Med. J. Cairo Univ., Vol. 87, No. 2 , March: 1083-1091, 2019
www.medicaljournalofcairouniversity.net

The Relationship between Sagittal Curvature (Lumbar Lordosis) and Extensor Muscle Volume in Lumbar Region: A Morphological and Radiological Study

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Abstract

Background: The vertebral column has a variable range of movements. It provides a load-carrying capacity that supports physical activities during daily life. The forces exerted by extensor muscles to stabilize the lumbar spines is related to its size which is affected by lumbar lordosis. The forces would be greater in cases of larger sagittal curvature (lordosis).

Aim of Study: Was to detect the relationship between extensor muscle volume and lumbar lordosis by using magnetic resonance imaging (MRI) of the lumber region and to Compare the results in subjects not complaining of low back pain with those presenting with low back pain. Findings could guide the physicians during training programs in the field of sports and rehabilitation.

Material and Methods: Two hundred subjects were classified into two groups; group (A) representing individuals with no history of back pain and group (B) with history of low back pain (LBP). Magnetic resonance imaging (MRI) examinations of the lumbar spines were done for all cases. Axial and sagittal T1WI, T2WI and gradient images were done. The lower lumbar curvature was determined from sagittal images. The volume of the extensor muscles caudal to the mid-lumbar level was estimated in axial MRIs spanning the lumbar spine.

Results: Statistically significant positive correlation between the angle of lumbar curvature and muscle volume was found at all ages of group A (p=0.001) and group B-III (p=0.008). While no statistically significant correlation was detected in group B-I: p=0.089 and group B-II: p=0.061. The mean muscle volume in LBP subjects (group B) was significantly smaller than group A in all ages.

Conclusion: The magnitude of the lumbar lordosis present in a normal subject is related to the quantity of the extensor muscle and any deviation in the angle of the lumbar curvature or the size of the muscle by decreasing or increasing than normal could be the beginning of low back pain or a pathological condition.

Key Words: Lumbar lordosis – Extensor muscle volume – MRI lumbar region – Low back pain.

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Introduction

THE vertebral column shows extensive range of movement and provides a load-carrying capacity that supports physical activities during daily life **[1]**. Vertebral curvatures from neck to pelvis help to distribute body load evenly during movement and to absorb impact due to sudden influences in a daily life **[2]**. Maintenance of normal vertebral curvatures protects the spinal cord from excessive movement **[3,4]**. So, the study of vertebral curvatures is important issue in assessing the function and range of movement of the vertebra **[5]**.

lumbar lordosis is the inner curvature of the lumbar spines. It is the principle factor in maintaining the sagittal balance of the body which is the goal for surgical and physiotherapeutic procedures **[6]**. The optimal range of lumbar lordosis angle is wide ranging from 300 to 800 **[7]**. Excessive lordosis is over 700º, lumbar kyphosis occurs if the angle less than 10º, and hypo-lordosis at 11-30º range **[8]**.

Maintaining proper lumbar lordosis has a protective effect on the structures of the spine in different positions **[9,10]**. Lumbar lordosis is seen in childhood and increases through adolescence. It is more evident in females than males **[11-13]**. The lumbar vertebra are seen smaller in size in females with wider range of movement **[13,14]**.

The extensor muscles of the lower part of the vertebral column (lumbar spine) are seen located posterior to the vertebral bodies. They play an important role in controlling movement, providing mechanical stability and the degree of lumbar lordosis. The forces generated by the extensor muscles are related to its size. The extensor muscles include two main groups: The transversospinalis (multifidus, rotatores, interspinales and intertransversarii) and the erector spinae (iliocostalis and longissimus). The transversospinalis muscles are deeply located. They are responsible for stabilizing the spines during small movements [15-17]. The erector spinae muscles are more superficially located and spanning larger sections of the lumbar spines. They have bigger role in the spinal movement [15,18].

MRI examination of the lumbar spines is considered non-invasive ideal imaging modality for assessment of extensor muscle size and the degree of lumbar lordosis without exposure to ionising radiation [19].

So, the aim of our study was to detect the relationship between extensor muscle volume and lumbar lordosis by using magnetic resonance imaging (MRI) of the lumber region and to Compare the results in subjects not complaining of low back pain with those presenting with low back pain. Findings could guide the physicians during training programs in the field of sports and rehabilitation.

