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Yu-Chang Chang

Sheng-Fen Kao

Ta-Shen Kuan

Chang-Zern Hong

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Yu-Chang Chang, Sheng-Fen Kao, Ta-Shen Kuan, Chang-Zern Hong

Department of Physical Medicine and Rehabilitation, National Cheng Kung University Hospital

Myofascial trigger point (MTrP) is a quite common painful muscular disorder in clinical practice. When an MTrP is mechanically stimulated (needling or snapping palpation), a local twitch response (LTR) can be elicited, which is one of the characteristics of MTrP. Recent studies on humans and rabbits suggest that an MTrP is at the endplate zone. The purpose of this study is to map the distribution of sensitive loci from which an LTR can be elicited by mechanical stimulation of it in rat skeletal muscle. A total of 39 Sprague-Dawley rats were studied in this experiment. After general anesthesia, the biceps femoris was exposed, and electrical stimulation with a threshold current of 0.5-1.0 mA was applied to identify the endplate zone. Nine to thirteen tracks (1 mm apart between tracks) were explored for each muscle. For each track, every 1 mm was an investigating site. To elicit LTRs, the needle was rapidly inserted perpendicularly into the muscle. It was found that, although some sensitive loci were distributed in the periphery, most of the sensitive loci were concentrated in the endplate zones, with statistical significance. This finding may further support the hypothesis that MTrPs are related to abnormal endplates. (J Rehab Med Assoc ROC 1998; 26(1): 1-8)

Key words: myofascial trigger point, rat, skeletal muscle, muscle twitch

INTRODUCTION

Myofascial trigger point (MTrP), a localized hyperirritable spot in a palpable taut band of skeletal muscle fibers, is a characteristic of myofascial pain syndrome. The trigger point can be induced by or associated with acute or chronic lesions originated from nerve, muscle, tendon, ligament, joint, disc or skeleton [1]. There are two important characteristics for MTrP: referred pain and local twitch response (LTR). By compression of an MTrP in a muscle, consistent and characteristic referred pain pattern specific for that muscle can be elicited [2, 3]. When an MTrP is mechanically stimulated (snapping or needle insertion), a brisk contraction of a group of muscle fibers, or LTR, can be identified, either by vision or by palpation. Through clinical experience, Hong [4-6] found that rapid needle insertion into an active MTrP can elicit LTRs to produce immediate relief of pain and tightness.

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Address correspondence to: Dr. Yu-Chang Chang, Department of Physical Medicine and Rehabilitation, National Cheng Kung University Hospital, No.138, Sheng Li Road, Tainan, Taiwan, R.O.C.

Tel: (06) 2353535 ext. 2666

Although much information has been obtained about myofascial trigger point, more have to be investigated, especially its mechanism & pathogenesis, in order to have a better treatment of this disorder. Therefore, more intrusive tests have to be performed. To subject humans for such experiments may raise the ethical concerns. Therefore, a good animal model should be used.

Recent animal studies have shown that rabbits are appropriate model for MTrP research. Hong and Torigoe [7] reported that rabbit myofascial trigger spots (MTrS) were comparable to human MTrPs in that rabbit localized twitch responses (R-LTRs) resembled human LTRs in five ways: 1) stimulation of a sensitive site (MTrP for human, MTrS for rabbit) elicited twitch responses; 2) EMG activities of R-LTRs of rabbit were analogous to LTRs of human; 3) EMG activity was unobtainable from resting muscles in both rabbit and human; 4) repeated stimulation of the sensitive site led to decrease or absence of LTRs; 5) inhibition of the transmission of innervating muscle nerve also led to decrease of LTRs of that muscle.

Possible Mechanism of An MTrP

Although many authors have offered explanations about the onset and the mechanism of the MTrPs, the issue is still widely debated.

