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The pelvic diaphragm represents a group of muscles located at the pelvic outlet and is involved in pelvic floor dysfunctions. Alternative therapies targeting obturator internus have been suggested in strengthening pelvic diaphragm (floor). The gross anatomical relationship between obturator internus and levator ani muscle is poorly understood and thus the goal of this study is to examine the attachment between pubic portion of the levator ani muscle and the fascia covering obturator internus, specifically the tendinous arch of levator ani in formalin embalmed cadavers. During dissection, the lateral margin of the pubic portion of levator ani muscle was noted to have origin along the tendinous arch. This attachment may serve as the reason why therapies involving obturator internus also positively impact pelvic floor strength.

AN ANATOMICAL STUDY OF THE

PELVIC DIAPHRAGM

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AN ANATOMICAL STUDY OF THE PELVIC DIAPHRAGM

INTERNSHIP PRACTICUM REPORT

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MASTER OF SCIENCE

By

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION TO STUDY

The following practicum report was performed as a requirement for the Master of Science-Anatomy Track program, from May 2018-June 2019, at the University of North Texas Health Science Center (UNTHSC). The study was conducted under the direct supervision of Rehana Lovely, PhD, in the Center for Anatomical Sciences and Department of Physiology and Anatomy at UNTHSC.

The human pelvis represents a distinct area located in the lower part of the trunk between the abdomen and the thighs (Chaudhry, 2018). The pelvis is composed of four parts: the bony pelvis, the pelvic cavity, the pelvic diaphragm, and the perineum (Chaudhry, 2018). The bony pelvis is a cylindrical canal that is inferiorly enclosed by a group of muscles that are collectively known as the pelvic diaphragm. Currently, the pelvic diaphragm is defined as two muscles: the coccygeus muscle and the levator ani muscle. The main function of these two pelvic diaphragm muscles is to support all the structures that reside in the human pelvis (Netter, 2019; Chaudhry, 2018).

Stress induced injuries that occur in the pelvic diaphragm are common. Pelvic floor dysfunction, which includes stress urinary incontinence, fecal incontinence, and pelvic organ prolapse occurs in 11% of American women (Olsen, 1997). Past studies have also established that loss of the pubic portion of the levator ani muscle occurs in 10% to 20% of women after their first vaginal childbirth (Miller, 2010). Supporting the pelvic organs within the human body requires a functional interaction between the levator ani muscles and the pelvic connective tissue (DeLancey, 2016). The levator ani muscles keep the pelvic floor closed and provide lifting forces to prevent organs of the pelvis from descending (DeLancey, 2016). When the muscles are damaged, a hiatus can open up in the pelvic floor, allowing the pelvic organs to descend. This is known as pelvic prolapse, which has a relatively high morbidity rate of 11.1% (Wu, 2014).

Pelvic organ prolapses and stress induced incontinence are often managed surgically (Wu, 2014). However, the risk of urinary incontinence caused by these surgical procedures are significant (Ismail, 2014; Wu, 2014). The less invasive method of pelvic floor strengthening is the more commonly recommended physical therapy for pelvic floor injuries such as stress urinary incontinence (Hay-Smith, 2001). These strengthening exercises are more colloquially known as Kegel exercises and, when performed correctly, can greatly benefit those who suffer from pelvic floor dysfunction (Sani, 2015). Through pelvic floor muscle training, muscle volume increases, which elevates the pelvic floor and organs, closes the levator hiatus, and elevates the bladder (Soave, 2019). Recent studies have also shown that muscles that are anatomically near the pelvic floor, particularly the obturator internus muscle, may be appropriate targets for pelvic floor muscle rehabilitation (Tuttle, 2019). Activating the obturator internus muscle may facilitate the pelvic floor muscles to contract, thus strengthening them (Tuttle, 2019).

The obturator internus muscle is typically defined as being either a lateral wall pelvic muscle or a deep gluteal muscle– its primary function is the external rotation of the lower limb (Netter, 2019). However, current research suggests a more significant relationship between the obturator internus muscle and the levator ani muscles. Tuttle et al. (2016, 2019) conducted studies on the effects of strengthening exercises targeting the obturator internus muscle and the impact they had on pelvic diaphragm muscle strength. Kim et al. (2014) microscopically investigated the lateral attachment of levator ani muscles in relation to the thickened portion of the fascia that lies on top of obturator internus; the tendinous arch of levator ani. This fascial attachment between the levator ani musculature and the obturator internus muscle could potentially serve as a strengthening point for the pelvic floor. Our goal is to examine this critical attachment from a gross anatomical perspective.

This project uses 6 formalin embalmed cadavers, 3 females, and 3 males (age range 31-81 years) to examine this attachment between the obturator internus muscle fascia, specifically the tendinous arch of levator ani and the pubic portion of the levator ani muscle. We hypothesize that the pubic portion of the levator ani muscle will also have origin on the tendinous arch of levator ani, and that this fascial attachment thus serves as a reason why strengthening exercises targeting the obturator internus muscle have also been shown to have positive impact on pelvic floor strength.

