

Myofascial Trigger Points: An Evidence-Informed Review

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Abstract: This article provides a best evidence-informed review of the current scientific understanding of myofascial trigger points with regard to their etiology, pathophysiology, and clinical implications. Evidence-informed manual therapy integrates the best available scientific evidence with individual clinicians' judgments, expertise, and clinical decision-making. After a brief historical review, the clinical aspects of myofascial trigger points, the interrater reliability for identifying myofascial trigger points, and several characteristic features are discussed, including the taut band, local twitch response, and referred pain patterns. The etiology of myofascial trigger points is discussed with a detailed and comprehensive review of the most common mechanisms, including low-level muscle contractions, uneven intramuscular pressure distribution, direct trauma, unaccustomed eccentric contractions, eccentric contractions in unconditioned muscle, and maximal or sub-maximal concentric contractions. Many current scientific studies are included and provide support for considering myofascial trigger points in the clinical decision-making process. The article concludes with a summary of frequently encountered precipitating and perpetuating mechanical, nutritional, metabolic, and psychological factors relevant for physical therapy practice. Current scientific evidence strongly supports that awareness and working knowledge of muscle dysfunction and in particular myofascial trigger points should be incorporated into manual physical therapy practice consistent with the guidelines for clinical practice developed by the International Federation of Orthopaedic Manipulative Therapists. While there are still many unanswered questions in explaining the etiology of myofascial trigger points, this article provides manual therapists with an up-to-date evidence-informed review of the current scientific knowledge.

Key Words: Myofascial Pain Syndrome, Trigger Points, Myofascial, Etiology, Pathophysiology

During the past few decades, myofascial trigger points (MTrPs) and myofascial pain syndrome (MPS) have received much attention in the scientific and clinical literature. Researchers worldwide are investigating various aspects of MTrPs, including their specific etiology, pathophysiology, histology, referred pain patterns, and clinical applications. Guidelines developed by the International Federation of Orthopaedic Manipulative

Therapists (IFOMT) confirm the importance of muscle dysfunction for orthopedic manual therapy clinical practice. The IFOMT has defined orthopedic manual therapy as “a specialized area of physiotherapy/physical therapy for the management of neuromusculoskeletal conditions, based on clinical reasoning, using highly specific treatment approaches including manual techniques and therapeutic exercises.” The educational standards of IFOMT require that skills will be demonstrated in—among others—“analysis and specific tests for functional status of the muscular system,” “a high level of skill in other manual and physical therapy techniques required to mobilize the articular, muscular or neural systems,” and “knowledge of various manipulative therapy approaches as practiced within physical therapy, medicine, osteopathy and chiropractic”¹.

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However, articles about muscle dysfunction in the manual therapy literature are sparse and they generally focus on muscle injury and muscle repair mechanisms² or on muscle recruitment³. Until very recently, the current scientific knowledge and clinical implications of MTrPs were rarely included⁴⁻⁷. It appears that orthopedic manual therapists have not paid much attention to the pathophysiology and clinical manifestations of MTrPs. Manual therapy educational programs in the US seem to reflect this orientation and tend to place a strong emphasis on joint dysfunction, mobilizations, and manipulations with only about 10%-15% of classroom education devoted to muscle pain and muscle dysfunction.

This review of the MTrP literature is based on current best scientific evidence. The field of manual therapy has joined other medical disciplines by embracing evidence-based medicine, which proposes that the results of scientific research need to be integrated into clinical practice⁸. Evidence-based medicine has been defined as “the conscientious, explicit, and judicious use of current best evidence in making decisions about the care of individual patients”^{9,10}. Within the evidence-based medicine paradigm, evidence is not restricted to randomized controlled trials, systematic reviews, and meta-analyses, although this restricted view seems to be prevalent in the medical and physical therapy literature. Sackett et al^{9,10} emphasized that external clinical evidence can inform but not replace individual clinical expertise. Clinical expertise determines whether external clinical evidence applies to an individual patient, and if so, how it should be integrated into clinical decision-making. Pencheon¹¹ shared this perspective and suggested that high-quality healthcare is about combining “wisdom produced by years of experience” with “evidence produced by generalizable research” in “ways with which patients are happy.” He suggested shifting from evidence-based to evidence-informed medicine, where clinical decision-making is informed by research evidence but not driven by it and always includes knowledge from experience. Evidence-informed manual therapy involves integrating the best available external scientific evidence with individual clinicians’ judgments, expertise, and clinical decision-making¹². The purpose of this article is to provide a best evidence-informed review of the current scientific understanding of MTrPs, including the etiology, pathophysiology, and clinical implications, against the background of extensive clinical experience.

Brief Historical Review

While Dr. Janet Travell (1901-1997) is generally credited for bringing MTrPs to the attention of health care providers, MTrPs have been described and rediscovered for several centuries by various clinicians and researchers^{13,14}. As far back as the 16th century, de Baillou (1538-1616), as cited by Ruhmann, described what is now known as myofascial pain syndrome (MPS)¹⁵. MPS is defined as

the “sensory, motor, and autonomic symptoms caused by MTrPs” and has become a recognized medical diagnosis among pain specialists^{16,17}. In 1816, British physician Balfour, as cited by Stockman, described “nodular tumors and thickenings which were painful to the touch, and from which pains shot to neighboring parts”¹⁸. In 1898, the German physician Strauss discussed “small, tender and apple-sized nodules and painful, pencil-sized to little-finger-sized palpable bands”¹⁹. The first trigger point manual was published in 1931 in Germany nearly a decade before Travell became interested in MTrPs²⁰. While these early descriptions may appear a bit archaic and unusual—for example, in clinical practice one does not encounter “apple-sized nodules”—these and other historic papers did illustrate the basic features of MTrPs quite accurately¹⁴.

In the late 1930s, Travell, who at that time was a cardiologist and medical researcher, became particularly interested in muscle pain following the publication of several articles on referred pain²¹. Kellgren’s descriptions of referred pain patterns of many muscles and spinal ligaments after injecting these tissues with hypertonic saline²²⁻²⁵ eventually moved Travell to shift her medical career from cardiology to musculoskeletal pain. During the 1940s, she published several articles on injection techniques of MTrPs²⁶⁻²⁸. In 1952, she described the myofascial genesis of pain with detailed referred pain patterns for 32 muscles²⁹. Other clinicians also became interested in MTrPs. European physicians Lief and Chaitow developed a treatment method, which they referred to as “neuromuscular technique”³⁰. German physician Gutstein described the characteristics of MTrPs and effective manual therapy treatments in several papers under the names of Gutstein, Gutstein-Good, and Good³¹⁻³⁴. In Australia, Kelly produced a series of articles about fibrositis, which paralleled Travell’s writings³⁵⁻³⁸.

In the US, chiropractors Nimmo and Vannerson³⁹ described muscular “noxious generative points,” which were thought to produce nerve impulses and eventually result in “vasoconstriction, ischaemia, hypoxia, pain, and cellular degeneration.” Later in his career, Nimmo adopted the term “trigger point” after having been introduced to Travell’s writings. Nimmo maintained that hypertonic muscles are always painful to pressure, a statement that later became known as “Nimmo’s law.” Like Travell, Nimmo described distinctive referred pain patterns and recommended releasing these dysfunctional points by applying the proper degree of manual pressure. Nimmo’s “receptor-tonus control method” continues to be popular among chiropractic physicians^{39,40}. According to a 1993 report by the National Board of Chiropractic Economics, over 40% of chiropractors in the US frequently apply Nimmo’s techniques⁴¹. Two spin-offs of Nimmo’s work are St. John Neuromuscular Therapy (NMT) method and NMT American version, which have become particularly popular among massage therapists³⁰.

