CHAPTER 4

RESULTS

4.1 Multifidus muscle size and symmetry among elite weightlifters

4.1.1 Introduction

Weightlifting is a sport that exposes the spine to extreme forces during the training and competitive events. Cholewicki et al (70) measured forces at the L4-L5 motion segment in 57 competitive weightlifters. The average compressive loads were more than 17,000 N. It has been suggested that weightlifting may predispose the athlete to spondylolysis (71-73) and it has been reported that weightlifters have a 36.2% incidence of spondylolysis (74), in comparison with a rate of 3-7% in other sports and general populations (30). Injury reports conducted over a six-year period among weightlifters during training at Olympic Training Centers showed that the low back was the most commonly injured area of the body in weightlifting, with 130 of the 560 injuries documented (23.1%) being in this region (30). The prevalence of LBP was shown to be even higher (41.67%) among Thai weightlifters (32). Former weightlifters have been shown to have a higher rate and more severe degenerative changes in the upper lumbar spine (109). Given the high incidence of LBP among weightlifters, it would seem appropriate to examine muscles which can protect the spine in this group.

During weightlifting, many muscles are recruited and good technique is required. It has been suggested that an emphasis should be placed on achieving correct motor patterns before substantial weight is attempted. Young Eastern

European athletes are reported to spend years in developing form by lifting broomsticks. Only when their form is perfect do they add weight to the bar (75). Preserving a neutral lumbar spine is thought to be essential for safe lifting (75). In one study of the mechanics of power lifters spines' while they lifted extremely heavy loads, video fluoroscopy was used to provide a sagittal view of the spine (76). During the execution of a lift, one lifter reported discomfort and pain. On examination of the records, one of the lumbar joints (L2-3) went into full flexion, while all other joints maintained their static position, resulting in what the authors described as 'buckling' of the spine and injury. The explanation for this, proposed by the authors, was that it was possibly due to an error in motor control of a segmental muscle such as the LM, resulting in a temporary reduction in activation and rotation at that single joint, which occurred to the point where passive or other tissues were injured. There is considerable evidence for the role of the LM muscle in segmental stabilization of the lumbar spine (10, 84, 110, 111). Biomechanical studies have highlighted the role of the LM muscle in provision of segmental stiffness (9, 84) control of the spinal segment's neutral zone (10, 112) and its capacity to stabilize the spine when spinal stability is challenged (110, 111). Furthermore, the LM muscle has been shown to contribute to proprioception of the lumbar spine (113).

Weightlifters are known to suffer LBP (28, 29), but the LM muscle has not been examined in this group. Imaging studies have been used to document the normal morphology of the LM muscle (25, 27, 54, 69), and have also been used to document impairments in terms of decreased CSA of the LM muscle in non-athletic populations (27, 35, 56, 114), and athletic populations with LBP (115). There is evidence that the CSA of the LM muscle is selectively decreased compared with other lumbopelvic muscles in patients with chronic LBP (56). MRI and CT scanning studies have shown both decreased LM muscle CSA (35, 56) and presence of alterations in LM muscle consistency due to fatty deposits or fibrous or connective tissue infiltration (116) and atrophy of this muscle is a common radiological finding (57). Atrophy and between-side asymmetry of the LM muscle has also recently been documented in elite cricketers (115). Cricketers with LBP demonstrated localized atrophy of the LM muscle, despite continued strength and cardiovascular training. No study has evaluated the CSA of the LM muscle in weightlifters. The aim of this study was to compare the CSA and symmetry of the LM muscles among elite weightlifters.

4.1.2 Methods

4.1.2.1 Subjects

The subjects in this study were 31 elite weightlifters (15 males and 16 females) who were selected to attend a national training camp. This sample represented the population of Thai weightlifters eligible for national selection. Subjects performed regular weightlifting training programs which consisted of one hour of cardiovascular and strength training and three hours of skill training per day, 6 days per week. The sample mean ± standard error (SE) of age, weight and height were 21.42 ± 0.59 years, 72.32 ± 3.69 kg 162.09 ± 1.91 cm. The exclusion criteria were observable spinal abnormalities, previous spinal or abdominal surgery and pregnancy. The study was approved by the Human Research Ethical Committee of the Faculty of Associated Medical Sciences, Chiang Mai University, Thailand.. Informed consent was obtained from all participants.