Patients and Methods

Material:

Our observational study included 200 subjects; 105 males and 95 females. Cases were referred from the orthopaedic clinic to the radiology department at our hospital and a private centre during the period from May 2014 to December 2015. The study was approved by the local ethics committee of our institution. Data for patients were collected after obtaining their informed consents. Cases were examined by magnetic resonance imaging (MRI) of the lumbar region. The subjects were divided into two groups; group A cases not presenting by low back pain (no LBP) and group B presenting with low back pain (LBP). Cases were further subdivided according to their ages into three categories:

I : From 21- 35 years (29 male, 37 female).

II : >35 - 50 years (36 male, 34 female).

III: >50 years (40 male, 24 female).

Inclusion criteria: Both sexes (males and females) were included.

Exclusion criteria: Patients with lumbar vertebral body deformities, diseased intervertebral discs (prolapse, herniation), cauda equine syndrome, previous back surgery, spinal tumours and pregnant females.

Technique of MRI lumbar spines:

Non-contrast MRI examinations of the lumbar region were performed in the supine position with extended legs. We didn't use general anaesthesia. Subjects were examined using Siemens aera 1 .5T and Intera 1 T devices with a standard spine coil. Preliminary coronal images were taken to ensure absence of significant scoliosis. T2-weighted turbo spin echo sagittal and axial scans were taken with TE of 120ms, TR of 3000 to 3500ms, a flip angle of 90º, and field of view 340mm in sagittal and 160mm in axial images, slice thickness 4mm. Sagittal T1-weighted spin-echo (SE) images were taken with TE of 10ms, TR of 400ms, a flip angle of 90º, and field of view 340mm and slice thickness 4mm. Gradient echo sequence with a repetition time (TR) of approximately 55ms and an echo time (TE) of 1.9ms. 48mm-thick slices, with a 1-mm gap were acquired; the in-plane resolution was between 1.76 and 1.95mm pixel1, depending on subject size. Images acquired in the axial plane were used to determine extensor muscle size in the lower part of the lumbar spine. These images were saved in TIFF format and regions of interest corresponding to the extensor muscles were segmented, by one observer, using GIMP software (GNU Image Manipulation Programme, version 2.6.10, www.gimp.com).

Estimating the angle of the lumbar curvature:

MR images acquired in the sagittal plane were used to determine the curvature of the lower lumbar part of the vertebral column. We identified the slice that was close to/or at the mid-line of the lumbar part by observing the conus medullaris and/or the spinous processes of the lumbar vertebra. The curvature was determined as the angle between the upper border (superior end plates) of L4 and S1 [20]. Although the examination was done in supine position, the results were highly correlated to the predictions models in the standing posture [21].

Muscle volume:

Assessment of the extensor muscle volume was done at the lower lumbar part of the vertebral column using axial images. Forty mm thick slices, with a 1mm gap were examined. The regions of interest (ROI) included the iliocostalis, longissimus and multifidus muscles, as well as the rotatores, interspinales and intertransversarii muscles. Areas where gross infiltrations of fat were excluded. The upper boundary of the muscle volume was selected at L3/L4 disc while the lower boundary was defined as the most caudal slice where the extensor muscle was observed. The number of slices were varied from 10 to 15 (mean=13) slice due to differences in the subjects 'height.

The extensor muscle volume was calculated by multiplying the cross-sectional areas by the effective slice thickness (acquired slice thickness plus slice gap) and summing across the appropriate number of slices. All measurements were carried out twice and the means of the recorded data were determined and analysed by the same investigator to reduce the percentage of error.

Statistical analysis:

Data were expressed as mean ±SD. Significant differences were determined by using ANOVA and post hoc tests for multiple comparisons using Statistical package for Social Science (SPSS) software version 17. Results were considered significant at p-value <0.05 and highly significant at p<0.01. Pearson's correlation coefficient was applied to determine whether there is an association between angle at L4-S 1 and muscle volume. Data of correlation were represented in scattered graphs with a line of bestfit.

Results

Our study included 95 females and 105 male cases. They were classified into two groups. Group A (98 cases. 49%); representing cases not complaining of low back pain (no LBP) and group B (112 cases, 51%); cases presenting with low back pain (LBP). Their ages ranging from 21 to 80 years, mean age was 43.51+14.076SD. both groups were further subdivided into three categories according to their age.

