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Effect of Conventional Physiotherapy on Pain and Muscle Stiffness in Patients with Low Back Pain Assessed by a Wireless Hand-held Tissue Ultrasound Palpation System (TUPS)

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Abstract

Background: Low back pain (LPB) is a common health problem. While physiotherapy can relieve pain and the muscle stiffness of patients with LBP was shown to be different from healthy people, few studies have investigated the effect of physiotherapy on back muscle stiffness in patients with LBP.

Objective: To investigate the effect of a 5-day conventional physiotherapy treatment on muscle stiffness of patients with LBP using a newly developed wireless hand-held ultrasound probe.

Methods: A total of ten patients with LBP participated in this study. They received customized conventional physiotherapy containing electrical therapy, traditional Chinese medicine, manipulation and wax therapy. The pain level was evaluated by the visual analogue scale (VAS), and the muscle stiffness was measured by a wireless hand-held tissue ultrasound palpation system. The muscle stiffness of left and right sides at L1 and L4 levels and pain level were evaluated in two conditions, including baseline and post 5-day treatment.

Results and discussion: After receiving the treatment, the muscle stiffness of all tested low back regions increased significantly (p=0.040). The muscle stiffness at L4 level was significantly higher than that of L1 level (p=0.021). No significant difference of muscle stiffness between left and right sides was found. The correlation between the muscle stiffness and VAS score appeared to decrease after receiving the treatment (R2 changed from 0.3598 to 0.0533).

Conclusion: A five-day conventional physiotherapy treatment could relieve the pain level and increase the muscle stiffness of patients with LBP as evaluated by a wireless hand-held ultrasound probe. The stiffness of back muscle at L4 level was significantly higher than that of L1 level in patients with LBP. The treatment may change the correlation between the muscle stiffness and VAS score at low back region.

Keywords: Back muscle; Low back pain; Muscle stiffness; Elastography; Physiotherapy; Rehabilitation

Introduction

Low back pain (LBP) is a very common health problem globally with a prevalence of 31.0% [1]. It is a heavy burden to the health care system with an estimated cost of $192 billion annually [2]. Patients with LBP suffered from depression, decreased quality of life, physical dysfunction, and insufficient exercise [3]. Physiotherapy has been widely used to treat the symptoms of LBP [4-9].

Clinical assessment is essential for managing LBP. Recently, a review of clinical practice guidelines of LBP treatment and assessment reported that there was no involvement of quantitative assessment regarding the severity of LBP among the commonly used guidelines [10]. Although it has not been included in the daily clinical practice, attempts to quantitatively measure the LBP is not new in clinical experiments. Previous studies have commonly evaluated the paraspinal muscle to investigate the mechanism of LBP [11], with numerous findings relating to the morphology of paraspinal muscle been reported [12,13]. However, the clinical relevance of those findings remained controversial [14]. Using the mechanical property of paraspinal muscle to quantitatively evaluate the LBP could be an alternative assessment option.

Ultrasound elastography is a non-invasive radiation-free method of quantitatively measuring muscle mechanical property in terms of stiffness. There are mainly two different approaches: 1) shear wave elastography (SWE) by recording the speed of the induced shear wave; and 2) tissue ultrasound palpation system (TUPS) by recording the force-deformation relationship, or similar indentation techniques. Significant difference of paraspinal muscle stiffness between healthy subjects and patients with LBP has been identified. Masaki et al. (2017)

studied 9 patients with LBP and 23 healthy control subjects using SWE, and reported significantly higher shear modulus among the LBP group (3.7-5.6 kPa) than the control group (3.5-4.8 kPa) [15]. Chan et al. (2012) studied 12 patients with LBP and 12 healthy control subjects using TUPS, and reported similar results of significantly higher Young's modulus of paraspinal muscle in LBP group (41.3-39.1 kPa) than in control group (36.4-37.4 kPa) [16]. Different versions of TUPS systems [17] had been reported for assessing different tissues *in vivo*, including diabetic foot [18], muscles [19], fibrotic tissues [20], scar [21], etc. However, these TUPS systems were comprised of a control box, PC, and probe linked with wires for data collection and process, which limited its application with a troublesome experimental/clinical setup of too many wires.

With the state-of-the-art technology, the previous TUPS could be updated with a probe that wirelessly connected to a laptop/tablet. Without the restrictions of the wires, the probe can be easily placed at different body regions that used to be difficult to evaluate [22], such as on the back of subject under different postures. To the best knowledge of the authors, no previous study has investigated the effect of conventional physiotherapy treatment on back muscle stiffness in patients with LBP, while the therapist's subjective feeling about stiffness change is commonly adopted for evaluation. This paper aimed to 1) introduce a wireless hand-held ultrasound system for muscle stiffness assessment, and 2) report the findings regarding the effect of a 5-day conventional physiotherapy treatment on muscle stiffness using the introduced wireless hand-held ultrasound probe in patients with LBP.