4.1.2.2 Procedure

All participants completed a self administered questionnaire. Hand preference was defined as the hand that was used for writing. LBP was defined as pain localized between T12 and the gluteal fold. Participants who reported current LBP plus pain provocation on manual examination were allocated to the "LBP group". Weightlifters, who did not report LBP on a body chart and pain provocation on manual examination, were coded as 'asymptomatic'. Weightlifters with LBP rated their pain intensity on a Visual Analogue Scale (VAS, rated 0-10), reported the duration of symptoms (in months) and the side of LBP was drawn on a body chart. The grouping of cases as 'bilateral' or 'unilateral' pain was based on body chart reports of LBP. Among the weightlifters, there were 5 who were asymptomatic, 9 with unilateral back pain and 17 with bilateral back pain. Based on duration of painful symptoms, the weightlifters that had positive findings on manual examination included 7 with acute LBP (less than 1 month), 7 with subacute LBP (less than 3 months) and 12 with chronic LBP (more than 3 months) (117).

The CSA of the LM muscles was measured using a Toshiba ultrasound scanner (Toshiba, Famio 8, SSA-530A) set in B-mode with a 5-MHz curvilinear transducer. Measurement of the LM muscle was performed with subjects in the prone position with a pillow placed under the abdomen to minimize the lumbar lordosis. The ultrasound images were taken from L2-L5 with subjects in a relaxed state and images were stored for offline analysis (Figure A1-4) following techniques as described in Appendix 1.

The program Image J was used to calculate the CSA of the LM muscle at the vertebral levels of L2-L5. The measurement was carried out three times on one image and averaged for each image.

4.1.2.3 Statistical analysis

Analysis of variance (ANOVA) was used to initially test for group similarity in age, height, weight, BMI and maximum lifting performance. In addition, the duration of pain and level of pain (VAS) were compared across the groups with unilateral and bilateral LBP using ANOVA.

An analysis of covariance (ANCOVA) was used to examine CSA and asymmetry of the LM muscles. As there is a systematic increase in the CSA of the LM muscle across vertebral levels, analyses were conducted separately for each level. The data for CSA of LM were averaged across the left and right sides. The variables of ‘age’, ‘weight’ and ‘height’ were entered as covariates in the analyses, resulting in effects being adjusted for age, weight and height. The between-subjects factors were ‘pain group’ (asymptomatic, bilateral, unilateral LBP) and ‘gender’ (male, female). Post-hoc was used to examine differences among the groups. Due to the relatively small number of weightlifters, interaction effects in the analytic model have been restricted to ‘pain group’ by ‘asymmetry’.

The degree of asymmetry of LM CSA was calculated as a percentage difference between sides relative to the larger side [%difference = (largest side-smallest side/largest side) x 100].

4.1.3 Results

The demographic characteristics of the weightlifters are shown in Table 4-1. There were no significant differences for age, height, weight, BMI and maximum lifting performance between the asymptomatic and LBP groups (p>0.05). In addition, there were no significant differences between those with unilateral and those with bilateral distributions of LBP in terms of pain intensity and duration of pain (p>0.05). Weightlifters with LBP (unilateral and bilateral distributions) reported a mean pain VAS score of 5.9 ± 0.3 and the mean duration of pain was 8.5 ± 3.1 months.

Table 4-2 shows the CSA of the LM muscle (cm^2) for each vertebral level in the weightlifters. Results of the analyses showed that LM muscle CSAs were not different among weightlifters with unilateral and bilateral pain symptoms ($p > 0.05$). Male weightlifters had significantly larger LM muscles only at the L4 (p<0.01) and L5 (p<0.001) vertebral levels compared to females.

The between side differences (relative to the side of the larger side) were shown in Table 4-3. Asymmetry of the LM muscle was not different across the LBP groups at any vertebral levels (p>0.05).