All cases were examined by MRI of the lumbar region. Assessment of the degree of lumbar lordosis was done at sagittal images while the extensor muscle volume was detected at axial images. The mean angle between L4-S 1 (degree) and mean muscle volume (cm^3) for the study groups were presented in Table (1) (Figs. 1-6).

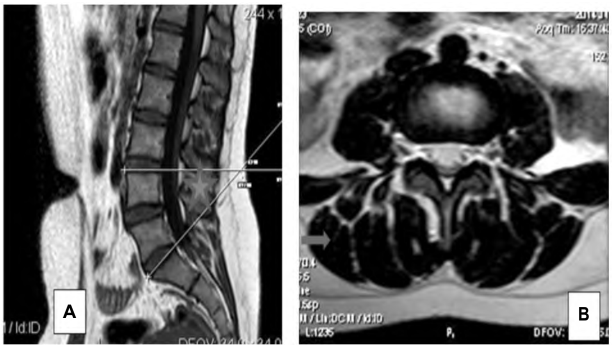

Fig. (1): Sagittal T1WI (A) and axial T2WI (B) of female subject aged 23 years from Group A (I) (no LBP) showing the curvature of the lumbar part of the vertebral column (star) angle between L4/S1=34º and cross-sectional area of the lumbar extensor muscles at the level of L3/L4 (arrow). muscle volume=276cm^3.

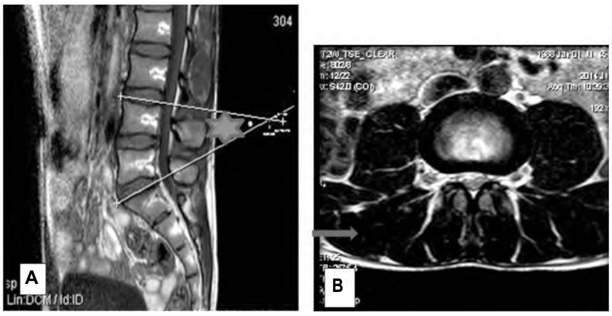

Fig. (2): Sagittal T1WI(A) and axial T2WI (B) of male subject aged 27 years from Group B (I) (LBP) showing the curvature of the lumbar part of the vertebral column (star) and cross sectional area of the lumbar extensor muscles at the level of L3/L4 (arrow). angle between L4/S 1=36º, muscle volume=245cm^3.

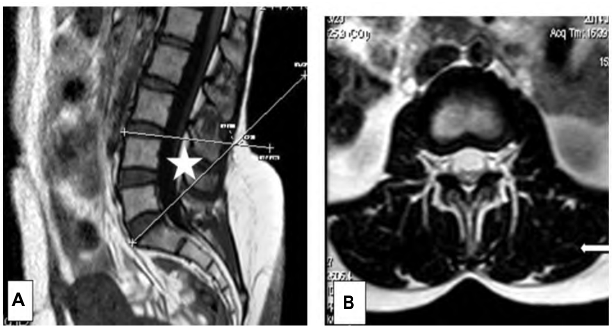

Fig. (3): Sagittal T1WI (A) and axial T2WI(B) of female subject aged 41 years from Group A (II) (no LBP) showing the curvature of the lumbar part of the vertebral column (star) and cross sectional area of the lumbar extensor muscles at the level of L3/L4 (arrow). angle between L4/S1=42º, muscle volume=280.8cm^3.

Fig. (4): Sagittal T1WI (A) and axial T2WI (B) of female case aged 45 years from Group B (II) (LBP) showing the curvature of the lumbar part of the vertebral column (star) and cross sectional area of the lumbar extensor muscles at the level of L3/L4 (arrow). angle between L4S 1=32º, muscle volume=214cm ^{3}.

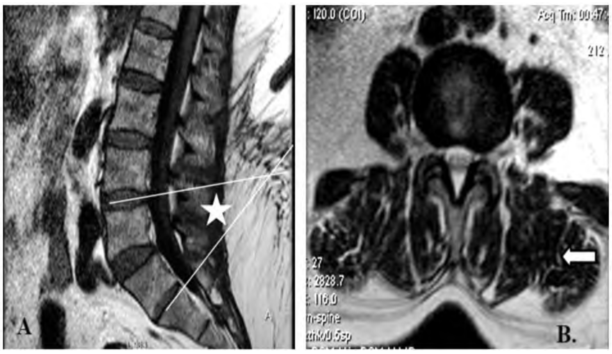

Fig. (5): Sagittal T1WI (A) and axial T2WI (B) of female case aged 57 years from Group A (III) (no LBP) showing the curvature of the lumbar part of the vertebral column (star) and cross sectional area of the lumbar extensor muscles at the level of L3/L4 (arrow). angle between L4S1=29º muscle volume=244.5cm ^{3}.

