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Changes in T₂-weighted MRI of supinator muscle, pronator teres muscle, and extensor indicis muscle with manual muscle testing

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Abstract (≤ 200 words):

[Purpose] In order to detect muscle activity with manual muscle testing, T₂-weighted magnetic resonance (T_{2w}-MR) images were detected by a 0.2 T compact MRI system.

[Subjects and Methods] The subjects were 3 adult males. Transverse T₂-weighted multi-slice spin-echo images of the left forearm were measured by a 39 ms echo-time with a 2,000 ms repetition time, a 9.5 mm slice thickness, 1 accumulation and a total image acquisition time of 4 min 16 s. First, T_{2w}-MR images in the resting condition were measured. Then, manipulative isometric contraction exercise (5 sec duration) to the supinator muscle, the pronator teres muscle or the extensor indicis muscle was performed using Borg's rating of perceived exertion (RPE) scale of 15-17. The T_{2w}-MR images were measured immediately after the exercise.

[Results] T_{2w}-MR image intensities increased significantly in the supinator muscle, the pronator teres muscle and the extensor indicis muscle after the exercise. However, the image intensities in the rest of the muscle did not change.

[Conclusion] Using T_{2w}-MR images, we could detect muscle activity in a deep muscle, the supinator muscle, and a small muscle, the extensor indicis muscle. These results also support the reliability of the manual muscle testing method.

Key words: (up to 3): Manual muscle test; magnetic resonance imaging; transverse relaxation time

INTRODUCTION

In physical therapy for patients of cerebrovascular, cardiovascular, respiratory or musculoskeletal diseases, assessments of muscle strength and the movement of joints are essential for treatment planning and also for lifestyle guidance. In order to evaluate patient performance, the range of motion test (ROM-T) is used to assess movement impairment of the joints¹⁾, and the manual muscle test (MMT) is used to assess muscle impairment²⁾. Both of these test methods are fundamental skills required of every physical therapist, which they have to master in training schools. The MMT is a manual maneuver to evaluate the strength of the prime mover muscles for a give motion of a joint. The procedures employed in the MMT were determined mainly based on our present knowledge of kinesiology and electromyography (EMG). Not only in diagnostic tests, the MMT has also been used for muscle training and maintaining muscle strength²⁾.

The muscles involved in finger function are one of the most important tasks for humans, since the function of the hands is strongly related with the quality of life. The MMT of the forearm muscles are also based on EMG. However, it is quite difficult to employ EMG for muscles located deeply beneath the skin. It is also difficult to discriminate the actual source of the EMG detected by surface electrodes³⁻⁶⁾. Recently, magnetic resonance imaging (MRI) has been used to monitor muscle activities by using the T_1 , T_2 , and water content values of skeletal muscles that increased after muscle exercise⁷⁻⁹⁾. Intensive studies have been conducted on the determination of agonist muscles using the increase in T_2 values^{10, 11)}, and Takamori detected increases in the T_2 weighted MR (T_{2w} -MR) image intensity of the extensor digiti minimi muscle after extension exercise of the MP joint of the digitus imnimus¹²⁾.

In this study, among the MMT for the forearm muscles, we selected 3 MMT for the primary mover muscles confirmed by the EMG. In order to confirm the reliability of the MR images, 1) the increase in the T_{2w} -MR image intensity was detected after the MMT of the supinator muscle or the

pronator teres muscle^{13, 14)}, and 2) we also aimed to detect the MMT of a smaller muscle of the forearm, the extensor indicis muscle¹⁵⁾.

SUBJECTS AND METHODS

Three healthy male volunteers participated in this study. The age, height, and weight of the subjects averaged 36.4 ± 12.3 years, 172.3 ± 6.9 cm, and 72.3 ± 17.0 kg (means \pm SD), respectively. The left forearms of the subjects were studied, and the MMT was applied by physical therapists with more than 10 years of experience. The details of the MMT will be shown later. The procedures, purpose, and risks associated with the study were explained to all of the subjects, and written consent was obtained prior to the commencement of the study. The study was approved by the Human Research Review Board at the Dokkyo Medical University School of Medicine (#27001).

MR images of each forearm were obtained with a 0.2 T compact MRI system (MRTechnology, Tsukuba, Japan) equipped with an oval ¹H solenoidal radiofrequency probe¹²⁾. The transverse T_{2w}-MR images were measured using multi-slice spin-echo MR image sequences with a 200 x 200 mm field-of-view, a 128 x 128 data matrix, a 39 ms echo-time with a 2,000 ms repetition time, 11 slices with an interval 10 mm, a 9.5 mm slice thickness, 1 accumulation and a total image acquisition time of 4 min 16 s. Each left forearm was fixed by a shell-type holder of the forearm¹²⁾, and a T_{2w}-MR image in the resting condition was measured at first. Then, manipulative isometric contraction exercise (5 sec duration) was applied to the supinator muscle, the pronator teres muscle or the extensor indicis muscle using Borg's rating of perceived exertion (RPE) scale of 15-17¹⁶⁾.

