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Latent Myofascial Trigger Points Are Associated With an Increased Intramuscular Electromyographic Activity During Synergistic Muscle Activation

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Abstract: The aim of this study was to evaluate intramuscular muscle activity from a latent myofascial trigger point (MTP) in a synergistic muscle during isometric muscle contraction. Intramuscular activity was recorded with an intramuscular electromyographic (EMG) needle inserted into a latent MTP or a non-MTP in the upper trapezius at rest and during isometric shoulder abduction at 90° performed at 25% of maximum voluntary contraction in 15 healthy subjects. Surface EMG activities were recorded from the middle deltoid muscle and the upper, middle, and lower parts of the trapezius muscle. Maximal pain intensity and referred pain induced by EMG needle insertion and maximal pain intensity during contraction were recorded on a visual analog scale. The results showed that higher visual analog scale scores were observed following needle insertion and during muscle contraction for latent MTPs than non-MTPs ($P < .01$). The intramuscular EMG activity in the upper trapezius muscle was significantly higher at rest and during shoulder abduction at latent MTPs compared with non-MTPs ($P < .001$). This study provides evidence that latent MTPs are associated with increased intramuscular, but not surface, EMG amplitude of synergist activation. The increased amplitude of synergistic muscle activation may result in incoherent muscle activation pattern of synergists inducing spatial development of new MTPs and the progress to active MTPs.

Perspective: ***This article presents evidence of increased intramuscular, but not surface, muscle activity of latent MTPs during synergistic muscle activation. This incoherent muscle activation pattern may overload muscle fibers in synergists during muscle contraction and may contribute to spatial pain propagation.***

Key words: *Intramuscular electromyography, isometric contraction, motor control, muscle synergy, myofascial trigger points.*

A latent myofascial trigger point (MTP) is defined as a focus of hyperirritability in a muscle taut band that is clinically associated with local twitch response and tenderness and/or referred pain upon manual examination.[8,11,21] Local tenderness and/or referred pain from a latent MTP are transient in duration upon mechanical stimulation, and a latent MTP exists without spontaneous pain.[8] Latent MTPs may not only become active MTPs, which contribute significantly to the pain profiles in myofascial pain conditions, but also induce motor dysfunctions, predisposing the muscle to further damage.[21] Recent experimental evidence has shown that the existence of latent MTPs contributes to the impaired muscle recruitment or activation timing when performing active joint movement,[16] to the restricted joint range of motion in the ankle[13] and in the neck,[1,19] and to an accelerated development of muscle fatigue with simultaneous overloading of the active motor units close to a latent MTP.[9] Moreover, latent MTPs may also contribute to the delayed and incomplete muscle relaxation, distorted fine movement control, and unbalanced muscle activation when performing joint movement involving an agonist and antagonist muscle pair.[14] To achieve optimal joint movement, a group of

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muscles have to work synergistically for certain motions. An example of muscle synergies can be observed during abduction of the arm, as the upper trapezius is synergistic with glenohumeral movement by the deltoid and supraspinatus muscles.[25] However, the effects of MTPs on the motor control between synergistic muscles are still unknown. Clinically, it is quite often that neck pain and shoulder pain coexist in chronic musculoskeletal pain conditions. Further understanding of the intramuscular activity from a latent MTP during joint movement involving a synergistic muscle group may provide evidence for the effects of MTPs on the motor control between synergistic muscles.

The aim of the study is to quantify intramuscular and surface electromyographic (EMG) activities from a latent MTP as compared to a non-MTP in the upper trapezius as a synergistic muscle during shoulder abduction in healthy humans.

Methods

Subjects

Fifteen healthy subjects (8 males and 7 females: mean age, 25 ± .8 years; mean weight, 66 ± 2.1 kg; mean height, 171 ± 1.5 cm), with no signs or symptoms of musculoskeletal pain, volunteered for this study. This study was approved by the local ethics committee (N-20100048) and conducted in accordance with the Helsinki Declaration. Informed consent was obtained prior to experiment.

Experimental Protocol

This experiment consisted of 2 sessions in which an intramuscular EMG needle electrode was inserted into either a latent MTP or a non-MTP in the upper trapezius muscle on the dominant side. There was a 1-day interval between 2 sessions. The intramuscular EMG needle insertion into the latent MTP or a non-MTP was randomized. Intramuscular EMG activities from the upper trapezius muscle and surface EMG activities from the middle deltoid muscle and upper, middle, and lower trapezius muscles were simultaneously recorded at rest and during 25% of maximal voluntary contraction (MVC) force of shoulder abduction at 90°. Local pain intensity was recorded on visual analog scale (VAS) immediately following EMG needle insertion and following isometric muscle contractions (detailed later). Referred pain pattern from needle insertion was recorded on an anatomic map at the end of each session.

