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Relationship between Normal Heart Size and Body Indices in Korean

We provided a curve-fit equation to predict the normal heart weight (g) in Koreans by examining 422 autopsies (215 males and 207 females, from newborn to age 77 yr) who were relatively in good general condition. Heart weight was well correlated with body surface area (m^2), body weight (kg), and body height (cm) but poorly with age in both sex. Heart weight progressively increased from birth to the earlier 3rd and 4th decades in male and female, respectively, and then gradually decreased; mean heart weight of all age group was greater in male than in female and significantly different from birth to 4th decade. In both sex, heart weight exponentially increased in accordance with the increase of body height, body weight, and body surface (in male, heart weight=0.00312 × body height$^{2.239}$, r^2=0.750, p<0.0001; in female, heart weight=0.00443 × body height$^{2.170}$, r^2=0.781, p<0.0001; in male, heart weight=9.22 × body weight$^{0.853}$, r^2=0.770, p<0.0001; in female, heart weight=9.00 × body weight$^{0.855}$, r^2=0.820, p<0.0001; in male, heart weight=155.18 × body surface area$^{1.290}$, r^2=0.808, p<0.0001; in female, heart weight=124.13 × body surface area$^{1.242}$, r^2=0.834, p<0.0001). These results indicate that heart weight is better correlated with body surface area than with body weight; however, body weight should be a better determinant of a predicted heart weight, since body surface area is entirely dependent on body height and body weight.

Key Words : *Body Indices; Korean; Heart Weight; Relationship*

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INTRODUCTION

Until the mid-1970s, the main causes of death in South Korea were infectious diseases such as tuberculosis, but in recent days population affected by infectious diseases decreased and the average life-span increased in our society. Cardiovascular disease is now known as the most common cause of death: WHO (1) reported that 156.4 Korean people per 100 thousands of population died from cardiovascular diseases in South Korea in the early 1990s. However, information on normal values for various cardiovascular structures in Korean as well as in other Mongolians is sparse; to our knowledge, no large-scale autopsy study of quantitative cardiac anatomy has included the appreciable numbers of age groups from birth to septuagenarians. Sagall (2) emphasized that the exact diagnoses of cardiovascular diseases are clinically important for cardiac surgeons, pathologists, and also for cardiologists. In this respect, this quantitative anatomic study was undertaken to establish age- or body index-related changes of Korean hearts from the actual specimens and to compare our data with those from Caucasians.

MATERIALS AND METHODS

Materials and Measurement

The study protocol was conformed by the Institutes. Actual specimens of normal hearts from autopsies performed between 1994 and 1998 were examined. The following cases were excluded: 1) deficiencies in nutrition or growth, 2) obvious gross lesion or defect in the heart or pericardium, 3) cardiac malformation or past history of heart disease, 4) past history of hypertension or atherosclesosis, 5) abnormal curvature of vertebral column, 6) accompaniment of putrefaction, 7) dehydration, ascites, edema, urinary distention, large cyst and tumor, pregnancy, or defect in a part of the body, and 8) functional thyroid disease. Body weight and body height (from occiput to heel in supine position) were measured. The emerging points of great vessels of the heart were interrupted and the heart was excised; each heart was cleaned in a tap water to remove intracardiac blood clots and was weighed to the nearest gram on a precision electronic balance. Histopathologic examination was accompanied to exclude the specimens with myocardial hypertrophy,

Table 1. Age-related body indices (mean±SD)

