Harmonic Technique

Rational for use

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CPM Creating an ideal environment for repair

Summary

Studies of passive motion have shown to beneficial to different aspect of repair, particularly, in acute musculoskeletal conditions.

Over the last two decades the importance of passive motion has come to light by the extensive research into the effects of passive motion on repair processes in the musculoskeletal system. There are several physiological mechanisms by which passive motion may be clinically useful:

1. Improving the quality of repair
2. Improving the rate of repair
3. Improving drainage of oedema following tissue damage
4. Reducing overall pain

The significant therapeutic effects of passive motion on tissue repair have been shown in connective tissue, joints and muscle.

Connective tissue: the importance of movement

There is a strong body of evidence to support the view that periodic, moderate stress is essential for connective tissue nutrition, homeostasis and repair.[1-6] In many of the studies remobilization was introduced with passive movement.[7-16] Moderate active movement has also been shown to beneficial in assisting tissue recovery following an injury and immobilization.[2,17-22]

These studies provide us with important general directions as to the use of passive motion or/and exercise in treating connective tissue damage.

Connective tissue matrix - Movement encourages the normal turnover of collagen and its alignment along the lines of mechanical stress. This provides the tissue with better tensile properties. Movement improves the balance of GAGs and water content within the tissue which helps maintain the inter-fibril distance and lubrication. This reduces the potential for abnormal cross-links formation and adhesion. In avascular structures, such as cartilage, ligaments and tendons, periodic stress provides a pumping effect for the flow of interstitial fluid. This may support the increased metabolic needs of the tissue during inflammation and repair.[1,23] Another important effect of early movement could be in preventing the secondary damage of the connective tissue matrix by distention from oedema. Movement within the pain-free range and low loading force may help drain the fluid build up and reduce distention.

Ligaments - Passive motion has been shown to stimulate various aspects of repair in ligaments. If a knee is mobilized soon after injury, the ligaments show higher strength and stiffness compared with immobilized ligaments (providing that the joint movements are not excessive and scar formation is not disturbed).[24,25] Similarly, the strength of repair ligaments has been shown to be greater in animals that were allowed to exercise.[26]

Tendons – After surgery, tendons that undergo mobilization have a higher tensile strength and rupture less often than immobilized tendons.[27-31] Early mobilization of an injured tendon reduces the proliferation of fibrous tissue and reduces the formation of adhesions between the tendon and its sheath.[32,33] Animal experiments have shown that tendons undergoing early mobilization are stronger than immobilized tendons. For example in one such study it was demonstrated that when the tendon was mobilized at 12 weeks post-operation, the angular rotation of the joint was 19% of the full range of movement. Mobilization delayed until after 3 weeks post-operation produced an angular rotation of 67%, while the early mobilization within a five days of surgery resulted in angular rotation of 95%.[27] The total DNA and cellularity content of mobilized tendons at the repair site were significantly higher than was found in immobilized tendons.[34] Increased DNA and cellularity signifies an accelerated tendon repair and maturation. Motion also stimulated the reorientation and revascularization of the blood vessels at the site of repair in a more normal pattern, which are well adapted to withstand the mechanical forces imposed on the tissue.

Skin - Wound repair in skin has also been shown to be affected by passive motion.[35,36] Mechanically stressed scars being much stronger and stiffer than unstressed scars. The mechanical properties of a scar closely resemble those of normal skin, the collagen fibres developing in a biaxial orientation. The cosmetic appearance of a scar healed under mechanical loading is greatly superior to that of unstressed scar.[36-39]

Importance of movement to joints

Articular cartilage homeostasis and repair, synovial fluid formation and flow and the connective tissue supporting the joints are all structures and processes responsive to mechanical stimulation.[40] These structures and processes respond to particular forms of mechanical events indicating that Harmonic Technique could be potent therapeutic tool in treating various joint pathologies.[40,41]