CHAPTER II
INTERNSHIP SUBJECT

BACKGROUND AND LITERATURE

Section 1: Pelvis Background

The pelvic region of the human body includes the bony pelvis, the pelvic cavity, the pelvic diaphragm, and the perineum (Chaudhry, 2018). The primary function of the pelvis includes structural support and stability for movement (Chaudhry, 2018). Each sub-structure of the human pelvis has functions that are specific to that part of the pelvis. It is important to understand the function of each of these components to understand the overall function of the human pelvis.

The bony pelvis primarily functions as a weight bearing and protective structure and can be divided into two parts: the anterior portion and the posterior portion (Moore, 2014). There are three anterior bones that join together to form what is known as the innominate bone: the pubic bone, the ischial bone, and the iliac bone (Chaudhry, 2018). The innominate bone exists on both the left side and the right side of the pelvis. These two are connected posteriorly by the pelvic spine which consists of the coccyx and the sacrum (Chaudhry, 2018). The bony pelvis is the entire structure that is formed by the joining of the two innominate bones and pelvic spine (Betts,

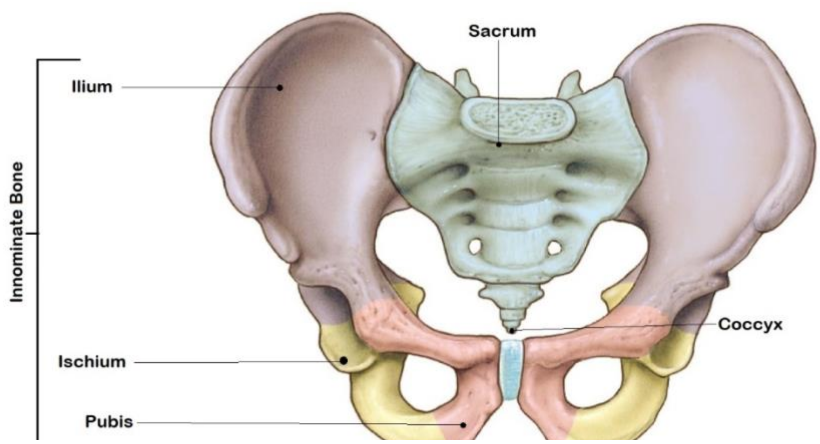


Figure 1: Anterior View of Bony Pelvis Structures

2017). This unique arrangement of bones has a role in the stability and weight bearing of everything superior to the pelvis as well as in the protection of the non-bony structures found within this region (Betts, 2017; Chaudhry, 2018).

The pelvic cavity is the structure that lies below the abdominal cavity (McEvoy, 2019). The two major landmarks of the pelvic cavity include the sacral promontory posteriorly and the pubic symphysis anteriorly (McEvoy, 2019; Netter, 2019). The sacral promontory represents the anterior margin of the superior sacrum (Betts, 2017). The pubic symphysis is the specialized joint where the two opposing pubic bones curve medially and join together (Betts, 2017). The pelvic cavity contains the bladder, rectum, reproductive organs, and part of the descending colon (McEvoy, 2019). Inferior to the pelvic cavity is a group of muscles known as the pelvic diaphragm whose function is primarily to support the structures found within the pelvis.

Anatomy textbooks historically state that the pelvic diaphragm consists of two distinct muscles: the coccygeus muscle and the levator ani muscle (Drake, 2005; Moore, 2014; Netter,