In 1966, Travell founded the North American Academy of Manipulative Medicine, together with Dr. John Mennell, who also published several articles about MTrPs^{42,43}. Throughout her career Travell promoted integrating myofascial treatments with articular treatments¹⁶. One of her earlier papers described a technique for reducing sacroiliac displacement⁴⁴. However, Travell, as cited by Paris⁴⁵, maintained the opinion that manipulations were the exclusive domain of physicians and she rejected membership in the North American Academy of Manipulative Medicine by physical therapists.

In the early 1960s, Dr. David Simons was introduced to Travell and her work, which became the start of a fruitful collaboration eventually resulting in several publications, including the *Trigger Point Manuals*, consisting of a 1983 first volume (upper half of the body) and a 1992 second volume (lower half of the body)^{46,47}. The first volume has since been revised and updated and a second edition was released in 1999¹⁶. The *Trigger Point Manuals* are the most comprehensive review of nearly 150 muscle referred-pain patterns based on Travell's clinical observations, and they include an extensive review of the scientific basis of MTrPs. Both volumes have been translated into several foreign languages, including Russian, German, French, Italian, Japanese, and Spanish. Several other clinicians worldwide have also published their own trigger point manuals⁴⁸⁻⁵⁴.

Clinical Aspects of Myofascial Trigger Points

An MTrP is described as “a hyperirritable spot in skeletal muscle that is associated with a hypersensitive palpable nodule in a taut band”¹⁶. Myofascial trigger points are classified into active and latent trigger points¹⁶. An active MTrP is a symptom-producing MTrP and can trigger local or referred pain or other paraesthesiae. A latent MTrP does not trigger pain without being stimulated. Myofascial trigger points are the hallmark characteristics of MPS and feature motor, sensory, and autonomic components. Motor aspects of active and latent MTrPs may include disturbed motor function, muscle weakness as a result of motor inhibition, muscle stiffness, and restricted range of motion^{55,56}. Sensory aspects may include local tenderness, referral of pain to a distant site, and peripheral and central sensitization. Peripheral sensitization can be described as a reduction in threshold and an increase in responsiveness of the peripheral ends of nociceptors, while central sensitization is an increase in the excitability of neurons within the central nervous system. Signs of peripheral and central sensitization are allodynia (pain due to a stimulus that does not normally provoke pain) and hyperalgesia (an increased response to a stimulus that is normally painful). Both active and latent MTrPs are painful on compression. Vecchiet et al⁵⁷⁻⁵⁹ described specific sensory changes over MTrPs. They

observed significant lowering of the pain threshold over active MTrPs when measured by electrical stimulation, not only in the muscular tissue but also in the overlying cutaneous and subcutaneous tissues. In contrast, with latent MTrPs, the sensory changes did not involve the cutaneous and subcutaneous tissues⁵⁷⁻⁵⁹. Autonomic aspects of MTrPs may include, among others, vasoconstriction, vasodilatation, lacrimation, and piloerection^{16,60-63}.

A detailed clinical history, examination of movement patterns, and consideration of muscle referred-pain patterns assist clinicians in determining which muscles may harbor clinically relevant MTrPs⁶⁴. Muscle pain is perceived as aching and poorly localized. There are no laboratory or imaging tests available that can confirm the presence of MTrPs. Myofascial trigger points are identified through either a flat palpation technique (Figure 1) in which a clinician applies finger or thumb pressure to muscle against underlying bone tissue, or a pincer palpation technique (Figure 2) in which a particular muscle is palpated between the clinician's fingers.



Fig. 1: Flat palpation



Fig. 2: Pincer palpation

By definition, MTrPs are located within a taut band of contracted muscle fibers (Figure 3), and palpating for MTrPs starts with identifying this taut band by palpating perpendicular to the fiber direction. Once the taut band is located, the clinician moves along the taut band to

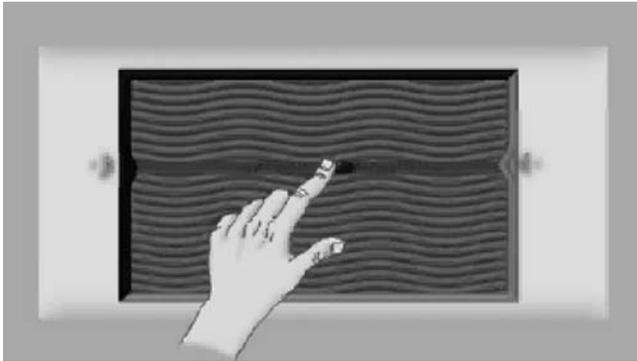


Fig. 3: Palpation of a trigger point within a taut band (reproduced with permission from Weisskircher H-W. Head Pains Due to Myofascial Trigger Points. CD-ROM, www.trigger-point.com, 1997)

find a discrete area of intense pain and hardness.

Two studies have reported good overall interrater reliability for identifying taut bands, MTrPs, referred pain, and local twitch responses^{65,66}. The minimum criteria that must be satisfied in order to distinguish an MTrP from any other tender area in muscle are a taut band and a tender point in that taut band⁶⁵. Although Janda maintained that systematic palpation can differentiate between myofascial taut bands and general muscle spasms, electromyography is the gold standard to differentiate taut bands from contracted muscle fibers^{67,68}. Spasms can be defined as electromyographic (EMG) activity as the result of increased neuromuscular tone of the entire muscle, and they are the result of nerve-initiated contractions. A taut band is an endogenous localized contracture within the muscle without activation of the motor endplate⁶⁹. From a physiological perspective, the term “contracture” is more appropriate than “contraction” when describing chronic involuntary shortening of a muscle without EMG activity. In clinical practice, surface EMG is used in the diagnosis and management of MTrPs in addition to manual examinations^{67,70,71}. Diagnostically, surface EMG can assist in assessing muscle behavior during rest and during functional tasks. Clinicians use the MTrP referred pain patterns in determining which muscles to examine with surface EMG. Muscles that harbor MTrPs responsible for the patient’s pain complaint are examined first. EMG assessments guide the clinician with postural training, ergonomic interventions, and muscle awareness training⁶⁷.

The patient’s recognition of the elicited pain further

guides the clinician. The presence of a so-called local twitch response (LTR), referred pain, or reproduction of the person’s symptomatic pain increases the certainty and specificity of the diagnosis of MPS. Local twitch responses are spinal reflexes that appear to be unique to MTrPs. They are characterized by a sudden contraction of muscle fibers within a taut band, when the taut band is strummed manually or needled. The sudden contractions can be observed visually, can be recorded electromyographically, or can be visualized with diagnostic ultrasound⁷². When an MTrP is needled with a monopolar teflon-coated EMG needle, LTRs appear as high-amplitude poly-phasic EMG discharges⁷³⁻⁷⁸.