Age (yr)	Number of specimen	Body height (cm)	Body weight (kg)	Body surface area (m^2)
Male				
0-4	4	87.5±12.4	14.0±3.4	0.57±0.11
5-9	5	116.6±9.7	21.2±6.3	0.83±0.15
10-14	7	151.3±2.6	43.2±2.5	1.35±0.11
15-19	24	169.5±6.9*	56.9±8.6†	1.65±0.13
20-29	47	169.9±6.5*	62.6±6.9†	1.72±0.11
30-39	61	167.9±5.8*	62.2±9.2†	1.60±0.13
40-49	40	167.2±6.2*	56.7±9.4	1.63±0.14
50-59	17	163.1±5.6*	55.6±9.5	1.59±0.15
60<	10	163.0±6.4*	52.2±9.1	1.54±0.15
Female				
0-4	7	82.1±21.5	10.5±4.9	0.58±0.23
5-9	6	125.7±11.1	27.9±8.9	1.19±0.23‡
10-14	6	149.8±12.8	40.0±1.1	1.58±0.18‡
15-19	21	160.5±5.5	49.0±6.0	1.81±0.13§
20-29	59	159.0±5.5	51.3±5.5	1.83±0.11§
30-39	50	159.0±5.4	54.5±8.6	1.87±0.14§
40-49	29	156.7±4.2	54.6±6.8	1.86±0.13§
50-59	12	156.3±5.3	54.7±8.0	1.85±0.15§
60<	17	150.4±4.1	46.3±8.1	1.68±0.14§

*$p<0.01$, †$p<0.01$, ‡$p<0.05$, §$p<0.01$, statistically compared by t-test

atrophy, and cardiomyopathies. Finally, a total of 422 specimens (215 in male; 207 in female) were included for examination; their age was between 1 and 76 yr in male, and between 0 and 77 yr in female (Table 1).

Statistics

Data were expressed as mean±standard deviation. All of the data were re-classified by sex, body weight, body height, and age, and body surface area was calculated by previously published formulas (3, 4), i.e., in male, body height $(cm)^{0.7250}\times$body weight $(kg)^{0.4250}\times 71.84$, and in female, body height $(cm)^{0.7763}\times$body weight $(kg)^{0.4081}\times 71.84$. SAS program (version 6.0) was used for statistical analyses: Pearson's correlation coefficients less than 0.05, among age, body height, body weight, body surface area, and heart weight, were considered to be significant, and curve-fit equations between body indices and heart weight were made.

RESULTS

Relationship between heart weight and age, body height, body weight and body surface

As shown in Table 2 and 3, age, body height, body weight, body surface area, and heart weight were correlated with each other in either sex. Pearson's correlation coefficients among age, body indices (body height, body weight, and body surface area), and heart weight were slightly higher in female except that between body

Table 2. Pearson correlation coefficients among parameters in the male

	Body weight	Body height	Body surface area	Heart weight
Age	0.205 $p<0.003$	0.300 $p<0.0001$	0.258 $p<0.0001$	0.324 $p<0.0001$
Body weight		0.765 $p<0.0001$	0.959 $p<0.0001$	0.744 $p<0.0001$
Body height			0.916 $p<0.0001$	0.721 $p<0.0001$
Body surface area				0.781 $p<0.0001$

Table 3. Pearson correlation coefficients among parameters in the female

	Body weight	Body height	Body surface area	Heart weight
Age	0.370 $p<0.0001$	0.290 $p<0.0001$	0.350 $p<0.0001$	0.535 $p<0.0001$
Body weight		0.793 $p<0.0001$	0.955 $p<0.0001$	0.793 $p<0.0001$
Body height			0.937 $p<0.0001$	0.721 $p<0.0001$
Body surface area				0.801 $p<0.0001$

surface area and heart weight. In male, body weight was well correlated with body surface area, and age was poorly correlated with body weight; heart weight was well correlated with body surface area, body weight, and body height, and poorly correlated with age. In female, body weight was well correlated with body surface area, but age was poorly correlated with body height; the heart weight was well correlated with body surface area, body weight, and body height, but poorly correlated with age.

Age-related changes in body height, body weight, and body surface area

As summarized in Table 1, body height in male progressively increased by age of 20 yr, after which it remained constant regardless of increasing age; body weight progressively increased by age of 30 yr and after that, it gradually decreased. In female, body height progressively increased by age of 20 yr, after which it gradually decreased; body weight progressively increased by age of 40 yr and after that, it gradually decreased. Body height in male was not different from that in female, from birth to age of 20 yr, but after that body height in male is greater than in female; body weight in male was greater than in female, from birth to age of 39 yr, but after that sex difference in body weight was not significant.