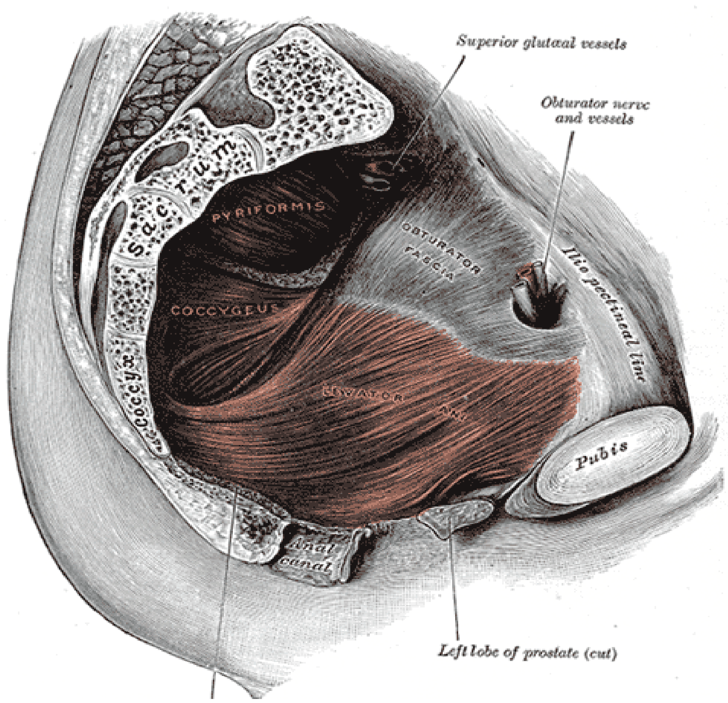


Figure 2: Medial View of Pelvic Diaphragm Muscles

2019). The other two muscles found within this region are the piriformis muscle and the obturator internus muscle. These two muscles are not traditionally included in the pelvic diaphragm (Drake, 2005; Moore, 2014; Netter, 2019). The origin and bony insertion pairs for the piriformis, coccygeus, and obturator internus muscles are generally agreed upon in both anatomy textbooks and literature. Some anatomy textbooks separate the four muscles into the gluteal region (obturator internus and piriformis) and the pelvic floor (coccygeus and levator ani) (Moore, 2014; Netter, 2019). It is also important to point out that some literature separates the four muscles into two distinct pairings, both of which are labeled as pelvic diaphragm: The lateral wall muscles, which consist of the obturator internus and the piriformis, and the pelvic floor muscles, which consist of the levator ani and coccygeus (Gilroy, 2016; Sharma, 2018).

According to both recent literature and textbooks, the coccygeus is noted to have an origin from the tip and posterior border of the ischial spine and an insertion point into the sacrum and coccyx lateral to the sacral foramina (Lawson, 1974; FCAT, 1998; Drake, 2005; Moore, 2014; Netter, 2019). The obturator internus originates from the pelvic surface of the obturator membrane and the surrounding bone (Derry, 1907; Drake, 2005; Moore, 2014; Giraudet, 2018; Netter, 2019). The insertion point lies on the medial surface of the greater trochanter of the femur (Giraudet, 2018; Netter, 2019). The piriformis muscle is noted to have an origin beginning on the anterior surface of sacral segments 2-4 with some fibers running from the sacrotuberous ligament and an insertion point along the superior margin of the greater trochanter of the femur (Netter, 2019).

Lastly, the origin-insertion pairing of the levator ani is the topic of much discussion in recent literature. The levator ani is noted to have three distinct parts; the iliococcygeus, the pubococcygeus, and the puborectalis (Netter, 2019). There is a consensus among authors that the iliococcygeus muscle arises from the arcus tendinous levator ani (tendinous arch of the levator ani) and has an insertion point in the anococcygeal raphe (Derry, 1907; Ayoub, 1979; DeLancey, 1999; Chou, 2001; DeLancey 2003; Kearney, 2004; Sharma, 2018). The tendinous arch is a thickened portion of the obturator fascia that lies on the medial aspect of the obturator internus muscle. This arch extends from the pubis to the ischial spine. The discrepancy lies within the two remaining parts of the levator ani; the pubococcygeus and the puborectalis muscles.