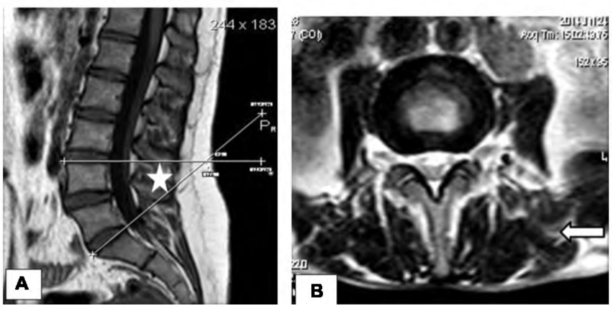

Fig. (6): Sagittal T1WI (A) and axial T2WI (B) of male subject aged 57 years from Group B (III) (LBP) showing the curvature of the lumbar part of the vertebral column (star) and cross sectional area of the lumbar extensor muscles at the level of L3/L4 (arrow). angle between L4/S1=38º muscle volume=242.2cm ^{3}.

Table (1): Number of subjects, mean angle between L4-S1 and mean muscle volume in the study groups.

Low Back Pain status	Sub-groups	No. of subjects	Mean angle between L4-S 1 (degree)	Mean muscle Volume (cm ^{3})
No low back pain (A)	A (I)	33	35.1±4.5	280.9±32.8
	A (II)	34	41.8±4.1	289.7±25.8
	A (III)	31	33.5±4.8	263.8±30.0
Low back pain (B)	B (I)	33	41.0±5.6	237.0±21.8
	B (II)	36	31.8±4.1	242.3±33.6
	B (III)	33	39.6±7.5	239.8±27.4

We found that the mean angle in age group A(I) (21-35 years) was 35.1º±4.5, in age group A (II) (36-50 years) was 41.8º±4.1 while in age group A (III) (above 51 years) was 33.5 °±4.8. The mean angle of the lumbar curvature of group A (II) was more than group A (I, III).

In group B (LBP), we found that the mean angle in age group B (I) was 41.0 ±5.6, in age group B (II) was 31.8±4.1 while in age group B (III) was 39.6±7.5. The mean angles of the lumbar curvature in LBP group were significantly different than that in group A in all age subgroups ($p<0.001$). However, this difference was significantly higher than group A in age subgroups B (I) and B (III) but was lower than group A in age group B (II). The mean angle of the lumbar curvature in group B (I) (LBP) was greater than that in group A (I) (no LBP) and this difference was highly significant ($p<0.001$) (Table 2).

Table (2): Comparison between group A (no LBP) and group B (LBP) regarding angle between L4-S 1 and muscle volume.

	Age subgroup	No LBP (A)	LBP (B)	p-value
Mean angle between L4-S 1 (degree)	I	35.1±4.5	41.0±5.6	0.001 **
	II	41.8±4.1	31.8±4.1	0.001 **
	III	33.5±4.8	39.6±7.5	0.001 **
Mean muscle Volume (cm ^{3})	I	280.9±32.8	237.0±21.8	0.001 **
	II	289.7±25.8	242.3±33.6	0.001 **
	III	263.8±30.0	239.8±27.4	0.001 **

Measurements of the mean muscle volume in the lower lumbar part of the vertebral column (caudal to L3-L4) in the three age subgroups of group A (no LBP) showed that the mean muscle volume in subjects of group A (I) was 280.9 ±32.8 cm ^{3}, in group A(II) was 289.7±25.8cm ^{3} while in group A (III) was 263.8±30.0cm ^{3}.

All measurements of the mean muscle volume in the lower lumbar part of the vertebral column in the three age subgroups with LBP were smaller than that in group A subjects (no LBP). The mean muscle volume in group B (I) was 237.0±21.8cm^3, in group B (II) was 242.3±33.6cm^3 while in group B (III) was 239.8±27.4cm^3.

