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The sonoanatomy of lumbar erector spinae and its iliac attachment – the potential substrate of the iliac crest pain syndrome, an ultrasound study in healthy subjects

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Keywords
ultrasound, erector spine muscle entheses, iliac crest pain syndrome, low back pain

Abstract

Background: Iliac crest pain syndrome is a regional pain syndrome that has been identified in many patients with low back pain. Based on anatomical studies, it was suggested that the potential substrate of this syndrome might be the enthesis of the erector spinae muscle at the posterior medial iliac crest. As there have been no imaging studies of this important enthesis, our aim was to assess its characteristics by ultrasound. **Methods:** Erector spinae enthesis was first studied in a cadaver. Then its characteristics were recorded in 25 healthy volunteers (median age: 28.92, SD: 5.31, mean Body Mass Index 22.61, SD: 3.38), with Esaote My Lab 7 machine using linear transducer (4–13 MHz). **Results:** The cadaver study confirmed the attachment of a substantial part of erector spinae to a well-defined region on the medial posterior iliac crest. The US study in the volunteers consistently showed the entheses as typical hyperechoic fibrillar structures, slightly oblique to the skin in the longitudinal plane and attaching to the iliac crest. In the transverse plane, the entheses were seen as oval, densely dotted structures in contact with the superior edge of posterior superior iliac spine. Their mean thickness (4.9 ± 0.6 and 5.2 ± 0.7 mm longitudinally; 4.3 ± 0.6 and 4.4 ± 0.7 mm transversely), maximum width (16.3 ± 2.8 and 15.7 ± 2.3 mm) and depth (10.8 ± 7.3 and 10.6 ± 6.2 mm) on the left and right side, respectively, as well as their echostructure were recorded and described. **Conclusions:** The erector spinae entheses could be assessed in detail by ultrasound, thus their pathological transformation associated with iliac crest pain syndrome could be identified.

Background

Regional soft tissue rheumatic pain syndromes (RPS) are common pathologies seen in rheumatology and orthopedic practices[1]. Two of these conditions have been identified very frequently in patients with "nonspecific" low back pain (NLPB): the Great Trochanteric Pain Syndrome (GTPS) and the Iliac Crest Pain Syndrome (ICPS). The latter in particular was found in 41% of patients with NLBP in an epidemiological study[2]. While the main pathology behind the GTPS was proved to be enthesopathy or tendinopathy of the Gluteus medius and minimus muscles[3], the cause of the ICPS has remained unidentified. As the pain generating area in ICPS coincides with the attachment site of the erector spinae muscle (ES) to the posterior medial iliac crest (PMIC) and posterior superior iliac spine (PSIS), it has been suggested that the latter syndrome is caused by pathology of these tendons and entheses[4]. Though that was never supported by imaging studies, empirical data from different authors showed that corticosteroid/anesthetic injections applied locally in the region of PMIC and PSIS led to pain alleviation in many patients with ICPS[5,6]. The detailed anatomical study of lumbar ES attachments performed by Macintosh and

Bogduk[7] showed that the lateral part of ES aponeurosis (which constituted the conjoint tendon of ES superficial or thoracic part) attaches to the PMIC and PSIS. The tendons of the deep (or lumbar) part of ES also congregate and attach to a small area on the PMIC beneath the aponeurosis and just rostral to the PSIS. Other researchers found that some of the fibers of the deep part are attached to the inferior surface of the aponeurosis rather than directly to the ilium[8]. Thus, the available anatomical data confirm that the location of the ES iliac entheses coincides well with the site of pain in ICPS. Moreover, recently another RPS of the pelvic girdle, namely the proximal iliotibial band syndrome, was found to be caused by an enthesopathy at the iliac crest as well[9].

Two imaging modalities are particularly suited for assessing entheses in vivo: MRI and ultrasound[10]. US has the advantage of being more readily available, cheaper and faster, while at the same time it has excellent spatial resolution, provided there is an acoustic window to the target structure[11]. Moreover, a recent review concluded that the relevance, accuracy, and reliability of US for the diagnostic evaluation of entheses is very good [12].

Aim

To assess the characteristics of the iliac entheses of the superficial and deep lumbar ES muscles in young healthy adults using high frequency US. To collect reference data for the entheses' thickness, width, depth and echostructure that could be used in further clinical US studies of ICPS.