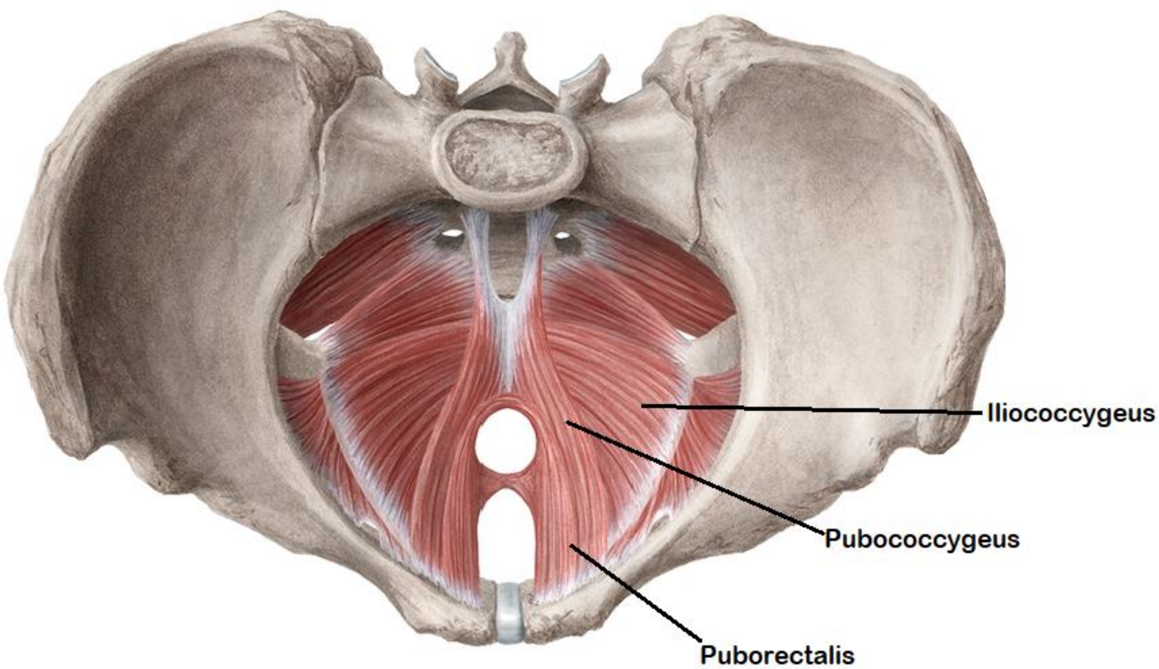


Figure 3: Levator Ani Muscles

It is difficult to note where the pubococcygeus ends and the puborectalis ends; as such, recent literature has presented various origin-insertion pairs. The puborectalis is also noted to arise from the body of the pubis and forms a sling behind the rectum (FCAT, 1998). There is agreement among literature that lists the origin of both the pubococcygeus and puborectalis as the pubic body. The discrepancy lies with the insertion point, which influences which part of the muscle the authors chose to label as pubococcygeus or puborectalis. For instance, the levator ani portion that originates from the body of the pubis and inserts into the plane between external anal sphincter and internal anal sphincter (intersphincteric groove) is listed as puborectalis by Lawson et al. (1974) and Courtney et al. (1950) (Courtney, 1950; Lawson, 1974). However, the same origin-insertion pair is described by Shafik et al. (1975) as being the pubococcygeus (Shafik, 1975). Bitti et al. (2014) describes the pubococcygeus as being the muscle that is located between the iliococcygeus and the puborectalis muscle and is inconsistently distinguished during MR imaging (Bitti, 2014). Giraudet et al. describes the pubococcygeus and puborectalis subdivisions as being difficult to individualize “particularly in their retropubic bone insertion” (Giraudet, 2018). Most the authors describe the puborectalis as having an origin on the body of the pubis on either sides and inserting into the fibers of the opposite side, forming a sling around the rectum (Courtney, 1950; Lawson, 1974; Shafik, 1975; Kearney, 2004; Bitti, 2014; Giraudet, 2018). There is also the interesting issue of male and female pelvic diaphragms as some authors have described parts of the levator ani having an insertion point into the vaginal wall (Lawson, 1974).

The levator ani muscle is further subdivided into three separate parts: the iliococcygeus, the pubococcygeus, and the puborectalis (Netter 2019). Past dissection articles have suggested that fibers from the pubococcygeus do not insert into the coccyx itself, but rather into vaginal wall of females and the urethra in males. Some fibers of this muscle are also attached to the anococcygeal raphe. This, in turn, leads to somewhat confusing terminology as the name pubococcygeus incorrectly implies a relationship between the pubis and the coccyx which is not the case. The pubococcygeus muscle controls urine flow and contracts during orgasms (Netter, 2019). In regards to naming muscles based on origin and insertion pairings, an argument could be made for changing the nomenclature of the pubococcygeus muscle.

Most anatomy textbooks tend to state generalized origin insertion pairs of the pelvic floor muscles. Terminolgia Anatomica lists the origin of the pubococcygeus as the body of the pubis and the insertion in the perineal body and lists puborectalis as a sling rather than having an insertion point as some other authors point out (FCAT, 1998). The levator ani is listed to have three separate parts, but the origin insertion pairs of each of the parts is not made clear (Netter, 2019). The other three muscles are similar to recent literature in regards to origins and insertions. While it is difficult to note the differentiation between the various portions of the levator ani muscles, Kearney et al. (2003) states that understanding and differentiating each origin-insertion pairing is significant in regards to knowing which portion of the muscle is damaged. Thus clarifying the anatomy and its respective terminology is particularly important to determining the consequences of injuries to specific parts of the muscles.

Research of the pelvic region has demonstrated that the pelvic floor muscles provide critical structural support and stability for everyday activities such as standing, walking, running etc. (Chaudhry, 2018). Considering that *Homo sapiens* are bipedal, the pelvic floor bears much more weight in humans compared to other species. As such, the pelvic floor has great clinical significance as many issues can occur within this region due to the added stress. Examples including pelvic inflammatory disease (PID), pelvic floor dysfunction, and fecal incontinence are all related to the pelvic floor muscles and may require surgical intervention to alleviate symptoms (Chaudry, 2018). Specifically, any form of pelvic floor dysfunction can cause unwanted contraction of the pelvic floor muscles and make defecation difficult, leading to a variety of issues (Chaudry, 2018). Despite this significance, the details of the floor muscles, specifically the levator ani muscles, are poorly understood. A better understanding of the relationship between pelvic floor muscles could positively affect the outcome of any clinical intervention performed in this region.

Section 2: Pelvic Floor Dysfunction Background

Pelvic floor dysfunction is a broad term used to label a variety of issues involving the impairment of the pelvic floor muscles (Louis-Charles, 2019). These disorders can be divided into various types of pelvic floor dysfunction (Louis-Charles, 2019). The most common type of pelvic floor dysfunction is known as relaxed pelvic dysfunction, and these include urinary incontinence, fecal incontinence, and pelvic organ prolapse (Faubion, 2012; Louis-Charles, 2019).

Urinary incontinence is defined as any ‘involuntary leakage of urine’ (Abrams, 2002). Incontinence symptoms occur in both sexes, but is much more prevalent among women (Aoki, 2017). Though there are some noted overlap in the pathophysiology behind urinary incontinence in both male and female, incontinence in men is most commonly a consequence of prostatic enlargement or damage to continence mechanisms during treatment for prostatic cancer (Aoki, 2017). These continence mechanisms involve a quiescent bladder, functional muscular and fascial support structures, and functional urethral sphincters (Herschorn, 2004). Urinary incontinence in females is much more frequent and is typically due to dysfunction of the pelvic floor muscles (Aoki, 2017).