In general, body surface area was greater in female than in male. Body surface area in male was increased after birth, reached its maximum value at age of 20-39 yr, and afterwards it gradually decreased; in female, it was not significantly changed between age 20 and 59 yr, and afterwards it gradually decreased.

Age-related change in heart weight

In male, heart weight progressively increased from birth to the earlier fourth decade, after which it gradually decreased (Fig. 1, heart weight=$120.6+9.87\times$age$-0.12\times$age^2, $r^2=0.417$, $p<0.001$); in female, heart weight progressively increased from birth to the earlier fifth decade, after which it gradually decreased (Fig. 2, heart weight=$91.69+8.65\times$age$-0.09\times$age^2, $r^2=0.565$, $p<0.001$). In general, heart weight was greater in male than in female; particularly it was significantly different after birth to age 39 yr.

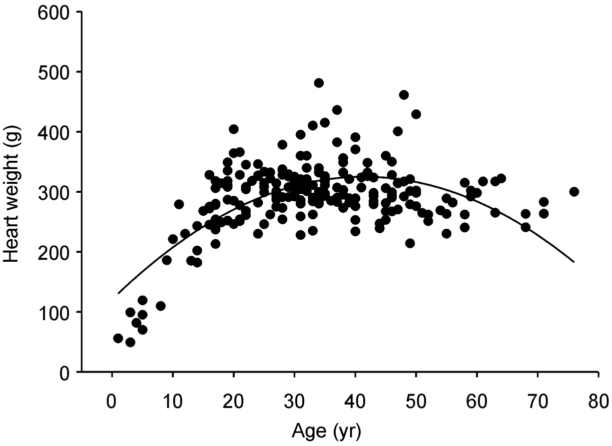

Fig. 1. Age-related heart weight in male. Heart weight increases from birth to near age of 40 yr before decreasing ($Y=120.6+9.87X-0.12X^2$, $r^2=0.417$, $p<0.001$).

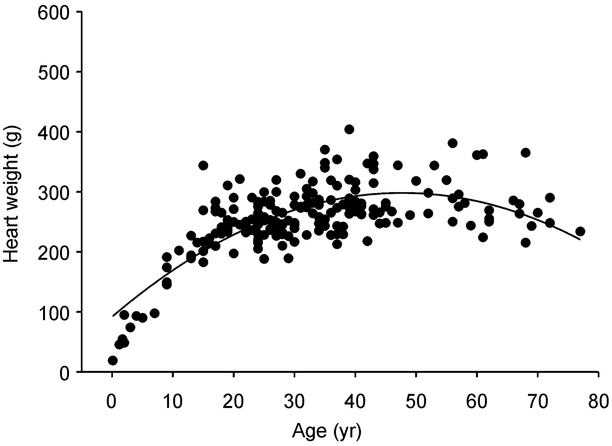

Fig. 2. Age-related heart weight in female. Heart weight increases from birth to middle age and then decreases ($Y=91.72+8.65X-0.09X^2$, $r^2=0.565$, $p<0.001$).

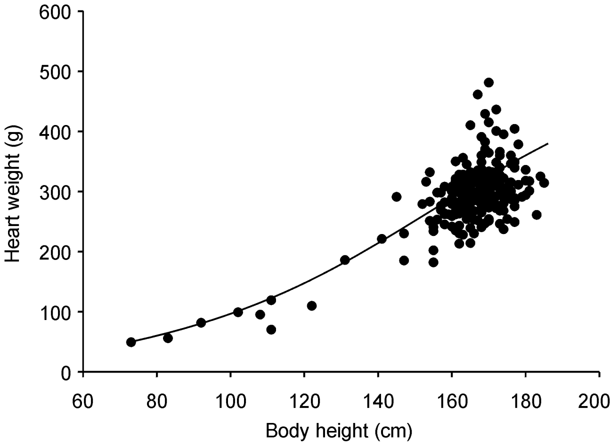

Fig. 3. Body height-related heart weight in male. Heart weight increases exponentially in accordance with the increase of body height ($Y=0.00312X^{2.239}$, $r^2=0.750$, $p<0.0001$).

