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An Autopsy Study of the Quantitative Anatomy of Human Heart

S. Raveendran[1*], M. Vidanapathirana[1] and S. R. Hulathduwa[1]

[1]Department of Forensic Medicine, Faculty of Medical Sciences, University of Sri Jayawardenepure, Nugegoda, Sri Lanka.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

There is no uniformity in obtaining anthropological measurements of the heart. Measurementsvary according to the methods used by different authors. The normality standard for organ weights should be established in a specific reference sample for each population, as the normality values can be different under genetic and environmental influences. This study is aimed to determine the average values of quantitative anatomy of the adult heart for the Sri Lanka population using autopsy data with an attempt to determine the relationship with sociodemographic factors such as the body weight, age, gender and the body length. Designed as a descriptive cross-sectional prospective study, it was performed on fresh (unfixed) adult hearts recovered at medico-legal autopsy on deaths due to non-cardiac natural causes and miscellaneous unnatural causes for a period of one year. Systematic consecutive sampling method was used from September 2018 to September 2019. Only 122 samples (68 males and 54 females) were included from among 282 adult hearts collected during this period due to strict inclusion and exclusion criteria. Average weight of the heart, thicknesses of the inter-ventricular septum, free wall of the left ventricle and right ventricle for males and females were 296.1 g, 236.85 g, 9.71 mm, 9.52 mm, 1.28 cm, 1.19 cm and 3.41mm, 3.02mm respectively. Male heart weight, interventricular septal thickness and other findings were compatible with contemporary Eastern studies. Significant association was

**Corresponding author: E-mail: sanjayarh@yahoo.co.uk, sanjaya@sjp.ac.lk;*

demonstrated in the wall thickness of right ventricle with gender (P- value being 0.038). Large scales multi centered studies to find out the normality standard for heart measurements in Sri Lankan population are recommended.

Keywords: Anthropometric studies (of heart); cardiac dimensions; left ventricle; interventricular septum; cardiac valves; heart weight.

1. INTRODUCTION

Cardiovascular disease is a leading cause for sudden and unexpected natural deaths across the globe, Sri Lanka being not an exception. Almost 80% of the causes for sudden and unexpected natural deaths are associated with cardiovascular pathology [1]. Structural and functional disturbances of the cardiovascular system could lead to death anytime during life-from birth to extreme old age [1,2]. Certain structural abnormalities and molecular level anomalies pose a challengeto the forensic pathologist. Structural anomalies such as Wolff-Parkinson White Syndrome and certain molecular-level anomalies such as cardiac ion channelopathies including but not limited to long QT syndrome, short QT syndrome, Brugada syndrome and Catecholaminergic polymorphic ventricular tachycardia (CPVT) etc. are extremely difficult to detect even after meticulous autopsy [2,3]. Most of the gross structural and morphological abnormalities of the heart could be detected evidentially by anthropometric studies including but not confined to the heart weight, wall thicknesses, valvular dimensions and anatomical structure of different parts of the heart [4-9]. Hearts with structural abnormalities are found to be electrically unstable and as such could lead to cause sudden death due to various mechanisms such as arrhythmias and pump failure [1-3]. Therefore, structural anomalies of a heart may lead to functional disturbances causing sudden death at stage of life [2]. This entity is considered as a separate phenomenon from ischemic heart disease caused due to coronary atherosclerosis. Most of the structural abnormalities of the heart could be detected with moderate accuracy by adapting anthropometric measures [4]. These methods are cost effective and bare a significant degree of scientific reliability if proper reference values are provided.

A national-level quantitative anthropometric researches enable on to produce a valid data set and reference values for a nation which is an ideal approach in the low income third-world countries where sophisticated tools such as CT, MRI, immunohistochemistry and genetic studies are often not freely available to conduct sophisticated postmortem research. This is a preliminary study of such nature done as a pilot study for Sri Lanka.

2. LITERATURE REVIEW

The quantitative anatomy of the heart varies with several variables such as body habits and gender. The existing practice in most of the less-developed countries is to apply the standard Western values without revalidation to one's own population. This may lead to either under-diagnoses or over-diagnoses of certainpathologic conditions of the heart. Inadvertent application of Western reference values of quantitative anatomy of the heart without regional and ethnic modifications could especially lead to under-diagnosis of left ventricular hypertrophy, dilation, cardiomegaly, mitral stenosis and aortic stenosis as well as mislead the postmortem diagnosis of hypertensive heart disease, hypertrophic obstructive cardiomyopathy, valvular heart diseases, congenital heart diseases, senile cardiomyopathy and etc. [4]. Sometimes, it would also lead to over-diagnosis of ischemic heart disease especially when it is combined with other cardiac pathology. Left ventricular thickness of average western population is 1.3 to 1.5 cm [4] though it is 1.1 cm to 1.3 cm in average Indian population [3]. In Sri Lanka, no effective studies have been conducted during the past on this matter. Thus resorting to Western values may lead to under-diagnosis of hypertensive heart disease while resorting to Indian values may lead to over-diagnosis of the same. As studies on comparative anatomy of the heart are scanty in Sri Lankan medical literature, this study was designed to find out the reference values for own population. The present study has some degree of limitations in samples selection, sample size and duration of the study. This study, therefore could be considered as a pilot study providing a good starting point. These values will assist in the standardizations of medicolegal autopsies in Sri Lanka. These values could also be used in other fields of medicine as their reference values as in Echocardiogram-related studies, post-mortem and ante-mortemechocardiography (MRI