Support of the pelvic organs is the result of an interaction between the pelvic floor musculature and pelvic connective tissues (DeLancey, 2016). The levator ani musculature consists of striated muscles which are known to be susceptible to injury during forced lengthening (Brooks, 1995). Injuries to the levator ani musculature caused by vaginal birth is prevalent and well documented (DeLancey, 2003; Miller, 2010). It has also been well documented that visible loss of the pubic portion of the levator ani muscle occurs in primiparous women after vaginal birth (DeLancey, 2003; Dietz, 2005). Failure of pelvic floor muscles exposes pelvic organs to pressure differential which produces abnormal tension on connective tissue attachment of the organs to the pelvic sidewall (DeLancey, 2016). This in turn causes pelvic organ prolapse.

A potential framework has also been suggested involving the two different types of maternal pubovisceralis muscle injury (Kim, 2014). “Type I” injuries are where the tendinous arch of levator ani remains intact, but the muscle fibers originating off the tendinous arch are lost (Kim, 2014). “Type II” injuries involve the detachment of the tendinous arch of levator ani from the pubic bone itself which causes a distortion in the pelvic diaphragm due to the loss of this critical attachment (Kim 2014). Both injuries are consistent with excessive tension created in the pelvic diaphragm during vaginal birth (Kim, 2014).

Treatment of pelvic floor dysfunction involves both non-invasive measures such as pelvic floor muscle exercises and lifestyle advice as well as surgical procedures (Hallam, 2012). As noted before, 11% of all American women require surgery at some point for pelvic floor dysfunction (Olsen, 1997). These include both pelvic organ prolapse and urinary incontinence. Pelvic organ prolapse has been shown to have a somewhat high morbidity rate of 11% (Ismail, 2012; Wu, 2014). Furthermore, the risk of invasive surgical treatment for pelvic organ prolapse leading to urinary incontinence is 11-20% (Ismail, 2012; Wu, 2014).

Pelvic floor muscle exercises (PMEs) are more commonly referred to as Kegel exercises and are recommended by primary care providers and gynecologists as treatment for pelvic floor disorders before patients are referred to specialists (Sani, 2015). Incorrect performance of Kegel exercises may lead patients to believe that these exercises are not effective and may seek additional, more invasive therapies (Sani, 2015). In a study conducted by Sani et al. (2015), nearly a quarter of patients who reported to have prior knowledge of how to correctly perform pelvic floor muscle exercises could not perform them correctly (Sani, 2015). Providing instructions on how to do pelvic floor muscle exercises with feedback was shown to have positive impact on the number of patients correctly performing these exercises (Sani, 2015).

Studies conducted by Tuttle et al. (2016, 2019) show a potential correlation between obturator internus muscle strength and pelvic floor strength (Tuttle, 2016; Tuttle, 2019). Both studies investigated the effects of obturator internus muscle strengthening on pelvic floor muscle strength. This was done utilizing exercise programs that included external rotation of the hip and testing maximum intravaginal squeeze pressure using the Peritron™ PFM manometer. Both studies concluded that hip external rotation exercises which strengthen the obturator internus muscle may be effective as an indirect form of pelvic floor muscle exercise.

In an investigation by Kim et al. (2014), it was noted through histological cross-sections of the pubovisceralis muscle (PVM) that in the lateral sections of PVM, the connective tissue band of the tendinous arch attaches to the pubic bone and forms the lateral margin of the pubic origin of PVM (Kim, 2014). This finding is very interesting when coupled with studies done by Tuttle et al. (2019) regarding the role of the obturator internus muscle in pelvic floor function (Tuttle, 2019). This fascial attachment noted between the lateral sections of the levator ani musculature and the obturator internus muscle could potentially serve as the strengthening point for the pelvic floor muscles. In this study, we investigate the fascial attachment between the pubic portion of the levator ani muscle and the tendinous arch of obturator fascia from a gross anatomical standpoint. In doing so, we hope to gain a better understanding of the relationship between the pelvic floor muscles and the surrounding fascia and musculature.

SPECIFIC AIMS

To test the hypothesis that the pubic portion of levator ani muscle will have origin on the tendinous arch of obturator internus fascia, and thus this fascial attachment serves as a reason why strengthening exercises targeting the obturator internus muscle have also been shown to have positive impact on pelvic diaphragm strength.

In this study, we examine the attachment between pubic portion of the levator ani muscle and the fascia covering obturator internus, the tendinous arch, in 6 formalin embalmed cadavers, 3 females and 3 males.

SIGNIFICANCE

Examining the attachment between the pelvic portion of levator ani muscle and the fascia covering the obturator internus muscle (the tendinous arch) will provide insight into the relationship between these two muscles. Having a better understanding of the relationship between muscles of the pelvic floor and the surrounding musculature and fascia could lead to more accurate diagnosis of ailments that occur there. Pelvic organ support is the result of an interaction between the pelvic floor musculature and pelvic connective tissues (DeLancey, 2016). Failure in any components that make up this interaction can lead to pelvic floor dysfunction, which includes incontinence and pelvic organ prolapse. As mentioned before, studies have concluded that external hip rotation exercises which strengthen the obturator internus muscle may be effective as an indirect form of pelvic floor muscle exercise (Tuttle, 2016; Tuttle, 2019). With better knowledge, we can improve both invasive and non-invasive methods to help treat pelvic floor dysfunction.