Trans-synovial pump

Some of the positive responses in joint repair seen in rhythmic passive approaches could be attributed to the activation of a physiological mechanism called the *trans-synovial pump*. This pump facilitates the formation and drainage of synovial fluid in the joint and is activated by movement (passive or active). The pump has three elements to it all stimulated by movement; a fluctuating intra-articular pressure,[42] an increased synovial blood flow and facilitated drainage into the lymphatics.[40] An increase in the intra-articular pressure produces an outflow, while a decrease in intra-articular pressure and increasing the influx into the joint cavity.[43,44] Another important part of the trans-synovial pump is the effect of movement on the periarticular vascular and lymphatic flow.[43] On one end of the pump movement causes increased blood flow around the synovium (which important for the formation of synovial fluid) and on the other end of the system it stimulate drainage into the interstitial spaces (lymphatic system).[45,46]

The pattern of pressure may vary on whether the joint is moved actively or passively. In the human knee, during passive motion the pressure in the knee tends to remain under negative pressure. It only rises at extreme flexion and extension. During active movement the overall pressure in the joint increases but the patterns remains similar to the one observed during passive movement.[47] It suggests that application of passive movement may be less stressful to the swollen synovium and capsule of inflamed and effused joints and therefore more appropriate in the treatment of acute joint injuries, in particular, in conditions where the patient is unable to initiate movement due to force losses of pain.

Cartilage nutrition

Articular cartilage has no direct supply route from the underlying bone and the nutrition and viability of the chondrocytes are totally dependent on synovial fluid.[48] The supply of nutrients to the cartilage is partly by diffusion and partly by hydrokinetic transport. Furthermore, movement produces smearing and agitation of the synovial fluid on the cartilage surface which aids this transport.[49-52]

Nutritional transport to the articular cartilage occurs over a relatively long distance. Different joint pathologies that alter the structure and function of the synovial membrane and the capsule will impede this transport.[53] For example joint effusion may result in synovial membrane ischaemia.[54] This could lead to damage and death of the chondrocytes and the subsequent degeneration of the articular cartilage.

Joint injuries and immobilization

Joint injuries can vary from mild sprains causing minor damage to the synovial lining, capsular and ligamentous structures to more severe articular surface damage. The damage to any of these join structures will initiate a repair process which is similar to the one described above in connective tissue.

The inflamed synovial lining follows a similar history of repair described above in connective tissue. Some important consideration for passive motion therapy is that the inflamed joint is usually hypoxic and acidotic. This is due to several factors; a high synovial metabolic rate, reduced synovial capillary density, capillary "burial" under thickened synovial lining, and in the end stages, a chronically reduced blood flow. The inflamed synovial linings will also demonstrate villus projection encroaching on the joint space.[46,55] These areas of the inflamed synovium may be crushed by excessive movement further aggravating the inflammation. In particular if this movement is active (active movement imposes greater stresses on joints).

Further complications to simple injuries can be the lack of mechanical stimulation brought about by inactivity or immobilization of the joint. In essence, joints being designed to be mobile and under repetitive mechanical stress are therefore very sensitive to immobility. The effects of immobility are usually quite extensive resulting in atrophy of the capsule, ligaments, synovial membrane and articular cartilage. Adhesions and abnormal cross-links can develop fairly rapidly after the onset of immobility resulting in reduced overall movement of the joint.

The synovial tissue of immobilized joints seems to be the most sensitive to the effects of immobilization. The synovial membrane in the immobilized joints undergoes fibrofatty changes. The resultant fibrofatty tissue proliferates into all the articular soft tissues, for example in the knee, into the cruciate ligament and the undersurface of the quadriceps tendon. With the passage of time, fibrofatty changes will proliferate to cover the non-articulating area of cartilage, with the subsequent formation of adhesions between the two surfaces as the fibrofatty tissue matures. The proliferation of fibrofatty tissue and adhesion formation has been shown to occur as early as 15 days after immobilization, becoming well established after 30 days.[56,57] These changes have been shown to occur in experimental animals as well as in human spine and knee joints.[36-59] In the knee, similar but less extensive changes have been observed in subjects with damage to the anterior cruciate ligament. Adhesion formation and fibrosis have been found between the patellar fat pad and the synovium adjacent to the damaged ligament.[59]

The chondrocytes are highly sensitive to compressive loading for normal homeostasis of the articular cartilage.[15,18-22,60-62] Immobilization has a deleterious affects resulting in reduction of GAGs thinning and softening of the articular cartilage. This degrades the mechanical strength of cartilage. Furthermore the chondrocytes are totally dependent on synovial fluid for their nutrition. As the synovial membrane progressively atrophies, there may be a decrease in nutrition and gradual destruction of the articular cartilage. Indeed, in animal studies the contents of synovial fluid itself were shown to be negatively effected by immobilization (these changes were normalized by remobilization).[63]