and CT) and in general pathology for pathological autopsies [10-12]. The researchers have identified that there was no uniformity in the methods of obtaining anthropological measurements. It varies from study to study, country to country, region to region and even within the same country, it varies from author to author. This fact should also be considered when interpreting the values and comparing the values obtained by different authors. This has been equally ignored by the clinicians and the pathologists. This is well demonstrated in studies done in formalin fixed and fresh samples obtained from cadavers as well as in studies involving echocardiography and explanted hearts following heart transplantation [13]. For example, non-compaction left ventricle (NCLV) could be diagnosed either with echocardiography or during autopsy examination by comparing the ratio of the thickness of the non-compacting endocardialtrabeculae with thickness of the left-ventricular wall. This is a type of cardiomyopathy not classified by WHO in ICD 10. It could be over diagnosed or underdiagnosed if measurements are not taken from the proper places of the heart [14]. Relevant literaturestates that over diagnosis is common due to the unavailability of a uniform protocol [14,15]. Measurements of left ventricular thickness may be taken from proximal/ middle or apex part of the free wall. Formation of a uniform protocol is crucial (at least within the country) to overcome these problems. One previous study indicated that the limitation of valve measurements at autopsy is less important when the measurements are taken after the annulus is opened [16]. The circularized aortic annulus was calculated for clinical comparison and insertion of a valve prosthesis. In this case The echo measurements of aortic valve reference studies may be more accurate than open dissection cadaveric studies though autopsy studies could still be used as measures of obtaining baseline values [16,17].

2.1 Objectives

The General objective of the study was to determine the average quantitative anatomy of the adult heart in autopsies done at Colombo South Teaching Hospital, Sri Lanka.

The specific objectives were to:

a. ascertain the weight of the heart
b. ascertain the thicknesses of the inter-ventricular septum and wall of the left and right ventricles
c. assess the variation of above variables with the demographic factors such as the body weight, age, gender and body length/height of the individual

3. METHODOLOGY

This study was designed as a cross -sectional descriptive study and conducted in a prospective observational manner where it was carried out at the Colombo South Teaching Hospital-Sri Lanka. Data collection was done for a period of one year from the 26th of September 2018 26th of September 2019. Ethical clearance had been obtained from the Ethics Review Committee of the Colombo South Teaching Hospital. Medicolegal autopsy cases of unnatural deaths (accidents, suicides, and homicides) and natural deaths of non-cardiac causes were studied. Though 282 samples of hearts were studied and analyzed, only 122 samples were included in this study for final data analysis due to strict inclusion and exclusion criteria. Written informed consent of the legal claimant of the dead body had been obtained prior to obtaining information and anonymity had been maintained at all times, denoting each case only with a serial number. Age of the deceased being between 18-65 years, absence of putrefactive changes and the circumstances of the death being unnatural or anything natural with a non-cardiac origin were taken as inclusion criteria. The deceased being outside the aforesaid age range, deaths of those who are not Sri Lankans, bodies with evidence of putrefaction, presence of malnutrition or debilitating illnesses such as cancer, tuberculosis, chronic kidney diseases and the presence of cardiac pathology such as hypertensive heart disease, valvular heart disease, ischemic heart disease, congenital heart disease and cardiomyopathy with structural disturbances were taken as exclusion criteria. Certain samples had to be removed from the study only after the discovery of histological evidence of cardiac pathologies including coronary a theroma or myocardial fibrosis. Data had been collected from the hospital records, attending police officers and the relatives of the deceased. Anatomical details of the heart were collected manually on a spread sheet during each autopsy. The weight of the corpse was measured in the dorsal decubitus position, by using an electronic platform weighing scale after removing all cloths, heavy ornaments and foot wear foot wear. The length of the corpse was measured in the dorsal decubitus position, using an inelastic measuring tape from the top of the

head (vertex) to the heel after removing the foot wear. The heart was eviscerated with epicardial fat including the proximal 1 cm part of the aorta, pulmonary artery and superior venacava. Inferior venacava was resected at diaphragmatic level. The heart was cut open according to the flow of blood pattern. All blood clots were removed. Gross findings at the autopsy including heart weight, wall thickness of the left ventricle, right ventricle and septum were recorded in the printed pro forma at the autopsy. The weight of the hearts was measured after dissection but with all parts intact, using a digital electronic weighing scale. Wall thicknesses was measured 1 cm below the annular ring of at rioventricular brim using a digital Vernier calliper.