Each subject was seated in a chair with back support. The subject was asked to relax the dominant arm on supporting plate to form a 90° of passive shoulder abduction. A force transducer (MC3 A; AMTI, Watertown, MA) was in close contact with the upper surface of the upper arm just above the elbow level. Following MVC determination, with the needle at a latent MTP or a non-MTP in the muscle, each subject was asked to gradually increase the contraction force to reach the target force level of 25% of the MVC within 2 seconds and then to keep at the target force level for 7 seconds. The target force was displayed on the monitor screen as the visual feedback.

Active shoulder abduction was achieved by the isometric contraction of the middle deltoid muscle (prime mover) against the force transducer. The upper trapezius worked synergistically with the prime mover to accomplish shoulder abduction. The isometric contraction, instead of dynamic contraction, was chosen in the current study because of the potential needle displacement out of the MTP during dynamic contraction of the upper trapezius muscle.

Palpation and Detection of MTP

A latent MTP was defined by the presence of a taut muscle band, local twitch response, and the most tender spot on digital palpation.[24] A non-MTP was defined by the absence of latent MTP characteristics. A latent MTP was further confirmed by the existence of spontaneous electrical activity (SEA), and a non-MTP was not showing SEA from intramuscular EMG recordings, as detailed later.

MVC Recordings

Middle deltoid muscle contraction force without needle in the muscle was measured using a force transducer mounted in custom-designed setups. Subjects were asked to maximally abduct the dominant shoulder for 3 seconds and repeated 3 times with 1-minute rest intervals between each repetition. The maximal force output of the 3 recordings was chosen as the value for the MVC.

EMG Recordings

A concentric intramuscular EMG needle (Ambu Neuroline Concentric, .25 × 45 mm; Ambu, Ballerup, Denmark) was inserted into a latent MTP or a non-MTP. A latent MTP was then confirmed by the presence of intramuscular SEA from the intramuscular EMG needle.[22,23,26] The procedure of searching for the SEA is similar to those reported previously.[14,22,23] The EMG needle was inserted at an angle of approximately 90° to the skin surface overlying an MTP (targeted to the nodule) for the first needle insertion. The second insertion was at an angle of approximately 80° directed proximally to the first track and for the third track was at 80° directed distally to the first track. Each advance continued until it encountered SEA with the amplitude of at least 50 μV when the muscle was at rest. On the contrary, a non-MTP was confirmed by the absence of SEA from the intramuscular EMG needle, which was placed in a non–taut-band muscle outside of the end plate zone (MTP region), 1 to 2 cm away from the site being examined.[14,22]

Following skin preparation, a pair of bipolar surface electrodes (Neuroline 720-01-k; Neuroline, Ølstykke, Denmark; intra-electrode distance of 2 cm) was placed 2 cm distal to the intramuscular EMG needle, and another 3 pairs of surface electrodes were placed on 1) the middle point of the middle deltoid; 2) the middle trapezius: approximately 20% medial to the midpoint between the medial border of the scapula and the T3

vertebrae; and 3) the lower trapezius: approximately 33% medial to the midpoint between the medial scapular and the T8 vertebra.[17] A reference electrode was placed on the process of C7 vertebra. With the needle in a latent MTP or a non-MTP in the muscle, each subject was asked to increase slowly the contraction force to reach the target force level to 25% of the MVC within 2 seconds and then to keep at the target force level for 7 seconds. The target force was displayed on the monitor screen as the visual feedback.

EMG signals from the intramuscular EMG needle and surface electrodes were amplified (Counterpoint MK2, Dantec, Skovlunde, Denmark) (gain of 500 μV/div), filtered (band pass 10 Hz–1 kHz), sampled at 2 kHz, and stored after 12 bits analog-to-digital conversion. Intramuscular and surface EMG root mean square (RMS) values were extracted from the last 3 seconds of the isometric contraction and 2 seconds before the start of the contraction.

Local Pain Intensity and Referred Pain

Subjects were asked to rate the pain intensity immediately following intramuscular needle insertion and immediately following isometric muscle contractions on a numerical VAS at the end of each session, where 0 represents no pain and 10 represents the maximal worst pain ever experienced. Referred pain pattern was drawn by the subjects on an anatomic map at the end of each session.