The relationship between the angle of lumbar curvature and muscle volume in both groups were computed examined. Data of correlation were represented in scattered graphs with a line of bestfit. There was statistically significant positive correlation between the angle of lumbar curvature and the muscle volume (p=0.001) in all age subgroups of in group A (Table 3) (Figs. 7-9). In group B (I and II); there was no statistically significant correlation between the angle of lumbar curvature and the muscle volume (group I: p=0.089, group II: p=0.061). However, there was statistically significant positive correlation in group B (III) (p=0.008) (Table 4) (Fig. 10).

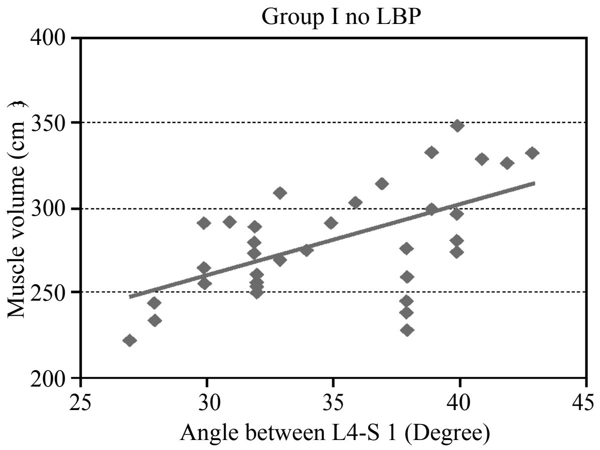

Fig. (7): A scattered graph showing the correlation between mean angle between L4-S 1 and mean muscle volume of group A (I) (no LBP).

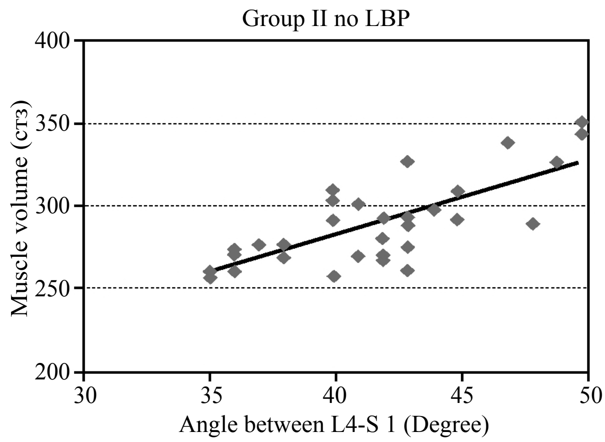

Fig. (8): A scattered graph showing the correlation between mean angle between L4-S 1 and mean muscle volume of group A (II) (no LBP).

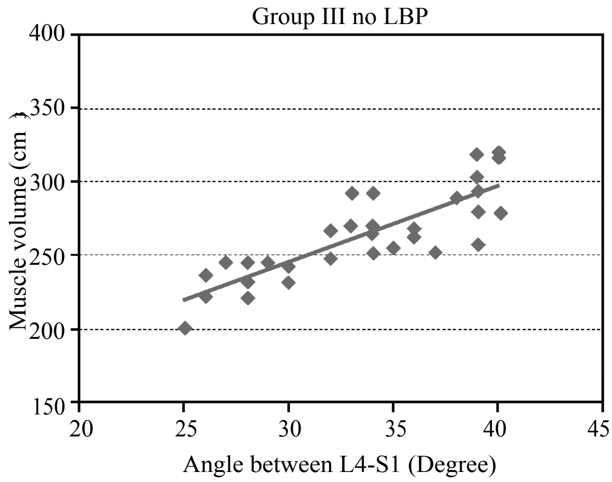

Fig. (9): A scattered graph showing the correlation between mean angle between L4-S 1 and mean muscle volume of group A(III) (no LBP).

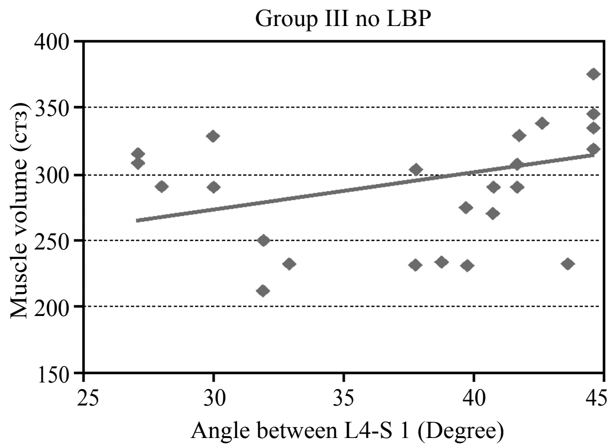

Fig. (10): A scattered graph showing the correlation between mean angle between L4-S 1 and mean muscle volume of group B (III) (with LBP).