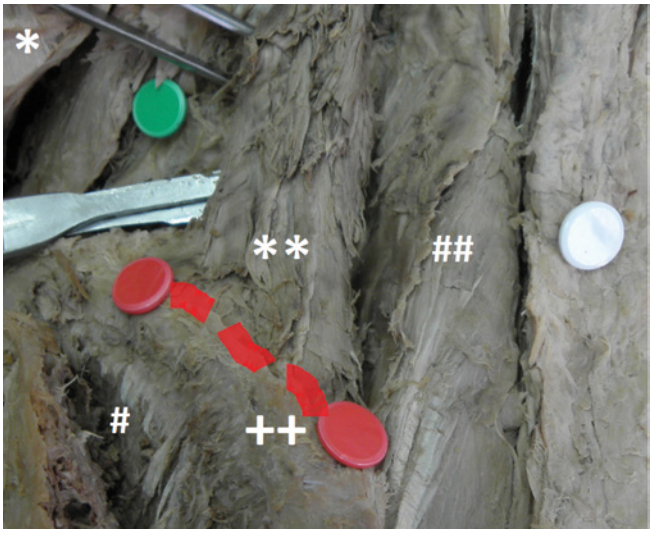

Fig. 1. *Caudal part of the left ES muscle (deep part) with its attachment to the PMIC in a cadaver (left side of the image is lateral). Erector spine enthesis spans between the red marks, depicted by the red dashed line. (**: the caudal part of the deep ES muscle; ++: posterior medial iliac crest; #: gluteus maximus muscle origin; ##: multifidus muscles, *: erector spinae aponeurosis (reflected); quadratus lumborum muscle is marked in green, the spinous process of the forth lumbar vertebra is marked in white)*

Material and methods

The study was approved by the ethical committee of the Medical University of Plovdiv and all enrolled subjects signed an informed consent form. We first performed an anatomical study of the most caudal part of the ES muscle, its tendons and their attachments to the PMIC in a formalin-preserved cadaver provided by the Department of Anatomy of the university (Fig. 1).

Next US was performed on 25 young healthy subjects, 13 men and 12 women, mean age 28.92 (± 5.31), mean BMI 22.61 (± 3.38), with no history of any LBP episode during the past year and no pathological signs on standard physical examination of the spine, pelvis and hips. Ultrasonography was performed with an Esaote My Lab 7 machine using a 4–13 MHz linear transducer by the same experienced sonographer (PT) who also conducted the preceding anatomic study.

All subjects were examined sonographically in a prone position, following a strict scanning protocol. First, the probe was placed in the transverse plane in the midline over the sacrum. After the characteristic contour of the sacral spinous processes was identified, the probe was moved laterally, first to the right, over the sacral wing. When the sacroiliac joint was reached, the probe, still kept in the transverse plane, was moved upwards following the contour of the iliac bone until the PSIS was identified. There, in contact with its superior surface, the tendon and aponeurosis of ES appeared as a well-defined oval or triangular, hyperechoic structure, showing a typical densely punctuated pattern in this transverse section. The probe was then adjusted slightly obliquely, with its medial end situated a few millimeters lower than the lateral one to be perpendicular to the tendon's fibers which run slightly obliquely in the frontal plane (Fig. 2). In this position, the probe was moved up and down to evaluate in full the terminal part of the tendon and its enthesis. Then the probe was rotated at 90 degrees to be parallel to the enthesis, and light pressure was exerted with its proximal part as the tendon fibers run slightly obliquely in the sagittal plane as well (Fig. 3)[7]. In this longitudinal scan, the ES terminal part and enthesis were seen as hyperechoic fibrillar structures attaching to the PMIC, and the probe was moved to the right and left to evaluate them in full. Then, the thickness of the ES entheses at the point where the deep margin of the tendon met the iliac bone was measured in both the longitudinal and transverse plane. In addition, in the longitudinal plane, the thickness of the aponeurosis attachment was measured separately, while in the transverse plane the maximum width of the enthesis and the depth of its superior margin were recorded. After that, the sonographic structure of the entheses was assessed in both US planes. The examination was performed on the right and left side separately, and the images were saved for documentation and further analysis.

Statistics: Descriptive statistics were used to report data. Kolmogorov-Smirnov and Shapiro-Wilk tests were done to check the pattern of numerical variables distribution. Fre-