In clinical practice, there is no benefit in using needle EMG or sonography, and its utility is limited to research studies. For example, Audette et al⁷⁹ established that in 61.5% of active MTrPs in the trapezius and levator scapulae muscles, dry needling an active MTrP elicited an LTR in the same muscle on the opposite side of the body. Needling of latent MTrPs resulted in unilateral LTRs only. In this study, LTRs were used to research the nature of active versus latent MTrPs. Studies have shown that clinical outcomes are significantly improved when LTRs are elicited in the treatment of patients with dry needling or injection therapy^{74,80,81}. The taut band, MTrP, and LTR (Figure 4) are objective criteria, identified solely by palpation, that do not require a verbal response from the patient⁸².

Active MTrPs refer pain usually to a distant site. The referred pain patterns (Figure 5) are not necessarily

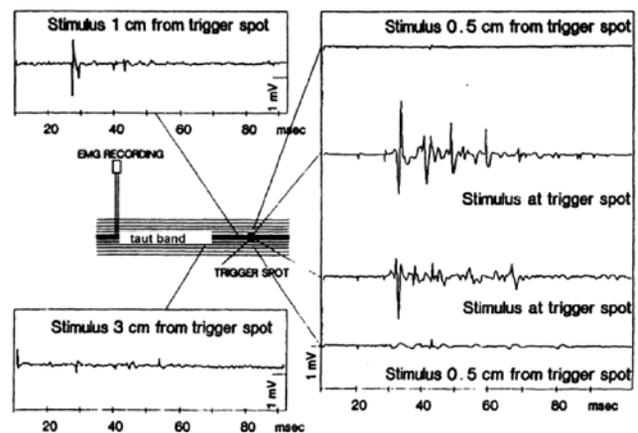


Fig. 4: Local twitch response in a rabbit trigger spot. Local twitch responses are elicited only when the needle is placed accurately within the trigger spot. Moving as little as 0.5 cm away from the trigger spot virtually eliminates the local twitch response (reproduced with permission from Hong C-Z, Torigoe Y. Electrophysiological characteristics of localized twitch responses in responsive taut bands of rabbit skeletal muscle. J Musculoskeletal Pain 1994;2:17-43)

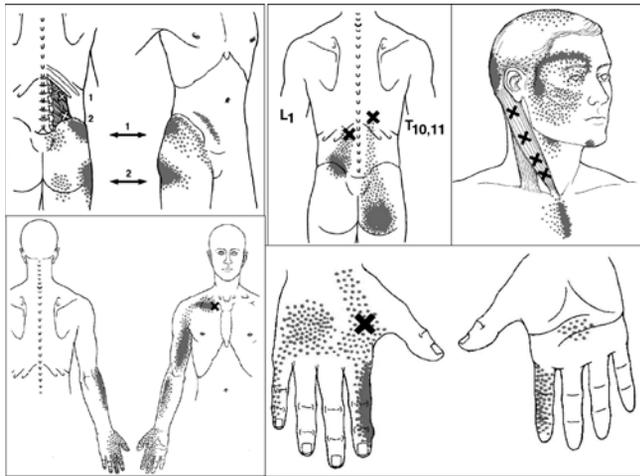


Fig. 5: MTrP referred pain patterns (reproduced with permission from MEDICLIP, *Manual Medicine 1 & 2, Version 1.0a, 1997, Williams & Wilkins*)

restricted to single segmental pathways or to peripheral nerve distributions. Although typical referred pain patterns have been established, there is considerable variation between patients^{16,48}.

Usually, the pain in reference zones is described as “deep tissue pain” of a dull and aching nature. Occasionally, patients may report burning or tingling sensations, especially in superficial muscles such as the platysma muscle^{83,84}. By mechanically stimulating active MTrPs, patients may report the reproduction of their pain, either immediately or after a 10-15 second delay. Normally, skeletal muscle nociceptors require high intensities of stimulation and they do not respond to moderate local pressure, contractions, or muscle stretches⁸⁵. However, MTrPs cause persistent noxious stimulation, which results in increasing the number and size of the receptive fields to which a single dorsal horn nociceptive neuron responds, and the experience of spontaneous and referred pain⁸⁶. Several recent studies have determined previously unrecorded referred pain patterns of different muscles and MTrPs⁸⁷⁻⁹⁰. Referred pain is not specific to MPS but it is relatively easy to elicit over MTrPs⁹¹. Normal muscle tissue and other body tissues, including the skin, zygapophyseal joints, or internal organs, may also refer pain to distant regions with mechanical pressure, making referred pain elicited by stimulation of a tender location a nonspecific finding^{84,92-95}. Gibson et al⁹⁶ found that referred pain is actually easier to elicit in tendon-bone junctions and tendon than in the muscle belly. However, after exposing the muscle to eccentric exercise, significantly higher referred pain frequency and enlarged pain areas were found at the muscle belly and the tendon-bone junction sites following injection with hypotonic saline. The authors suggested that central sensitization may explain the referred pain

frequency and enlarged pain areas⁹⁷.

While a survey of members of the American Pain Society showed general agreement that MTrPs and MPS exist as distinct clinical entities, MPS continues to be one of the most commonly missed diagnoses^{17,98}. In a recent study of 110 adults with low back pain, myofascial pain was the most common finding affecting 95.5% of patients, even though myofascial pain was poorly defined as muscle pain in the paraspinal muscles, piriformis, or tensor fasciae latae⁹⁹. A study of adults with frequent migraine headaches diagnosed according to the International Headache Society criteria showed that 94% of the patients reported migrainous pain with manual stimulation of cervical and temporal MTrPs, compared with only 29% of controls^{100,101}. In 30% of the migraine group, palpation of MTrPs elicited a “full-blown migraine attack that required abortive treatment.” The researchers found a positive relationship between the number of MTrPs and the frequency of migraine attacks and duration of the illness¹⁰⁰. Several studies have confirmed that MTrPs are common not only in persons attending pain management clinics but also in those seeking help through internal medicine and dentistry¹⁰²⁻¹⁰⁷. In fact, MTrPs have been identified with nearly every musculoskeletal pain problem, including radiculopathies¹⁰⁴, joint dysfunction¹⁰⁸, disk pathology¹⁰⁹, tendonitis¹¹⁰, craniomandibular dysfunction¹¹¹⁻¹¹³, migraines^{100,114}, tension-type headaches^{7,87}, carpal tunnel syndrome¹¹⁵, computer-related disorders¹¹⁶, whiplash-associated disorders^{60,117}, spinal dysfunction¹¹⁸, and pelvic pain and other urologic syndromes¹¹⁹⁻¹²². Myofascial trigger points are associated with many other pain syndromes¹²³, including, for example, post-herpetic neuralgia^{124,125}, complex regional pain syndrome^{126,127}, nocturnal cramps¹²⁸, phantom pain^{129,130}, and other relatively uncommon diagnoses such as Barré-Liéou syndrome¹³¹ and neurogenic pruritus¹³². A recent study suggested that there might be a relationship between MTrPs in the upper trapezius muscle and cervical spine dysfunction at the C3 and C4 vertebrae, although a cause-and-effect relationship was not established in this correlational study¹³³. Another study described that persons with mechanical neck pain had significantly more clinically relevant MTrPs in the upper trapezius, sternocleidomastoid, levator scapulae, and suboccipital muscles as compared to healthy controls⁵.