MATERIALS AND METHODS

Section 1: Material

The entirety of this investigation was done through human cadavers donated to the UNTHSC Willed Body Program. The sample size included 6 formalin embalmed cadavers, 3 females and 3 males (range 31-81 years). The cadavers were recently dissected by the medical school students during their anatomy course and thus were in various states of preservation. All of the bodies that were investigated had one lower limb hemisected at the sacral promontory. These hemisected portions along with the portion that was still attached to the cadaver were used in the investigation.

Section 2: Dissection

We began the dissection of the pelvic floor muscles with the removal of venous structures and removing parts of the visceral organs for better visibility of the muscle fibers. Important landmark structures such as lumbosacral trunk was left intact as reference points.

We began with the removal of fascia covering the piriformis muscle found in the anterior surface of the sacrum. The lumbosacral trunk was left intact as an identifying landmark.

Using the piriformis muscle as a landmark, we worked our way inferiorly to the coccygeus, noting its insertion on the posterior border and tip of the coccyx. We then traced the coccygeus muscle to its origin in the ischial spine.

The obturator internus muscle was dissected out. The fascia covering the OI muscles was cleaned out, save for the thickened tendinous arch that formed the origin of the levator ani muscles. The tendinous arch length and thickness varied from specimen to specimen.

The levator ani muscles were dissected out from its origin along the tendinous arch of the obturator fascia. The pubic portion of levator ani was dissected out starting from the pubic bone. During the dissection, we noticed no clear demarcation between the three muscles of the levator ani. The muscle fibers of the levator ani were observed from their origin along the pubic bone and the tendinous arch of obturator fascia. They were then traced along the fibers towards the attachment to the visceral organs and the anococcygeal raphe. These attachments were noted and photographs were taken of the dissected pelvic floor from medial and lateral views.