Hubbard and Berkoff [8] demonstrated the presence of spontaneous electrical activity (SEA) in minute loci in an MTrP region. SEA consists of continuous, low-amplitude noise-like action potentials (5-50 microvolts, occasionally up to 80 microvolts). It may be accompanied by intermittent large-amplitude spikes (100-600 μV, biphasic, initially negative). These investigators hypothesized that SEA was originated from muscle spindles. To date, there has been no evidence that SEA is from a muscle spindle based on histological study [9]. Simons et al.[10] found that the spikes potential during SEA recording propagated at least 2.6 cm along the length of the taut band, which is far beyond the maximum 1 cm length of a muscle spindle. This would further support that MTrPs are of extrafusal origin.

Recently, a more favorable hypothesis has been postulated to explain the mechanism of MTrPs. In this motor endplate hypothesis [11], dysfunctional extrafusal motor endplates are thought to be a major cause of MTrPs. In electromyographic study, SEA is recorded most frequently from the endplate zone [12,13], and is similar to endplate activities mentioned by electromyographer [14]. Normal endplate potentials (EPPs) are occasional, discrete, short, and negative monophasic miniature action potentials. The normal EPP pattern can be converted into an abnormal noise-like pattern by applying mild mechanical stimulation to the terminal nerve fiber or the endplate region [15], or by application of rabbit serum to induce excessive release of acetylcholine (Ach) pockets from the presynaptic nerve terminals [16]. Therefore, Simons [11,12,17] suggested that SEA found in an MTrP region corresponds to an abnormal pattern of endplate activity, due to excessive Ach release. The excessive Ach may depolarize the post-junctional membrane to a more positive membrane potential which cause local increase in Ca^{++} release. The ionized calcium may cause uncontrolled shortening of muscle fibers and further compromise local circulation and increase the metabolic demands. These may aggravate the taut band phenomenon through the mechanism of energy crisis theory, which was previously proposed by Simons [18].

Spinal Cord Mechanism of LTR

The importance of eliciting LTRs during MTrP injection to obtain an immediate and effective pain relief has been demonstrated [4-6]. Dry needling is as effective as lidocaine injection to inactivate an active MTrP [6], but with somewhat shorter pain-relief period.

EMG activity of LTR can be recorded in both human and rabbits [7]. The duration of EMG activity of an LTR varies from 20 msec to 300 msec. This activity can be greatly reduced after lidocaine block or transaction of the innervating muscle nerve. This activity was disappeared temporarily during the spinal shock stage, and gradually recovered later [7]. All of the above information suggests that the LTR is mediated through the spinal cord, possible a polysynaptic reflex.

In a pilot study, the experimenters have demonstrated similar taut bands and sensitive spots with LTRs in rats (r-LTRs) [19]. The purpose of this project is to study the rat as a potential animal model of myofascial trigger point by investigating the distribution of the sensitive loci (for r-LTRs) in the rat biceps femoris muscle, and their relation to the endplate zone.

MATERIALS AND METHODS

Animal Preparation

Thirty-nine rats were investigated in this study (12 of them were tested unilaterally, and the remaining 27 bilaterally). Each rat was anesthetized with an intraperitoneal injection of pentobarbital (0.05mg/GBW). In order to maintain anesthesia, the rat was intraperitoneally injected with 0.1-0.15 ml of pentobarbital every 20-30 minutes. After the rat was anesthetized, the thighs were shaved bilaterally, and the biceps femoris muscle was exposed. The anesthetic level was controlled so that most of the spinal reflexes were preserved. In such condition, LTRs would not be affected by the anesthesia.

Determination of Endplate Zone

Electrical stimulation with a threshold current between 0.5-1.0 mA was applied to locate the endplate zone. It was identified as the area in the muscle that greatest muscle twitch could be observed during electrical stimulation. The number of electrical stimulation applied was minimal (to prevent the diminution of twitch response), but sufficient to clearly identify the location of the endplate zone. This area was then marked with ink (Fig. 1).