Though assistance from two medico-legally trained doctors had been sought for collecting historical and clinical data, the dissection of the hearts, obtaining anatomical details and preparation and interpretation of histological slides were done by the investigators themselves. Hematoxylin and Eosin slides were prepared from standard sections of the heart muscle and coronary vessels and histological evidence of significant coronary atherosclerosis and myocardial disease such as myocarditis and myocardial fibrosis were excluded before selecting/including each case for the study. Though 282 cases were collected initially, only 122 had been selected for the study as the bulk of exclusions had taken place at the level of histological exclusion. Raw data collected on spread sheets were shifted to an electronic format. Data were coded and entered in Microsoft excel worksheets and analysed by using Statistical Package for Social Sciences (SPSS) version 21. Graphs and tables were used as appropriate to present the findings.

4. RESULTS

Out of the initial 282 autopsies, only 122 cases fulfilled all criteria of selection for this study. Out of 122, 68 (55.7%) were male and 54 (44.3%) were female. Thus the male - female ratio of 1.25: 1 was observed. The majority was in the age group of 50-64 years.

The length/height was in the range of 142 cm-186 cm and the weight in the range of 35.5 kg-102 kg. The heart weight of the autopsy was observed in the range of 150 g to 435 g. Male had the higher mean value than female.

The distribution of heart weight with the body weight and body length are illustrated in the Fig. 1. Results showed that there was a linear relationship between heart weight with body weight and body length of the deceased.

The weight of the heart increased with the body weight and body length in both males and females. Weight of the heart was comparatively higher in the male than in the female. Average heart weight was (Average heart weight / weight percentage – 0.473) 0.47% of the body weight in our study sample. The average heart weight, wall thickness of the right ventricle (RV), the left ventricle (LV) and the inter ventricular septum (IVS) were higher in the male compared to the female. The heart weight and wall thicknesses were highest in the age group of 35-49 years.

Table 1. The distribution of gender with age groups

Age group	Gender		Total
	Male	Female	
<35 years	20 (16.4%)	24 (19.7%)	44 (36.1%)
35 – 49 years	22 (18.0%)	10 (8.2%)	32 (26.2%)
50 – 64 years	26 (21.3%)	20 (16.4%)	46 (37.7%)
Total	68 (55.7%)	54 (44.3%)	122 (100.0%)

Table 2. The distribution of average heart weight (g) among age groups and gender

Age group	Gender	
	Male	Female
<35	249.35	202.67
35-49	325.5	272
50-64	307.30	260.3
Average heart weight (g)	296.14	236.85