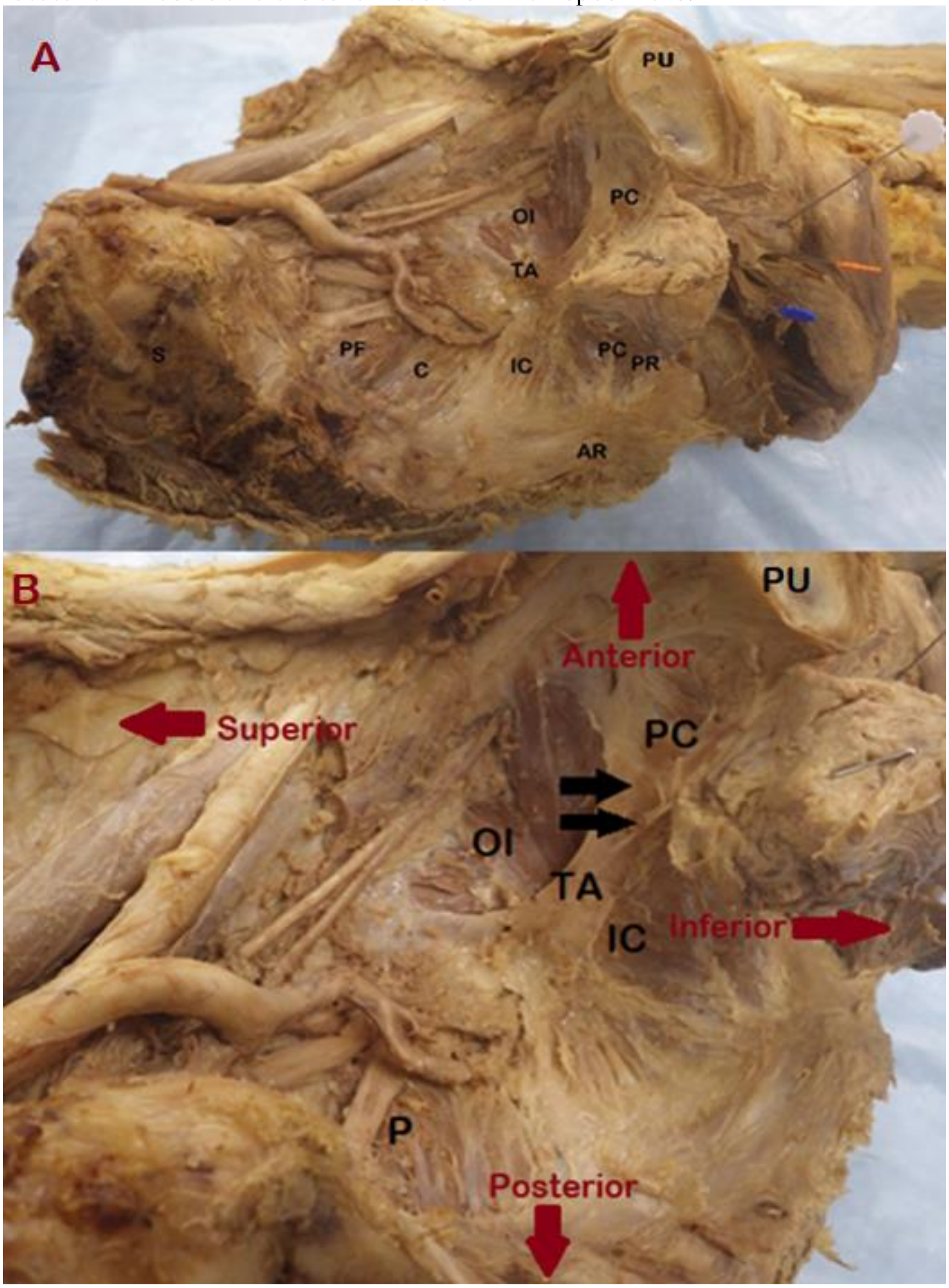
RESULTS

In our observational study we examine the attachment between pubic portion of the levator ani muscle and the fascia covering obturator internus, the tendinous arch.

Pubic portion of the levator ani muscle was noted to have origin along the pubic bone. Obturator internus muscle was dissected out with the tendinous arch of levator ani being the topic of interest. In dissection of the obturator internus muscle, the tendinous arch of levator ani was noted to have variable length along the medial border of the obturator internus. All specimens had the lateral fascial attachment of the pubic portion of levator ani to the tendinous arch as well as an origin from the pubic bone as shown in Figure 4-B and Figure 5-A. A majority of the lateral fibers of pubic portion of the levator ani muscle originating from the pubic bone and tendinous arch had insertion into the visceral organs (not shown). The remaining fibers were found inserting into the anococcygeal raphe as shown in Figure 4-A and Figure 5-A. These findings are consistent with the study involving the microscopic examination of the pubic portion of the levator ani muscle which showed lateral fascial attachment from the pubic portion of the levator ani to the tendinous arch of obturator fascia. (Kim, 2014).

A review on other dissection studies done in the pelvic region was conducted. Studies that were selected contained reports from investigators who examined the muscles of the pelvic diaphragm. These studies also specifically described the origins and insertions of said muscles. A table (**Table 1**) organized by authors and the nomenclature they used for specific origin and insertion pairings is included in the results section. The table also notes whether the authors observed levator ani muscles as having origin in the tendinous arch of levator ani. A second table (**Table 2)** is also included in the results section which describes the origin and insertion pairs of the levator ani muscles described by commonly-used resources for anatomical education. The meta-analysis table serves to organize the findings of various other dissection studies and what nomenclature they used for specific origin-insertion pairing portions of the levator ani muscle.

Figure 4: Medial view of female pelvic diaphragm with obturator fascia and venous structures removed. Black arrow shows the point of interest with the lateral attachment of the pubic portion of levator ani muscle to tendinous arch. We noted this lateral attachment point between the levator ani muscle and the tendinous arch in all specimens.



PU – Pubis, PC – Pubococcygeus, TA – Tendinous Arch, IC- Iliococcygeus, OI – Obturator Internus, PF – Piriformis, C – Coccygeus, S – Sacrum, PR – Puborectalis, AR – Anococcygeal raphe

Figure 5: Medial view of male pelvic diaphragm with labeled muscles. Major landmarks such as superior gluteal artery and sacral plexus were left intact. Dotted line marks the tendinous arch. We noted the lateral attachment of the pubic portion of levator ani muscle to tendinous arch with the dotted line.

PU - Pubis, PC – Pubococcygeus, IC – Iliococcygeus, TA – Tendinous Arch of Levator Ani, OI – Obturator Internus, C – Coccygeus, PF – Piriformis, **S** – Sacrum, AR – Anococcygeal raphe

Table 1: Author's Description Based on Insertion of Levator Ani Fibers

Author	Origin	Insertion	Nomenclature used for Levator Ani Muscle	Tendinous Arch Origin Noted
Lawson	Pubic Bone	Vaginal Wall (F)	Pubovaginalis	Yes
		Urethra (M)	Pubourethralis	
		Anococcygeal Raphe	Puboperineus	
		Anal Canal	Puboanalis	
Roberts	Pubic Bone	Vaginal Wall (F)	Pubococcygeus	No
		Urethra (M)	Pubococcygeus	
		Anococcygeal Raphe	Pubococcygeus	
		Anal Canal	Puborectalis	
Courtney	Pubic Bone	Vaginal Wall (F)	Pubococcygeus	Yes
		Urethra (M)	Pubococcygeus	
		Anococcygeal Raphe	Pubococcygeus	
		Anal Canal	Puborectalis	

Table 2: Origin/Insertion Used in Anatomical Resources

Anatomical Resource	Origin	Insertion	Nomenclature
Terminolgia Anatomica	Tendinous Arch of LA	2 sides fused in iliococcygeal raphe (anococcygeal raphe)	Iliococcygeus
	Pubis	Perineal body	Pubococcygeus
	Pubis	Forms sling posterior rectum	Puborectalis
Netters	Tendinous Arch of LA	Anococcygeal raphe	Iliococcygeus
	Pubis	Perineal Body	Pubococcygeus
	Pubis	Forms sling around rectum	Puborectalis
Clinical Anatomy by Regions 8th Edition	Tendinous Arch of LA	Anococcygeal body	Iliococcygeus
	Pubis body	Anococcygeal body	Pubococcygeus
	Pubis	Deep external anal sphincter/forms sling	Puborectalis

DISCUSSION

In this study, we investigated the attachment between the levator ani musculature and the fascia covering the obturator internus. The aim of this study was to examine the attachment between the pubic portion of the levator ani muscle and the fascia covering the obturator internus, specifically the tendinous arch.

