Sri Lanka Journal of Forensic Medicine, Science & Law — May 2025;16(Special Issue):1-5
DOI: https://doi.org/10.4038/sljfmsl.v16i5.8020

ORIGINAL ARTICLE

ANALYSIS OF DIAPHRAGMATIC MORPHOLOGY AND CAUSE OF DEATH: AN AUTOPSY STUDY AT DISTRICT GENERAL HOSPITAL, KEGALLE, SRI LANKA

Nayakarathne NMTB[1]*, Vadysinghe AN[2], Wijerathne NASP[1], Ekanayake EMKB[2]
[1]*Office of the Judicial Medical Officer, District General Hospital, Kegalle, Sri Lanka*
[2]*Department of Forensic Medicine, Faculty of Medicine, University of Peradeniya, Peradeniya, Sri Lanka*

ABSTRACT

The lack of detailed morphology of the diaphragm limits the understanding of its pathological manifestations. Objective: The objective of this study was to assess the diaphragmatic morphology of the height, sex, age, and the organ systems involved in the cause of death (COD). This prospective cross-sectional autopsy study was conducted at the District General Hospital, Kegalle, Sri Lanka. Diaphragms, dissected using Letulle's technique at the autopsy, were measured for weight, anteroposterior (APD) and transverse (TD) diameters, costal and vertebral thicknesses, and the demographic features, body height and COD were recorded. The sample of 252 individuals consisted of 57.9% males, and the mean body height was 156.68 cm. Multiple comorbidities were recorded in 34.1% of the cases, and cardiovascular diseases contributed to 28.2% as COD, while the respiratory system and central nervous system contributed with 20.2% and 11.1% of cases, respectively. Means of weight, APD, TD, left and right costal thickness, and left and right vertebral thickness were 187.5 g, 19.4 cm, 33.1 cm, 1.6 cm, 1.6 cm, 2.7 cm, and 2.8 cm, respectively. All the diaphragmatic parameters showed positive linear correlations with body height. When the Kruskal-Wallis test was applied, males recorded higher mean rank values in diaphragmatic parameters, and the difference between the sexes was statistically significant. Diaphragmatic parameters showed statistically significant differences across age groups, with the youngest subjects recording higher values in diaphragmatic measurements. There were statistically significant differences across organ systems in all diaphragmatic parameters. Diaphragmatic measurements showed positive linear correlations with the subjects' heights, and males recorded higher values in diaphragmatic parameters than females. Values of the diaphragm measurements decreased with increasing age and showed significant differences across the organ systems involved in CODs.

Keywords: *Autopsy; diaphragm; morphology*

Corresponding author: Nayakarathne NMTB
tharanga.nayakarathne@yahoo.com
https://orcid.org/0000-0003-3232-3552

ARTICLE HISTORY
Received: 28.12.2024
Received in revised form: 09.02.2025
Accepted: 21.02.2025
Available online: 30.05.2025

INTRODUCTION

The diaphragm is a dome-shaped fibromuscular structure separating the thoracic and abdominal cavities. The most common pathologies of the diaphragm include hernias and phrenic nerve damage. The phrenic nerve is commonly damaged due to trauma or surgery. Compressive space-occupying lesions in the thorax, including mediastinal tumours, lung cancers, aortic aneurysms, substernal goitres, and cervical spondylosis, can cause diaphragmatic weakness due to phrenic nerve compression[1]. Many neurological and inflammatory conditions will cause impairment of the phrenic nerve and diaphragmatic weakness[2]. Due to some diseases like emphysema, sarcoidosis, amyloidosis, and muscular dystrophy, the configuration of the diaphragm will be changed.

As discussed above, the diaphragm is one of the most important organs of the human body, and many disease conditions affect its morphology. However, in most routine autopsies, the diaphragm is not considered a major contributing organ in a death investigation[3]. This study aimed to emphasise the importance of the diaphragm in death investigation and improve the standards of autopsy practice.

OBJECTIVES

The main objective of this study was to assess the morphological pattern of the diaphragm in the Sri Lankan population. Specific objectives included the assessment of the morphology of the diaphragm related to the height, sex, age, and the organ systems involved in the cause of death (COD).

METHODS

This prospective cross-sectional study was commenced after obtaining ethical approval from the Ethics Review Committee of the Teaching Hospital, Kurunegala, Sri Lanka (Ref. No ERC/2022/15). All autopsies, where the deceased was 18 years and older, conducted consecutively during the period between the 1st of August and the 31st of December 2022, at the District General Hospital, Kegalle, Sri Lanka, were included. Foreign nationals, previously diagnosed individuals with congenital or acquired anatomical defects of the diaphragm, and putrefied bodies were excluded.