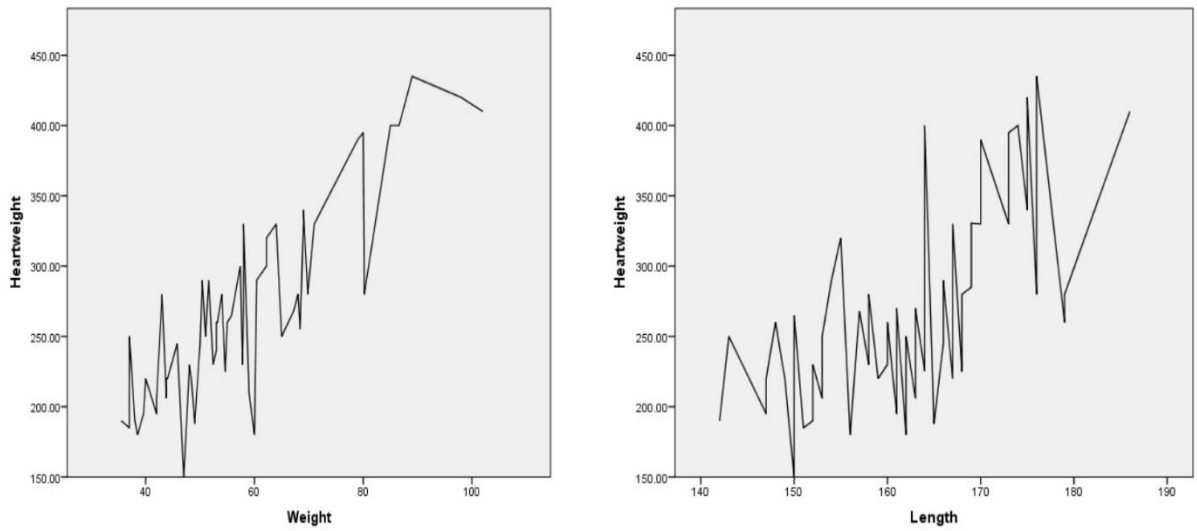

Fig. 1. The distribution of heart weight with body weight and body length

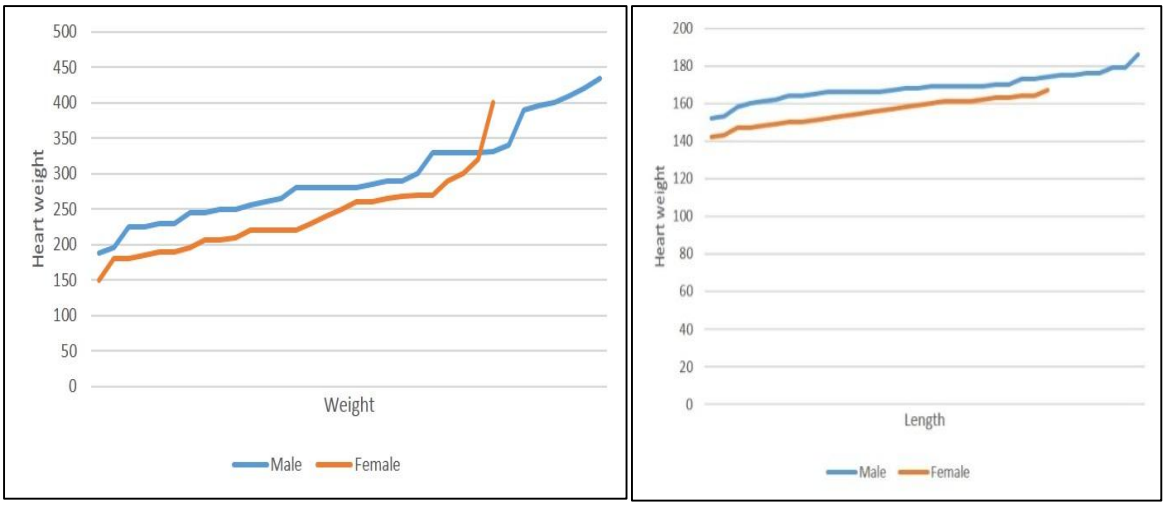

Fig. 2. The distribution of the heart weight with the bodyweight and body length among males and females

Table 3. Average heart weight, wall thickness of right ventricle (RV), left ventricle (LV) and inter ventricular septum(IVS) with age group and gender

Age group (years)	Average Heart weight (g)		Average Wall thickness LV (cm)		Average Wall thickness of RV (cm)		Average wall thickness of IVS (cm)	
	Male	Female	Male	Female	Male	Female	Male	Female
<35	249.4	202.7	1.19	1.09	3.01	2.61	9.28	8.97
35-49	325.5	272	1.33	1.29	3.43	3.53	9.88	10.86
50-64	307.3	260.3	1.29	1.25	3.71	3.26	9.89	9.51
	296.2	236.9	1.28	1.19	3.41	3.02	9.71	9.52
Average	269.9(SD 66.52)		1.24(SD 0.16)		3.24(SD 0.63)		9.62 (SD 1.39)	

The average values of the circumference of mitral valve, aortic valve, tricuspid valve and pulmonary valve were higher in the male than in the female.

Table 4. Pearson chi square test for association of heart measurements

Association of measurements	P value
Association of heart weight with gender	0.134
Association of heart weight with age	0.250
Association of heart weight with weight	0.428
Association of heart weight with length	0.404
Association of wall thickness of LV with gender	0.248
Association of wall thickness of LV with age	0.656
Association of wall thickness of LV with weight	0.723
Association of wall thickness of LV with length	0.095
Association of wall thickness of RV with gender	**0.038**
Association of wall thickness of RV with age	0.628
Association of wall thickness of RV with weight	0.918
Association of wall thickness of RV with length	0.057
Association of wall thickness of IVS with gender	0.278
Association of wall thickness of IVS with age	0.239
Association of wall thickness of IVS with weight	0.905
Association of wall thickness of IVS with length	0.814

5. DISCUSSION

Since this study was done on freshly autopsied adult human hearts, it excludes the error due to fixation [18]. It is designed to gather anthropometric cardiac measurements in a sub set of Sri Lankan population. This type of anthropometric data are a prerequisite for the accurate interpretation of echocardiography, ante-mortem and post-mortem cardiac MRI and CT [10-12], surgical reconstruction and repair of the heart and valves [18,19] and interpretation of cardiac measurements in pathological and medico-legal autopsies. There appears to be a geographical/racial variation on the norms of measurements for the heart and it was proven in most of the studies done in other countries [20-22] as well as in Sri Lanka [18,19]. Data on normal cardiac anthropometric measurements for the Sri Lankan population are scarce and scanty. In the present study, the researchers adhered to a uniform protocol during all steps of sample collection to increase the internal validity of the study as described in 'methodology'.

The normality standard for organ weights must be established in a specific reference sample for each population, as the normality values can be different under genetic and environmental influences [23]. This fact is corroborated by the study of Dadgar et al. [24] who, after examination of 100 bodies with no cardiac abnormalities, reported that the mean total weight of the Indian hearts was lower than what is reported in literature for other racial groups.