Materials and Methods

Subjects

A total of ten subjects were recruited from the Northern Hospital, Shenyang, China. All subjects were screened before participating in this study, using the following inclusion criteria: patients had pain at low back region with a moderate or higher intensity (≥ 3 based on the visual analogue scale) at rest and/or during daily activities [15]. The exclusion criteria were history of fracture at spine or lower limbs, history of spinal surgery, and history of spinal malformation [16]. Ethical approval was granted by the authority of authors' institution. The written informed consent was obtained from all subjects.

Wireless hand-held tissue ultrasound palpation system (TUPS)

The muscle stiffness was measured with an updated TUPS containing a probe wirelessly connected to a laptop *via* Wi-Fi (Figure 1a). The probe was palm-size with a 7.5 MHz 128-elements ultrasound transducer and a 20 N load cell. The probe is powered by a rechargeable 4300 mAh lithium battery. The ultrasound image and force data were sampled simultaneously and were transmitted in real-time to a laptop workstation installed with a custom-developed program *via* 802.11.n WiFi protocol. The frame rate of ultrasound image and sampling rate of force data were 12 Hz. Three compression-release cycles with a duration of approximately 10 second was required for each measurement. The muscle stiffness was calculated based on the force applied to the muscle and its corresponding deformation.

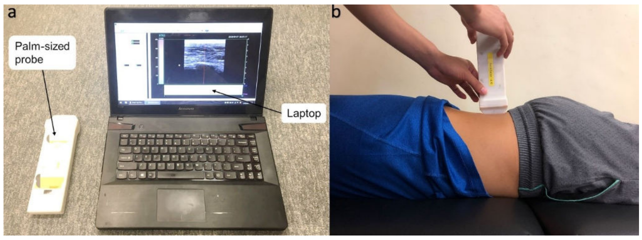

Figure 1: The upgraded tissue ultrasound palpation system (TUPS). (a) The hand-held ultrasound probe wirelessly connected to a laptop *via* Wi-Fi. (b) Measurement of muscle stiffness at low back region with the hand-held wireless probe.

Physiotherapy treatments

All subjects received the conventional physiotherapy treatments aiming at reducing pain that have been commonly used in clinical practice in patients with LBP. The subjects were recruited from a clinic dedicated for pain relief treatment, where using multiple modalities of treatment for patients is a common practice. The whole treatments lasted for 5 days, including 1) electrical therapy including interferential therapy [6], and transcutaneous electrical nerve stimulation [6]; 2) therapeutic ultrasound treatment [5], 3) traditional Chinese medicine including acupuncture [7] and moxibustion; 4) manipulation [8]; and 5) wax [9]. All treatments were applied at the painful area, 20 minutes of each treatment, and once a day. The treatment intensity or temperature of the wax was custom-designed for patients by clinicians based on the condition of the patient.

Experimental procedure

The muscle stiffness of each subject was assessed before and after receiving the 5-day conventional physical therapy. The muscle stiffness measurement was conducted with the subjects prone lying on a bed and the low back region exposed. Subjects' shoulders were kept at 90 degrees of abduction, with the arms rested alongside the bed. Head position was decided by subjects to ensure comfortableness and was maintained the same throughout the measurement. Spinal processes of L5 to L1 were identified by palpation and marked with a pen by a physiotherapist. The wireless probe was put along the muscle belly at L4 and L1 level and was 2-3 cm lateral to the spinal process (Figure 1b). The selection of the two points of L4 and L1was based on previous studies using EMG [23] and ultrasound elastography [16,24]. It was assumed that the stiffness measured at L1 level represented the erector spinae muscle stiffness and that measured at L4 level represented the multifidus. The spinal transverse process was identified *via* the B-mode ultrasound image with the probe location fixed. Gentle compression was applied at muscle belly to create approximately 20% of tissue deformation, which could be visualized in real-time from the ultrasound image. A total of three compression-release cycles were performed in 10 seconds for one measurement at one assessed point.

Outcome measurements

The pain level was assessed by the visual analogue scale (VAS, scored 0-10) as verbally reported by the patient [25]. Higher score indicated higher pain level [25]. The muscle stiffness measurement was

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assessed by the introduced hand-held wireless TUPS and was expressed in kPa.

Statistical analysis

Statistical analysis was conducted using SPSS (Version 24, SPSS Inc, Chicago, IL, USA). Three-way Analysis of variance (ANOVA) was used to determine if there was a three-way interaction effect between condition (baseline and post-treatment), level (L1 and L4), and side (left side and right side); as well as to determine the main effect of condition (baseline *vs.* post-treatment), main effect of level (L1 *vs.* L4), and main effect of side (left side *vs.* right side) on muscle stiffness. If significant interaction effect was found, post-hoc pairwise comparison with Bonferroni correction would be conducted to determine if there was significant difference in muscle stiffness between two conditions of baseline and post-treatment (baseline *vs.* post-treatment), between two sides of left and right (left side *vs.* right side), as well as between the two levels of L1 and L4 (L1 *vs.* L4) using paired t-test.