Etiology of MTrPs

Several possible mechanisms can lead to the development of MTrPs, including low-level muscle contractions, uneven intramuscular pressure distribution, direct trauma, unaccustomed eccentric contractions, eccentric contractions in unconditioned muscle, and maximal or submaximal concentric contractions.

Low-level muscle contractions

Of particular interest in the etiology of MTrPs are low-level muscle exertions and the so-called Cinderella

Hypothesis developed by Hägg in 1988¹³⁴. The Cinderella Hypothesis postulates that occupational myalgia is caused by selective overloading of the earliest recruited and last de-recruited motor units according to the ordered recruitment principle or Henneman's "size principle"^{134,135}. Smaller motor units are recruited before and de-recruited after larger ones; as a result, the smaller type 1 fibers are continuously activated during prolonged motor tasks¹³⁵. According to the Cinderella Hypothesis, muscular force generated at sub-maximal levels during sustained muscle contractions engages only a fraction of the motor units available without the normally occurring substitution of motor units during higher force contractions, which in turn can result in metabolically overloaded motor units, prone to loss of cellular Ca^{2+} -homeostasis, subsequent activation of autogenic destructive processes, and muscle pain^{136,137}. The other pillar of the Cinderella Hypothesis is the finding of an excess of ragged red fibers in myalgic patients¹³⁶. Indeed, several researchers have demonstrated the presence of ragged red fibers and moth-eaten fibers in subjects with myalgia, which are indications of structural damage to the cell membrane and mitochondria and a change in the distribution of mitochondria or the sarcotubular system respectively¹³⁸⁻¹⁴².

There is growing evidence that low-level static muscle contractions or exertions can result in degeneration of muscle fibers¹⁴³. Gissell^{144,145} has shown that low-level exertions can result in an increase of Ca^{2+} -release in skeletal muscle cells, muscle membrane damage due to leakage of the intracellular enzyme lactate dehydrogenase, structural damage, energy depletion, and myalgia. Low-level muscle stimulation can also lead to the release of interleukin 6 (IL-6) and other cytokines^{146,147}.

Several studies have confirmed the Cinderella Hypothesis and support the idea that in low-level static exertions, muscle fiber recruitment patterns tend to be stereotypical with continuous activation of smaller type 1 fibers during prolonged motor tasks¹⁴⁸⁻¹⁵². As Hägg indicated, the continuous activity and metabolic overload of certain motor units does not occur in all subjects¹³⁶. The Cinderella Hypothesis was recently applied to the development of MTrPs¹¹⁶. In a well-designed study, Treasters et al¹¹⁶ established that sustained low-level muscle contractions during continuous typing for as little as 30 minutes commonly resulted in the formation of MTrPs. They suggested that MTrPs might provide a useful explanation for muscle pain and injury that can occur from low-level static exertions¹¹⁶. Myofascial trigger points are common in office workers, musicians, dentists, and other occupational groups exposed to low-level muscle exertions¹⁵³. Chen et al¹⁵⁴ also suggested that low-level muscle exertions can lead to sensitization and development of MTrPs. Forty piano students showed significantly reduced pressure thresholds over latent MTrPs after only 20 minutes of continuous piano playing¹⁵⁴.

Intramuscular pressure distribution

Otten¹⁵⁵ has suggested that circulatory disturbances secondary to increased intramuscular pressure may also lead to the development of myalgia. Based on mathematical modeling applied to a frog gastrocnemius muscle, Otten confirmed that during static low-level muscle contractions, capillary pressures increase dramatically especially near the muscle insertions (Figure 6). In other words, during low-level exertions, the intramuscular

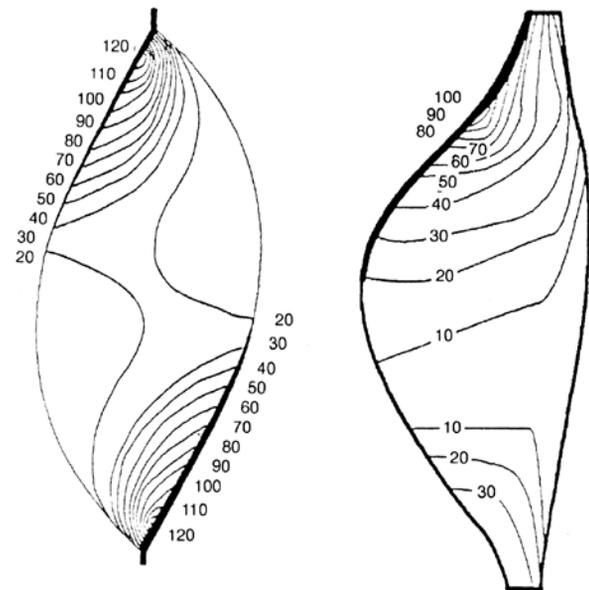


Fig. 6: Intramuscular pressure distribution in the gastrocnemius muscle of the toad (reproduced with permission from E. Otten, 2006)

pressure near the muscle insertions might increase rapidly, leading to excessive capillary pressure, decreased circulation, and localized hypoxia and ischaemia¹⁵⁵. With higher level contractions in between 10% and 20% of maximum voluntary effort, the intramuscular pressure increases also in the muscle belly^{156,157}. According to Otten, the increased pressure gradients during low-level exertions may contribute to the development of pain at the musculotendinous junctions and eventually to the formation of MTrPs (personal communication, 2005).

In 1999, Simons introduced the concept of "attachment trigger points" to explain pain at the musculotendinous junctions in persons with MTrPs, based on the assumption that taut bands would generate sufficient sustained force to induce localized enthesopathies^{16,158}. More recently, Simons concluded that there is no convincing evidence that the tension generated in shortened sarcomeres in a muscle belly would indeed be able to generate passive or resting force throughout an entire taut band resulting in enthesopathies, even though

there may be certain muscles or conditions where this could occur (personal communication, 2005). To the contrary, force generated by individual motor units is always transmitted laterally to the muscle's connective tissue matrix, involving at least two protein complexes containing vinculin and dystrophin, respectively¹⁵⁹. There is also considerable evidence that the assumption that muscle fibers pass from tendon to tendon is without basis¹⁶⁰. Trotter¹⁶⁰ has demonstrated that skeletal muscle is comprised of in-series fibers. In other words, there is evidence that a single muscle fiber does not run from tendon to tendon. The majority of fibers are in series with inactive fibers, which makes it even more unlikely that the whole muscle length-tension properties would be dictated by the shortest contracted fibers in the muscle¹⁶¹.

In addition, it is important to consider the mechanical and functional differences between fast and slow motor units^{162,163}. Slow motor units are always stiffer than fast units, although fast units can produce more force. If there were any transmission of force along the muscle fiber, as Simons initially suggested, fast fibers would be better suited to accomplish this. Yet, fast motor units have larger series of elastic elements, which would absorb most of the force displacement^{164,165}. Fast fibers show a progressive decrease in cross-sectional area and end in a point within the muscle fascicle, making force transmission even more unlikely¹⁶³. Fast fibers rely on transmitting a substantial proportion of their force to the endomysium, transverse cytoskeleton, and adjacent muscle fibers^{162,163}. In summary, the development of so-called "attachment trigger points" as a result of increased tension by contracted sarcomeres in MTrPs is not clear and more research is needed to explain the clinical observation that MTrPs appear to be linked to pain at the musculotendinous junction. The increased tension in the muscle belly is likely to dissipate across brief sections of the taut band on both sides of the MTrP and laterally through the transverse cytoskeleton¹⁶⁶⁻¹⁶⁸. Instead, Otten's model of increased intramuscular pressure, decreased circulation, localized hypoxia, and ischaemia at the muscle insertions provides an alternative model for the clinically observed pain near the musculotendinous junction and osseous insertions in persons with MTrPs, even though the model does not explain why taut bands are commonly present¹⁵⁵.