The average heart weight in the present study was calculated as 270 g [SD 66.5] and mean heart weight was higher in males (296 g SD 11.2) and lower in females (237 g SD 10.15). The average heart weight for male was almost the same as the Caucasian and Korean [25,26] but higher than for Indians [22,24] and Bangladeshi [27]. The mean female heart weight is lower than that of Caucasian [21,23] and Korean [25,26] females, higher than that of Bangladeshi females [27] and almost the same as Indian [22] and Thai population [28]. In Uttarakhand region, case materials collected from 109 autopsies for a period of one year revealed that average heart weight was 270.28±54.41 g and in for the males and 204.35±57.35 g for the females [22]. A Korean study including 422 samples revealed that the average heart weight in male was 305 g and in females it was 265 g [25]. For Caucasians populations, it was revealed that the average heart weight ranged between 280-340 g for the male and 230 – 280 g for the female [21]. In Bangladesh, a total of fifty normal human hearts from both sexes were collected during routine postmortem examinations and these were subjected to anthropometric studies. This study revealed that the average heart weight was 247.92 (+/-40.26) g inmales and 164.29 (+/-33.56) g in females [27]. Among the Thai populations, the average heart weight was found to be 291g for males and 246 g for females [28].

Another study done in Colombo North with 38 heart samples revealed that the mean values of the heart weight was 280.52g (SD+/- 42.60), while it was calculated as 293.94 g (SD+/-39.29) for males and 267.15 g (SD+/-42.64) for females. However, there was no significant association of heart weight with gender (P= 0.46410) according

to the above study, though the representativeness of the population (N= 38) has to be considered cautiously in this study [29].

Our descriptive analysis highlights that there is a difference in heart weight among races and also between the two genders. Male heart is heavier than the female heart. Heart weight tends to increase with the body weight in both sexes. It was compatible with several studies conducted in Japan [30], China [31] and India [32] while being inconsistent with certain other studies. Some studies highlight that heart weight is independent on body weight [29]. The same authors suggest that the heart weight is dependent on the Body Mass Index (BMI) [29] or on the body surface area.

The heart weight was increasing significantly up to the age of fifty years both in males and females in our study. At this point, it has to be emphasized that this is pertaining to the individuals with no demonstrable cardiac pathology. Then it was slightly but gradually reducing until the age of sixty-five, though this reduction was not significant. This may be due to pure chance or age related atrophy of the cardiac muscle or owing to the reduction of epicardial fat. We do not have any significant data for individuals after the age of 65 as those were excluded from the study. These findings were compatible with some previous studies [30-32] while not in keeping with certain other studies [26]. In one study based on Japanese populations, it was evident that the heart weight increases with age up to 90 years and only there after starts to decrease [33]. This should be considered in the light of their average life expectancy which is higher than the average for Sri Lankan populations. In the Chinese population, heart weight was found to be constant after adulthood with a slight increase with advancement of age [34].

Weight of the heart was found to be increasing with body-length/height of the individual in both genders in our study though this increase of heart weight was not statistically significant (Figs. 1 and 2). It was compatible with some studies conducted in Japan [30], China [31], India [32] and Mayo Clinic [35,36] while inconsistent with certain other studies [26]. Some studies highlight that the heart weight is independent of the body length/height [26], though it was dependent upon the body mass index [29] or the body surface area [26].

The average wall thickness of the left ventricle was 1.24 cm (SD 0.16) in our study population and the mean values were almost same for males (1.28 SD 0.03) and females (1.19 SD 0.03). The average left ventricular wall thickness in our study was quite similar to the values for Asians and Indians [4] while lesser than the value for Caucasians [1,2]. It should be highlighted here that there is a significant difference between the Western text book values for the left ventricular wall thickness and the values for Sri Lankans as discovered by our research [21]. This fact has to be considered when interpreting the findings of hypertrophic cardiomyopathy, non-compaction of left ventricle(NCLV) and hypertensive heart disease in echocardiography, MRI as well as in the interpretation of autopsy findings of the Sri Lankan populations.

The left ventricular free wall thickness was 12.3 mm (SD: 1.6 mm) in Mayo Clinic investigation [36] and 12.6 mm in another contemporary research [37] both of which were quite proximate to the value obtained in our study. The left ventricular free wall thickness was 15.0 mm in certain other reports [38,39] which were significantly higher than the value found in our study. A good correlation exists between ventricular wall thicknesses measured in autopsy specimens and those measured during systole by two-dimensional echocardiography in living patients [40,41].

The average wall thickness of the right ventricle was 3.24mm (SD 0.63) in our samples and the mean values were slightly higher in males (3.41mm SD 0.09) compared to females (3.02 SD 0.13). The average wall thickness of our sample was quite similar to the values for Asians, Indians [4] and the Caucasians [1-3]. Caucasian value was between 3-5mm [1-3] and there is no significant difference between this and the Western text book values [4,21]. The mean thickness of the right ventricular free wall was 3.8 mm (SD 0.9 mm) in Mayo Clinic study [36] and 3.9 mm and 4.0 mm in two other studies [38,39]. In another large-scale study it was found that the ventricular wall thicknesses were similar for women and men and that the thicknesses of the right and left ventricular free walls, indexed by body surface area, remained relatively constant throughout the adult life [36]. These facts should be considered when interpreting the thickness of the right ventricular wall for hypertrophy fallowing pulmonary hypertension due to lung parenchymal diseases fallowing various intrinsic

and extrinsic causes in Echocardiography and MRI and also in autopsy studies of Sri Lankan population.

