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A Cadaver Study of the Quadratus Lumborum Muscle and its Application to the Relaxation Effect for Fencers

Estudio Cadavérico del Músculo Cuadrado Lumbar y su Aplicación al Efecto de Relajación en Esgrimistas

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SUMMARY: The aim of this study is to conduct an anatomical investigation of the morphology and innervation of the quadratus lumborum muscle in order to provide clinically relevant insights. This study was conducted on twenty-three QL muscles obtained from embalmed Korean cadavers. Regarding the superior attachment, 9.0 % of cases showed insertions extending from the 12th rib to the L3 vertebra, 48.0 % from the 12th rib to L4, and 43.0 % from the 12th rib to L5. In the investigation of the innervation of the QL muscle, 81.0 % of specimens demonstrated neural supply from the T12 to L3 spinal nerves, while 19.0 % exhibited innervation extending from T12 to L4. It is hoped that the results of this study will enhance the clinical understanding of the relationship between the quadratus lumborum muscle and its neural connections depending on muscle condition, thereby contributing to more effective analysis of pain.

KEY WORDS: Anatomy; Quadratus lumborum muscle; Entrapment; Pain.

INTRODUCTION

The quadratus lumborum (QL) muscle is a paired structure located within the posterior abdominal wall and is considered the deepest of the abdominal musculature, though it is often functionally categorized as the back muscle. Each muscle presents an irregular quadrilateral shape, from which its anatomical nomenclature is derived. Anatomically, the QL originates from the iliac crest and iliolumbar ligament, inserting onto the transverse processes of the upper four lumbar vertebrae and the inferior margin of the 12th rib. Unilateral contraction facilitates ipsilateral lateral flexion of the lumbar spine and elevation of the corresponding hemipelvis, whereas bilateral contraction contributes to lumbar extension and stabilization.

Although the functions of QL are not yet fully understood, it is generally recognized to contribute to lumbar extension, lateral flexion, and respiration. Despite the limited understanding of its precise functions, QL is commonly selected as a target for nerve block interventions in the treatment of lumbar pain in clinical settings (Uppal *et al*., 2020; Long *et al*., 2023). In addition, the quadratus lumborum block is increasingly utilized as an effective method for postoperative pain control in patients undergoing total hip arthroplasty (Huda & Minhas, 2022).

As the QL muscle has been reported as a site of injury in athletes, investigating its anatomical characteristics and exploring recovery strategies aimed at preventing sports-related injuries may provide valuable insights for pain management and nerve block interventions in medical practice. Furthermore, such research could contribute to reducing the incidence of injuries that most commonly affect athletes, thereby supporting performance enhancement and athletic longevity. Moreover, several studies have reported that many fencing athletes suffer from low back pain, which negatively affects their athletic performance. Based on the assumption that dysfunction or abnormal condition of the QL muscle may be a contributing factor to such pain, it is considered essential to explore strategies for restoring QL function. This anatomical investigation underscores the necessity of establishing foundational knowledge to guide effective recovery strategies and address the prevention and management of low back pain in fencing athletes.

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In recent years, in line with its growing clinical relevance, several studies have investigated the fiber orientation of the QL muscle and employed Sihler's staining technique to examine motor points and intramuscular nerve branches from a morphological perspective (Yi *et al*., 2024). However, detailed gross anatomical studies focusing on the precise origin and insertion of the muscle, the morphological patterns by which spinal nerves enter the muscle, and the distribution of nerves within the muscle tissue remain limited.

As previously noted, the QL muscle plays a critical role in both clinical and athletic contexts, particularly with regard to its involvement in lower back pain, therapeutic interventions such as nerve blocks, and its susceptibility to injury in athletes. Despite its recognized clinical relevance and frequent implication in musculoskeletal dysfunction, the precise anatomical structure and functional biomechanics of the QL muscle remain insufficiently characterized in the current literature. This gap in understanding underscores the need for further anatomical and functional investigations to support both medical and sports science applications.