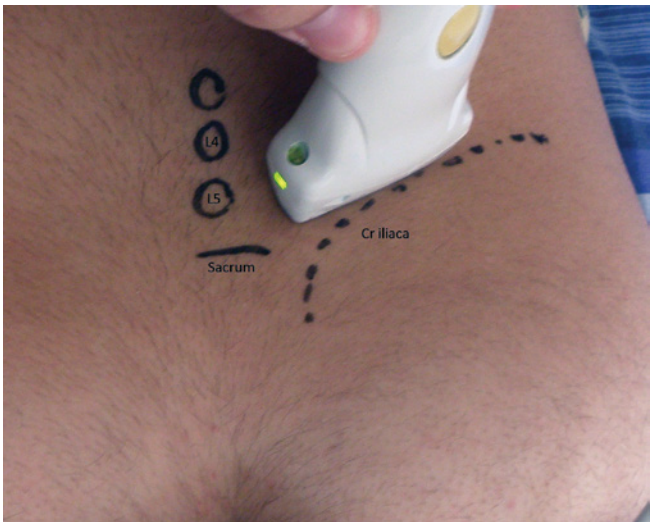

Fig. 2. *Position of the ultrasound probe for scanning of the right ES enthesis in the transverse plane (left side of the image is medial)*

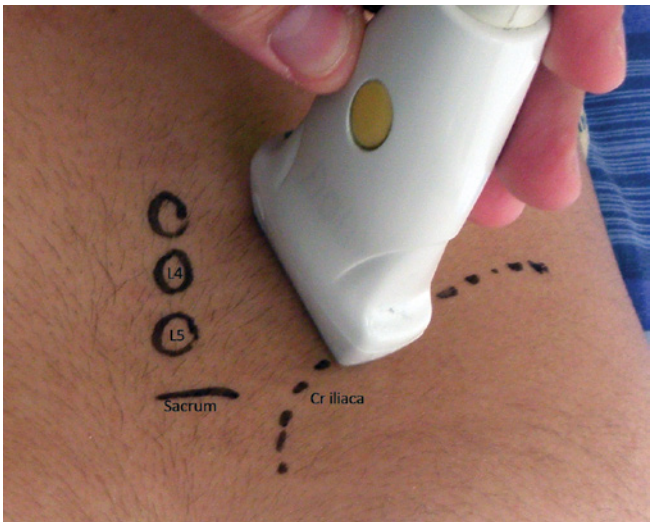

Fig. 3. *Position of the ultrasound probe for scanning of the right ES enthesis in the longitudinal plane (left side of the image is medial)*

quencies and percentages were calculated for the categorical variables. In addition, paired samples statistics were employed where appropriate (p <0.05 indicates a significant difference).

Results

The preceding cadaver study confirmed that the ES muscle has enthesis on a well-defined area at the PMIC, just above the PSIS (Fig. 1).

These ES entheses could be identified in detail by US in all enrolled healthy subjects via the posterior paravertebral acoustic window described above. In the longitudinal plane, the ES aponeurosis was seen as a well-defined, linear and hyperechoic fibrillar stricture, running slightly obliquely to the skin and situated below the subcutaneous fat tissue and superficial fascia (Fig. 4). The ES aponeurosis (lateral part) grew in thickness just before it attached to the PMIC, while its medial part went on caudally over the multifidus muscle. Due to this thickening, the most terminal part of the lateral aponeurosis was about two times thicker than its more proximal part. The tendons of the deep (lumbar) part of the ES muscle were observed in the longitudinal plane as typical hyperechoic fibrillar structures originating from the respective muscle bodies and orientated at a slight angle to the aponeurosis. They attached without terminal enlargement to the PMIC with and just below the ES aponeurosis. Some of the more proximal musculotendinous fibers inserted to the deep surface of the aponeurosis instead of to the ilium. The muscle bellies of the deep ES could be followed cranially to their origin from the transverse processes of the lumbar vertebrae.

In the transverse plane, the ES aponeurosis was seen as a flattened hyperechoic, densely punctuated structure just above and medially to the PSIS. The tendon of the deep (lumbar) part of ES could be identified beneath the aponeurosis and in contact with it and with the superior surface of PSIS. It was more oval in shape, had a dotlike pattern as well, but was more hypoechoic as compared to the aponeurosis (Fig. 5). The ES entheses gradually thinned caudally along the PSIS, becoming more triangular in shape, and finally merged with the origin of the posterior sacroiliac ligament.

