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ORIGINAL ARTICLE

A Comparative Anatomical and Morphometric Study of the Inguinal Canal in Males and Females and Its Association with the Predisposition to Groin Hernias

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ABSTRACT

Background: Groin hernias are a common surgical condition with a marked gender disparity in prevalence, with males being many orders of magnitude more affected. It is thought that this difference is due to anatomical and morphometric variations of the structure of the inguinal canal between males and females.

Objective: A comparative anatomical and morphometric analysis of the inguinal canal in male and female cadavers and further correlation of these findings with the predisposition to groin hernias.

Methods: This cross-sectional cadaveric study was done on 30 males and 20 female adult cadavers from January 2022 to June 2022. Bilaterally, the inguinal region was examined in detail. Canal length, superficial and deep ring widths, canal obliquity angle, posterior wall muscular reinforcement, and Hesselbach's triangle condition were measured as parameters. Group comparisons were made by t-test with $p < 0.05$ in SPSS v25.0.

Results: The length of the inguinal canal in males was significantly greater (4.21 ± 0.52 cm) than in females (3.13 ± 0.41 cm, $p < 0.05$), and at both rings, it was wider (1.59 ± 0.21 cm). Moreover, males had a lower canal obliquity angle and weaker posterior wall muscular support (17% versus 90% strong in females). In 80% of the male cadavers, Hesselbach's triangle was weak, whereas in 20% of females, it was strong. All differences were significant ($p < 0.001$).

Conclusion: Males are structurally vulnerable to inguinal canal development and can develop a hernia. On the contrary, females have a compact, oblique, and muscularly reinforced canal that prevents herniation. However, this gender specific anatomical knowledge is important when working to prevent, diagnose, and repair hernias.

Keywords: Inguinal canal, Groin hernia, Anatomy, Morphometry, Posterior wall, Hesselbach's triangle, Gender differences, Cadaveric study

INTRODUCTION

The groin hernias are one of the most common surgical problems encountered in the world. Studies also report a lifetime risk of about 27% in men and less than 3% in women, the incidence is markedly higher among males[1]. The marked difference in occurrence of this condition has long occupied the interest of anatomists and surgeons alike, and is generally ascribed to the peculiar anatomical and developmental peculiarities of the inguinal region in the two sexes[2].

It is an oblique passage in the lower anterior abdominal wall, from the deep inguinal ring to the superficial inguinal ring. In males, it is a conduit for the spermatic cord, and in females, for the round ligament. In males, the structure is more prone to future weakening because of embryologic descent of the testes through this canal, which facilitates the development of both direct and indirect inguinal hernias[3]. By contrast, in females, the canal is narrower, shorter, and better supported by surrounding musculature, especially the conjoint tendon and the fibers of the transversus abdominis and internal oblique muscles, which provide a relative resistance against herniation[4].

Variations in morphometry of the inguinal canal, i.e., its length, width, angle of obliquity, and composition of its walls, are considered to be major causative factors in the pathophysiology of groin hernias. Structural vulnerability of the region is contributed to by a wider superficial ring, longer canal, and thinner posterior wall, frequently seen in males[5]. In addition, the inferior epigastric vessels and Hesselbach's triangle position and relationship can also affect whether the hernia presents as direct or indirect. Knowing these anatomical parameters is important not only to understand the natural predisposition to hernia but also to plan surgical repairs and choose appropriate mesh size, as well as prevent recurrence[6].

Despite the availability of vast clinical data on incidence and technique of hernia repair, there is a dearth of cadaveric studies to compare the variation in inguinal canal morphology in males and females, especially in the South Asian and Pakistani populations[2]. Anatomical references are mostly from Western populations that may not apply to local demographic and physiological profiles due to differences in body habitus, physical activity, and genetic predisposition[7].