This study aims to elucidate the morphological features of the QL muscle, with particular emphasis on the patterns of neural distribution both on its surface and within its internal structure. Furthermore, it seeks to assess the subjective effects of QL muscle recovery as experienced by fencing athletes.

MATERIAL AND METHOD

Cadaveric Dissection. This study was conducted on twenty-three QL muscles obtained from embalmed Korean cadavers (8 males, 5 females; mean age 71.1 years; age range 49–93 years). All specimens were free of any evidence of trauma or prior surgical intervention in the lumbar region. Following the removal of the anterolateral abdominal wall and intra-abdominal organs, the parietal peritoneum and retroperitoneal structures were removed. The psoas major muscle was carefully dissected and removed to expose the QL muscle, with specific attention paid to identifying its anatomical attachments and neural innervation. The morphological parameters of the QL muscle were measured relative to bony landmarks, including the iliac crest, the twelfth rib, and the spinous processes of the lumbar vertebrae. The most lateral point of the QL muscle was measured along the iliac crest from the midline in a posterior view (Figs. 1-3).

Participants. As part of the study, fifteen elite fencers from professional teams participated in an intervention targeting the QL muscle. A manual physical stimulation technique was employed, involving repeated pressure and release applied directly to the QL muscle until the participant reported the alleviation of local discomfort. Following the intervention, assessments were conducted to evaluate changes in trunk and lumbar mobility, as well as subjective feedback from each athlete regarding perceived improvements in physical condition and performance.

Sihler's Staining Protocol. To analyze the intramuscular nerve distribution, a modified Sihler's staining technique was applied. Originally developed by Charles Sihler in 1985, this method renders soft tissue translucent while selectively staining nerve fibers, thereby allowing for detailed visualization of neural arborization without compromising the structural integrity of the muscle. Using Sihler's staining method; this study investigated the presence of communicating branches within the muscle and examined the patterns of neural distribution **(Fig. 4).** All linear measurements were performed in millimeters using a precision digital caliper (CD-20PSX, Mitutoyo, Japan; resolution 0.01 mm). Data were tabulated and processed using Microsoft Excel 2016 (Microsoft Corp., Redmond, WA, USA).

Ethical Considerations. All cadaveric specimens were legally donated to the University College of Medicine, with informed consent provided by donors or their families. The study protocol was reviewed and approved by the Institutional Review Board and was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki.

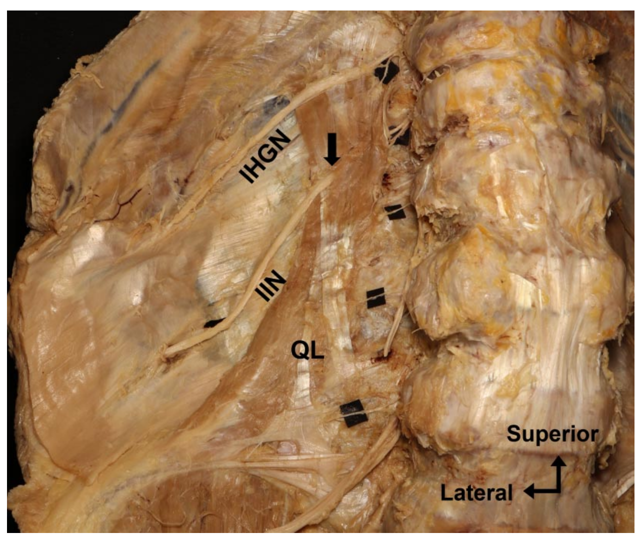

Fig. 1. Anatomical dissection image of the quadratus lumborum (QL) muscle illustrating the course of the ilioinguinal nerve (IIN). The nerve is shown traversing superficially across the QL muscle, with the arrow indicating a rare variation where the IIN penetrates the muscle belly. IHGN: iliohypogastric nerve, Nerve branches over the black background area: spinal nerve branches entering the QL muscle.