The height of the body was measured in centimetres. The diaphragm was dissected using Letulle's method. The weights, diameters, and thicknesses were measured in grams, centimetres, and millimetres, respectively. Data was analysed using IBM SPSS Statistics version 26. Associations between continuous variables were analysed using Spearman's correlation test, while associations between categorical variables were analysed using non-parametric tests, including the Mann Whitney-U test and the Kruskal-Wallis test. A 95% confidence interval was considered for all the statistical tests.

RESULTS

The study sample consisted of 252 deaths, comprising 146 males (57.9%). The mean height of the study sample was 156.68 cm.

Table 1: Descriptive statistics of the morphology of the diaphragm

Parameter	Mean	Standard deviation	Minimum	Maximum
Weight(g)	187.5	49.508	106	322
Diameter(cm)				
Antero-posterior Diameter (APD)	19.4	1.725	15	24
Transverse Diameter (TD)	33.1	2.242	28	37
Thickness(mm)				
Costal thickness				
Left	1.6	0.471	0.8	2.9
Right	1.6	0.464	0.8	2.7
Vertebral thickness				
Left	2.7	0.657	1.3	4.3
Right	2.8	0.697	1.4	4.4

Table 2: Organ systems involved in the cause of death

Organ system	Cause of death, n (%)
Cardiovascular system (CVS)	72 (28.2)
Respiratory system (RS)	51(20.2)
Central nervous system (CNS)	28(11.1)
Gastrointestinal system (GIS)	12(4.8)
Genitourinary system (GUS)	10(4.0)
Musculoskeletal system (MS)	2(0.8)
Other	77(30.6)

Table 3: Correlation coefficients between the height and measurements of the diaphragm

Correlation with height		Spearman's rho	p-value
Weight (g)		0.598	<0.001
Diameter (cm)	APD	0.465	<0.001
	TD	0.472	<0.001
Costal thickness (mm)	Left	0.340	<0.001
	Right	0.025	0.694
Vertebral thickness (mm)	Left	0.259	<0.001
	Right	0.123	0.052

Upon analysing the relationship between COD and diaphragmatic morphology, important insights emerge. The leading COD in this study was related to the cardiovascular system (Table 2). The weight of the diaphragm in association with cardiovascular COD was the highest among the mean ranks of organ systems when the Kruskal-Wallis test was used. It suggests that there could be a relationship between the two. It has been shown using animal models and ultrasound studies that the diaphragm may show adaptations to chronic heart failure[5,6]. Obesity, which is a risk factor for cardiovascular disease, is known to alter the morphology of the diaphragm, leading to its dysfunction[7,8]. Hence, it could be assumed that diaphragmatic morphology can be related to cardiovascular pathologies, but needs more research-based evidence.

Table 4: Associations between diaphragmatic measurements and categorical variables

Variable		Sex		Age group		Organ system in COD	
Test		Mann-Whitney U	p-value	Kruskal-Wallis H	p-value	Kruskal-Wallis H	p-value
Weight (g)		2078.500	<0.001	102.208	<0.001	29.311	<0.001
Diameter (cm)	APD	4428.000	<0.001	108.863	<0.001	19.795	0.003
	TD	3717.000	<0.001	67.875	<0.001	37.332	<0.001
Costal thickness mm)	Left	4300.000	<0.001	76.705	<0.001	16.147	0.013
	Right	7245.000	0.386	27.590	<0.001	17.994	0.006
Vertebral thickness (mm)	Left	6500.500	0.030	69.922	<0.001	25.472	<0.001
	Right	6692.500	0.067	42.323	<0.001	27.331	<0.001

DISCUSSION

The current study demonstrated linear positive relationships between the height of the individuals and the diaphragmatic measurements. The mean values of the morphological characters assessed in this study were greater in men than in women, and the differences were statistically significant except for two parameters (Table 4). Differences in body dimensions between the sexes and hormonal activity may have played a role in the difference in morphology between males and females[4]. Younger populations showed heavier and larger diaphragms compared to the older, as indicated by the higher mean ranks obtained in the Kruskal-Wallis test, and these values gradually reduced as the age progressed.