Mapping the Distribution of r-LTRs.

To elicit r-LTRs, each biceps femoris muscle was explored systematically in 9-13 tracks from the posterior to anterior border, at a track interval of 1 mm (Fig 2). For each track, the needle was inserted rapidly and perpendicularly to different sites of the muscle from the distal to the proximal end of the track. In one track, every mm was an investigating site. The distance from one end to the endplate ranged from "-9 mm" to "+9 mm", with the "0 mm" at the end plate. For each track, approximating 11-19 investigating sites were studied (depending on available space). After all sites were tested in the whole track, the needle was reinserted into next track in the muscle, 1 mm anterior to the previous track.

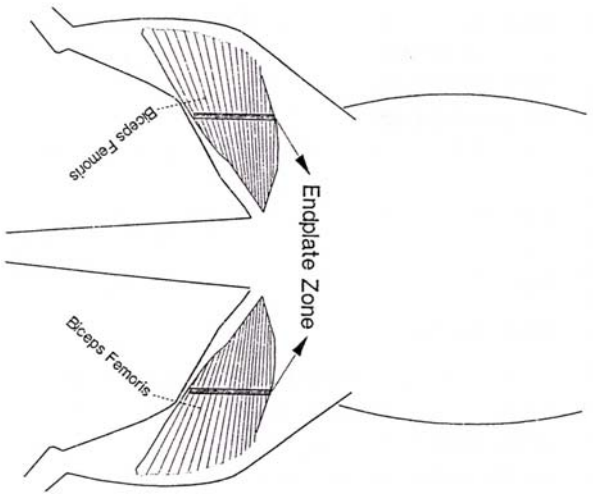

Fig. 1. Biceps femoris muscle with its endplate zone of rat.

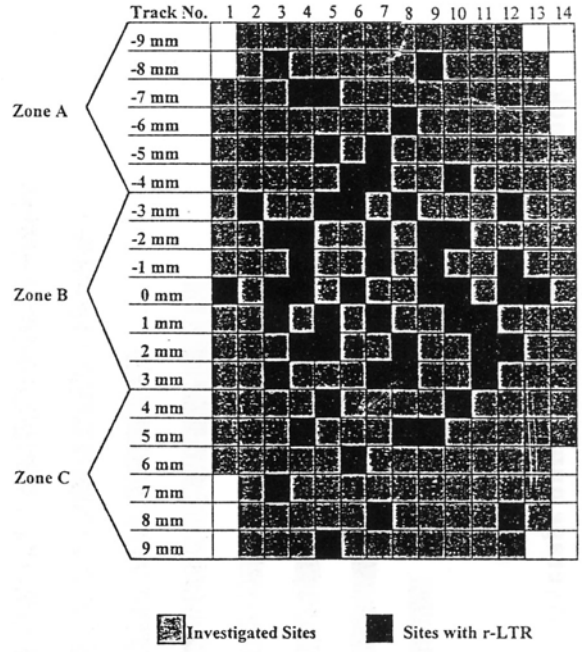

Fig. 2. Distribution of LTRs in one biceps femoris muscle of rat.
LTRs = local twitch responses; 0 mm = at the endplate site.

In order to elicit r-LTRs, the needle was controlled manually with a depth of penetration of 1-2 mm approximately, and at a speed of one-third to one-half second for an "in-and -out" procedure, a pattern similar to MTrP injection suggested by Hong [4-6]. A visible brisk and powerful contraction of a bundle of muscle fibers indicated the presence of r-LTRs (Often trembling of the needle was also felt at the same time). The same procedure was repeated until all the available tracks were studied, then biceps femoris muscle on the other side was exposed for further tests, if the animal was still alive.

