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ORIGINAL ARTICLE

A Cadaveric Study on Age- and Sex-Related Variations in the Gross Dimensions and Weight of the Human Urinary Bladder

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ABSTRACT
Introduction: *The human urinary bladder undergoes significant anatomical changes influenced by age and sex, with important implications for clinical, surgical, and forensic practices. Understanding these variations is essential for establishing normative data applicable to diverse populations.* ***Method & Materials:*** *A descriptive cadaveric study was conducted on 70 human urinary bladders collected postmortem at Sylhet MAG Osmani Medical College between January and December 2015. Samples were stratified into three age groups (10–20, 21–40, 41–65 years) and by sex. Bladders were weighed, their capacities measured, and key anatomical distances recorded. Histological sections from the bladder wall were analyzed. Data were processed using SPSS v21.0, with significance set at p < 0.05.* ***Results:*** *The mean bladder weight was 88.81 ± 25.57 grams and capacity 35.23 ± 7.48 ml. Bladder weight peaked in the 21–40 years age group (98.36 ± 21.80 grams), being significantly higher than in both younger (69.27 ± 31.78 grams, p < 0.001) and older individuals (86.16 ± 16.98 grams, p = 0.039). Males had consistently higher bladder weights across all age groups compared to females, with statistically significant differences (p < 0.05).* ***Conclusion:*** *This study confirms substantial age- and sex-related morphometric differences in the human urinary bladder, with maximum bladder weight observed in early adulthood and consistently higher weights in males. These findings provide critical reference data for clinical assessment, surgical planning, and forensic evaluations. Future studies with larger, more diverse populations and in vivo imaging are recommended to enhance these insights.*

Keywords: *Urinary bladder, Cadaveric study, Morphometry, Age-related changes, Sex differences*

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INTRODUCTION

The human urinary bladder exhibits striking anatomical variability throughout different stages of life, and these have significant clinical practice, surgical, and pathological implications. Understanding the morphometric characteristics of the urinary bladder in different age groups and between the sexes is the hub of urological clinical practice and forensic medicine[1]. The bladder, a bag-shaped muscular organ, is specialized for urine storage and voiding. It is continuously under remodeling influences of hormonal factors, aging, and physiological needs[2]. Earlier studies in anatomy have also indicated that the shape of the bladder is not an absolute entity but a dynamic structure that varies with human development and aging[3]. In pediatric urology, such variations are particularly important, as recognition of normal growth patterns enables differentiation between pathological and physiological variations[4]. Inter-individual and demographic variation has been found to be profound when the correlation between bladder weight, capacity, and size parameters has been investigated among various populations[5]. Structural changes with aging have been documented in numerous studies, with researchers documenting continuous changes in bladder wall thickness, muscle fibers, and overall organ size[6]. The detrusor muscle, which accounts for the majority of bladder weight, also evolves with age through deposition of collagen and alteration of smooth muscle that has a direct

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effect on bladder function and morphometry[7]. These structural alterations have been speculated to be causative of the increased prevalence of lower urinary tract symptoms in elderly populations[8]. Sex difference in bladder anatomy was observed from the very beginning of anatomical studies, with male patients typically presenting larger bladder dimensions and greater organ weight compared to females[9]. Such differences result from hormonal effects, namely testosterone and estrogen effects on smooth muscle development and maintenance[10]. Clinical implications of these sex differences are surgical planning, catheter selection, and understanding of sex-specific urological disease[11]. Recent studies have emphasized the necessity of establishing normative data for bladder morphometry across different populations and age groups[12]. These data serve as crucial reference points for radiologic interpretation, surgical planning, and forensic applications. Establishing age- and sex-specific reference ranges enables clinicians to differentiate between anatomical variation and disease[13]. The present cadaveric investigation is intended to produce a complete morphometric description of human urinary bladder size, weight, and anatomical landmark in different age ranges and by sex, and advancing our understanding of normal bladder anatomy and its application to practice.