Statistics

Paired t-test was used to analyze the differences in EMG RMS values at rest and during isometric shoulder abduction between latent MTPs and non-MTPs. Paired t-test was also used to compare pain intensity during intramuscular EMG needle insertion and the number of EMG needle insertions between latent MTPs and non-MTPs. The data are presented as mean ± standard error of the mean, and the significance level was set to $P < .05$.

Results

Pain Intensity and Distribution Following Needle Insertion and Contraction

A latent MTP was identified in every subject in the upper trapezius muscle. There were no significant differences ($t = 1.87$, $P = .07$) in the number of needle insertions between the latent MTP group (1.67 ± .14) and the non-MTP group (1.33 ± .12). The VAS scores after needle insertion in the upper trapezius were significantly higher following needle insertion into latent MTPs (4.51 ± .41) than non-MTPs (1.71 ± .32, $P < .001$, Fig 1A). The VAS scores in the upper trapezius were statistically higher in the latent MTP (.68 ± .23) than non-MTP (.08 ± .08) following isometric shoulder abduction ($P < .05$, Fig 1A).

Referred pain was induced following EMG needle insertion into 7 of 15 MTPs. Referred pain was observed unilaterally to the upper part of the shoulder in 6 subjects and to the lower part of the neck in 1 subject (Fig 1B). No referred pain was observed following EMG needle insertion into non-MTPs.

Muscle Activity at Rest and During Contraction at Latent MTPs

An example of the original recordings showed that the SEA was present only at latent MTPs (Fig 2A), but not at non-MTPs (Fig 2B) at rest when there was no force output. A higher intramuscular electrical activity was observed at latent MTPs than at non-MTPs in the upper trapezius either at rest or during shoulder abduction, whereas surface EMG activities in the middle deltoid were similar. Statistical analysis revealed that the intramuscular EMG RMS at latent MTPs in the upper trapezius muscle was significantly higher than non-MTP either at rest ($P < .0001$, Fig 3) or during isometric shoulder abduction ($P < .0001$, Fig 3). However, there were no significant differences in the surface EMG RMS values between MTPs and non-MTPs in the middle deltoid, upper trapezius, middle trapezius, and lower trapezius muscles either at rest or during contraction (all, $P > .05$; Fig 4).

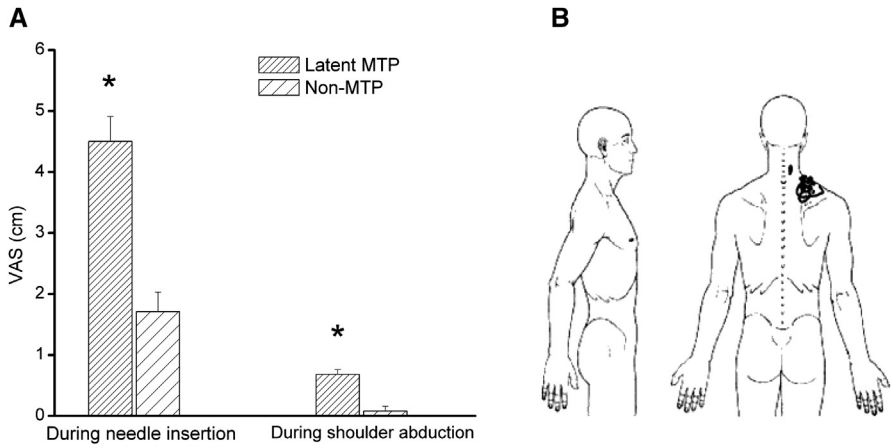

Figure 1. **(A)** Higher local pain intensity (VAS) during intramuscular needle electrode insertion into latent MTPs and during isometric shoulder abduction than non-MTPs. **(B)** Referred pain pattern following EMG needle insertion into latent MTPs. *$P < .001$.