Immediately after the exercise, the arm position was restored to the original position, and another T_{2w}-MR image was measured. The increase in the T_{2w}-MR image intensity of muscle was evaluated by 3 physical therapists (M.T., S.A. and K.Y.) with 4-5 years of experiences with 0.2 T MRI. The epimysium of the muscle was traced by hand, and used for the same trace for the T_{2w}-MR image of

the resting muscle. The image intensity of a circular region of interest (ROI) with 25 pixels was measured by ImageJ software 1.46r (NIH, Bethesda, USA). In each slice, 3 ROIs were set in the muscle without overlapping each other, and the average image intensity (C_m) was obtained. In the same slice, an ROI was set in the background and SD (SD_{air}) was obtained. The image intensity of the muscle was represented by the contrast-noise ratio (CNR): $I = C_m / SD_{air}$ ¹⁷. An image intensity outside of the 99.9% of confidence interval ($I_R \pm 3.3$) was considered as a significant increase ($CL = 99.9\%$), and an image intensity within 99.9% of the confidence interval was considered not significant (N.S.), where I_R was the CNR for resting muscle. This criterion is almost the same as used in our previous report¹².

RESULTS

Figure 1A represents a typical result of the MMT of the supinator muscle sliced at one-third of the length of the ulna from the olecranon. The function of the supinator muscle is to supinate the forearm. The subjects were sitting, arm at the side, with the elbow flexed to 90°, and the forearm in full pronation to neutral. Then, the examiner supported the elbow, and applied resistance with the heel of the hand over the dorsal (extensor) surface at the wrist (Fig. 5-131 in Hislop²). The subjects #1, #2 and #3 did the exercise 82, 40 and 40 times until they reached Borg's RPE scale of 15-17, respectively. The image intensity of the T_{2w} -MR image increased more than 1.7 times compared with the resting muscle, showing a significant increase ($CL = 99.9\%$) (Table 1A). No significant changes were shown in the image intensities for the rest of the muscles.

Figure 1B represents a typical result of the MMT of the pronator teres muscle sliced at one-third of the length of the ulna from the olecranon. The function of the pronator teres muscle is to pronate the forearm with the pronator quadratus muscle. The subjects were sitting, arm at the side with the elbow flexed to 90° and the forearm in supination. Then, the examiner supported the elbow, apply

resistance with hypothenar eminence over radius on the volar (flexor) surface of the forearm at the wrist (Fig. 5-140 in Hislop²). The subjects #1, #2 and #3 did the exercise 45, 40 and 50 times until they reached Borg's RPE scale of 15-17, respectively. Image intensity of the T_{2w}-MR image increased more than 1.8 times compared with the resting muscle, and represented significant increase (CL = 99.9%) (Table 1B). No significant changes were shown in the image intensity of the rest of the muscles.

Figure 1C represents a typical result of the MMT of the extensor indicis muscle sliced at two-third of the length of the ulna from the olecranon. The extensor indicis muscle is a deep-layer, narrow skeletal muscle and its function is the extension of the index finger. The subjects were sitting with the forearm in pronation, the wrist in neutral, and the MP and IP joints in a relaxed flexion posture. Then, the examiner stabilized the wrist in neutral, and placed the index finger of the resistance hand cross the dorsum of all proximal phalanges just distal to the MP joints, and applied resistance in the direction of the flexion (Fig. 5-182 in Hislop²). The subjects #1, #2 and #3 did the exercise 40, 40 and 40 times until they reached Borg's RPE scale of 15-17, respectively. The image intensity of the T_{2w}-MR image increased more than 1.8 times compared with the resting muscle, showing a significant increase (CL = 99.9%) (Table 1C). No significant changes were shown in the image intensity of the rest of the muscles.

DISCUSSION

In this study, the T_{2w}-MR image intensity of the supinator muscle, the pronator teres muscle and the extensor indicis muscle increased (CL = 99.9%) with the MMT for these muscles with Borg's REP scale of 15-17. The primary mover muscles agreed with those detected by the EMG¹³⁻¹⁵. We did not detect any increases in the image intensity of the rest of the muscles.