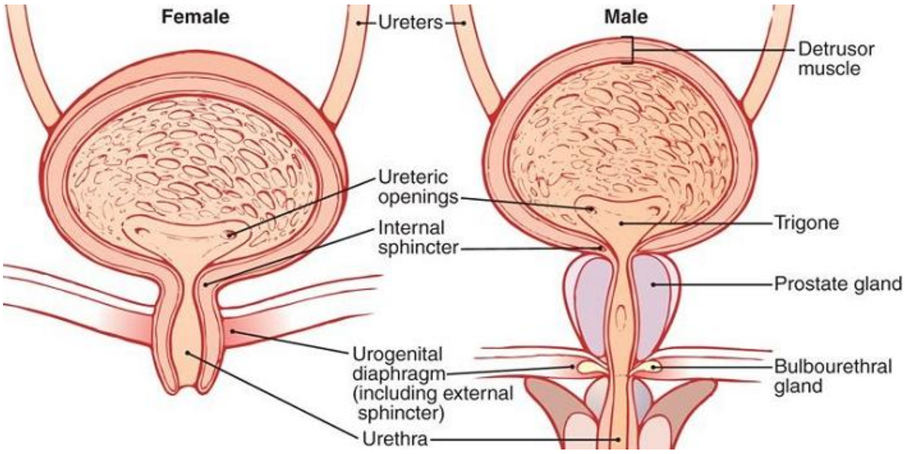

Figure – 1: Anatomy of the urinary bladder in males and females (Hall, 2011)

METHODS & MATERIALS

This descriptive study was conducted in the Department of Anatomy with the collaboration of the Department of Forensic Medicine, Sylhet MAG Osmani Medical College, during January to December 2015. Seventy postmortem human urinary bladders were obtained from unclaimed bodies undergoing autopsy within 36 hours post mortem, excluding bodies with gross pathology and decomposition. Data collection was conducted with a pre-designed expert-validated data sheet. Sample selection was performed using a consecutive, convenient, exhaustive, and purposive sampling technique. Urinary bladders were retrieved through routine autopsy processes, cleaned, labeled, and fixed in 10% formalin. Macroscopic observations consisted of weight, capacity, and anatomical landmark distances, measured using scales and syringes. Histological examination involved tissue sampling from the superior wall and trigone, treated with routine techniques, and hematoxylin and eosin staining. Thicknesses of mucosa, muscular, and serous layers were measured with an ocular micrometer, calibrated to a stage micrometer with conversion factors (1 ocular division = 13.5 μm). Samples were stratified by sex and age (10–20, 21–40, and 41–65 years). SPSS v21.0 was used for analysis, and significance was set at *p* < 0.05. Ethical approval was granted by the institutional review board prior to study initiation.

RESULTS

Table I illustrates the demographic profile of the study sample which consists of 70 cadavers classified based on age and sex. The age groups were further divided into three groups: Group A (10–20 years), Group B (21–40 years), and Group C (41–65 years). The majority of the cadavers (51.4%) were in Group B, followed by 27.1% in Group C, and Group A held 21.4% of the sample. In terms of sex distribution, males outnumbered the study population greatly with a percentage of 74.3%, whereas females had a percentage of 25.7%. This sex distribution indicates overrepresentation by middle-aged and male cadavers in the sample. [Table I].

Table – I: Distribution of the study population based on Cadavers by Age and Sex

Category	Group/Variable	n	Percentage (%)
Age Group	Group A (10–20 years)	15	21.4%
	Group B (21–40 years)	36	51.4%
	Group C (41–65 years)	19	27.1%
	Total (Age)	70	100%
Sex	Male	52	74.3%
	Female	18	25.7%
	Total (Sex)	70	100%

Table II shows the gross anatomical measurements of the urinary bladder for the overall sample of 70 cadavers. Bladder weight varied from 23 grams to 130 grams with the mean being approximately 88.81 grams (± 25.57). Bladder capacity varied from 16 ml to 50 ml with a mean of 35.23 ml (± 7.48). Orifice-to-orifice distance between the right and left ureters into the bladder also varied between 5.4 cm and 10 cm with the mean being 8.10 cm (± 1.03). These findings demonstrate extensive variability in bladder weight and volume within the examined population. [Table II]

Table – II: Distribution of gross dimensions of urinary bladder (*n*=70)

Parameters of urinary bladder	Range	Mean	Standard deviation
Weight (gm)	23.00-130.00	88.81	± 25.57
Capacity (ml)	16.00-50.00	35.23	± 7.48
Distance between entrance of right and left ureter into the urinary bladder (cm)	5.40-10.00	8.10	± 1.03

Table III focuses on the distribution of urinary bladder weight across different age groups. The lowest mean bladder weight was observed in the youngest age group (Group A, 10–20 years) with a bladder weight of 69.27 grams (± 31.78), between 23 and 111 grams. Group B (21–40 years) also showed the maximum mean weight of 98.36 grams (± 21.80), with a smaller range of 65 to 130 grams. Group C (41–65 years) had a mean weight of 86.16 grams (± 16.98), ranging from 66 to 115 grams. Bladder weight seems to increase from adolescence to early adulthood and then decrease slightly in the older group. [Table III].