Data Analysis

The occurrence of r-LTRs at each investigating site was then mapped on a worksheet (Fig. 2). The percentage of identified r-LTRs was calculated for each investigating site. For example, in the investigating site of "-2 mm" in Fig 2, 6 of the 14 tracks (or 43%) showed r-LTRs. The value for each of the different investigating sites was then compared to the values for the endplate site (" 0 mm"). However, since electrical stimulation gave only an approximate location of the endplate, the investigating sites were grouped into 3 proximal-to-distal zones, each 6-7 mm in length, with "zone A " at the distal end of the muscle, and "zone C" at the proximal end. "Zone B" was the endplate zone, and it included site "-3 mm, -2 mm, -1 mm, 0 mm, 1 mm, 2 mm, 3 mm. Kruskal-Wallis test was used to statistically compare the frequency of r-LTRs between zone A and zone B, zone B and zone C, or zone C and zone A. A p value less than or equal to 0.05 was considered to be statistically significant.

RESULTS

The frequencies of finding sensitive loci at each zone are listed in Table 1. The occurrence of r-LTR in each biceps femoris muscle was between 1.21% and 71.8%, with an average of 16.1% for all the sixty-six muscles. The number of r-LTRs elicited from " zone B" were significantly higher than that elicited from peripheral zones (Fig. 3 and Table 2). We also found a positive correlation between the frequencies of r-LTRs

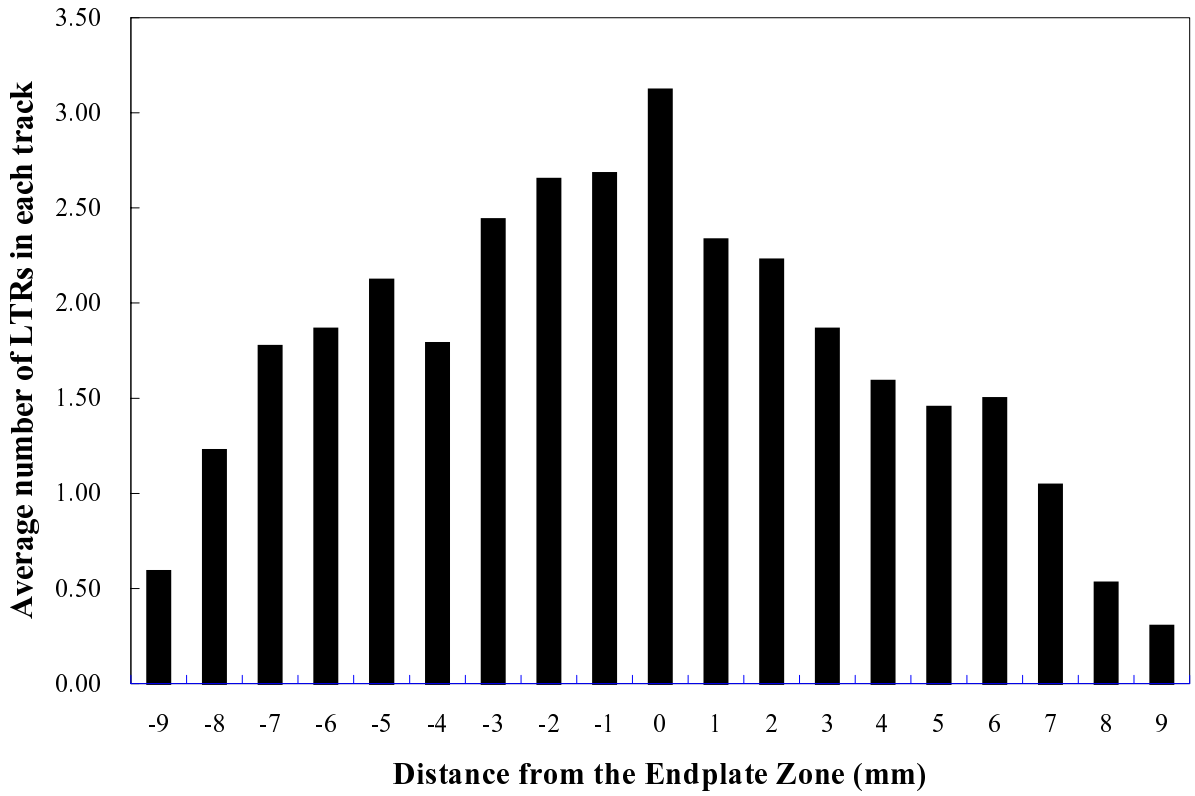

Fig. 3. Localized twitch response recorded from biceps femoris muscle of rat.