Wilcoxon Signed Rank test was used to determine if there was a significant difference in pain level between the baseline and post-treatment conditions (baseline *vs.* post-treatment). Spearman's rank correlation was used to test the correlation between the averaged muscle stiffness and the VAS score in baseline and post-treatment conditions. The significant level was set to 0.05.

Results

A total of ten subjects (eight males and two females; aged 32.2 ± 6.7 years, height 176.2 ± 5.5 cm, and weight 71.1 ± 3.7 kg) participated in this study. As shown in Figure 2, the mean baseline VAS score was 5.6. No adverse effect of the treatment was reported.

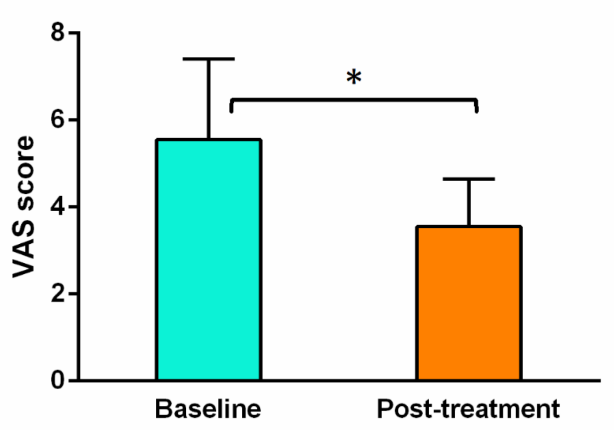

Figure 2: VAS score used to evaluate pain level in baseline and post-treatment conditions. *: Significant difference existed in pairwise comparison (p<0.05).

As shown in Figure 2, the VAS score decreased significantly from 5.6 to 3.6 after receiving the conventional physiotherapy treatment (p=0.016). The muscle stiffness of left and right sides at L1 and L4 levels is illustrated in Figure 3. While no significant three-way interaction effect between condition, level, and side was found; significant main effect of condition (baseline *vs.* post-treatment, p=0.040) and level (L1 *vs.* L4, p=0.021) on muscle stiffness was found. The muscle stiffness at L4 level was significantly higher than that of L1 level in all two conditions (p=0.021). After receiving the treatment, the muscle stiffness of all tested regions increased significantly (p=0.040). No significant effect of side (left side and right side) on muscle stiffness was found.

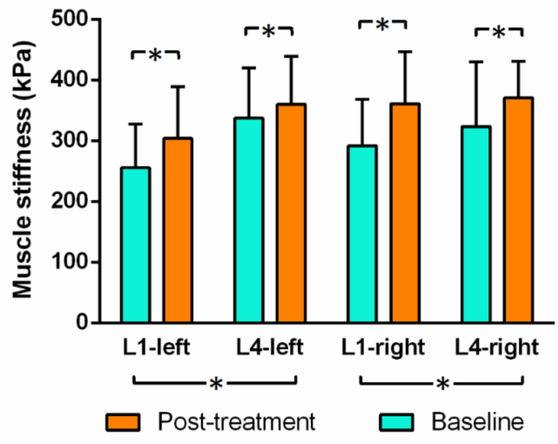

Figure 3: Muscle stiffness at two sides of L1 and L4 levels in baseline and post-treatment conditions. *Significant main effect of condition (baseline *vs.* post-treatment) and level (L1 *vs.* L4) on muscle stiffness existed (p <0.05).

As shown in Figure 4, there was moderate correlation between the averaged muscle stiffness of the four low back regions and the VAS score in baseline condition (R2=0.3598). Such correlation then became very weak (R2=0.0533) after receiving the conventional physiotherapy treatment.

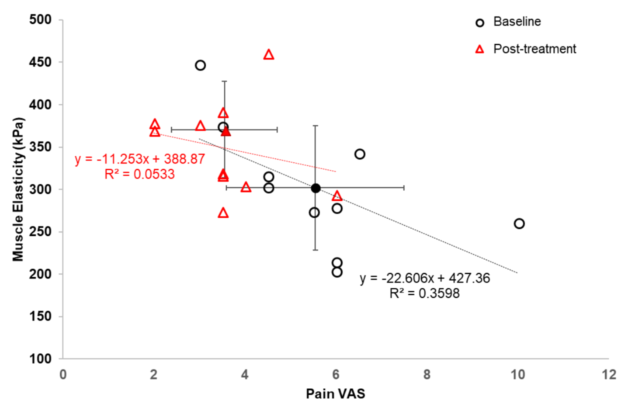

Figure 4: Correlation between the muscle stiffness and the VAS score in baseline and post-treatment conditions.