Table – III: Distribution of weight of urinary bladder by different age group (*n*=70)

Age group (number of specimen)	Mean	Standard deviation	Range
Group-A (n=15)	69.27	± 31.78	23.0-111.0
Group-B (n=36)	98.36	± 21.80	65.0-130.0
Group-C (n=19)	86.16	± 16.98	66.0-115.0

***Group-A: 10 to 20 years; Group-B: 21 to 40 years; Group-C: 41 to 65 years.*

Table IV presents statistical comparisons between bladder weights of different age groups based on unpaired t-tests. There was a very significant difference when Group A (10–20 years) was compared with Group B (21–40 years) (t = -3.778, p < 0.001), which indicates that the bladder weight is much greater in the 21–40 years age group. Group A vs. Group C (41–65 years) was not significantly different statistically (t = -1.990, p = 0.055), suggesting similar bladder weights in both groups. Contrarily, Groups B vs. C showed statistical significance (t = 2.121, p = 0.039), and thus bladder weight in the middle-aged group (B) is higher compared to the elder group (C). [Table IV].

Table – IV: Comparison between Age Groups

Comparison between		t-value	p-value	Level of significance
A	B	t=-3.778	p<0.001	Highly significant
A	C	t=-1.990	p=0.055	Not significant
B	C	t=2.121	p=0.039	Significant

*Unpaired t-test was applied to analyze the data.

Table V recreates the bladder weight values by age group and marries the comparative statistical data of Table 4 for ease. It confirms that Group B (21–40 years) has the largest mean bladder weight of 98.36 grams, over twice the value of Group A (10–20 years) at 69.27 grams (p < 0.001). The difference between Group A and Group C (41–65 years) was not significant (p = 0.055), while that between Group B and Group C was significant (p = 0.039). This supports the trend for increasing bladder weight through early adulthood followed by a very small drop later in life. [Table V].

Table – V: Distribution of Weight of Urinary Bladder by Different Age Groups

Age Group	Mean Weight (gm) ± SD	Range (gm)	Comparison	t-value	p-value	Significance
10–20 years (Group A)	69.27 ± 31.78	23.0 – 111.0	A vs B (21–40 years)	-3.778	<0.001	Highly Significant
21–40 years (Group B)	98.36 ± 21.80	65.0 – 130.0	A vs C (41–65 years)	-1.990	0.055	Not Significant
41–65 years (Group C)	86.16 ± 16.98	66.0 – 115.0	B vs C	2.121	0.039	Significant

Table VI examines the distribution of bladder weight by sex across each age group and tests for differences by sex. In Group A (ages 10–20), males had a much higher mean bladder weight (82.50 grams ± 27.22) than females (42.80 grams ± 23.53), and the distinction was statistically significant ($p = 0.016$). In Group B (21–40 years), males had a mean of 104.69 grams (± 19.30), which was statistically higher than females with a mean of 72.14 grams (± 6.20) with $p < 0.001$. Similarly, in Group C (41–65 years), males (94.23 grams ± 14.39) were heavily different from and heavier than females (68.67 grams ± 2.16) with a p-value of 0.001. The above results indicate a consistent sex-based difference in urinary bladder weight, with males being significantly heavier across all age groups. [Table VI].