The average thickness of the septum was 9.62 mm (SD 1.39) in our samples and the mean values were almost the same in males (9.71mm SD 0.25) and in females (9.52 SD 0.26). The average wall thickness of our sample was almost similar to the Asians and Indians [4] though lower than the average value for Caucasian populations [1,22,36,38].The mean ventricular septal thickness was 13.6 mm (SD, 2.0 mm) in Mayo clinic study [36] and 15.0 mm in another study done in 1973 based on the Western populations [38].

For the dimensions of the ventricular septal thickness, there is no significant difference between Western text book values and our values [21]. The interventricular septal thickness increased from a median of 8.3 mm in the 20-29year-old age group to 11.2 mm median for the group between 60-70 years of age, according to one Caucasian study [36]. Further, this study suggests that the interventricular septal thickness should be co-related with the age of the individual when assessing the significance of its thickness. According to our study, there was no age-related increase in the thickness of the ventricular septal wall in males though the thickness was increased in the middle aged (35-50 year) group of females.

Appreciable increase in indexed ventricular septal thickness was observed in the 7th through 10th decades of life in Mayo Clinic study [36] and this would probably have been due to the age-related changes in the angle between the ventricular septum and aorta-the so called angled or sigmoid septum. As a result, the ratio between ventricular septal and left ventricular free wall thicknesses tend to widen during these decades which may often exceeded 1.3.

One of the Brazilian study reveals that there is no significant difference in the thickness of the septum with age or gender [42]. In this study, the septal thickness in millimeters was 8.1 (0.8), 8.4 (0.8), 8.5 (0.8) and 8.5 (0.6) for the age groups 30-39 years (n = 57),40-49 years (n= 39), 50-59 years (n = 75) and ≥60 years (n = 37) respectively [42].

Occupation and exercise can significantly alter the heart weight by inducing physiological hypertrophy in regular athletes, professional swimmers and gymnastic players [43]. Heart samples from heavy athletes was excluded in this study to increase the internal validity of the study. Heart weight changes with occupation was not analyzed in this study due to lack of accurate data in the history. Exercise-induced cardiac hypertrophy is no different from mild cardiac hypertrophy resulting from other pathological causes. Sudden death in trained athletes who have no evidence of specific heart disease may be a direct consequence of cardiac hypertrophy and altered repolarization [43]. Not only hypertrophy, exercise induce remodeling causes reduced resting heart rate and increased Calcium release from sarcoplasmic reticulum also may promote extra systoles and arrythmogenic triggers and sudden death [44]. This condition is termed 'Athlete's Heart' by some authors though this conclusion may not be totally accepted by certain other authorities [45]. As such there is still an unsettled proposition on 'Athlete's heart' in the scientific community. Data from 20 years of echocardiographic investigations of athletes and non-athletes indicate that differences in cardiac dimensions are not very significant [46].

Our study was a simple cross sectional descriptive study, which was designed to demonstrate the anthropometric measurements of the adult human heart. Changes of the values were analyzed with socio-demographic factors such as body weight, age, gender and the body length/height. These were described already in the discussion above. Finally, we did a parametric test to determine whether these associations are actually significant or whether they are simply due to chance. P value of Pearson chi square test was applied to test the hypotheses even though the sample size was 122. (Most of the contemporaneous or older studies done elsewhere in the globe had lesser sample sizes compared to our research).

No significant association was demonstrable between the heart weight and the gender, age, body weight or the length/height of the individualthe p values being 0.134, 0.250, 0.428, 0.404 respectively. This was again the same for the left ventricular thickness against gender, age, body weight and the length/height where respective p values are 0.248, 0.656, 0.723 and 0.095. This might be due to several causes such as inadequate sampling (qualitative and quantitative), presence of extreme outliers or true absence of correlation with socio demographic factors.

A significant association was demonstrated in the wall thickness of right ventricle with gender where the P value was 0.038.

6. CONCLUSIONS AND RECOMMENDATIONS

This study gives detailed knowledge of the macroscopic anatomy of the heart with anthropometric measurements in a sub set of Sri Lankan population who were residing in or near Colombo South. This study gives valuesof average quantitative anatomy of the adult heart based on autopsies done in Teaching Hospital, Colombo South. It gives the average weight of the heart, thicknesses of the inter-ventricular septum, left ventricle and right ventricle and circumferential length of the mitral, aortic, tricuspid and pulmonary valves. This study also ascertains the variation of heart measurements with the demographic factors such as weight, age, gender and the body length/height. Though this is a preliminary study, the data could be used as baseline information for the Sri Lankan populations minimizing the errors incurred due to importation of Western data without a proper validation for Sri Lanka.

Anatomical measurements of the heart in the light of an understanding of the pathophysiological mechanisms and an appropriate interpretation of these reference values with age, gender, body weight and body length help to minimize the errors incurred in the interpretation of a wide spectrum of cardiac conditions during clinical interventions, imaging or at the autopsy.