Other complications of joint injury may be brought about by joint effusion. Above a critical effusion pressure, there may be an impairment of synovial blood flow. [54,64-66] This could impede the normal functioning of the trans-synovial pump reducing the movement of nutrients and metabolic waste products through the joint cavity. For example, it has been shown in osteoarthritic knees that increased intra-articular pressure reduces synovial blood flow, which may contribute to joint anoxia and cartilage damage in chronic arthritis.[67,68]

Joints: the importance of movement

The introduction of movement at an early stage after injury can help protect the joint against many of the changes described above as well as reversing some of these changes. The effects of passive motion can be observed in several areas:

- Range of movement/joint stiffness
- Quality of repair
- Pain levels and pain medication
- Return to normal activity

Range of movement/joint stiffness

Initially, the most common cause for joint stiffness and a reduced range is intraarticular swelling (edema and blood), periarticular swelling and later adhesion of the different joint structures.[69] Early mobilization with CPM could help reduce joint swelling by activating the trans-synovial pump and draining the edematous periarticular structures. Early passive movement was shown to increase the rate of improvement in range after joint injury or surgery.[70-74]

Passive motion has been shown to facilitate the transport of synovial fluid contents by activating the trans-synovial pump. When a tracer substance was used to study the nutrition of the anterior cruciate ligament under conditions of passive motion and immobilization, it was found that in the mobilizes knees, the clearance rate of the tracer was so rapid that it did not have sufficient time to diffuse into the intracapsular structures.[75] Other studies have shown the benefits of passive motion in reducing haemartherosis.[76] After 1 week of treatment with passive motion, there was a significant decrease in the amount of blood in the mobilized, compared with the immobilized. Passive motion was shown also to affect the outcome of septic arthritis, leading to less damage of the articular cartilage.[77] This was attributed to the effective removal of the damaging lysosomal enzymes by accelerated clearance rate.

Activating the trans-synovial pump could be also important in inflamed joints where there is an increased in synovial fluid volume and pressure (a common cause for the sensations of tension, pain and limitation of movement). Passive or low stress active motion of joints may help to reduce effusion and facilitate the rate of repair.[78,79] It was shown in swollen knees that the clearance rate in the knee joint was increase with dynamic (active movement in this study) cyclical activities such as cycling and walking.[79] Passive cycles of flexion and extension of the spine have been shown to produce pressure fluctuations within the facet joints.[80] When saline was injected into the facet joint artificially to increase intra-articular pressure (as if the joint is effused), cycles of active and passive motion caused a drop in this pressure. This effect was greater when the movement was specific to the effused joint.

Apart from activating the trans-synovial pump, passive motion assist the joint range by pumping blood and edema fluid away from periarticular tissues. This may account for some improvement in range seen with the use of passive motion after surgery.[73]

Adhesions that form later after injury are also a common cause for a reduced range of movement.[59] Intra-articular adhesions that were formed during immobilization were shown to be reduced by passive motion and the return to active movement.[57] This is of particular interest to our clinical work, demonstrating that the adhesion is a “living” adaptable tissue like other connective tissue, and that it has the capacity to remodel itself in response to its mechanical environment. This remodelling was taking place without any forceful stretching of the joint. Connective tissue adhesion affecting the periarticular structures the (capsule and ligaments) may also be reduced by passive or active movement.

Quality of repair

Passive motion has a beneficial effect on the quality of repair of different joint structures and is extensively used postoperatively to facilitate joint repair.[71,81,82] The ligaments, tendons, synovial tissue have all been shown to have better repair with early introduction of passive movement. The effects of passive movement on ligaments, capsules and tendons have been discussed above. [7,8,9-14,15,16] In cartilage passive motion has been shown to promote the repair of minor damage in experimental animals (Fig.5.15).[83] Cyclical stress brought about by movement stimulates the metabolic activity of chondrocytes, resulting in proteoglycans and collagen synthesis.[84] The viability and repair of the articular cartilage depends on these cyclical mechanical stresses.[18,19,21,22,85,86,87] Even slight degrees of motion or intermittent pressure are sufficient to stimulate the production of small amounts of cartilage.[8]