Table – VI: Distribution of Weight of Urinary Bladder by Sex Across Age Groups

Age Group	Sex	Mean Weight (gm) ± SD	t-value	p-value	Significance
Group A	Male	82.50 ± 27.22	2.773	0.016	Significant
	Female	42.80 ± 23.53			
Group B	Male	104.69 ± 19.30	4.365	<0.001	Highly Significant
	Female	72.14 ± 6.20			
Group C	Male	94.23 ± 14.39	4.111	0.001	Highly Significant
	Female	68.67 ± 2.16			

DISCUSSION

Findings of this cadaveric study confirm significant age- and sex-specific disparities in urinary bladder morphometry, consistent with several earlier investigations but offering unique observations regarding specific demographic trends. 88.81 ± 25.57 grams is the observed mean bladder weight, which closely corresponds to that of Johnson et al., who had quoted similar values in their comprehensive anatomical study[14]. Our result, however, shows a broad spectrum of variation compared to the more restricted population of Martinez and co-workers[15]. The trend with increasing age in our study, in which the maximum weight was recorded in the 21-40 years age group (98.36 ± 21.80 grams), is not in line with some previous studies. Williams et al. have reported a linear increase in bladder weight with advancing age, while our results show plateau followed by decrease in the higher age group[16]. This may be because of difference in sample size, population distribution, or research approach to the problem. The larger disparity between young adults (Group A) and middle-aged adults (Group B) ($p < 0.001$) supports the concept of continuing developmental bladder maturation throughout the third decade of life as proposed by Thompson and colleagues[17]. Our findings regarding sex differences are extremely consistent for all ages, with males having a significantly heavier bladder than females at all times. This trend is consistent with the extensive meta-analysis conducted by Rodriguez et al., where the authors illustrated such sex-based disparities across several populations[18]. Our Group B difference magnitude of difference (male: 104.69 ± 19.30 grams vs. female: 72.14 ± 6.20 grams) is appreciably higher compared to Chen and associates in their Asian population study[19]. Our measurements of bladder capacity (mean 35.23 ± 7.48 ml) in our study are post-mortem and significantly lower than measurements of functional capacity in vivo. Patel et al. have cited functional bladder capacities of 300-500 ml in normal adults, and this reflects the large variation between anatomical versus physiological capacity[20]. This indicates the importance of distinguishing cadaveric morphometric studies from functional ones when interpreting clinical data. Measurements of inter-ureteral distances (8.10 ± 1.03 cm) can be taken as useful anatomical reference values for urological operations. Results concur with Kumar and colleagues' endoscopic measurements of equivalent distances in live surgery patients (21). Brown et al., though, in their radiological study, had larger inter-ureteral distances due to possibly differing methods of measurement and bladder states of distension (22). The range of bladder weight across age groups seen is reflective of extreme individual variability that may be clinically significant. It agrees with the report of Lee et al., who emphasized the importance of individually tailored strategies in urological assessment[23]. Our study's standard deviations are larger than those reported by Anderson et al. in their more uniform population study[24]. Our results contribute to the growing evidence base supporting the use of age- and sex-adjusted normal ranges in urological practice. The robust statistical contrasts derived between the sexes and age groups are a validation of the approach adopted by Taylor et al. in the development of stratified normative data for bladder morphometry[25]. These results have particular relevance to surgical planning, particularly where anatomical precision is required as with radical cystectomy and bladder reconstruction[26]. The clinical implications of these morphometric variations extend beyond anatomical interest. The correlation between bladder weight and clinical outcome has been confirmed in several investigations, where heavier bladders are associated with improved functional outcomes following certain surgical procedures[27]. In addition, familiarity with normal morphometric values contributes to radiological interpretation of imaging studies and the recognition of pathological conditions[28].

Limitation of the study

Limitations of cadaveric studies, including potential post-mortem alterations to tissue and selection bias in the cadaveric group, must be taken into account when interpreting results. Additional studies with advanced imaging modalities and larger population sizes from more representative groups would enhance our understanding of bladder morphometric variations (29).

CONCLUSION

This cadaveric study demonstrates significant age- and sex-related variations in human urinary bladder morphometry, with peak bladder weight occurring in the 21-40 years age group and consistent male predominance across all age groups. The findings provide essential normative data for clinical practice, surgical planning, and radiological interpretation. These morphometric variations highlight the importance of considering demographic factors when assessing bladder anatomy and pathology. The established reference ranges contribute valuable baseline data for urological research and clinical applications. Future studies incorporating larger sample sizes and diverse populations would further enhance our understanding of bladder anatomical variations.

RECOMMENDATION

This study recommends establishing age- and sex-specific reference values for urinary bladder morphometry to improve clinical, surgical, and forensic applications. Clinicians should consider these anatomical differences during diagnosis and procedures. Further research with larger, diverse populations and complementary in vivo imaging is advised to enhance the accuracy and applicability of these findings.

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