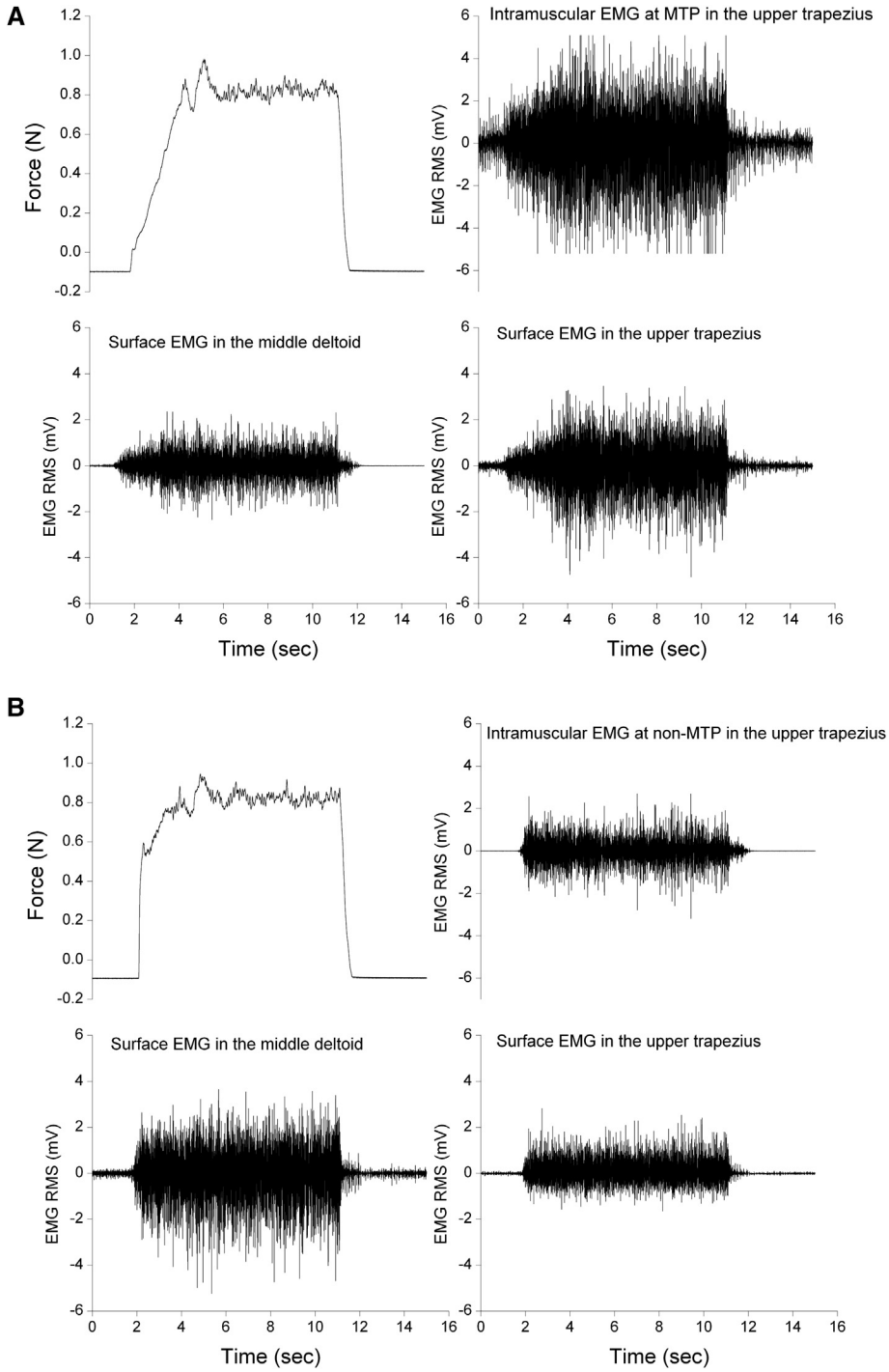

Figure 2. A typical example of original recordings showing a higher intramuscular EMG RMS from latent MTPs **(A)** than nontrigger points **(B)** in the upper trapezius at rest and during shoulder abduction at 90° as controlled by force transducer and surface EMG. The spontaneous electrical activity (end plate noise and spikes) was present only at latent MTPs at rest, that is, when there was no force output **(A)**.

Discussion

This is the first study showing that latent MTPs are associated with an increased intramuscular, but not surface, muscle activity during synergistic muscle contraction. Latent MTPs may impair muscle synergies and lead to poor motor control during joint movements. The increased hyperactivity may overload synergists during joint movements contributing to spatial pain propagation.