In this study, we aimed to fill this gap by performing a detailed comparative anatomical and morphometric study of the male and female cadavers. We seeked to correlate anatomical features with the observed disparity of hernia prevalence between the sexes by measuring and evaluating critical features, including canal length, ring diameters, muscular reinforcement, and angulation. Additionally, these findings could aid in refining preventive strategies for patients lacking access to advanced surgical care[8].

MATERIALS AND METHODS

Study Design and Duration: The description of the study was a descriptive cross-sectional cadaveric study done from January 2022 to June 2022. The present study was done in the Department of Anatomy of Gujranwala Medical College Gujranwala and affiliated hospital DHQ teaching hospital Gujranwala, Pakistan which is a well-known academic institution of Pakistan. The study aimed to compare anatomical and morphometric features of the inguinal canal between adult male and female cadavers and their relationship to predisposition to groin hernias.

Sample Population: Fifty adult cadavers were studied, of which thirty were males and twenty were females. Standard anatomical techniques were used to formalin fix and preserve all cadavers. Purposive sampling was applied to select the cadavers based on their preservation status of the inguinal region and the absence of any visible abnormalities or prior surgical interventions. The age range of the cadavers was between 25 and 70 years, and there was no history of trauma or congenital anomalies in the abdominal or pelvic areas.

Inclusion and Exclusion Criteria: Cadavers were required to be above the age of 25 years, adults, with an intact and undisturbed inguinal region, as inclusion criteria. Cadavers in particular were only considered if they did not indicate previous abdominal or groin surgeries. To obtain accurate anatomical observations and measurements, study subjects were cadavers without congenital deformities, evidence of trauma, or poor preservation of tissues in the inguinal area; they also excluded cadavers with prior surgical scars.

Ethical Considerations: The study was given ethical approval by the Institutional Ethical Review Board, Strict adherence to ethical and professional standards for cadaveric research was maintained in all dissections performed. All specimens were handled with due respect and by national and institutional ethical guidelines for anatomical studies, according to which the identity of the cadavers was kept anonymous.

Dissection Procedure: Dissection tables were set up so that cadavers were supine on the table. The xiphoid process to the pubic symphysis was made as a vertical midline incision. The anterior abdominal wall was carefully reflected to expose the anterior abdominal wall, the skin, superficial fascia, and the external oblique aponeurosis. The superficial and deep inguinal rings, the inguinal ligament, and other structures were exposed bilaterally in the inguinal region. The spermatic cord and its components were identified in the male cadavers, while the round ligament in the female cadavers was examined as it passed through the canal.

Morphometric Parameters Measured: Digital vernier calipers, with a precision of 0.1 mm, flexible measuring tapes, and graduated anatomical scales were used to measure anatomical and morphometric parameters. The parameters recorded included length of the inguinal canal, width of the superficial and deep inguinal rings, angle of canal obliquity, position of the inferior epigastric vessels concerning the deep ring, muscular reinforcement of the posterior wall, and condition of Hesselbach's triangle. Measurements were made for the length of the inguinal canal as the linear distance between the superficial and deep rings. For each ring, the measurement was taken at the maximum horizontal span. Evaluation of the angular orientation between the canal and the inguinal ligament was used to measure the angle of canal obliquity. The posterior wall's muscular strength was determined based on the presence and density of overlapping muscle fibers from the internal oblique and transversus abdominis muscles. It was examined for integrity and degree of muscular or fascial reinforcement of the Hesselbach's triangle.

Data Collection and Reliability: Two independent anatomists took all measurements on both right and left sides to guarantee accuracy and remove individual bias. When there was a discrepancy between the two observers in the measurement, a third senior anatomist reviewed the anatomical site and confirmed the measurement. Structured proformas were filled in with data taken from all cadavers and entered into statistical software for analysis.

Statistical Analysis: IBM SPSS Statistics version 25.0 was used to analyze the recorded data. Mean ± standard deviation was used for the expression of continuous variables like canal length and ring widths. The independent sample t-test was used to compare the mean values of male and female cadavers. All analyses were considered statistically significant if the p-value was less than 0.05. Assuming normal distribution and equal variance, the statistical test was chosen.