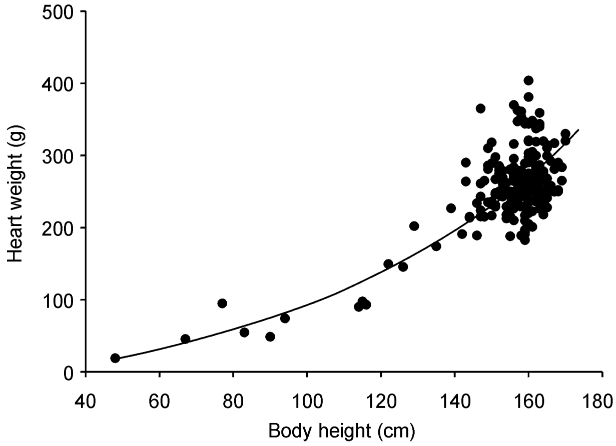

Fig. 4. Body height-related heart weight in female. Heart weight increases exponentially in accordance with the increase of body height ($Y=0.00443X^{2.170}$, $r^2=0.781$, $p<0.0001$).

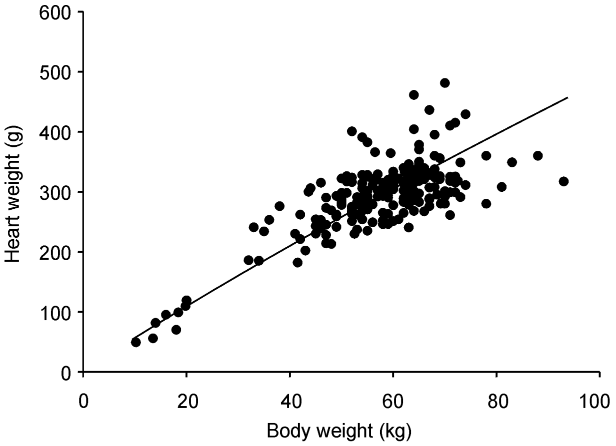

Fig. 5. Body weight-related heart weight in male. Heart weight increases exponentially in accordance with the increase of body weight ($Y=9.22X^{0.853}$, $r^2=0.770$, $p<0.0001$).

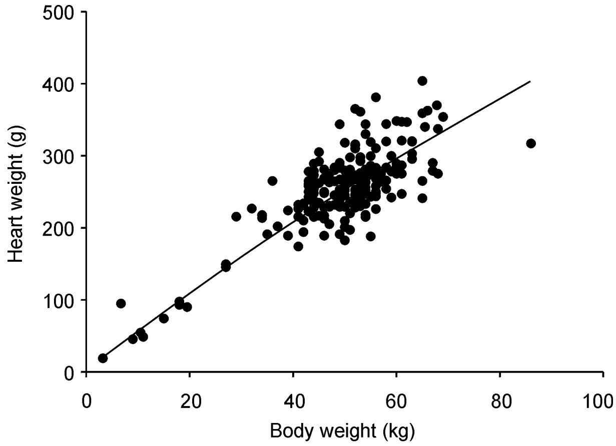

Fig. 6. Body weight-related heart weight in female. Heart weight increases exponentially in accordance with the increase of body weight ($Y=9.00X^{0.855}$, $r^2=0.820$, $p<0.0001$).

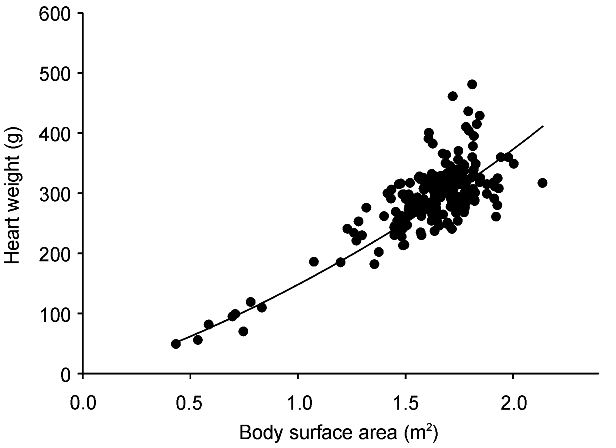

Fig. 7. Body surface area-related heart weight in male. Heart weight increases exponentially in accordance with the increase of body surface area ($Y=155.18X^{1.290}$, $r^2=0.808$, $p<0.0001$).