Table 1. Numbers and percentage of LTRs in each zone

Zone	Numbers of LTRs	Percentage of Occurrence
Zone A	9.36 ± 13.66	4.4% ± 6.5%
Zone B	17.32 ± 21.18	7.9% ± 8.7%
Zone C	6.42 ± 10.12	3.7% ± 6.1%

LTRs = local twitch responses;
Zone A = -9, -8, -7, -6, -5, -4 mm;
Zone B = -3, -2, -1, 0, 1, 2, 3 mm;
Zone C = 4, 5, 6, 7, 8, 9 mm;
0 mm = at the endplate sites.

Table 2. P value in comparing the occurrence of LTRs in any two zones in the Krusal-Wallis test

Any Two Zones	*P* value
Zone A & Zone B	$P < 0.0005$
Zone B & Zone C	$P < 0.0001$
Zone C & Zone A	$P > 0.0843$

LTRs = local twitch responses;
Zone A = -9, -8, -7, -6, -5, -4 mm;
Zone B = -3, -2, -1, 0, 1, 2, 3 mm;
Zone C = 4, 5, 6, 7, 8, 9 mm;
0 mm = at the endplate sites.

elicited and the body weight of rats. (R-Square = 0.40, correlation coefficient = 0.63, $p = 0.0001$)

DISCUSSION

The findings from this study indicated a significant correlation between r-LTR sites and the endplate zone. (zone B:-3 mm, -2 mm, -1 mm, 0 mm, 1 mm, 2 mm, 3mm).

Although sensitive loci where r-LTRs can be elicited may be found even far away from the endplate zone (ex: -9 mm) in this study, it is obvious that these sensitive loci are more concentrated near the endplate zone. This is consistent with findings in electrophysiological study on rabbit by Simons et al [12].

A positive correlation was found between rat's body weight and the occurrence of r-LTRs. Since the rat's body weights are proportionate to their age, it is possible that more r-LTRs could be elicited in older rats than the young ones. As a rat grows, the biceps femoris muscles are used more frequently, which may result in chronic repetitive microtrauma. Sensitive loci are then formed and accumulated, thus more r-LTRs elicited in older (heavier) rats than young ones. The sensitive loci from where LTRs could be elicited are usually widely distributed. Based on current histological study [20], the sensitive loci are apparently sensitized nociceptive nerve endings. The are mostly found in the endplate zone, but can be identified in the peripheral sites (although the occurrence is much less than the central zone). In old animals (rats with heavy weight), higher percentage of occurrence (up to 71.8%) of LTRs (or sensitive loci) could be identified as compared to the young ones (could be as low as 1.21% in the study). This is also consistent with our clinical observations that old patients usually have more MTrPs than young ones.

In clinical practices, an active MTrP, which contains many sensitive loci, is usually found near the endplate zone for a specific muscle during trigger point injection. Since LTRs should be elicited during MTrP injection in order to obtain an immediate and desirable pain relief, sensitive loci (from which LTRs can be elicited) are quite important in the pathogenesis of an MTrP.