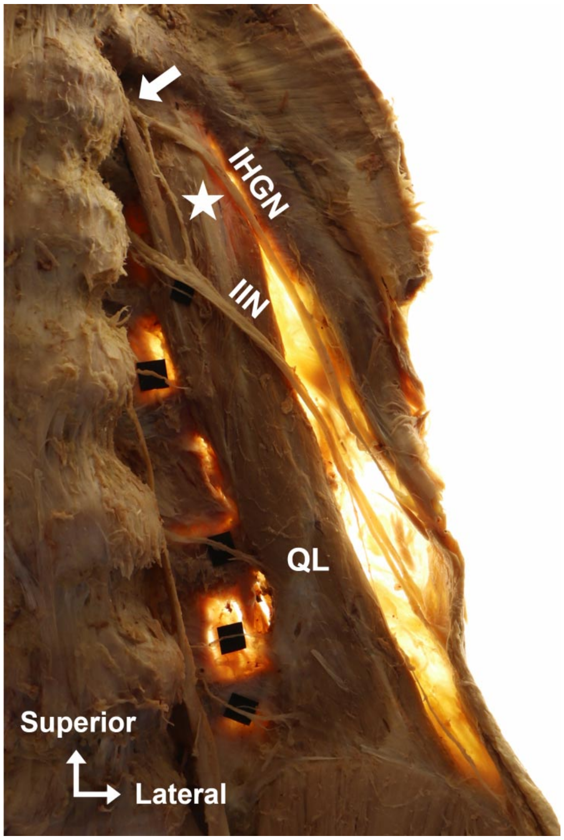

Fig. 2. Anatomical image of quadratus lumborum (QL). IHGN: iliohypogastric nerve, IIN: ilioinguinal nerve. Arrow: Point at which the IHGN pierces the QL muscle. Asterisk: Communicating branch between the IHGN and the IIN, Nerve branches over the black background area: spinal nerve branches entering the QL muscle.

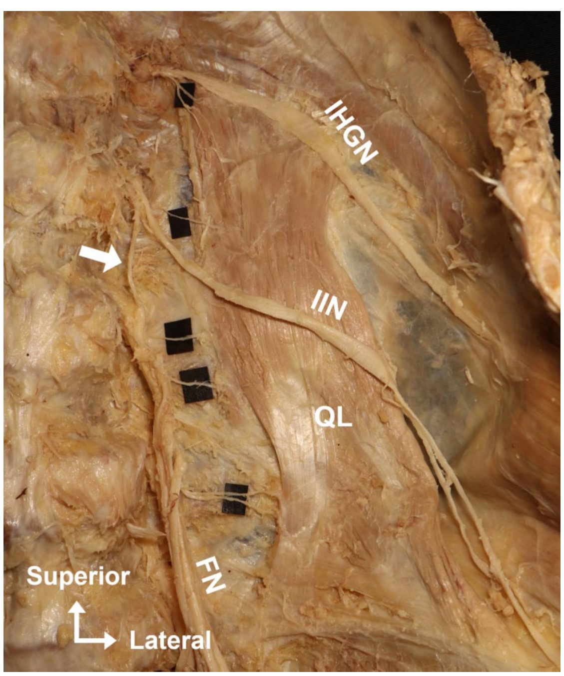

Fig. 4. A Shiler's staining photograph demonstrated the formation of a communicating branch between the L3 and L4 spinal nerves within the quadratus lumborum muscle. Arrow: communicating branch.

RESULTS

Based on the findings of this study, the QL muscle was consistently found to attach to both the iliac crest and the iliolumbar ligament in all specimens. Based on the iliac crest, the most lateral attachment point of the quadratus lumborum muscle was located at 9.3 ± 0.6 cm in males and 9.1 ± 1.5 cm in females. Regarding the superior attachment, 9.0 % of cases showed insertions extending from the 12th rib to the L3 vertebra, 48.0 % from the 12th rib to L4, and 43.0 % from the 12th rib to L5. Notably, attachment from the 12th rib to at least the L3 vertebra was consistently observed across all specimens (Table I).

Fig. 3. An image demonstrated a communicating branch between the ilioinguinal nerve (IIN) and the femoral nerve (FN). IHGN: iliohypogastric nerve. Arrow: communicating branch, Nerve branches over the black background area: Spinal nerve branches entering the QL muscle.