Pain levels and pain medication

Passive motion has been shown to be useful in reducing pain and pain medication in different joint conditions including back pain sufferers. Passive motion into full extension has been shown significantly to improve the range of movement and to reduce pain in spinal disc injuries.[88] A treatment of 20–30 minutes produces immediate positive changes (the frequency used being 10 cycles/min). In another study a 12-minute daily passive motion using BackLife CPM of the lower back into flexion-extension cycles produced significant relief of back pain.[89]

Passive movement is also used postoperatively to facilitate joint repair.[81,82,71] This form of treatment tends to reduce the recovery time and pain level and improve the quality of repair. Passive motion provided on a daily basis was shown to reduce pain in patients with osteoarthritis of the hip.[72] Some of the pain relief may be associated with the direct effects of movement in activating the trans-synovial pump. This may increase the clearance rate of the inflammatory by-products from the site of damage and reduce the swelling in the joint. Another mechanism for pain relief could be related to movement facilitating the repair process. Neurological gating of pain may be another possible mechanisms producing pain relief by movement.

Return to normal activity

Generally, patient who receive early passive motion for joint surgery tend to have reduced hospital stay and early return to normal daily activities.[35,74]

The addition of passive motion was shown to reduce pain in frozen shoulder[118] and to be beneficial and safe and useful after rotator cuff repair.[119,120]

Muscle Tissue

Muscle is the main tissue to undergo shortening and is often the cause of restriction of the range of movement after joint injury. Such changes in length are due to adaptive sarcomere and connective tissue changes.[90,91] It has been demonstrated that in muscle immobilized in its shortened length, there is a reduction in the number of sarcomeres (up to 40% within a few days). This is accompanied by shortening and proliferation of the muscle's connective tissue elements (epimysium, perimysium and endomysium).[92-95] Such changes account for some of the stiffness and reduced extendibility of muscle during passive stretching.[90] Without movement or muscle contraction, there may be excessive oedema and stasis in the tissue spaces.[93] This may eventually lead to excessive connective tissue deposition rather than regeneration of the contractile elements. Some of the changes in innervated and denervated immobilized muscle are very similar, suggesting that the structural changes are largely a result of the absence of mechanical stress on muscle tissue.[35]

Effects of movement on muscle

As with other tissues in the body, muscle regeneration is dependent on *dynamic* longitudinal mechanical tension (stretching or muscle contraction) for homeostasis, regeneration and adaptation.

Longitudinal tension promotes the normal parallel alignment of the myotubes to the lines of stress,[93,96] and is also required for the restoration of the connective tissue component of the regeneration muscle.[93] The normal development of connective tissue in muscle is important for the development of internal tendons, fasciculi and adequate well-defined skeletal attachments. If normal development of connective tissue fails muscle function will not be restored even when full muscle fibre regeneration has taken place.[96]

Tissue culture experiments highlight the importance of both stress and motion to repair and adaptation in muscle. Passive stretching of muscle activates intracellular mechanisms that result in hypertrophy (increase in cell size) of the muscle cells.[97] Smooth muscle cells that are cyclically stretched demonstrate increased synthesis of proline, a major constituent of collagen.[98] Studies using skeletal tissue culture have shown that muscle cells incubated under constant tension synthesize protein at 22% of the rate observed in vivo, whereas passive intermittent stretching resulted in a level of 38% of that found in vivo.[99]

During remobilization of muscle, the number and size of the sarcomeres generally return to preimmobilization levels.[90] Animal studies show that passive muscle stretching leads to increased muscle length, hypertrophy[100] and increased capillary density.[101] In humans rhythmic muscle tension brought about by passive joint movement has also been shown to promote muscle hypertrophy.[102] Such hypertrophy has been observed in diverse conditions such as muscle wasting in patients who are terminally ill.[103] In subjects with osteoarthritis of the hip, passive manual muscle stretching has been shown significantly to increase the range of movement as well as the cross-sectional area of muscle fibres and their glycogen content (decreased muscle mobility leading to muscle atrophy and reduced glycogen content).[101] Patients who had surgery for rotator cuff tears were shown to undergo hypertrophy when passive movement was added.[104]

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