Based on results of animal studies and clinical experiences, LTRs can also be elicited from non-MTrP region, although they are often encountered in MTrP region. It is very likely that LTR-sites are sensitized nerve endings [20], so we can observe LTRs through the possible polysynaptic spinal reflex when these nerve endings are stimulated. On the other hand, animal studies have also suggested that an active locus (where SEA could be recorded) of MTrS is a dysfunctional endplates [11,13]. Either SEAs or LTRs or both could be observed at different loci in an MTrP region during searching for SEA [12,17]. Both SEAs and LTRs are often associated with sharp pain sensation, which is similar to patient's usual complaints. Therefore a sensitive locus is probably very close to an active locus. It is possible that sensitive loci are widely distributed in the whole muscle but are more concentrated in the MTrP region, since referred pain (ReP) can also be elicited in normal muscle tissue. It could be assumed that the sensitive locus is the sensory

component, and the active locus is the motor constituent of an MTrP locus, which is a basic unit of an MTrP. The pathophysiology of MTrPs is probably related to integrated mechanism in the spinal cord level (a possible polysynaptic reflex) in response to sensitized sensory nerve fibers (nociceptors) and associated with dysfunctional endplates. Further studies for mapping SEA-sites should be conducted for comparison to LTRs-site to support this hypothesis.

In summary, it is very likely that the sensitive loci where LTRs can be elicited are important in the formation of an MTrP. These loci could be sensitized nerve endings resulting from trauma (acute injury or chronic repetitive microtrauma). The sensitive loci may "spread" to the neighboring regions, via possible integration at the spinal cord level, and cause accumulation of sensitive loci in one area. When the number of sensitive loci is large enough in the endplate region where contains many active loci (dysfunctional endplates), a palpable taut band and an MTrP may develop, causing pain and hypersensitivity to pressure. Mechanical stimulation to these loci elicits LTRs via spinal reflexes. Once LTRs are elicited, the abnormal spinal cord integration may be corrected; subsequently, the taut band and MTrP pain can be relieved.

This study only focused on the endplate zone of the rat biceps femoris. No effort was made to locate taut bands within the muscle studied. Further studies should address taut bands of these muscles to assess the value of using rats as an animal model, and more studies for mapping SEA-sites should be performed for comparison with the LTR-sites. In addition, more reliable methods for identifying the presence of LTR, and more precise measurement of the investigating sites should be developed.

CONCLUSION

The findings of this study suggest that the rat may be a potential animal model for studying MTrPs. The distribution of the sensitive loci where LTRs could be elicited seems to be concentrated near the endplate zone.

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大白鼠骨骼肌中可誘發局部抽搐反應部位之分佈

張育彰　高聖芬　官大紳　洪章仁

成大醫院復健部

臨床上，肌筋膜引痛點(myofascial trigger point)是相當常見的肌肉疼痛問題。當引痛點受到刺激時(如針刺、指頭掐捏)，則會引發局部抽搐反應(local twitch response)，此亦爲引痛點的特徵。近來的研究顯示，引痛點乃位於神經肌肉交界處之終板帶(endplate zone)。本實驗的目的即在藉由大白鼠骨骼肌中敏感小點(sensitive loci)的分佈，來看引痛點是否集中於終板帶。總計本實驗共使用了 39 隻大白鼠，麻醉後在兩側的股二頭肌(biceps femoris)繃緊肌帶(taut band)上，經由閾值(threshold current)電流 0.5-1.0 毫安培定出終板(endplate sites)位置。再以終板區爲基準，每一公釐爲一軌，軌上每隔一公釐便以針頭快速垂直刺入肌肉，以觀察是否有局部抽搐反應。結果顯示，雖然有部份的局部抽搐反應分佈於周圍，但多數的局部抽搐反應則集中於神經肌肉交界處附近，且有統計學上的意義。此結果更支持引痛點與不正常之終板有關的假說。（中華復健醫誌 1998; 26(1): 1-8）

關鍵詞：肌筋膜引痛點(myofascial trigger point)，大白鼠(rat)，骨骼肌(skeletal muscle)，肌肉抽搐(muscle twitch)

抽印本索取地址：張育彰，台南市勝利路 138 號，成大醫院復健部
電話：(06) 2353535 轉 2666