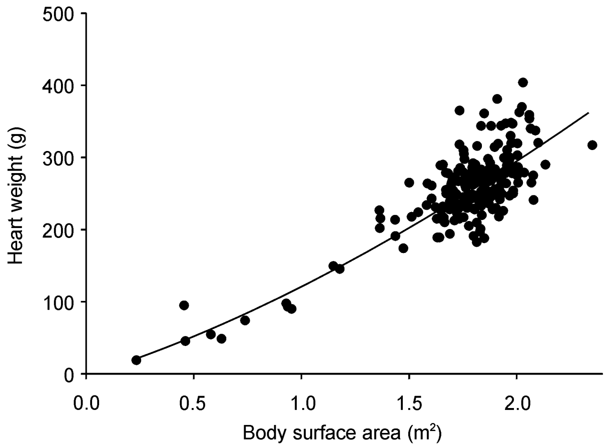

Fig. 8. Body surface area-related heart weight in female. Heart weight increases exponentially in accordance with the increase of body surface area ($Y=124.13X^{1.242}$, $r^2=0.834$, $p<0.0001$).

Body indices-related change in heart weight

In either sex, heart weight exponentially increased in accordance with the increase of body height, body weight, and body surface area (Fig. 3, in male, heart weight=0.00312×body height$^{2.239}$, r^2=0.750, p<0.0001; Fig. 4, in female, heart weight=0.00443×body height$^{2.170}$, r^2=0.781, p<0.0001; Fig. 5, in male, heart weight=9.22 ×body weight$^{0.853}$, r^2=0.770, p<0.0001; Fig. 6, in female, heart weight=9.00×body weight$^{0.855}$, r^2=0.820, p<0.0001; Fig. 7, in male, heart weight=155.18×body surface area$^{1.290}$, r^2=0.808, p<0.0001; Fig. 8, in female, heart weight=124.13×body surface area$^{1.242}$, r^2=0.834, p<0.0001).

DISCUSSION

Results from the previous studies (5-10) are less reliable in predicting the normal heart size, since age distribution and number of specimens were limited in most cases; even in studies with large number of specimen, source of measurements was from autopsy records, and not from investigators. In this regard, Edwards' group (11, 12) from Mayo Clinic, Rochester, examined relatively a large number of specimens and their results were highly reliable and useful; however, it may not be adequate to apply their results to Koreans (as well as to other Mongolians) because body indices and body proportion are different from races. Despite these facts, no large-scale quantitative study of the normal heart from autopsies of Korean, evenly distributed by sex and age, has been performed. For these reasons, we selected actual specimens to get more reliable and clinically applicable data, and histopathological examination was performed to exclude specimens with lesions such as cardiomyopathies; all of the finally selected specimens were normal and their age distribution was from birth to 8th decade.

As a result from this study, in male, body height progressively increased from birth to age of 20 yr, and after which it remained constant; body weight also progressively increased up to age of 30 yr and afterwards it gradually decreased. In female, body height and body weight progressively increased up to age of 20 and 40 yr, respectively, and afterwards they gradually decreased. Body height between both sexes is not different up to age of 20 yr; it becomes greater in male after age of 20 yr. Body weight is also greater in the male up to age of 39 yr, but after that it is not different between sexes. Body surface area in male increased after birth, reached its maximum value between age of 20 and 39 yr, and afterwards it gradually declined; in female, it was not different between age 20 and 59 yr, and after it gradually declined; however, mean body surface area was greater in female. Heart weight progressively increased from birth to the earlier 20s in male and to the earlier 30s in female, and it gradually decreased. Heart weight was greater in male than in female, particularly from birth to age of 39 yr, as seen in the studies of Gray (13) or Kitzman et al. (11).