Table (3): Correlation between angle at L4-S1 and muscle volume in groups A.

	Angle between L4-S1(degree)					
	Group A (I)		Group A (II)		Group A (III)	
	r	p-value	r	p-value	r	p-value
Muscle volume (cm^3)	0.5	0.001**	0.7	0.001**	0.8	0.001**

** HS: p-value <0.01 (highly significant).

Table (4): Correlation between angle at L4-S1 and muscle volume in groups B.

	Angle between L4-S1(degree)					
	Group B (I)		Group B (II)		Group B (III)	
	r	p-value	r	p-value	r	p-value
Muscle volume (cm^3)	0.3	0.089 (NS)	0.3	0.061 (NS)	0.4	0.008**

** HS: p-value <0.01 (highly significant). NS: Non significant .

Discussion

Back pain affects about 80% of people during their lives [22]. Back pain can be caused by postural changes and pathological affection of the lumbar spines [23,24]. Meakin & Aspden [25] proved the presence of relationship between the degree of lumbar lordosis and the extensor muscle volume.

According to the mean angle of the lumbar curvature in three age subgroups with no LBP, the mean angle of the lumbar curvature of group A (II) was more than in group A (I). This could be attributed to increased weight bearing due to increased body weight. Also, it was found that the mean angle was least in the age group A (III). This reduction in lumbar lordosis in elderly has been observed by Hammerberg & Wood [26] and Takeda et al., [27]. This can be explained by structural changes of the lumbar spines related to age; such as an increased height of the spinous process [28] or decrease in disc height and anterior wedging of the vertebral bodies [27]. However, the results of the present study disagreed with those of Tüzün et al., [29] who claimed that lumbar lordosis and thoracic kyphosis are increased with age.

In LBP groups, we found that the mean angle of the lumbar curvature was significantly different than group A (no LBP) in all age subgroups ($p<$ 0.001). However, this difference was significantly higher than group A in age subgroups B (I) and B (III) but was lower than group A in age subgroup B (II).

The increase in mean angle of the lumbar curvature in group B (I) and B(III) than no LBP group was highly significant ($p<0.001$) which could be caused by obesity. This agree with Howard [30], Bayramoglu et al., [31] and Kim et al., [32] who stated that obesity reduced the lumbar lordotic curve. They suggest that normally aligned vertebral column commonly found in individuals with strong paraspinal muscles and normal body weights.

In the present study, the measurements of the mean muscle volume in the lower lumbar part of the vertebral column (caudal to L3-L4) in the three age groups with no LBP was least at age group A (III) as ageing is known to be associated with reduced muscle size throughout the body [33,34]. The reduction of muscle volume occurs due to various cellular and molecular changes [35].

In the present study, all measurements of the mean muscle volume in the lower lumbar part of the vertebral column in the three age groups with LBP were smaller than individuals without LBP. The mean muscle volume was highly significantly lower than group A in all age subgroups. These results are consistent with Wallwork et al., [36] who reported smaller muscle volume in individuals with LBP. Several studies have shown that patients with LBP have small lumbar muscles in comparison to normal volunteers [37-38].

However, the results of the present study disagreed with Lee et al., [39] who reported no difference in muscle volume between patients with LBP and the control group. In our study, the extensor muscle volume was defined as the volume caudal to the level of L3/L4 as estimated from measurements of cross-sectional area. The cross-sectional area of extensor muscles either in the form of the anatomical cross-sectional area (perpendicular to the long axis of the muscle) or the physiological cross-sectional area (perpendicular to the muscle fibres) [20]. In the present study, the cross-sectional area was measured from images acquired in the axial plane and due to the varying orientations of the extensor muscles being considered, was not a true anatomical or true physiological cross-sectional area. One problem in defining muscle volume by the cross-sectional area, whether anatomical or physiological, is that it is influenced by a number of extrinsic factors. Jorgensen et al., [40] stated that active muscle contraction will increase the cross-sectional area compared to the relaxed state and passive elongation. The second factor is related to the spine, as it has a large degree of flexibility. It has been shown that trunk flexion leads to reduced cross-sectional area of the extensor muscles.