Parameter	**Thickness**						**Width**		**Width**	
US plane	**Longitudinal**		**Transverse**		**Longitudinal**		**Transverse**		**Transverse**	
Structure	**ESE-L**	**ESE-R**	**ESE-L**	**ESE-R**	**ESAE-L**	**ESAE-R**	**ESE-L**	**ESE-R**	**ESAE-L**	**ESAE-R**
Men (*N*13)	5,1 ± 0,6	5,5 ± 0,6	4,4 ± 0,6	4,4 ± 0,8	2,2 ± 0,4	2,3 ± 0,5	15,4 ± 2,7	15,5 ± 2,5	7,9 ± 3,1	8,2 ± 2,7
Women (*N*12)	4,5 ± 0,5	4,8 ± 0,7	4,3 ± 0,6	4,4 ± 0,7	1,9 ± 0,3	2,1 ± 0,5	17,0 ± 2,7	15,8 ± 2,7	13,0 ± 10,2	11,9 ± 9,7
All subjects (*N*25)	4,9 ± 0,6	5,2 ± 0,7	4,3 ± 0,6	4,4 ± 0,7	2,1 ± 0,4	2,2 ± 0,5	16,3 ± 2,8	15,7 ± 2,3	10,8 ± 7,3	10,6 ± 6,2

ESE – erector spinae enthesis (of both the superficial and deep part of the muscle together)
ESAE – erector spinae aponeurosis enthesis (only the enthesis of the superficial part – the ES aponeurosis)
L – left; R – right; SD – standard deviation

Tab. 1. *Thickness, width and depth of ES entheses in the study population (all values are in millimeters ± SD)*

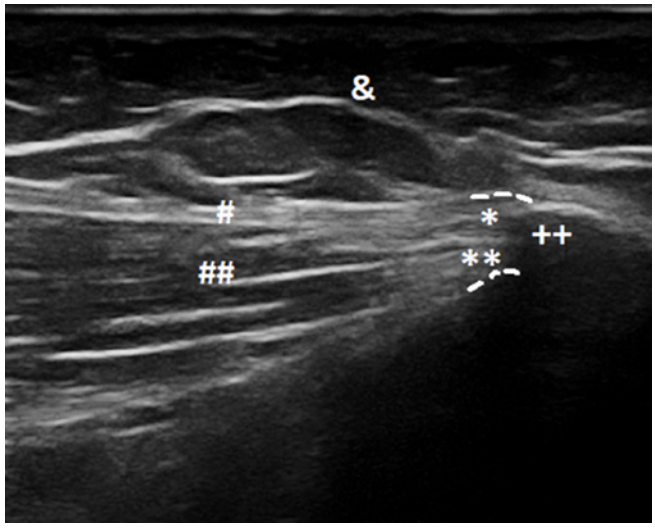

Fig. 4. *US image of the normal distal part of the right ES muscle with its enthesis on the iliac crest in the longitudinal plane (left side of the image is cranial). The superior and inferior margins of the enthesis are outlined with the dashed white line. (#: erector spinae aponeurosis; *: the enthesis of erector spinae aponeurosis; ##: the deep part of erector spinae muscle; **: the enthesis of the deep part of erector spinae muscle; ++: posterior medial iliac crest; &: superficial fat pad)*

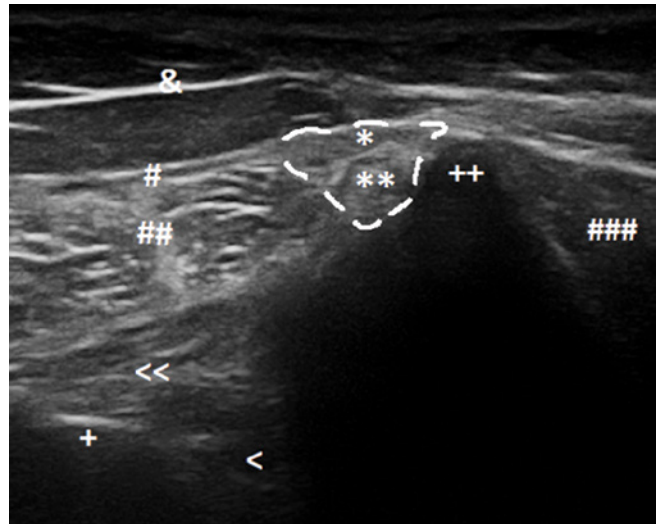

Fig. 5. *US image of the normal enthesis of the right ES muscle (superficial and deep parts) in the transverse plane (left side of the image is medial). The enthesis is outlined by the dashed white line. (*: the enthesis of the lateral part of the erector spinae aponeurosis; **: the enthesis of the deep part of erector spinae muscle; #: the medial part of the erector spinae aponeurosis; ##: multifidus muscles; ###: gluteus maximus muscle; ++: posterior superior iliac spine; +: dorsal surface of sacrum; &: superficial fat pad; <: sacroiliac joint; <<: long posterior sacroiliac ligament)*

ES entheses' thickness, width and depth, measured in millimeters and recorded in both longitudinal and transverse planes, are summarized in Table 1. All these numerical values had a normal pattern of distribution.