Direct trauma

There is general agreement that acute muscle overload can activate MTrPs, although systematic studies are lacking¹⁶⁹. For example, people involved in whiplash injuries commonly experience prolonged muscle pain and dysfunction¹⁷⁰⁻¹⁷³. In a retrospective review, Schuller et al¹⁷⁴ found that 80% of 1096 subjects involved in low-velocity collisions demonstrated evidence of muscle pain with myogeloses among the most common find-

ings. Although Schuller et al¹⁷⁴ did not define these myogeloses, Simons has suggested that a myogelosis describes the same clinical entity as an MTrP¹⁷⁵. Baker¹¹⁷ reported that the splenius capitis, semispinalis capitis, and sternocleidomastoid muscles developed symptomatic MTrPs in 77%, 62%, and 52% of 52 whiplash patients, respectively. In a retrospective review of 54 consecutive chronic whiplash patients, Gerwin and Dommerholt¹⁷⁶ reported that clinically relevant MTrPs were found in every patient, with the trapezius muscle involved most often. Following treatment emphasizing the inactivation of MTrPs and restoration of normal muscle length, approximately 80% of patients experienced little or no pain, even though the average time following the initiating injury was 2.5 years at the beginning of the treatment regimen. All patients had been seen previously by other physicians and physical therapists who apparently had not considered MTrPs in their thought process and clinical management¹⁷⁶. Fernández-de-las-Peñas et al^{177,178} confirmed that inactivation of MTrPs should be included in the management of persons suffering from whiplash-associated disorders. In their research-based treatment protocol, the combination of cervical and thoracic spine manipulations with MTrP treatments proved superior to more conventional physical therapy consisting of massage, ultrasound, home exercises, and low-energy high-frequency pulsed electromagnetic therapy¹⁷⁷.

Direct trauma may create a vicious cycle of events wherein damage to the sarcoplasmic reticulum or the muscle cell membrane may lead to an increase of the calcium concentration, a subsequent activation of actin and myosin, a relative shortage of adenosine triphosphate (ATP), and an impaired calcium pump, which in turn will increase the intracellular calcium concentration even more, completing the cycle. The calcium pump is responsible for returning intracellular Ca^{2+} to the sarcoplasmic reticulum against a concentration gradient, which requires a functional energy supply. Simons and Travell¹⁷⁹ considered this sequence in the development of the so-called "energy crisis hypothesis" introduced in 1981. Sensory and motor system dysfunction have been shown to develop rapidly after injury and actually may persist in those who develop chronic muscle pain and in individuals who have recovered or continue to have persistent mild symptoms^{172,180}. Scott et al¹⁸¹ determined that individuals with chronic whiplash pain develop more widespread hypersensitivity to mechanical pressure and thermal stimuli than those with chronic idiopathic neck pain. Myofascial trigger points are a likely source of ongoing peripheral nociceptive input, and they contribute to both peripheral and central sensitization, which may explain the observation of widespread allodynia and hypersensitivity^{60,62,63}. In addition to being caused by whiplash injury, acute muscle overload can occur with direct impact, lifting injuries, sports performance, etc.¹⁸².

Eccentric and (sub)maximal concentric contractions

Many patients report the onset of pain and activation of MTrPs following either acute, repetitive, or chronic muscle overload¹⁸³. Gerwin et al¹⁸⁴ suggested that likely mechanisms relevant for the development of MTrPs included either unaccustomed eccentric exercise, eccentric exercise in unconditioned muscle, or maximal or sub-maximal concentric exercise. A brief review of pertinent aspects of exercise follows, preceding linking this body of research to current MTrP research.

Eccentric exercise is associated with myalgia, muscle weakness, and destruction of muscle fibers, partially because eccentric contractions cause an irregular and uneven lengthening of muscle fibers¹⁸⁵⁻¹⁸⁷. Muscle soreness and pain occur because of local ultra-structural damage, the release of sensitizing algogenic substances, and the subsequent onset of peripheral and central sensitization^{85,188-190}. Muscle damage occurs at the cytoskeletal level and frequently involves disorganization of the A-band, streaming of the Z-band, and disruption of cytoskeletal proteins, such as titin, nebulin, and desmin, even after very short bouts of eccentric exercise^{186,189-194}. Loss of desmin can occur within 5 minutes of eccentric loading, even in muscles that routinely contract eccentrically during functional activities, but does not occur after isometric or concentric contractions^{193,195}. Lieber and Fridén¹⁹³ suggested that the rapid loss of desmin might indicate a type of enzymatic hydrolysis or protein phosphorylation as a likely mechanism.

One of the consequences of muscle damage is muscle weakness¹⁹⁶⁻¹⁹⁸. Furthermore, concentric and eccentric contractions are linked to contraction-induced capillary constrictions, impaired blood flow, hypoperfusion, ischaemia, and hypoxia, which in turn contribute to the development of more muscle damage, a local acidic milieu, and an excessive release of protons (H^+), potassium (K^+), calcitonin-gene-related-peptide (CGRP), bradykinin (BK), and substance P (SP), and sensitization of muscle nociceptors^{184,188}. There are striking similarities with the chemical environment of active MTrPs established with microdialysis, suggesting an overlap between the research on eccentric exercise and MTrP research^{184,199}. However, at this time, it is premature to conclude that there is solid evidence that eccentric and sub-maximal concentric exercise are absolute precursors to the development of MTrPs. In support of this hypothesized causal relation, Itoh et al²⁰⁰ demonstrated in a recent study that eccentric exercise can lead to the formation of taut and tender ropy bands in exercised muscle, and they hypothesized that eccentric exercise may indeed be a useful model for the development of MTrPs.

Eccentric and concentric exercise and MTrPs have been associated with localized hypoxia, which appears to be one of the most important precursors for the development of MTrPs²⁰¹. As mentioned, hypoxia leads to the release of multiple algogenic substances. In this

context, recent research by Shah et al¹⁹⁹ at the US National Institutes of Health is particularly relevant. Shah et al analyzed the chemical milieu of latent and active MTrPs and normal muscles. They found significantly increased concentrations of BK, CGRP, SP, tumor necrosis factor- α (TNF- α), interleukin-1 β (IL-1 β), serotonin, and norepinephrine in the immediate milieu of active MTrPs only¹⁹⁹. These substances are well-known stimulants for various muscle nociceptors and bind to specific receptor molecules of the nerve endings, including the so-called purinergic and vanilloid receptors^{85,202}.