We recommend large scale studies on this topic to minimize the errors and to increase the internal validity of the study and multi centered studies to increase the external validity of the study so that accurate reference values for the anatomical variations of the human heart may be compiled for Sri Lankan population.

CONSENT

Written informed consent of the legal claimant of the dead body had been obtained prior to obtaining information and anonymity had been maintained at all times, denoting each case only with a serial number.

ETHICAL APPROVAL

Ethical clearance had been obtained from the Ethics Review Committee of the Colombo South Teaching Hospital. Medicolegal autopsy cases of unnatural deaths (accidents, suicides, and homicides) and natural deaths of non-cardiac causes were studied.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Frederick JS, Richard NM. The heart; Robbins and Cotran Pathologic basis of disease. 1st ed. In.: Thomson Press ltd India. 2015;523-78.
2. Saukko P, Knight B. The pathology of sudden death. Knight's Forensic Pathology. 4th ed. In. New York: CRC Press. 2016;515-52.
3. DiMaio VJ, DiMaio D. Death due to natural diseases, Forensic Pathology, 2nd ed.. In. New York: CRC Press. 2001;64-80.
4. Umadethan B. Principles and practice of Forensic Medicine. 2nd ed. India: CBS Publishers; 2016.
5. Kitzman DW, Scholz DG, Hagen PT, Ilstrup DM, Edwards WD. Age-related changes in normal human hearts during the first 10 decades of life. Part II (Maturity): A quantitative anatomic study of 765 heart specimens from subjects 20 to 99 years old. Mayo Clin Proc. 1988;137-46.
6. Rosahn PD. The weight of the normal heart in adult males. Yale J Biol Med. 1941;209-23. Available:https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2601062.
7. Richard NM. Blood vessels; Robbins and Cotran Pathologic basis of disease. 1st ed. India: Thomson Press ltd; 2015.
8. Sampson BA, Adams VI, Hirsch CS. Sudden and unexpected death from natural causes in adults. In: Spitz and Fisher's Medico legal investigation of death. 4th ed. U.S.A: Charles C Thomas Publishers Ltd; 2005.
9. Noone P, Vasu S. Age as a predictive tool of aortic valve dimensions- An autopsy based observational study. World Journal of Pathology; 2015. Available:www.npplweb.com/wjp/fulltext/4/3.
10. Okuma H, Gonoi W, Ishida M, et al. Heart wall is thicker on postmortem computed tomography than on antemortem

computed tomography: The first longitudinal study. PLoS One. 2013; e76026.
DOI: 10.1371/journal.pone.0076026

11. College of Pathologist of Sri Lanka. Guidelines for Autopsy Pathology, National Guidelines. 2016;10-53.
Available:https://www.medicos.lk › Library › Guidelines.
12. Royal College of Pathologists of Australasia. Post-mortem in sudden unexpected death in the young. Guidelines on Autopsy Practice. 2008;21-29.
Available:https://www.rcpa.edu.au/Guidelines-on-Autopsy-Practice.
13. Song J, Xing Y, Chen X, Song Z, Teng X, Wang M, Zheng Z, Hu S. Processing of the explanted heart. N Am J Med Sci. 2014; 613-7.
PMID: 25599048
PMCID: PMC4290049.
14. Kubik M, Dąbrowska KA, Lewicka E, Daniłowicz SL, Raczak G. Predictors of poor outcome in patients with left ventricular noncompaction: Review of the literature. Adv Clin ExpMed. 2018;415-422.
15. Sarmaa RJ, Amar C, Elkayam U. Left Ventricular Non compaction. Progress in Cardiovascular Diseases. 2010;264–273.
16. Kunzelman KS, Grande KJ, David TE. Aortic root and valve relationships. Impact on surgical repair. J Thorac Cardiovasc Surg. 1994;162-70.
17. Westaby S, Karp RB, Blackstone EH, Bishop SP. Adult human valve dimensions and their surgical significance. Ame J Cardiol. 1984;552-6.
18. Udhayakumar S, Yasawardene SG. Aortic annular measurements in fresh post-mortem hearts; A study in Sri Lankans. Ceylon Med J. 2015;148-51.
19. Udhayakumar S, Yasawardene SG. Fresh autopsy study of dimensions of adult mitral valve in Sri Lankans. Peradeniya Univ. International Research Sessions. 2014; 275.
20. Mohammadi S, Hedjazi A, Sajjadian M, Ghoroubi N, Mohammadi M, Erfani S. Study of the normal heart size in Northwest part of Iranian population: A cadaveric study. J Cardiovasc Thorac Res. 2016; 119-125.
21. Gray H. Gray' Anatomy, The heart. 39th ed. In. London: Churchill. 2005;997-1003.
22. Prakash C, Deopa D, Thakkar HK. Study of internal organ weight and its correlation to body weight in Kumaon Region of Uttarakhand. J Indian Acad Forensic Med. 2013;29–32.
23. Grandmaison GL, Clairand I, Durigon M. Organ weight in 684 adult autopsies: New tables for a Caucasoid population. Forensic Sci Int. 2001;149-54.
24. Dadgar SK, Tyagi SP, Singh RP, Hameed S. Factors influencing the normal heart weight – a study of 140 hearts. Jpn Circ J. 1979;77-82.
25. Kim Y, Kim D, Cho SY, Kim MH, Yang KM, Lee HY. Statistical analysis for organ weights in korean adult autopsies. Korean J Anat. 2009;219–24.
26. Seo JS, Lee SY, Won KJ, Kim DJ, Sohn DS, Yang KM. et al. Relationship between normal heart size and body indices in Korean. J Korean Med Sci. 2000;641–6.
27. Mannan S, Khalil M, Rahman M, Ahmed MS. Measurement of different external dimensions of the heart in adult Bangladeshi cadaver. Mymensingh Med J. 2009;175-8.
28. Narongchai P, Narongchai S. Study of the normal internal organ weights in Thai population. J Med Assoc Thai. 2008;747–53.
29. Vidanapathirana, M. Abstracts of oral presentations of the 18th annual academic sessions of the College of Forensic Pathologists of Sri Lanka. Medico-Legal Journal of Sri Lanka. 2019;1–60.
DOI: http://doi.org/10.4038/mljsl.v.
30. Ogiu N, Nakamura Y, Ijiri I, Hiraiwa K, Ogiu T. A statistical analysis of the internal organ weights of normal Japanese people. Health Phys. 1997;368-83.
31. Li S, Luo D, Li Z. Study on the organ weight of sudden death cases. Zhonghua Bing Li Xue Za Zhi. 1996;86-8.
32. Shirley E. The analysis of organ weight data. Toxicology. 1977;13-22.
33. Ogiu N, Nakamura Y, Ijiri I, Hiraiwa K, Ogiu T.. A statistical analysis of the internal organ weights of normal Japanese people. Health Phys. 1997;368-83.
34. Adebo OA, Lun KC, Lee CN, Chao TC. Age-related changes in normal Chinese hearts. Chin Med J. 1994;88-94.
35. Scholz DG, Kitzman DW, Hagen PT, Ilstrup DM, Edwards WD. Age-related changes in normal human hearts during the first 10 decades of life. Part I (Growth): A quantitative anatomic study of 200 specimens from subjects from birth to 19 years old. Mayo Cli.Proc. 1988;126-36.