Table 4-1. Characteristics of elite weightlifters (mean ± SE) (n=31)

Variables	Asymptomatic (n=5)	Unilateral LBP (n=9)	Bilateral LBP (n=17)	Total (n=31)
VAS score	0	5.33± 0.7	6.3 ± 0.4	5.9 ± 0.4
Age (yr)	20.6 ± 1.6	20.8 ± 0.9	22.0 ± 0.8	21.4 ± 0.6
Weight (kg)	58.2 ± 2.8	83.2 ± 6.3	70.7 ± 5.3	72.3 ± 3.7
Height (cm)	156.0 ± 2.5	166.6 ± 3.8	161.5 ± 2.6	162.1 ± 1.9
BMI (kg/m^2)	23.9 ± 0.8	29.7 ± 1.6	26.6 ± 1.1	27.0 ± 0.8
Experience of training (yr)	8.6 ± 0. 7	7.1 ± 0.9	6.9 ± 0.6	7.2 ± 0.4
Maximum snatch lifting (kg)	105.4 ± 7. 8	132.6 ± 8.4	110.8 ± 5.7	116.4 ± 4.6
Maximum clean and jerk lifting kg)	134.0 ± 10.0	167.7 ± 10.8	141.0 ± 6.6	147.6 ± 5.4
M:F ratio (n)	2:3	6:3	7:10	15:16

Abbreviations: SE, standard error; M, male; F, Female; VAS, visual analogue scale

Table 4-2. Marginal means* of CSA of LM muscle (cm^2)

Variables	L2 (Mean (SE)) (cm^2)	*p*	L3(Mean (SE)) (cm^2)	*p*	L4(Mean (SE)) (cm^2)	*p*	L5(Mean (SE)) (cm^2)	*p*
Pain group								
Asymptomatic	2.92 (0.23)	.492	4.68 (0.27)	.583	8.05 (0.53)	.814	10.07 (0.44)	.941
Bilateral	2.52 (0.12)		4.42 (0.14)		7.98 (0.28)		9.75 (0.23)	
Unilateral	2.88 (0.17)		4.31 (0.21)		7.74 (0.40)		9.63 (0.34)	
Gender								
Males	2.92 (0.16)	.258	4.57 (0.19)	.501	8.75 (0.37)	.010	10.98 (0.31)	.001
Females	2.63 (0.16)		4.36 (0.19)		7.09 (0.38)		8.65 (0.32)	

Abbreviations: SE, standard error.
*Marginal means (adjusted for age, weight, height).

Table 4-3. Asymmetry (percentage difference between sides, relative to larger side) of MF for elite weightlifters with symptomatic LBP and asymptomatic LBP*

Variables	L2 (Mean (SE)) (%)	*p*	L3(Mean (SE)) (%)	*p*	L4(Mean (SE)) (%)	*p*	L5(Mean (SE)) (%)	*p*
Pain group								
Asymptomatic	4.09 (3.14)	.589	4.61 (2.40)	.676	4.24 (3.19)	.168	2.56 (3.37)	.357
Bilateral	7.60 (1.65)		7.19 (1.26)		9.27 (1.67)		7.71 (1.77)	
Unilateral	6.93 (2.41)		6.89 (1.84)		6.06 (2.44)		8.30 (2.58)	
Gender								
Males	4.87 (2.21)	.415	5.51 (1.69)	.662	5.21 (2.24)	.323	4.79 (2.37)	.530
Females	7.54 (2.26)		6.96 (1.72)		7.83 (2.29)		7.58 (2.42)	

Abbreviations: SE, standard error.
*Marginal means (adjusted for age, weight, height).

4.1.4 Discussion

The results of this study showed that elite Thai weightlifters with LBP did not show specific deficits in the CSA of the LM muscle. This result is in contrast to two previous studies where investigators have found a deficit in this muscle in elite athletes (115, 118). Roy et al (118) used power spectral analysis of EMG activity to examine fatigue rates of the LM muscle in male varsity rowers. Using the fatigue rates of the LM to discriminate between subjects with chronic LBP and control subjects, the investigators correctly identified all control subjects and 93% of the subjects with LBP.