In the investigation of the innervation of the QL muscle, 81.0 % of specimens demonstrated neural supply from the T12 to L3 spinal nerves, while 19.0 % exhibited innervation extending from T12 to L4. Notably, in all cases, the QL muscle consistently received innervation from the T12 to L3 spinal nerves (Table II).

In one case, the iliohypogastric nerve was observed to traverse through the tendon of the QL muscle. In all specimens, the ilioinguinal nerve consistently coursed superficially over the surface of the QL muscle; however, in one case, it was found to penetrate through the muscle belly of the QL.

Following a recovery exercise in which fencers repeatedly pressed and released the posterior portion of the iliac crest for 5 seconds, 30 times, the athletes reported a subjective sense of relief and improvement in their lower back, suggesting a positive effect.

Table I. Anatomical analysis of the superior attachments of the quadratus lumborum muscle.

Superior attachment						Frequency of appearance % (*n*)
12^{th} rib	LI	LII	LIII	LIV	LV	
o	o	o	o			9 % (2)
o	o	o	o	o		48 % (11)
o	o	o	o	o	o	43 % (10)

LI: transverse process of 1st lumbar vertebra, LII: transverse process of 2nd lumbar vertebra, LIII: transverse process of 3rd lumbar vertebra, LIV: transverse process of 4th lumbar vertebra, LV: transverse process of 5th lumbar vertebra, n: number.

Table II. Results of the anatomical distribution of spinal nerve branches supplying the quadratus lumborum muscle.

Innervation					Frequency of appearance % n
T12	L1	L2	L3	L4	
o	o	o	o		74 % (17)
o	o	o	o	o	26 % (6)

T12: 12th thoracic nerve, L1: 1st lumbar nerve, L2: 2nd lumbar nerve, L3: 3rd lumbar nerve, L4: 4th lumbar nerve, n: number.

DISCUSSION

The QL functions as an extensor and stabilizer of the lumbar spine and contributes to lateral flexion (Grzonkowska *et al*., 2018). And in a textbook has been described as also playing a role in respiration (Bordoni *et al*., 2024). According to Standring (2015) the QL muscle is innervated by the twelfth thoracic nerve and the ventral rami of the L1 to L3 or L4 spinal nerves. Functionally, unilateral contraction of the QL contributes to lateral flexion of the lumbar spine when the pelvis is fixed, whereas bilateral contraction results in extension of the lumbar spine. Furthermore, it has been reported that hypertrophy of the QL muscle may occur in athletes due to repetitive loading and mechanical demands. In contrast, other anatomical textbooks do not provide detailed descriptions regarding the specific spinal nerve levels involved in the innervation of the quadratus lumborum. Furthermore, their accounts of the muscle's function are generally limited, with only brief references to its involvement in respiration and lumbar extension, lacking the specificity found in Standring (2015). In the present study, the QL muscle was found to attach to the L4 vertebra in 9.0 % of the specimens, whereas in the remaining cases, the attachments were limited to the region spanning from T12 to L3. Notably, no attachments were observed at the L5 vertebra. These findings suggest that the QL muscle does not directly contribute to movements involving the L4 vertebra in the majority of cases (81.0 %) and is unlikely to play a direct role in L5 vertebral motion in any case (Table I). Instead, it may be inferred that the QL primarily influences movements of the upper lumbar spine, with any effects on the lower lumbar levels being more indirect or secondary in nature. The results of the present anatomical investigation revealed that spinal nerve branches originating from T12 to L3 consistently contributed to the innervation of the QL muscle across all examined specimens. Additionally, in 19.0 % of cases, a supplementary innervation from the L4 spinal nerve was also observed (Table II). Although comprehensive and detailed studies focusing specifically on the neural distribution to the QL muscle remains scarce in the current body of literature, certain classical anatomical textbooks do acknowledge these segmental contributions. These findings underscore the importance of revisiting and refining our understanding of the neuromuscular architecture of the QL, particularly in the context of its clinical and rehabilitative relevance.