Pain Associated With Latent MTPs

The current study showed a higher pain intensity following needle insertion into latent MTPs compared with normal muscle point (non-MTP, Fig 1A),

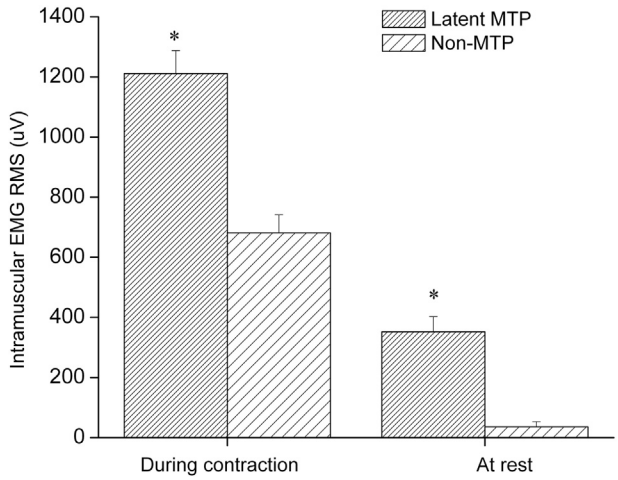

Figure 3. Higher intramuscular EMG RMS values at latent MTPs than nontrigger points in the upper trapezius muscle at rest and during isometric shoulder abduction at 90°. *$P < .0001$.

demonstrating that latent MTPs are hyperalgesic spots in the muscle.[8,10] Referred pain was also induced by needle insertion into latent MTPs (Fig 1B), indicating that latent MTPs are able to induce central sensitization.[8,12] In addition to the higher pain intensity following needle insertion into latent MTPs than normal muscle point, pain intensity was also higher during isometric muscle contraction when the needle was in the latent MTP than in normal muscle point (Fig 1A), though the pain intensity was relatively low. The movement-related pain may partly explain the transient pain characteristic following mechanical stimulation of latent MTP during daily physical activities.

Increased Synergistic Muscle Activity Associated With Latent MTPs

The major finding of the current study was that intramuscular (Figs 2,3), but not surface (Fig 4), muscle activity of latent MTPs was significantly increased in the upper trapezius muscle as compared to non-MTPs. During isometric shoulder abduction, the middle deltoid muscle acts as the prime mover and the upper trapezius muscle as a synergist. Under the similar level of central drive as designed in the current study, active motor units from latent MTPs have to work more (significantly increased intramuscular EMG amplitude) than the active motor units from non-MTPs in order to maintain the similar level of force output, leading to an incoherent muscle activation pattern of a synergist. This result suggests that the existence of latent MTPs may impair muscle synergies during joint motions.

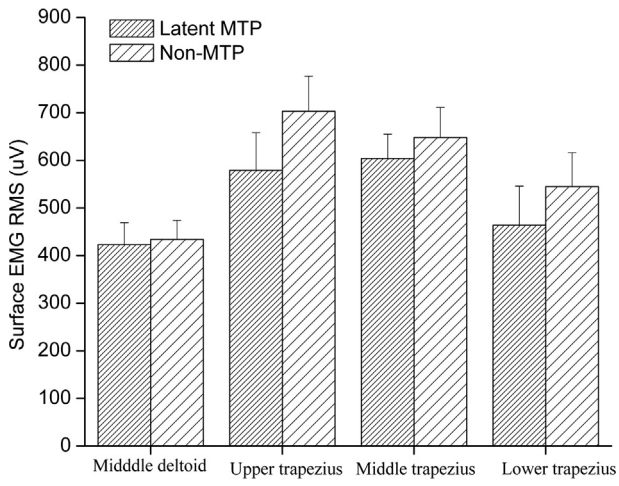

Figure 4. Surface EMG RMS values during shoulder abduction at 90° in the middle deltoid and the upper, middle, and lower parts of the trapezius. There were no significant differences in surface EMG RMS between MTP and non-MTP sessions.

There exists a set of time-varying muscle synergies when achieving a variety of behavioral goals, and a few muscle synergies are combined at different proportions to form a continuum of muscle activation pattern for smooth motor control during various tasks.[6] Muscle synergy is defined as coherent activations, in space or time, of a group of muscles and can be assessed by the relative amplitude and timing of muscle activity.[2] Latent MTPs have been shown to contribute to the chaotic timing of muscle activation under the conditions of either unloaded[15] or loaded[16] shoulder joint movements as assessed with a surface EMG technique. The current study provides new evidence demonstrating the association of latent MTPs with incoherent muscle activation pattern within a synergist as shown by the significantly increased amplitude as assessed directly from latent MTPs with intramuscular EMG technique. It is noticeable that in the present study, only 1 recording from the latent MTP is analyzed in each subject. However, several latent MTPs may exist in the upper trapezius muscle, and the incoherent muscle activation pattern may be even more evident and/or spread to a larger area of the muscle because of the effect of spatial summation. In addition, the present study does not record intramuscular EMG activities from 2 or more synergists because of technical difficulties; however, the unbalanced muscle activation pattern due to a latent MTP within a synergist can apply to any synergists with MTPs during a joint movement; this may eventually lead to disordered muscle activation patterns among synergists. Future studies are needed to confirm and broaden the relationship between MTPs and muscle synergy.