Discussion

This study introduced and applied a hand-held wireless ultrasound probe to assess the muscle stiffness of patients with LBP before and after receiving a 5-day conventional physical treatment. The results of this study demonstrated a conventional physiotherapy lasting for 5 days could effectively relieve pain and increase muscle stiffness at low back region in patients with LBP. It has also been identified that the back muscle at L4 level was significantly stiffer than that of L1 level in patients with LBP. The findings of this study provide more evidence for future clinical practice.

The significantly decreased VAS score in this study suggested that the pain level has significantly reduced after receiving a 5-day conventional physiotherapy. This implied that the 5-day conventional physiotherapy treatment involving electrical therapy, traditional Chinese medicine, manipulation, and was effective for relieving pain in patients with LBP. This is in accordance with the results of previous studies about the reduction in pain level after receiving electrical therapy [26] and manipulative therapy [27]. The finding of this study provides clinicians and physical therapists with more evidence regarding the prescription of combined physical therapies for patients with LBP when making clinical decisions in the future.

In addition to the significantly relieved pain level, this study also found that the muscle stiffness has significantly increased in patients with LBP after receiving the treatment. The findings related to effect of physical therapy on muscle stiffness has remained controversial. While some previous studies reported increased muscle stiffness after static stretching [28] and manipulative therapy [27], some other studies reported decreased muscle stiffness following thermal ultrasound [29] and passive stretching [30]. The current study further identified that a conventional physiotherapy containing electrical therapy, traditional Chinese medicine, manipulation and wax increased the muscle stiffness at low back region. This could be due to the fact that the conventional physiotherapy received by patients was mainly prescribed for relieving pain [27]. It was reported that other methods of therapy, involving exercise components might reduce muscle stiffness [30]. Future studies with longer follow-up period could be conducted to compare the changes in muscle stiffness after different combination of treatment modalities in patients with LBP. This will facilitate the understanding regarding the effect of various physical treatments on muscle stiffness to identify more optimized treatment protocol.

It was demonstrated that the muscle stiffness at L4 level was significantly higher than that of L1 level [31]. This is in line with previous findings of larger Young`s modulus of fiber bundle of the multifidus (mainly L4 level) than that of the erector spinae (mainly L1 level) *in-vitro* [32], as well as the *in-vivo* studies reporting larger shear modulus of the multifidus than that of the erector spinae in resting condition [15,33]. The different muscle stiffness values across various studies could be explained by the different methods to measure the muscle stiffness. The wireless TUPS used in this study measured the muscle stiffness based on the relationship between the tissue deformation and the force applied on the skin surface [16], while the SWE system estimated the muscle stiffness based on the propagation speed of the induced shear wave [34,35]. While it is an engineering topic about how to precisely convert the stiffness values measured by different methods, it is important to note that the focus of the present study is to compare the muscle stiffness before and after treatment, between different levels, and between two sides. Therefore, the stiffness values obtained from the updated TUPS was sufficient enough for such relative comparison [31].

The correlation between the muscle stiffness and VAS score appeared to decrease after receiving the conventional physiotherapy treatment in this study. This may generally suggest that pain-relief treatment could reversely change the correlation between pain level and muscle stiffness at low back region. Previous studies have documented the correlation between low back pain and backpack weight [36], as well as the correlation between low back pain and disability and quality of life [37]. This study further reported the correlation between low back pain and muscle stiffness at low back region in patients before and after the pain-relief treatment. However, the number of subjects included in this study is small to make a strong conclusion about the relationship between the muscle stiffness and VAS. Future studies with a larger group of subjects can be conducted to investigate the relationship between the muscle stiffness and the pain level, for subjects with different types of pains and at different low back regions. Those additional results will further facilitate the understanding of whether the muscle stiffness can be clinically useful as an indication for pain level or for treatment outcome measurement, both in objective and qualitative manner.

In addition to the small sample size discussed above, another limitation of this study is the use of VAS pain level to assess the severity of LBP symptom, which is a subjective method. Further efforts are needed to involve more objective assessment tools to comprehensively evaluate the severity of the symptoms, so as to uncover the potential correlation between the muscle stiffness and pain level.

Conclusion

The hand-held wireless ultrasound probe can be used to assess the effect of treatments on muscle stiffness of patients with LBP. The results supported that a 5-day conventional physical treatment could effectively relieve pain and increase muscle stiffness at low back region in patients with LBP. It was demonstrated that the back muscle at L4 level was significantly stiffer than that of L1 level in patients with LBP. It appears that the treatment decreased the correlation between the muscle stiffness and VAS score at low back region. The feasibility demonstrated in this study paved ways for applying this wireless ultrasound-based muscle stiffness measurement tool for a larger scale clinical study.

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