Muscle nociceptors are dynamic structures whose receptors can change depending on the local tissue environment. When a muscle is damaged, it releases ATP, which stimulates purinergic receptors, which are sensitive to ATP, adenosine diphosphate, and adenosine. They bind ATP, stimulate muscle nociceptors, and cause pain. Vanilloid receptors are sensitive to heat and respond to an increase in H^+ -concentration, which is especially relevant under conditions with a lowered pH, such as ischaemia, inflammation, or prolonged and exhaustive muscle contractions⁸⁵. Shah et al¹⁹⁹ determined that the pH at active MTrP sites is significantly lower than at latent MTrP sites. A lowered pH can initiate and maintain muscle pain and mechanical hyperalgesia through activation of acid-sensing ion channels^{203,204}. Neuroplastic changes in the central nervous system facilitate mechanical hyperalgesia even after the nociceptive input has been terminated (central sensitization)^{203,204}. Any noxious stimulus sufficient to cause nociceptor activation causes bursts of SP and CGRP to be released into the muscle, which have a significant effect on the local biochemical milieu and microcirculation by stimulating “feed-forward” neurogenic inflammation. Neurogenic inflammation can be described as a continuous cycle of increasing production of inflammatory mediators and neuropeptides and an increasing barrage of nociceptive input into wide dynamic-range neurons in the spinal cord dorsal horn¹⁸⁴.

The Integrated Trigger Point Hypothesis

The integrated trigger point hypothesis (Figure 7) has evolved since its first introduction as the “energy crisis hypothesis” in 1981. It is based on a combination of electrodiagnostic and histopathological evidence^{179,183}.

Already in 1957, Weeks and Travell²⁰⁵ had published a report that outlined a characteristic electrical activity of an MTrP. It was not until 1993 that Hubbard et al²⁰⁶ confirmed that this EMG discharge consists of low-amplitude discharges in the order of 10-50 μV and intermittent high-amplitude discharges (up to 500 μV) in painful MTrPs. Initially, the electrical activity was termed “spontaneous electrical activity” (SEA) and thought to be related to dysfunctional muscle spindles²⁰⁶. Best available evidence now suggests that the SEA is in fact endplate noise (EPN), which is found much more

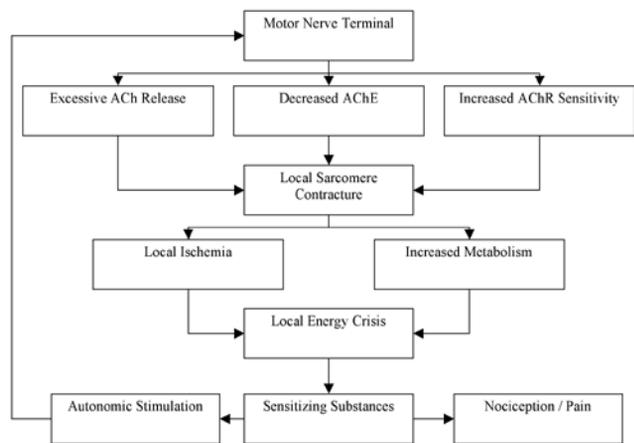


Fig. 7: The integrated trigger point hypothesis. Ach- acetylcholine; AchE- acetylcholinesterase; AchR- acetylcholine receptor

commonly in the endplate zone near MTrPs than in an endplate zone outside MTrPs²⁰⁷⁻²⁰⁹. The electrical discharges occur with frequencies that are 10-1,000 times that of normal endplate potentials, and they have been found in humans, rabbits, and recently even in horses^{209,210}. The discharges are most likely the result of an abnormally excessive release of acetylcholine (ACh) and indicative of dysfunctional motor endplates, contrary to the commonly accepted notion among electromyographers that endplate noise arises from normal motor endplates¹⁸³. The effectiveness of botulinum toxin in the treatment of MTrPs provides indirect evidence of the presence of excessive ACh²¹¹. Botulinum toxin (BoTox) is a neurotoxin that blocks the release of ACh from presynaptic cholinergic nerve endings. A recent study in mice demonstrated that the administration of botulinum toxin resulted in a complete functional repair of dysfunctional endplates²¹². There is some early evidence that muscle stretching and hypertonicity may also enhance the excessive release of ACh^{213,214}. Tension on the integrins in the presynaptic membrane at the motor nerve terminal is hypothesized to mechanically trigger an ACh release that does not require Ca^{2+} ²¹³⁻²¹⁵. Integrins are receptor proteins in the cell membrane involved in attaching individual cells to the extracellular matrix.

Excessive ACh affects voltage-gated sodium channels of the sarcoplasmic reticulum and increases the intracellular calcium levels, which triggers sustained muscle contractures. It is conceivable that in MTrPs, myosin filaments literally get stuck in the Z-band of the sarcomere. During sarcomere contractions, titin filaments are folded into a gel-like structure at the Z-band. In MTrPs, the gel-like titin may prevent the myosin filaments from detaching. The myosin filaments may actually damage the regular motor assembly and prevent

the sarcomere from restoring its resting length²¹⁶. Muscle contractures are also maintained because of the relative shortage of ATP in an MTrP, as ATP is required to break the cross-bridges between actin and myosin filaments. The question remains whether sustained contractures require an increase of oxygen availability.

At the same time, the shortened sarcomeres compromise the local circulation causing ischaemia. Studies of oxygen saturation levels have demonstrated severe hypoxia in MTrPs²⁰¹. Hypoxia leads to the release of sensitizing substances and activates muscle nociceptors as reviewed above. The combined decreased energy supply and possible increased metabolic demand would also explain the common finding of abnormal mitochondria in the nerve terminal and the previously mentioned ragged red fibers. In mice, the onset of hypoxia led to an immediate increased ACh release at the motor endplate²¹⁷.

The combined high-intensity mechanical and chemical stimuli may cause activation and sensitization of the peripheral nerve endings and autonomic nerves, activate second order neurons including so-called “sleeping” receptors, cause central sensitization, and lead to the formation of new receptive fields, referred pain, a long-lasting increase in the excitability of nociceptors, and a more generalized hyperalgesia beyond the initial nociceptive area. An expansion of a receptive field means that a dorsal horn neuron receives information from areas it has not received information from previously²¹⁸. Sensitization of peripheral nerve endings can also cause pain through SP activating the neurokinin-1 receptors and glutamate activating N-methyl-D-aspartate receptors, which opens post-synaptic channels through which Ca^{2+} ions can enter the dorsal horn and activate many enzymes involved in the sensitization⁸⁵.

Several histological studies offer further support for the integrated trigger point hypothesis. In 1976, Simons and Stolov published the first biopsy study of MTrPs in a canine muscle and reported multiple contraction knots in various individual muscle fibers (Figure 8)²¹⁹. The knots featured a combination of severely shortened sarcomeres in the center and lengthened sarcomeres outside the immediate MTrP region²¹⁹.