Similar to the significantly increased intramuscular EMG amplitude from latent MTPs, a significantly increased amplitude of SEA at latent MTPs was also observed when the muscle is at rest (Fig 3). The SEA represents muscle contraction and/or muscle cramp potentials[11,26] from dysfunctional motor end plate at MTPs.[24] The sustained local muscle contraction and/or muscle cramp may induce muscle ischemia and the accumulation of algesic substances,[20] leading to pain/tenderness and motor dysfunctions.[8,24] Thus, treatment of latent MTPs may have beneficial effects in healthy subjects and in patients with chronic pain conditions associated with MTPs.

In the current study, no significant increase in the surface EMG amplitude over latent MTPs in the upper trapezius muscle during low-load (25% MVC) and short-term (less than 10 seconds) static muscle

contraction may suggest that active motor units close to a latent MTP may not be overloaded during transient muscle contraction whereas low-load (about 25% MVC) and long-term (about 7 minutes) static and fatiguing muscle contraction induces significant increase in surface EMG activity over a latent MTP, suggesting the overloading of active motor units close to a latent MTP as shown in our previous study.[9]

The increased intramuscular, but not surface, muscle activity from a latent MTP during synergistic muscle activation in the current study may have significant clinical implications. The chaotic and increased amplitude of muscle recruitment pattern may lead to muscle overuse and premature fatigue of the muscles harboring latent MTPs. In turn, accelerated muscle fatigue may further overload other muscle fibers within the same muscle.[9] Muscle fatigue may also increase the amplitude of force fluctuations in task-related and tangential directions changing muscle activity level between multiple synergists.[18] The increased intramuscular, but not surface, amplitude of muscle activation of synergists associated with latent MTPs may play a role in the formation of new latent MTPs in the synergists, as muscle overuse is one of the factors for the development of latent MTPs and for the progression to active MTPs.[4,8,10] Thus, the chaotic and increased amplitude of muscle recruitment pattern of synergists may have implications in pain propagation as manifested in chronic musculoskeletal pain conditions. In addition, the increased amplitude of muscle recruitment measured with intramuscular EMG directly from latent MTPs in healthy subjects in the current study may partly explain the increased coactivation of neck muscles in chronic headache patients[7] and increased low back muscle activity during gait in low back pain patients[3] as measured with surface EMG. This study provides further support to the notion that treatment of latent MTPs may have beneficial effect in both healthy subjects and musculoskeletal pain patients.

Limitations of the Study

First, intramuscular EMG recordings were taken in isometric contraction of shoulder abduction in order to prevent the EMG needle from moving out of the latent MTPs, so the results in the current study might be different from dynamic contractions. Second, the effect of needle retaining in the latent MTPs on force output cannot be excluded, though subjects were asked to reach the same force output level in both sessions and confirmed by nonsignificant differences in surface EMG recordings between sessions. Third, the rating of VAS scores by the subjects might be influenced by their past pain experiences, because the 10 in the VAS (0–10 cm) was used in the current study to represent "the maximal worst pain ever experienced" instead of "the maximal worst pain imaginable." Finally, the influence of tissue damage from needle insertions on pain intensity and EMG activity cannot be excluded in the current study with 1-day interval, instead of a 3-day interval, between 2 sessions. However, the similar number of needle insertions and randomization between 2 groups and the distance of 1 to 2 cm between latent MTP and non-MTP sites may minimize the influence of tissue damage on pain intensity. Resting intramuscular EMG activities from MTPs have been reported to be decreased following repeated needle insertions[5]; however, no significant differences in surface EMG activities between groups and significantly increased intramuscular EMG activities from latent MTPs during muscle contraction in the current study suggest that a 1-day interval between sessions had a minimal effect on EMG activity.

Conclusion

The current study shows that latent MTPs are associated with an increased intramuscular, but not surface, synergistic muscle activity, which may result in incoherent muscle activation of synergists inducing impaired motor control strategies and spatial pain propagation.

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