In this group of weightlifters, 84% reported symptomatic LBP. Atrophy of the LM muscle in those with LBP has been demonstrated in several studies in the non-athletic population (27, 35, 56, 114). Authors have explained this atrophy to be related to pain inhibition involving reflex loops (23), and disuse atrophy (119). One other study of athletes has also found that athletes with LBP did not show atrophy of the LM muscle. A study of elite oarsmen found that rowers with a history of LBP had larger LM muscles (120). It can therefore be hypothesized that elite athletes have competing influences of pain (23, 119) and increased physical demands (120, 121). Weightlifters with LBP in current study continued their training program and competed at high level and this may minimize muscle atrophy. Hypertrophy of the LM muscle in response to weightlifting can be confirmed by comparing the CSA of the LM muscle in weightlifters with those of normal healthy subjects. Various studies of the morphometry of the LM muscle in healthy, non-athletes have provided consistent data (25, 54, 69, 122). At the level of the 4th lumbar vertebra (L4), the mean CSA of LM in healthy subjects has been reported to be approximately 6 cm^2 in females and

8 cm^2 in males (123). The weightlifters measured in the current study had larger LM muscles (females: 7.09 ±0.38; males: 8.75±0.37 cm^2) at L4. At L5 in healthy subjects, the muscle becomes larger than at L4 (approximately 7 cm^2 in females and 9 cm^2 in males) (123). Again, the weightlifters in the current study had larger muscles (females: 8.65±0.32, males: 10.95±0.31 cm^2). These results would suggest that weightlifting hypertrophies the LM muscle or those that reach the elite levels of weightlifting tend to have larger multifidus.

Fatty infiltration that has been associated with individuals LBP can lead to the muscle appearing hypertrophied on ultrasound image. Fatty infiltration would have appeared as white patches on the images, most commonly present in the deep ventromedial corner (116). However, in this study there was no evidence of fatty infiltration on the ultrasound images from the weightlifters.

In previous studies where LBP and decreased CSA of the LM muscle has been demonstrated, rehabilitation resulting in an increase in CSA of the LM has been commensurate with a decrease in painful symptoms, decreased disability levels and decreased recurrence rates on LBP (23, 27). The current study did not find a difference between those with unilateral or bilateral LBP for the CSA of the LM muscle. However, we cannot confirm that the LM muscle is functioning optimally. Other parameters are yet to be assessed in this population, such as proprioception (113) and the ability to voluntarily contract the muscle at individual vertebral levels (114). Neurophysiological investigations, such as timing using firewire EMG (124) and power spectral analysis of EMG activity (118) could also be undertaken in this group. It is possible that precise motor control of the vertebral segment, rather than just CSA of the muscle at each segment could be important parameters to assess in these athletes.

This theory may be supported by the work of Cholewicki and McGill (76), who showed using video fluoroscopy that during the execution of a lift, one lifter reported discomfort and pain associated with one of the lumbar joints moving into full flexion, while all other joints maintained their static position, resulting in buckling of the spine and injury.

Between-side comparisons are performed in the clinical situation to examine for unilateral abnormalities in size or asymmetry. Previous studies showed that LM muscles in normal subjects are symmetrical between sides (25, 54, 69). Symmetrical between sides of LM muscles were also demonstrated in asymmetrical weightlifters (ranged from 2.6% to 4.6%). Localized LM asymmetry with atrophy ipsilateral to symptom at specific vertebral in unilateral LBP patients (25, 35). This study founded between-side difference in symptomatic weightlifters ranged from 6.1% to 9.3%. LM asymmetries were less than 10% relative to larger side. Hides et al (27) suggested that LM asymmetry more than 10% could be regarded as a potential abnormality. The size differences between those with and without LBP are less than 10%. It is possible that weightlifters do not have atrophy despite having LBP. This would be most likely related to the role of the LM in weightlifting, as the LM muscle controls the lumbar lordosis and is stimulated by axial gravitational loading. When axial loading is removed in bedrest studies, selective multifidus muscle atrophy was reported (103). It could be argued that even if the weightlifters have LBP, they need to have good control of the lordosis to withstand the large compressive forces.

There are some limitations of this study. The main limitation is the small subject sample size, which is common in research involving elite athletes. As the entire available sample (elite Thai weightlifters eligible for national representation) was included in the study, a larger sample was not possible. The lack of sufficient numbers of asymptomatic weightlifters may not be able to be addressed in other studies. However, the result indicating a lack of asymmetry in this sample of weightlifters needs to be replicated in future. Notably, a small number of asymptomatic subjects is representative of this group limits comparisons to the LBP groups. We are unable to determine from this study whether weightlifting in itself hypertrophies the multifidus muscle or if individuals who are elite weightlifters have a specific morphology that suits the sport. Future studies could explore this relationship. Furthermore, only one trunk muscle was examined in this study. Other trunk extensor muscles can contribute to segmental control of the lumbar vertebrae, and numerous trunk muscles are recruited in the complex skill of professional weightlifting.