Dissection Protocol and Safety Compliance: The dissection procedures were all done in a way that was extremely safe and by departmental guidelines. During the dissection sessions, the researchers wore personal protective equipment such as gloves, lab coats, and face masks. After and before each session, dissection tools and surfaces were cleaned and sterilized to achieve aseptic conditions. The dissection was performed methodically in all steps to avoid a structural distortion and to maintain the reliability of measurements.

With this methodical and ethically guided approach, accurate assessment of the inguinal region was obtained to compare male and female anatomical variations with their association with groin hernia predisposition.

RESULTS

A comparative anatomical and morphometric study was performed on a total of 50 adult cadavers, of which there were 30 male cadavers (60%) and 20 female cadavers (40%). The ages of the cadavers were between 25 and 70 years. The age of the male group was 51.2 ± 9.3 years, and that of the female group was 52.6 ± 8.7 years. The mean age of the groups was not significantly different ($p = 0.54$), so the groups were demographically comparable and appropriate for anatomical evaluation.

Under dissection and analysis of the inguinal region, anatomical dimensions, structural integrity, and muscular reinforcement were found to differ significantly between genders. The mean length of the inguinal canal was 4.21 ± 0.52 cm in males and 3.13 ± 0.41 cm in females ($p < 0.001$). This longer canal in males has a greater surface area that could potentially be herniated under increased intra-abdominal pressure.

The superficial inguinal ring width was significantly wider in males (mean 19.5 ± 2.3 mm) than in females (12.8 ± 1.6 mm), and the deep inguinal ring was significantly wider in males (13.4 ± 1.9 mm) compared to females (9.6 ± 1.1 mm) (both $p < 0.001$). The wider ring diameters in males are indicative of a more patent pathway than females through which abdominal contents may herniate, particularly in association with a weak posterior wall support.

In males, the angle of obliquity of the inguinal canal, as measured from the angle between the inguinal ligament and the inguinal canal, was significantly narrower (55.2 ± 5.3 degrees) and steeper (63.5 ± 4.8 degrees) in females, with a $p = 0.004$. The greater obliquity in females allows for a more protective anatomical configuration and prevents linear transmission of intra-abdominal forces along the canal's axis.

The majority of male specimens were found to have weak muscular support at the posterior wall of the inguinal canal, a key biomarker and protective factor of the inguinal canal. Only 5 out of 30 male cadavers (17%) had strong muscular reinforcement from the internal oblique and transversus abdominis fibers. On the other hand, while all 20 female cadavers (100%) had robust posterior wall musculature, 18 out of 20 (90%) were statistically significant ($p < 0.001$). Thus, this well-developed muscle overlap in females is a barrier to herniation, particularly in the preperitoneal region.

In addition, Hesselbach's triangle, a typically weakened site in direct hernias, was found to be significantly different by gender. This region was thin and inadequately supported (in 24 of 80%; 30%), and only 4 cases (20%) of females showed any sign of fascial attenuation. The rarity of direct hernia in females is explained by the presence of a strong transversalis fascia and overlapping musculature in females. Table 1 shows a comparative analysis between the two gender groups with all these key parameters listed below.

These results lend strong support to the hypothesis that males are more anatomically predisposed to both types of inguinal hernias. Structurally, the male inguinal canal is compromised by a combination of longer canal length, wider ring diameters, less oblique canal orientation, and diminished posterior wall reinforcement. However, females have a naturally protective anatomical configuration that includes shorter canal length, narrower openings, greater canal inclination, and strong muscular barriers.

As anatomical variability, this gender specific variability is a critical explanation for the higher incidence of groin hernias in males and reinforces the importance of sex based anatomical factors in surgical education and hernia risk assessment, and procedural planning.