Since the first report by Lovett in 1915¹⁸⁾, the MMT has been applied to evaluate the musculoskeletal and nervous systems, and the reliability and validity of the MMT is well established¹⁹⁾. The MMT depends on manual procedures for joint motion, such as flexion of the MP joint. Although the prime movers of a movement can be identified, secondary or accessory movers may be equally important, but definitive studies remain incomplete²⁾. Compared with EMG, MRI can image all of the muscles in a single FOV in the arm. Moreover, we can observe 11 slices simultaneously along the longitudinal axis of the forearm using a multi-slice spin-echo MR sequence. Thus, MRI can detect secondary or accessory movers located even distant from the primary movers in the same FOV. Therefore, even with a low number of subjects, the 3 in this study, we can conclude that muscle activity was not detected in other than the primary mover muscles of the 3 MMT used in this study. It can be considered that the strength of the manual resistance of the MMT is important. In a previous report¹²⁾, the MMT for the extensor digiti minimi muscle was applied until the subjects were unable to continue the extension of the digitus minimus. As a result, we detected other muscle activity in the extensor carpi ulnaris muscle that acts to extend and adduct at the carpus, in addition to the extension of the digitus minimus. Therefore, in this study, we adjusted the strength of the exercise to Borg's RPE scale of 15-17, as that might be suitable for the MMT of the extensor indicis muscle. The results of this study suggest that MR imaging could be useful in training physical therapists in using the MMT, because muscle activity can be visualized by MR images.

Some of the MMT of the forearm muscles were not confined by EMG²⁾. We plan to study using the MMT for these muscles, such as the flexor carpi radialis muscle and the flexor carpi ulnaris muscle. In these muscles, we can expect activity due to not only the primary mover muscles, but also accessory muscles. It can be considered that MRI technique will be useful to analyze MMT

results, since we need not predict specific candidate muscles. Thus, MRI techniques should be useful to increase the reliability of the MMT.

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Table 1. T_{2w}-MR image intensity before and after exercise

Subject	#1	#2	#3
A) Supinator muscle			
Before exercise	19.8	13.5	16.8
After exercise	33.5	30.3	43.5
B) Pronator teres muscle			
Before exercise	14.4	16.7	25.4
After exercise	30.9	30.6	46.3
C) Extensor indicis muscle			
Before exercise	15.5	14.9	20.0
After exercise	29.2	30.2	36.6

Image intensity was represented by the contrast-noise ratio. Image intensity increased more than the 99.9% confidence limit after exercise.

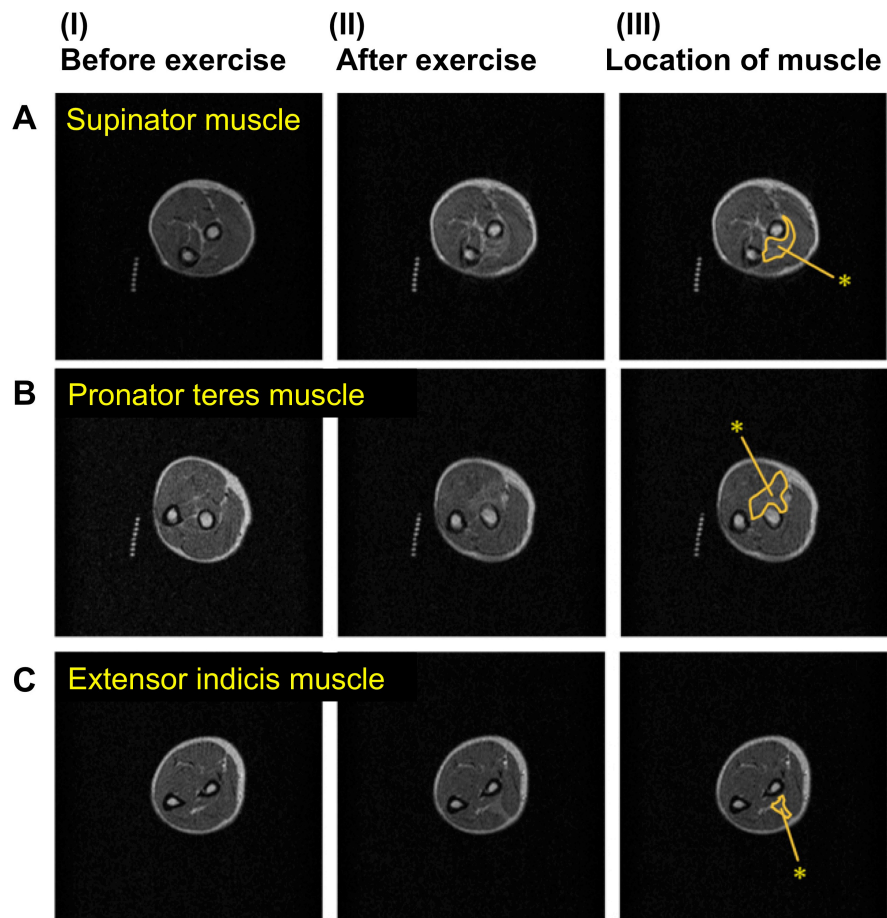


Figure 1. Transverse T_{2w} -MR images of the supinator muscle (A), the pronator teres muscle (B) and the extensor indicis muscle (C) of the subject #1. (I) T_{2w} -MR images before the exercise, (II) T_{2w} -MR images after the exercise, (III) The trace around muscle (*).