Respiratory system-related CODs showed relatively higher mean ranks in diaphragmatic measurements. A previous study of breathing patterns in females showed significant differences in diaphragm thickness with breathing pattern disorders compared to control groups[7]. This indicates that acute and chronic diseases in the respiratory system are likely to cause functional and morphological changes in the diaphragm[9,10]. This may be the explanation for the findings of the current study.

CONCLUSION

Diaphragmatic measurements showed positive linear correlations with the subject's height, with males having higher values in diaphragmatic parameters than females. Values of the diaphragm measurements decreased with increasing age. A significant difference was observed across the organ systems involved in the COD and diaphragm measurements.

ACKNOWLEDGMENTS

None.

CONFLICTS OF INTEREST

The author declared no conflicts of interest.

DISCLOSURE

ANV and EMKBE are members of the Editorial Board of the Sri Lanka Journal of Forensic Medicine, Science & Law. Therefore, they did not participate in any way in the publication/decision-making process of this submission, as per journal policy.

ETHICAL ISSUES

The ethical approval for this study was obtained from the Ethics Review Committee of the Teaching Hospital, Kurunegala, Sri Lanka (Ref. No. ERC/2022/15).

SOURCES OF SUPPORT

None.

AUTHOR CONTRIBUTIONS

NMTBN: Conception and design of the work; the acquisition, analysis, and interpretation of data for the work; drafting the work and revising it critically for important intellectual content; and approval of the version to be published. **ANV:** Conception and design of the work; the acquisition, analysis, and interpretation of data for the work; drafting the work and revising it critically for important intellectual content; and approval of the version to be published. **NASPW:** Conception and design of the work; the acquisition, analysis, and interpretation of data for the work; drafting the work and revising it critically for important intellectual content; and approval of the version to be published. **EMKBE:** Analysis, interpretation of data for the work; drafting the work and revising it critically for important intellectual content; and approval of the version to be published.

REFERENCES

1. Liu S, Dai M, Ye B, Zhao Z, Shi Y, Peng L. Diaphragmatic hernia as a rare complication of colonoscopy: Case report and literature review. *Medicine*. 2018;97(3):e9660. https://doi.org/10.1097/MD.0000000000009660.

2. Ricoy J, Rodríguez-Núñez N, Álvarez-Dobaño JM, Toubes ME, Riveiro V, Valdés L. Diaphragmatic dysfunction. *Pulmonology*. 2019;25(4):223-35. https://doi.org/10.1016/j.pulmoe.2018.10.008.

3. Gurses MS, Eren F, Inanir NT, Eren B, Çetin S. Diaphragmatic Eventration: *Autopsy Case Report*. Maedica. 2016;11(1):84.

4. LoMauro A, Aliverti A. Sex and gender in respiratory physiology. *European Respiratory Review*. 2021;30(162). https://doi.org/10.1183/16000617.0038-2021.

5. De Sousa E, Veksler V, Bigard X, Mateo P, Serrurier B, Ventura-Clapier R. Dual influence of disease and increased load on diaphragm muscle in heart failure. *Journal of Molecular and Cellular Cardiology*. 2001;33(4):699-710. https://doi.org/10.1006/jmcc.2000.1336.

6. Peirce S, Mooney S, Rohan M, Ellis R. Ultrasound imaging measurements to determine reduced diaphragm thickness and relevance to breathing pattern disorders diagnosis in females. *WFUMB Ultrasound Open*. 2023;1(2):100010. https://doi.org/10.1016/j.wfumbo.2023.100010

7. Boriek AM, Lopez MA, Velasco C, *et al*. Obesity modulates diaphragm curvature in subjects with and without COPD. *American Journal of Physiology-Regulatory, Integrative and Comparative Physiology*. 2017;313(5):R620-9. https://doi.org/10.1152/ajpregu.00173.2017.

8. Rodrigues GC, Rocha NN, Maia LdA, *et al*. Impact of experimental obesity on diaphragm structure, function, and bioenergetics. *Journal of Applied Physiology*. 2020;129(5):1062-74. https://doi.org/10.1152/japplphysiol.00262.2020

9. Donovan AA, Johnston G, Moore M, *et al*. Diaphragm morphology assessed by computed tomography in chronic obstructive pulmonary disease. *Annals of the American Thoracic Society*. 2021;18(6):955-62. https://doi.org/10.1513/AnnalsATS.202007-865OC.

10. Reid DW, Sharma A, Elliott MW, Davis JE. Diaphragm morphology at postmortem in people with acute and chronic respiratory disease. *Cardiopulmonary Physical Therapy Journal*. 2004;18(2):3-12.