In conclusion, elite Thai weightlifters with LBP did not show specific deficits in the CSA of the LM muscle when compared with those without LBP. In addition, the LM muscle shows symmetry between sides among elite weightlifters. The lack of atrophy may be related to the type of training in elite weightlifters. Although, LM muscles demonstrate symmetry in elite weightlifters, specific training of LM activation may gain more benefits to protect the spine. The type of training adopted by elite weightlifters may affect the LM muscle function. The results suggest future studies could investigate other aspects of neuromotor control of the LM muscle to determine if there are impairments which could be addressed in an attempt to decrease the high prevalence of LBP in this population. In addition, influence of gender on CSA of LM muscle should be investigated in the future as male exhibited larger LM than female at L4 and L5 vertebral level.

4.2 Lumbar multifidus muscles contraction ratio among elite weightlifters with and without low back pain

4.2.1 Introduction

LM muscle is considered to play an important role in segmental stabilization of lumbar spine. Dysfunction of LM has been linked to LBP (25, 36). Previous studies focused on characteristic of LM muscle in healthy population and LBP using RUSI (23, 25, 27, 54, 86). CSA and thickness of LM muscle at various lumbar vertebral levels were commonly reported. In healthy population, linear measurements of LM muscle (anteroposterior distance [thickness] x mediolateral distance [width]) correlated well with CSA at the L4 and L5 vertebral levels (r= 0.92-0.98)(25, 54, 69). LM muscle thickness was measured using RUSI in parasagittal (longituditional) orientation of the transducer. In parasagittal plane, the zygapophyseal joints, the overlying LM bulk and TLF can be visualized (16, 22, 87). This orientation allows measurement of LM muscle thickness and change during contraction to be observed more easily than in the transverse plane. It has been successfully used to provide feedback of LM recruitment and grater improvement in LM contraction performance (22, 23, 83). Wallwork et al (87) reported high intrarater and interrater reliability of LM muscle thickness measurement between an experienced and a novice assessor at the level of L2-3 and L4-5 zygapophyseal joints on the basis of an average of three trials. Kisel et al (16) reported high intrarater reliability for LM thickness measurement at L4-5 and L5-S1 zygapophyseal joints during resting and contraction stage. Koppenhaver et al (89, 107) reported high reliability in LM thickness measurement in patients with LBP and SEM was 50% decreased when using an average of three trials.

The impairment in LM muscle was founded in the individual with LBP (25, 36). Previous study demonstrated that LBP patients lack the ability to activate the LM contraction at L4-5 and L5 –S1 zygapophyseal joints (106). TrA also play important role in LPS control and was reported to be dysfunction in LBP (94, 102, 103). The ability to contract of TrA muscle during ADIM was decreased in patients with LBP (7, 13). In a recent study conducted on elite cricketers (103), the ability to contract the TrA muscle during ADIM was reduced in cricketers with LBP. Weightlifters athletes were frequently exposed the extreme load to the spine and suffered from LBP. However, there was no study reported on LM function in weightlifters. The aim of this study was to investigate the contraction ratio in elite weightlifters with and without LBP.

4.2.2 Methods

4.2.2.1 Subjects

The subjects in this study were 31 elite weightlifters. Details of inclusion and exclusion criteria were described in section 4.1.2.1.

4.2.2.2 Procedures

The thickess of the LM muscles was measured using a Toshiba ultrasound scanner (Toshiba, Famio 8, SSA-530A) set in B-mode with a 5-MHz curvilinear transducer. Images of the LM muscles were taken in prone position during resting and contraction stage. The transducer was placed longitudinally along the L4-5 and L5-S1 zygapophyseal joint following techniques as described in Appendix 1. Subjects were instructed to take a relaxed breath in and out, hold the breath out, and try to “swell” or contract the LM muscle(22). They were also instructed not to move their spine or pelvis when they contracted the muscle. The LM contraction required a slow gentle sustained contraction and hold for 5-seconds. At the end of 5-seconds period, the image was saved. Subjects performed LM contraction for three trials and the image was saved at the third trial. All images were measured offline using NIH, Image J programme. The LM thickness measurement was made between the tip of the L4-5 and L5-S1 zygapophyseal joint to the inside edge of the superior border of LM muscle (16, 22, 87, 89) (Figure A1-5). Contraction thickness ratio of LM muscle was calculated by the thickness during contraction divided by the resting thickness.