In our study, we found that the mean angle of the lumbar curvature of group B (I and III) was significantly higher than that of group A (I and III) while in group B (II) was significantly lower than group A (II). The mean muscle volume of group B was significantly lower than that of group A.

Also, we reported statistically significant positive correlation between the angle of lumbar curvature and the muscle volume in group A (no LBP). This was explained by Meakin & Aspden [25] who stated that larger muscle forces are required to provide stability in lumbar spines that have larger curvatures. The force-generating capacity of a muscle is related to its size. Variation in extensor muscle size might be related to variation in lumbar curvature [37,38, 41-43].

We found statistically significant positive correlation between the angle of lumbar curvature and the muscle volume in group B (III) while in group B (I and II), no statistically significant correlation was detected. The results of the correlation tests between the angle and muscle volume in subjects with LBP are disagreeing with Meakin et al., [25] as regard group I and II [41]. However, it is in accordance with them as regard group III as the authors found statistically significant difference between lumbar curvature between L4 and S 1 and extensor muscles caudal to L3/L4 in subjects with LBP in all age groups. Latimer et al., [44] reported strong relation between back stiffness and low back pain. Another study of lumbar lordosis using MRI examination in patients with and without low back pain suggested that "reduced lumbar lordosis" is considered a very weak clinical sign for low back pain [45].

Assessment of paraspinal muscles morphology and size has an important role in diagnosis of cases presenting with LBP. Imaging studies of patients complaining of LBP suggest smaller cross-sectional area of multifidus muscle compared with asymptomatic cases [37,38,41].

Conclusion and Recommendations:

The results of the present study showed that the magnitude of the lumbar lordosis present in a normal subject is related to the quantity of the extensor muscle and any deviation in the angle of the lumbar curvature or the size of the muscle by decreasing or increasing than normal could be the beginning of low back pain or a pathological condition. So, the results of this study recommends a routine magnetic resonance imaging (MRI) to be done annually to estimate any deviations from normal curvature or muscle volume for an individual.

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العلاقة بين أنحناء سهمى (قطنى) وحجم العضلات الباسطة فى منطقة أسفل الظهر: دراسة مورفولوچية وإشعاعية

الهدف من دراستنا هو الكشف عن العلاقة بين حجم العضلات الباسطة والإنحناء القطنى بإستخدام التصوير بالرنين المغناطيسى ومقارنة النتائج فى الأشخاص التى لا تشكو من آلام أسفل الظهر مع أولئك الذين يعانون من آلام أسفل الظهر. النتائج يمكن أن ترشد الأطباء خلال برامج التدريب فى مجال الرياضية وإعادة التأهيل.

المواد والطرق: تم تصنيف مائتى موضوع فى مجموعتين. (A) تمثل الأفراد الذين ليس لديهم تاريخ لآلام الظهر والمجموعة (B) مع تاريخ آلام أسفل الظهر تم إجراء فحوصات بالرنين المغناطيسى لفحص العمود الفقرى القطنى فى جميع الحالات. تم إجراء صور T1WI محورية وسهمية، T2WI وصور متدرجة. تم تحديد التقوس القطنى السفلى من الصور السهمية. وقدرت حجم العضلات الباسطة الذيلية إلى مستوى أسفل الظهر فى التصوير بالرنين المغناطيسى المحورى الذى يمتد على العمود الفقرى القطنى.

النتائج: تم العثور على علا قة إيجابية ذات دلالة إحصائية بين زاوية إنحناء أسفل الظهر وحجم العضلات فى جميع الأعمار من مجموعة A (p=0.001) ومجموعة B-III (p=0.008) فى حين لم يتم الكشف عن أى علاقة ذات دلالة إحصائية فى المجموعة B-I (p=0.098) والمجموعة B-II (p=0.016) كان متوسط حجم العضلات فى مجموعة B أصغر بكثير من المجموعة A فى جميع الأعمار.

الخلاصة: إن حجم الإنحناء القطنى مرتبط بكمية العضلة الباسطة وأى أنحراف فى زاوية الإنحناء القطنى أو حجم العضلة عن طريق التناَص أو زيادة من الطبيعى أن يكون ألم الظهر أو حالة مرضية.