In all specimens examined in the present study, the ilioinguinal nerve was observed to course superficially to the muscle belly of the QL. In one case, however, the nerve was found to traverse through the QL muscle belly before emerging (Fig. 1). Ilioinguinal nerve entrapment syndrome is clinically characterized by localized pain in the iliac fossa with myofascial features, often radiating toward the groin, the proximal scrotum, labia majora, upper medial thigh, and occasionally the lower back. A hallmark of the condition includes altered sensation such as hyperesthesia, hypoesthesia, or dysesthesia within the cutaneous distribution of the affected nerve. Additionally, a consistent clinical finding is the presence of a trigger point situated medial and inferior to the anterior superior iliac spine (Knockaert *et al*., 1989; Melville *et al*., 1990). Although such symptoms are commonly considered to arise following abdominal surgery, the findings of this study suggest that a tight or dysfunctional condition of the quadratus lumborum muscle may also contribute to the development of these clinical manifestations.

Additionally, the iliohypogastric nerve was observed to penetrate the tendinous region in the superior part of the QL muscle in three specimens. Furthermore, a communicating branch between the ilioinguinal nerve and the femoral nerve was identified in a single case (Fig. 2). Iliohypogastric nerve entrapment may occur as a complication following abdominoplasty involving plication of the anterior rectus sheath. In such cases, when patients report persistent lower abdominal pain in the absence of gastrointestinal or gynecological pathology, clinicians should maintain a high index of suspicion for nerve entrapment as a potential underlying etiology (Liszka *et al*., 1994; El-Minawi & Howard, 1998). Based on the findings of this study, although rare, a tight QL muscle may be considered a potential contributing factor to iliohypogastric nerve entrapment. Furthermore, the presence of a communicating branch between the iliohypogastric and ilioinguinal nerves raises the possibility that, in cases where both nerves are reported to be entrapped, the communication itself may play a role in the shared symptomatology (Fig. 2). In addition, intramuscular formation of communicating branches was observed. Specifically, communicating branches between the L3 and L4 spinal nerves were identified in three cases, while one case demonstrated a branch between the L2 and L4 spinal nerves. These findings may contribute to a better understanding of pain mechanisms in clinical settings (Fig. 3).

Although previous studies investigating the relationship between QL muscle symmetry and injury in certain athletes have concluded that no significant correlation exists, the present findings suggest a different perspective (Hides *et al*., 2010; Kountouris *et al*., 2012). In this study, all fencers subjectively reported enhanced lumbar flexibility and comfort following the application of manual pressure to the QL muscle at the level of the iliac crest, intended to induce relaxation. These responses support the notion that maintaining a relaxed state of the QL muscle may be a beneficial strategy in both athletic and general populations. Moreover, it is widely recognized that small periarticular muscles contribute significantly to joint stabilization. Therefore, applying controlled pressure to these muscles to promote relaxation could serve as an effective approach for improving musculoskeletal balance and reducing discomfort.

Through the results of this study, it is hoped that it will contribute to the analysis and treatment of pain originating from QL.

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RESUMEN: El objetivo de este estudio fue realizar una investigación anatómica de la morfología e inervación del músculo cuadrado lumbar (MCL) para obtener información clínicamente relevante. Este estudio se realizó en 23 músculos MCL obtenidos de cadáveres coreanos embalsamados. En cuanto a la inserción superior, el 9,0 % de los casos presentó inserciones que se extendían desde la duodécima costilla hasta la vértebra L3, el 48,0 % desde la duodécima costilla hasta L4 y el 43,0 % desde la duodécima costilla hasta L5. En la investigación de la inervación del MCL, el 81,0 % de los especímenes presentó inervación neural proveniente de los nervios espinales T12 a L3, mientras que el 19,0 % presentó inervación que se extendía de T12 a L4. Se espera que los resultados de este estudio mejoren la comprensión clínica de la relación entre el MCL y sus conexiones neurales según la condición muscular, contribuyendo así a un análisis más eficaz del dolor.

PALABRAS CLAVE: Anatomía; Músculo cuadrado lumbar; Atrapamiento; Dolor.

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