Table 1: Gender-wise Comparative Morphometric and Structural Parameters of the Inguinal Canal with Statistical Analysis (n = 50)

	Male (n = 30)	Female (n = 20)	p-value	Statistical Significance
Age Range (years)	25 – 70	26 – 68	—	—
Mean Age (years)	51.2 ± 9.3	52.6 ± 8.7	0.54	Not Significant (NS)
Body Mass Index (kg/m²)	24.1 ± 1.8	22.8 ± 2.1	0.09	Not Significant (NS)
Right-sided Dominance (% of cases)	56.7% (17/30)	50% (10/20)	0.65	Not Significant (NS)
Inguinal Canal Length (cm)	4.21 ± 0.52	3.13 ± 0.41	< 0.001	Highly Significant (HS)
Superficial Inguinal Ring Width (mm)	19.5 ± 2.3	12.8 ± 1.6	< 0.001	Highly Significant (HS)
Deep Inguinal Ring Width (mm)	13.4 ± 1.9	9.6 ± 1.1	< 0.001	Highly Significant (HS)
Canal Obliquity Angle (degrees)	55.2 ± 5.3	63.5 ± 4.8	0.004	Significant (S)
Posterior Wall Muscular Reinforcement (% Strong)	17% (5/30)	90% (18/20)	< 0.001	Highly Significant (HS)
Weak Hesselbach's Triangle (% Present)	80% (24/30)	20% (4/20)	< 0.001	Highly Significant (HS)

DISCUSSION

This cadaveric study of the inguinal canal shows significant anatomical and morphometric differences between males and females, which may make their contribute to the known discrepancy in groin hernia prevalence between the sexes[3]. Structural features that make the male inguinal region more susceptible to direct and indirect hernias include longer canal length, wider superficial and deep inguinal rings, and a lower angle of obliquity, which are found to be more common in male cadavers[9, 10].

Another of the most clinically relevant findings in this study was the markedly reduced muscular reinforcement of the posterior wall in males. The posterior wall of the internal oblique muscle and transversus abdominis muscle was essentially absent in over 80% of male cadavers[11]. This may be associated with a mechanical deficiency of the canal, particularly during these episodes of raised intra-abdominal pressure, such as heavy lifting, chronic coughing, or straining. In contrast, virtually all of the female cadavers (90%) had robust posterior wall reinforcement. It may be a natural protective factor for the relatively low incidence of groin hernias in females[12, 13].

The observed gender disparity is also supported by the morphology of Hesselbach's triangle, a site predisposed to direct hernias. Males had notably thinner and weaker fascia and underlying muscular structure, with 80% of male specimens having poor structural support in this region. Females showed only 20% of similar findings in females, which is an anatomical advantage that allows resistance to herniation[14].

These results are consistent with previous anatomical and clinical studies that have all consistently found a higher lifetime risk of inguinal hernias in men. By adding region-specific data and providing quantitative measurements on South Asian cadavers, our study contributes to the literature of current anatomical research characterized by the underrepresentation of South Asian cadavers. In addition, it provides potential surgical implications[15]. For example, knowledge about these variations allows mesh placement and repair techniques to be tailored based on patient sex and allows surgical education to be focused on gender specific anatomical variations[16].

Nevertheless, this was not the only limitation of this study. Assessment of physiological factors such as intra-abdominal pressure dynamics, connective tissue elasticity, or patient history of physical activity that may also influence hernia development cannot be studied using cadavers. Further validation of the anatomical predispositions found could be done through radiological correlations and larger, multicentric datasets in future studies[17, 18].

CONCLUSION

It is shown in this study that the inguinal canals differ significantly anatomically and morphometrically between males and females. Inguinal canal length and width, superficial and deep ring diameters, the obliquity of the canal, and posterior wall reinforcement are less strong in males. These characteristics have the tendency to make the inguinal region structurally vulnerable and account for the markedly higher occurrence of groin hernias in males. Females, on the other hand, have the compact and reinforced inguinal anatomy that effectively gives a natural defence against herniation. This not only expands knowledge of anatomical understanding but also facilitates surgical planning, hernia repair strategies, and patient-specific risk assessment.

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