Ten image of LM muscle was used to calculate the intraimage intra rater reliability of the LM thickness at L4-5 and L5-S1 zygapophyseal joint. Excellent reliability were found at both levels ($ICC_{3,1}$ = 0.998 (95%CI 0.992-0.999) and 0.995 (95%CI 0.995-0.999) respectively). Response stability was calculated using SEM and MDC 95. SEM were low at both levels (L4-5 = 0.20 mm and L5-S1= 0.19 mm) and MDC_{95} of the LM thickness at L4-5 and L5-S1 zygapophyseal joint were 0.56 mm and 0.53 mm respectively.

4.2.2.3 Statistical analysis

An analysis of covariance (ANCOVA) was used to examine contraction ratio of the LM muscles. As there is a systematic increase in the CSA of the LM muscle across vertebral levels, analyses were conducted separately for each level. The data for CSA of LM were averaged across the left and right sides. The variables of ‘age’, ‘weight’ and ‘height’ were entered as covariates in the analyses, resulting in effects being adjusted for age, weight and height. The between-subjects factors were ‘pain group’ (asymptomatic, bilateral, unilateral LBP). Post-hoc was used to examine differences among the groups.

4.2.3 Results

The contraction ratio of LM at the levels of L4-5 and L5-S1 zygapophyseal joint among elite weightlifters with and without LBP are shown in Table 4-4. The result showed that the contraction ratio of LM was significantly different between weightlifters with and without LBP at the level of L5-S1 zygapophyseal joint (p<0.01).

Table 4-4 Marginal means* of the contraction ratio in elite weightlifters with and without LBP

LM contraction ratio	Asymptomatic Mean ± SE (n=5)	Unilateral LBP Mean ± SE (n=9)	Bilateral LBP Mean ± SE (n=17)
L4-5	1.16±0.03	1.11± 0.02	1.08 ± 0.15
L5-S1	1.12 ± 0.02	1.07 ± 0.01	1.06 ± 0.01†

Abbreviations: SE, standard error.

*Marginal means (adjusted for age, weight, height).

† Significant difference between asymptomatic and bilateral LBP group at $p < 0.01$

4.2.4 Discussion

Contraction ratio appears to be more clinically useful than muscle thickness measures. Contraction ratio represented the ability of muscle to increase thickness during contraction relative to resting. Greater contraction of LM muscle may contribute to motor control of LPS. The present study demonstrates that contraction ratio of the LM in elite weightlifters with bilateral LBP was lesser than asymptomatic at the level of L5-S1 zygapophyseal joint. Previous studies reported subjects with LBP had difficulty in performing isometric contraction of LM muscle. This may be due to the reflex inhibition (24, 25). Decreasing the ability to voluntary contract the stabilizing muscles were found in LBP patients. Stuge et al (125) reported TrA contraction ratio of 1.5 in pelvic girdle pain women and the result was similar to recovered pelvic girdle pain group (TrA contraction ratio 1.5-1.6). The results highlight dysfunction of LM muscle in pain recovery group. Koppenhaver et al (107) reported a percentage change of LM thickness during contraction to resting of 11.2% (thickness during contraction 38 mm, thickness resting 34 mm or contraction ratio 38/34 = 1.12). The current study showed the same range of LM contraction ratio (1.1) with other studies. Although this study demonstrated significant decrease in contraction ratio at the level of L5-S1 zygapophyseal joint, it may raise question on the clinical significant. Decreasing in contraction thickness ratio may be markers of motor control dysfunction, normal adaptation to pain or both. Further study need to investigate intervention effect of specific exercise on normalized motor control dysfunction in the LM muscle among this population.

In conclusion, bilateral LBP weightlifters showed significant lesser contraction ratio of LM than the asymptomatic group at L5-S1 zygapophyseal joints. The changes may be an adaptation to pain among elite weightlifters with bilateral LBP.