angled in relation to the femur, called vastus medialis oblique. This portion is often separated from the vastus medialis by a fascial septum (Lieb 1968). The dominant features of vastus medialis are: -
  1. the fascia lata being the epimysium of this muscle,
  2. its wide attachment into, and continuity with the medial patellar retinaculum,
  3. its medial attachments into the distal tendon and fascia of adductor magnus,
  4. the fascia continuing medially forming the fascial sheath and network for the pes anserinus.

This fascial/myofascial arrangement, coupled with the higher counts of free nerve endings in the medial structures, makes vastus medialis the ideal proprioceptive and feedback controller of the knee joint during all activities. It is constantly monitoring relationships between femur and tibia, adductors, flexors and extensors, dynamized ligaments and stabilizers as well as monitoring the work done by the other three heads of the quadriceps through its sharing of tendon and aponeurosis. Because of this monitoring role, vastus medialis can at any time add to or modify the power output for safe and smooth functioning of the knee joint complex.

Clinical relevance.

The relevance of the above observations is the new level of clinical reasoning this makes possible. Understanding the quadriceps and knee as a unit in its relationships to all the other muscles and structures of the thigh, makes therapeutic intervention more specific after injury or surgery.

Unless troublesome myofascial and connective tissue relationships have been identified and attended to, full rehabilitation of the knee cannot be achieved. Scaring within the medial patellar retinaculum will reduce the effectiveness of the vastus medialis proprioceptive feedback system, resulting in muscle inhibition and wasting of the quadriceps.

Interference with the freedom of sliding and gliding of any of the numerous muscular structures due to scarring may change the quality of patellofemoral of tibiofemoral movement, leading to early degenerative changes or chronic painful conditions due to changed or compromised biomechanics.

After surgery (even "minimal damage" arthroscopic surgery) adhesions and scarring may greatly interfere with function, and needs to be attended to before any exercises could be safely incorporated into the rehabilitation routine. It is not feasible to exercise a joint before maximum restoration of tissue homeostasis and biomechanics as close to normal has been achieved.

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