Our results showed that from a gross anatomy perspective, the lateral sections of the pubic portion of the levator ani muscle has fascial attachments to the tendinous arch of obturator fascia. This finding is also supported by an investigation by Kim, who noted through histological cross-sections of the pubovisceralis muscle (PVM) that in the lateral sections of PVM, the connective tissue band of the tendinous arch attaches to the pubic bone and forms the lateral margin of the pubic origin of PVM (Kim, 2014).

Studies were conducted by Tuttle et al. (2019) regarding the role of the obturator internus muscle in pelvic floor function (Tuttle, 2019). Both studies investigated the effects of obturator internus muscle strengthening on pelvic floor muscle strength. This was done utilizing exercise programs that included external rotation of the hip and testing maximum intravaginal squeeze pressure using the Peritron™ PFM manometer. Both studies concluded that hip external rotation exercises which strengthen the obturator internus muscle may be effective as an indirect form of pelvic floor muscle exercise.

This fascial attachment between the levator ani musculature and the tendinous arch which is a continuation of obturator fascia could potentially be reason as to why external rotation exercises which strengthen the obturator internus may be effective form of strengthening pelvic floor muscles. Future studies to consider should include observation of the biomechanical effects of external rotation of the obturator internus muscle on the levator ani musculature with fascia intact.

In a study conducted by Kim et al. (2014), the pubococcygeus muscle is labeled as the puboviscerai muscle which was also the term used Lawson (Kim, 2014; Lawson 1974). As noted by Kearney et al. (2003), we would also consider the term puboviscerialis as a replacement for the more commonly used term pubococcygeus muscle (Kearney, 2004). The puboviscerialis nomenclature should be favored over the more common term pubococcygeus as it describes the sites of its origin and insertion in humans. Most of the pubococcygeus muscle inserts into the vaginal walls in females and the urethra in males. It was noted that the medial portion of the puboviscerai muscle (pubococcygeus) had direct attachment of the muscle to the pubic bone while the lateral origin is made through the levator arch. The term puboviscerialis should be considered as a potential replacement for the more common term pubococcygeus.

In recent years, there has there been a large influx of research concerning this area of the body. Magnetic resonance imaging research has shown defects of the pelvic floor in women that occur during vaginal delivery of babies (Hoyte, 2001). A potential framework has also been suggested involving the two different types of maternal puboviscerialis muscle injury (Kim, 2014). “Type I” injuries are where the tendinous arch of levator ani remains intact, but the muscle fibers originating off the tendinous arch are lost (Kim, 2014). “Type II” injuries involve the detachment of the tendinous arch of levator ani from the pubic bone itself which causes a distortion in the pelvic diaphragm due to the loss of this critical attachment (Kim 2014). Both injuries are consistent with excessive tension created in the pelvic diaphragm during vaginal birth (Kim, 2014). Injuries that occur during vaginal childbirth also influence the development of pelvic organ prolapse and urinary incontinence (Hoyte, 2001; DeLancey, 2003). The main concern with changing the more common term “pubococcygeus” with the more accurate term “puboviscerالis” is the fact that there are generations of students who have already learned the more common term.

SUMMARY AND CONCLUSIONS

The pelvic diaphragm is a group of muscles located inferiorly to the pelvic cavity. In this study, we examine the attachment between the pubic portion of the levator ani muscle and the fascia covering obturator internus, the tendinous arch, in 6 formalin embedded cadavers, 3 females and 3 males.

For the aim, we tested the hypothesis that the pubic portion of levator ani muscle will have origin on the tendinous arch of obturator internus fascia, and thus this fascial attachment serves as a reason why strengthening exercises targeting the obturator internus muscle have also been shown to have positive impact on pelvic diaphragm strength. The pubic portion of the levator ani muscles were noted to have lateral fascial attachment on the tendinous arch of obturator fascia as well as origin along the pubic bone.

In conclusion, our findings are consistent with previous studies done regarding the origin of the levator ani musculature that show lateral attachment to the tendinous arch of levator ani (Kim, 2014). In the future, a continuation of this study should include a larger sample size. During the study, we noted that a biomechanical approach could provide additional insight to our project. A potential future study could be conducted that leaves the obturator fascia intact while observing the effects of external rotation the lower limb on the pelvic floor muscles. This would aid in determining the role that the attachment observed in our study has in relation to pelvic floor strength.

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