Reitinger et al²²⁰ reported pathologic alterations of the mitochondria as well as increased width of A-bands and decreased width of I-bands in muscle sarcomeres of MTrPs in the gluteus medius muscle. Windisch et al²²¹ determined similar alterations in a post-mortem histological study of MTrPs completed within 24 hours of time of death. Mense et al²²² studied the effects of electrically induced muscle contractions and a cholinesterase blocker on muscles with experimentally induced contraction knots and found evidence of localized contractions, torn fibers, and longitudinal stripes. Pongratz and Spath^{223, 224} demonstrated evidence of a contraction disk in a region of an MTrP using light microscopy. New MTrP histopathological studies are currently being conducted at the Friedrich

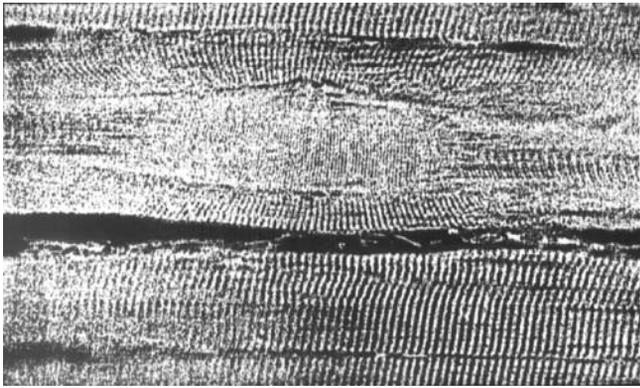


Fig. 8: Longitudinal section of a contraction knot in a canine gracilis muscle (reproduced with permission from: Simons DG, Travell JG, Simons LS. Travell and Simons' Myofascial Pain and Dysfunction: The Trigger Point Manual. Vol. 1. 2nd ed. Baltimore, MD: Williams & Wilkins, 1999)

Baur Institute in Munich, Germany. Gariphanova²²⁵ described pathological changes with biopsy studies of MTrPs, including a decrease in quantity of mitochondria, possibly indicating metabolic distress. Several older histological studies are often quoted, but it is not clear to what extent those findings are specific for MTrPs. In 1951, Glogowsky and Wallraff²²⁶ reported damaged fibril structures. Fassbender²²⁷ observed degenerative changes of the I-bands, in addition to capillary damage, a focal accumulation of glycogen, and a disintegration of the myofibrillar network.

There is growing evidence for the integrated trigger point hypothesis with regard to the motor and sensory aspects of MTrPs, but many questions remain about the autonomic aspects. Several studies have shown that MTrPs are influenced by the autonomic nervous system. Exposing subjects with active MTrPs in the upper trapezius muscles to stressful tasks consistently increased the electrical activity in MTrPs in the upper trapezius muscle but not in control points in the same muscle, while autogenic relaxation was able to reverse the effects²²⁸⁻²³¹. The administration of the sympathetic blocking agent phentolamine significantly reduced the electrical activity of an MTrP^{228,232,233}. The interactions between the autonomic nervous system and MTrPs need further investigation. Hubbard²²⁸ maintained that the autonomic features of MTrPs are evidence that MTrPs may be dysfunctional muscle spindles. Gerwin et al¹⁸⁴ have suggested that the presence of alpha and beta adrenergic receptors at the endplate provide a possible mechanism for autonomic interaction. In a rodent, stimulation of the alpha and beta adrenergic receptors stimulated the release of ACh in the phrenic nerve²³⁴. In a recent study, Ge et al⁶¹ provided for the first time experimental evidence of sympathetic facilitation of me-

chanical sensitization of MTrPs, which they attributed to a change in the local chemical milieu at the MTrPs due to increased vasoconstriction, an increased sympathetic release of noradrenaline, or an increased sensitivity to noradrenaline. Another intriguing possibility is that the cytokine interleukin-8 (IL-8) found in the immediate milieu of active MTrPs may contribute to the autonomic features of MTrP. IL-8 can induce mechanical hyper-nociception, which is inhibited by beta adrenergic receptor antagonists²³⁵. Shah et al found significantly increased levels of IL-8 in the immediate milieu of active MTrPs (Shah, 2006, personal communication).

The findings of Shah et al¹⁹⁹ mark a major milestone in the understanding and acceptance of MTrPs and support parts of the integrated trigger point hypothesis¹⁸³. The possible consequences of several of the chemicals present in the immediate milieu of active MTrPs have been explored by Gerwin et al¹⁸⁴. As stated, Shah et al found significantly increased concentrations of H⁺, BK, CGRP, SP, TNF- α , IL-1 β , serotonin, and norepinephrine in active MTrPs only. There are many interactions between these chemicals that all can contribute to the persistent nature of MTrPs through various vicious feedback cycles²³⁶. For example, BK is known to activate and sensitize muscle nociceptors, which leads to inflammatory hyperalgesia, an activation of high-threshold nociceptors associated with C-fibers, and even an increased production of BK itself. Furthermore, BK stimulates the release of TNF- α , which activates the production of the interleukins IL-1 β , IL-6, and IL-8. Especially IL-8 can cause hyperalgesia that is independent from prostaglandin mechanisms. Via a positive feedback loop, IL-1 β can also induce the release of BK²³⁷. Release of BK, K⁺, H⁺, and cytokines from injured muscle activates the muscle nociceptors, thereby causing tenderness and pain¹⁸⁴.

Calcitonin gene-related peptide can enhance the release of ACh from the motor endplate and simultaneously decrease the effectiveness of acetylcholinesterase (AChE) in the synaptic cleft, which decreases the removal of ACh^{238,239}. Calcitonin gene-related peptide also up-regulates the ACh-receptors (AChR) at the muscle and thereby creates more docking stations for ACh. Miniature endplate activity depends on the state of the AChR and on the local concentration of ACh, which is the result of ACh-release, reuptake, and breakdown by AChE. In summary, increased concentrations of CGRP lead to a release of more ACh, and increase the impact of ACh by reducing AChE effectiveness and increasing AChR efficiency. Miniature endplate potential frequency is increased as a result of greater ACh effect. The observed lowered pH has several implications as well. Not only does a lower pH enhance the release of CGRP, it also contributes to a further down-regulation of AChE. The multiple chemicals and lowered pH found in active MTrPs can contribute to the chronic nature of MTrPs, enhance the segmental spread of nociceptive input into the dorsal horn of the

spinal cord, activate multiple receptive fields, and trigger referred pain, allodynia, hypersensitivity, and peripheral and central sensitization that are characteristic of active myofascial MTrPs¹⁸⁴. There is no other evidence-based hypothesis that explains the phenomena of MTrPs in as much detail and clarity as the expanded integrated trigger point hypothesis (Figure 9).

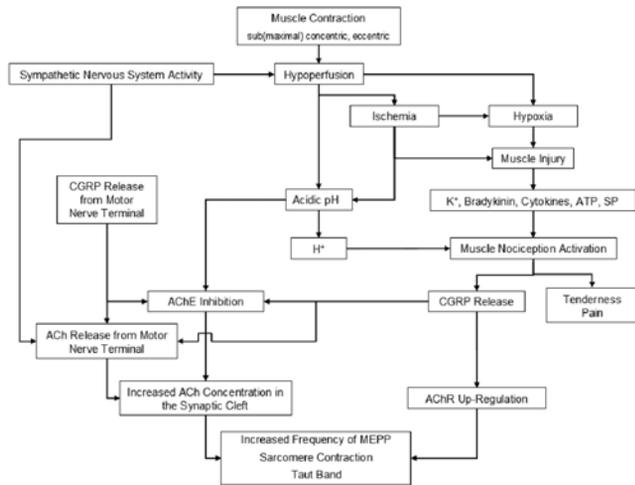


Fig. 9: The expanded MTrP hypothesis (reproduced with permission from: Gerwin RD, Dommerholt J, Shah J. An expansion of Simons' integrated hypothesis of trigger point formation. *Curr Pain Headache Rep* 2004;8:468-475). Ach- acetylcholine; AchE- acetylcholinesterase; AchR- acetylcholine receptor; ATP- adenosine triphosphate; SP- substance P; CGRP- calcitonin gene-related peptide; MEPP- miniature endplate potential

Perpetuating Factors

There are several precipitating or perpetuating factors that need to be identified and, if present, adequately managed to successfully treat persons with chronic myalgia. Even though several common perpetuating factors are more or less outside the direct scope of manual physical therapy, familiarity with these factors is critical especially considering the development of increasingly autonomous physical therapy practice. Simons, Travell, and Simons¹⁶ identified mechanical, nutritional, metabolic, and psychological categories of perpetuating factors. Mechanical factors are familiar to manual therapists and include the commonly observed forward head posture, structural leg length inequalities, scoliosis, pelvic torsion, joint hypermobility, ergonomic stressors, poor body mechanics, etc.^{16,102,116,240}.