When these parameters were compared for the left and the right side of the body by the T-test, only the enthesial thickness measured in the longitudinal plane showed a significant ($p = 0.02$) between-side difference. For all the other measurements, the left-right differences were non-significant ($p > 0.05$).

The assessment of the echostructure of the entheses revealed sonographic lesions in 13 of the 50 entheses studied (26%) in 10 of the 25 subjects (40%). However, in only two of the entheses (4%), both in the same individual, there were two lesions simultaneously, while all the others had only a single abnormal US feature (Tab. 2).

Discussion

Entheses have attracted considerable clinical and research interest over the past years, as their inflammation (enthesitis) constitutes one of the hallmark features of spondyloarthritis, while their damage due to overload or mechanical traumas (enthesopathies) is the cause for some of the most frequent and debilitating RPSs[14]. Data show that paraspinal muscle tendinosis and enthesopathy could be a common source for NLBP[15]. The sequence of pathological transformation is proposed to start with an abnormal electrophysiological activity of the muscles as a response to an increased mechanical demand. Initially, the muscles become bigger and stronger, but as the stress continues, their tendons could develop enthesopathy[15]. Concerning US assessment of these structures, numerous publications indicate that pathologically transformed entheses display a variety of

Sonopathological features with descriptions:	Left ESE (*N* = 25)	Right ESE (*N* = 25)	Total (*N* = 50)
Presence of calcification foci in the enthesis	0	0	0
Major irregularities of the bony contour at the tendon insertion	3	4	7
Hypoechoic appearance of the enthesis	2	3	5
Altered normal fibrillar structure of the terminal tendon/enthesis	1	0	1
Presence of well-defined anechoic zones in the terminal tendon substance within 10 mm from the insertion	0	2	2
ESE – erector spinae enthesis			

Tab. 2. *Sonopathological features (based on Terslev L. et al.[13] and Long S. et al.[3]) identified in the studied ES entheses*

sonographic markers that allow the differentiation of a normal from abnormal tissue[16].

In the present study, we describe the ultrasonographical characteristics of the iliac enthesis of the ES muscle in healthy subjects. The clinical importance of this structure is twofold: on the one hand, it constitutes the attachment site of the biggest and biomechanically very important muscle in the lumbar region[17], and on the other – its anatomical location coincides precisely with the site of pain in ICPS[4] that is a RPS particularly common in NLBP[2]. It has been suggested that pathology of ES tendons and entheses could be an unrecognized cause of pain in ICPS[4]. We have shown that US could be used to identify and assess in detail this complex enthesis. Data on the average enthesial thickness, width, depth and echostructure have been collected. This is to our knowledge the first detailed ultrasound study of a clinically and biomechanically important spinal enthesis.

As an interface between tissues with different mechanical proprieties, entheses are particularly prone to injury, and there are observations that this damage accumulates with age[18,19]. This was one of the reasons why we chose specifically young adults (18–38 years of age) for our US study of the normal ES entheses. Nevertheless, even in this asymptomatic young population, we found US lesions in 26% of the entheses, in 40% of the subjects. However, in only 4% of the entheses there were simultaneously two pathological features, while all other exhibited a single lesion only. Consequently, care should be taken, in future clinical US studies in patients with ICPS and LBP, not to diagnose enthesopathy on the basis of only a single (especially structural) sonopathological feature.

We have also described the normally present considerable thickening of the lateral part of the ES aponeurosis as it attached to the ilium that should not be confused with pathological thickening as a feature of enthesopathy.

Finally, US is also increasingly used in rheumatology and orthopedics to guide articular and periarticular interventions. Studies have shown that steroid injections in the region of PSIS lead to significant pain improvement in many patients with ICPS[7,8]. This could be related to the infiltration of the ES entheses. US could provide efficient guidance for safe and more precise injections.

A limitation of the current study could be the fact that it was carried out in young people with relatively low BMI. The assessment of ES entheses could be more challenging in the clinical settings when more obese patients are examined. However, our study aimed to give a precise US description of a normal structure, and this could be accomplished in sufficient details only in such a population.

Conclusions

In conclusion, our study shows that there is a good acoustic window to the ES entheses that allows their detailed assessment by US. The study also provides descriptive and nominative data about these structures. As they are the potential source of pain, or the anatomical substrate, in the ICPS, an RPS frequently seen in NLBP, this information could be used in future clinical US studies of patients. Such further studies could determine pathological transformations of the ES entheses and their relevance to the clinical picture of ICPS and NLBP.

Conflict of interest

Authors do not report any financial or personal connections with other persons or organizations that might negatively affect the contents of this publication and/or claim authorship rights thereto.

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