36. Scholz DG, Kitzman DW, Hagen PT, Ilstrup DM, Edwards WD. Age-related changes in normal human hearts during the first 10 decades of life. Part II (Maturity): A quantitative anatomic study of 765 specimens from subjects 20 to 99 years old. Mayo Clin Proc. 1988;137-4.
37. Dadgar SK, Tyagi SP, Singh RP, Hameed S. Factors influencing the normal heart weight: A study of 140 hearts. Jpn Circ J. 1979;77-82.
38. Hutchins GM, Anaya OA. Measurements of cardiac size, chamber volumes and valve orifices at autopsy. Johns Hopkins Med J. 1973;96-106.
39. Reiner L, Mazzoleni A, Rodriguez FL, Freudenthal RR. The weight of the human heart. I. "Normal" cases. Arch Pathol. 1959;58-73.
40. Prakash R, Umali SA. Comparison of echocardiographic and necropsy measurements of left ventricular wall thickness in patients with coronary artery disease. Am J Cardiol. 1984;838-841.
41. Feigenbaum H. Echocardiography. Third edition ed.: Philadelphia, Lea & Febiger; 1981.
42. Souza ALC, Campos VML, Lamêgo RS, Lírio MR, Alexandre C, Geraldo MJ. Echocardiographic reference values in a sample of asymptomatic adult Brazilian population. Arq. Bras. Cardiol. 2007;184-190.
43. Emery MS, Kovacs RJ. Sudden Cardiac Death in Athletes. JACC Heart Fail. 2018;6(1):30-40.
DOI: 10.1016/j.jchf.2017.07.014
PMID: 29284578
44. Gazdag P, Oravecz K, Acsai K, Demeter-Haludka V, Ördög B, Szlovák J, Kohajda Z, Polyák A, Barta BA, Oláh A, Radovits T, Merkely B, Papp JG, Baczkó I, Varró A, Nagy N, Prorok J. Increased Ca2+ content of the sarcoplasmic reticulum provides arrhythmogenic trigger source in swimming-induced rat athlete's heart model. Sci Rep. 2020;10(1):19596.
DOI: 10.1038/s41598-020-76496-2
45. Abulí M, de la Garza MS, Sitges M. Differentiating Athlete's Heart from Left Ventricle Cardiomyopathies. J Cardiovasc Transl Res. 2020;13(3):265-273.
DOI: 10.1007/s12265-020-
46. Perrault H, Turcotte RA. Exercise-induced cardiac hypertrophy. Fact or fallacy? Sports Med. 1994;17(5):288-308.
DOI: 10.2165/00007256-199417050-00003
PMID: 8052767.

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