In recent review articles, Gerwin^{241,242} provided a comprehensive update with an emphasis on non-structural perpetuating factors. Management of these factors usually requires an interdisciplinary approach, including

medical and psychological intervention^{64,82}. Common nutritional deficiencies or insufficiencies involve vitamin B1, B6, B12, folic acid, vitamin C, vitamin D, iron, magnesium, and zinc, among others. The term “insufficiency” is used to indicate levels in the lower range of normal, such as those associated with biochemical or metabolic abnormalities or with subtle clinical signs and symptoms. Nutritional or metabolic insufficiencies are frequently overlooked and not necessarily considered clinically relevant by physicians unfamiliar with MTrPs and chronic pain conditions. Yet any inadequacy that interferes with the energy supply of muscle is likely to aggravate MTrPs²⁴². The most common deficiencies and insufficiencies will be reviewed briefly.

Vitamin B12 deficiencies are rather common and may affect as many as 15%-20% of the elderly and approximately 16% of persons with chronic MTrPs^{103,243}. B12 deficiencies can result in cognitive dysfunction, degeneration of the spinal cord, and peripheral neuropathy, which is most likely linked to complaints of diffuse myalgia seen in some patients. Serum levels of vitamin B12 as high as 350 pg/ml may be associated with a metabolic deficiency manifested by elevated serum or urine methylmalonic acid or homocysteine and may be clinically symptomatic²⁴⁴. However, there are patients with normal levels of methylmalonic acid and homocysteine, who do present with metabolic abnormalities of B12 function²⁴². Folic acid is closely linked to vitamin B12 and should be measured as well. While folic acid is able to correct the pernicious anaemia associated with vitamin B12 deficiency, it does not influence the neuromuscular aspects.

Iron deficiency in muscle occurs when ferritin is depleted. Ferritin represents the tissue-bound non-essential iron stores in muscle, liver, and bone marrow that supply the essential iron for oxygen transport and iron-dependent enzymes. Iron is critical for the generation of energy through the cytochrome oxidase enzyme system and a lack of iron may be a factor in the development and maintenance of MTrPs²⁴². Interestingly, lowered levels of cytochrome oxidase are common in patients with myalgia¹⁴⁰. Serum levels of 15-20 ng/ml indicate a depletion of ferritin. Common symptoms are chronic tiredness, coldness, extreme fatigue with exercise, and muscle pain. Anaemia is common at levels of 10 ng/ml or less. Although optimal levels of ferritin are unknown, Gerwin²⁴² suggested that levels below 50 ng/ml may be clinically significant.

Close to 90% of patients with chronic musculoskeletal pain may have vitamin D deficiency²⁴⁵. Vitamin D deficiencies are identified by measuring 25-OH vitamin D levels. Levels above 20 ng/ml are considered normal, but Gerwin²⁴² suggested that levels below 34 ng/ml may represent insufficiencies. Correction of insufficient levels of vitamin B12, vitamin D, and iron levels may take many months, during which patients may not see much improvement.

Even when active MTrPs have been identified in a particular patient, clinicians must always consider that MTrPs may be secondary to metabolic insufficiencies or other medical diagnoses. It is questionable whether physical therapy and—as an integral part of physical therapy management—manual therapy intervention can be successful when patients have nutritional or metabolic insufficiencies or deficiencies. A close working relationship with physicians familiar with this body of literature is essential. Therapists should consider the possible interactions between arthrogenic or neurogenic dysfunction and MTrPs^{4,5,118,133,246,247}.

Clinically, physical therapists should address all aspects of the dysfunction. There are many other conditions that feature muscle pain and MTrPs, including hypothyroidism, systemic lupus erythematosus, Lyme disease, babesiosis, ehrlichiosis, candida albicans infections, myoadenylate deaminase deficiency, hypoglycaemia, and parasitic diseases such as fascioliasis, amoebiasis, and giardia^{64, 242}. Therapists should be familiar with the symptoms associated with these medical diagnoses⁶⁴.

Psychological stress may activate MTrPs. Electromyographic activity in MTrPs has been shown to increase dramatically in response to mental and emotional stress, whereas adjacent non-trigger point muscle EMG activity remained normal^{229, 230}. Relaxation techniques, such as autogenic relaxation, can diminish the electrical activity²³¹. In addition, many patients with persistent MTrPs are dealing with depression, anxiety, anger, and feelings of hopelessness²⁴⁸. Pain-related fear and avoidance can lead to the development and maintenance of chronic pain²⁴⁹. Sleep disturbance can also be a major factor in the perpetuation of musculoskeletal pain and must be addressed. Sleep problems may be related to pain, apnea, or to mood disorders like depression or anxiety. Management can be both pharmacologic and non-pharmacologic. Pharmacologic treatment utilizes drugs that promote normal sleep patterns and induce and maintain sleep through the night without causing daytime sedation. Non-pharmacologic treatment emphasizes sleep hygiene,

such as using the bed only for sleep and sex, and not for reading, television viewing, and eating²⁵⁰. Therapists must be sensitive to the impact of psychological and emotional distress and refer patients to clinical social workers or psychologists when appropriate.

The Role of Manual Therapy

Although the various management approaches are beyond the scope of this article, manual therapy is one of the basic treatment options and the role of orthopedic manual physical therapists cannot be overemphasized^{82,158}. Myofascial trigger points are treated with manual techniques, spray and stretch, dry needling, or injection therapy. Dry needling is within the scope of physical therapy practice in many countries including Canada, Spain, Ireland, South Africa, Australia, the Netherlands, and Switzerland. In the United States, the physical therapy boards of eight states have ruled that physical therapists can engage in the practice of dry needling: New Hampshire, Maryland, Virginia, South Carolina, Georgia, Kentucky, New Mexico, and Colorado⁸⁰. A promising new development used in the diagnosis and treatment of MTrPs involves shockwave therapy, but as of yet, there are no controlled studies substantiating its use^{251,252}.

Summary

Although MTrPs are a common cause of pain and dysfunction in persons with musculoskeletal injuries and diagnoses, the importance of MTrPs is not obvious from reviewing the orthopedic manual therapy literature. Current scientific evidence strongly supports that awareness and a working knowledge of muscle dysfunction; in particular, MTrPs should be incorporated into manual physical therapy practice consistent with the IFOMT guidelines for clinical practice. While there are still many unanswered questions with regard to explaining the etiology of MTrPs, this article provides manual therapists with an up-to-date evidence-informed review of the current scientific knowledge. ■

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