In this study, mean heart weights of Korean adults over age of 20 yr were 305 g in men and 265 g in women; it was approximately 15% greater in men than in women (p<0.01), particularly different between the age of 20 and 39 yr. In Caucasian adults, the heart weight varies: 280-340 g in men and 230-280 g in women (13); however, our data are significantly different from the previous studies on Caucasians (14) in whom heart weight was 7-10% greater in both sex. Heart weight-to-body weight ratio in all age group or adults over age of 20 yr, is 0.51 (%) in both sexes, respectively; this means the proportion of heart to the whole body remains constant throughout life regardless of age and sex. The heart weight-to-body weight ratios in this study are different from those of Ludwig (14); he reported that the ratios in men and women are 0.45 and 0.4, respectively. The ratio is 13% greater in Caucasians than in Koreans. The reason that our data are different from the previous study on Caucasian hearts is not clear. Racial difference of statue, body proportion, or method of specimen collection (it is not clear whether cardiomyopathic hearts were included or not for analysis, in the study of Ludwig) may affect the results. Random sampling without discriminating cause of death or without performing histopathological examination should bring unpredictable errors since diseased hearts could be included for analysis. In this respect, only normal specimens (selected by macro- and microscopic examinations) were included in this study.

Heart weight tended to exponentially increase in accordance with the increase of body indices, i.e., body height, body weight, and body surface area, and there are close relations among them. In male, heart weight progressively increased from birth to the earlier 20s and afterwards it gradually decreased; in female it progressively increased from birth to the earlier 30s and afterwards it gradually decreased. In either sex, the relation coefficient between heart weight and body indices is greater than 0.7, and that between heart weight and age is less than 0.5. Our results indicate that body weight, body height, and body surface area are better univariate predictors of normal heart weight than age. In general, it is simpler to measure body height which remains relatively constant and is not changed by disease in adult, while body weight could be affected by certain diseases. However, in either sex, heart weight is better correlated with body surface area and body weight than with body height, and much better with body surface area. Although body surface area is a much better univariate predictor of normal heart weight, we choose body weight as the most reliable predictor since body surface is calculated from body weight and body height and its practical use is lower (11). However, relatively large number of specimens between the 3rd and 4th decades and small numbers in the 7th decade in either sex remain as limitations in this study.

REFERENCES

1. WHO. *Annals of World Health Statistics 1992, 1993.*
2. Sagall EL. *Cardiac evaluations for legal purposes. In: Alexander W, ed. Hurst's the heart. 7th ed. New York: McGraw-Hill, 1990; 1651-66.*
3. Choi WR. *Body surface area for the Korean. Korean J Aviat Med 1956; 4: 1-21.*
4. Du Bois D, Du Bois EF. *A formula to estimate the approximate surface area if height and weight be known. Arch Intern Med 1916; 17: 863-71.*
5. Smith HL. *The relation of the weight of the heart to the weight of the body and of the weight of the heart to age. Am Heart J 1928; 4: 79-93.*
6. Zeek PM. *Heart weight. I. The weight of the normal human heart. Arch Pathol 1942; 34: 820-32.*
7. Reiner L, Mazzoleni A, Rodriguez FL, Freudenthal RR. *The weight of the human heart. I. "Normal" cases. Arch Pathol 1959; 68: 58-73.*
8. Eckner FAO, Brown BW, Davidson DL, Glagov S. *Dimension of normal human hearts: after standard fixation by controlled pressure coronary perfusion. Arch Pathol 1969; 88: 497-507.*
9. Dadgar SK, Tyagi SP, Singh RP, Hameed S. *Factors influencing the normal heart weight: a study of 140 hearts. Jpn Circ J 1979; 43: 77-82.*
10. Westaby S, Karp RB, Blackstone EH, Bishop SP. *Adult human valve dimensions and their surgical significance. Am J Cardiol 1984; 53: 552-6.*
11. 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 spepcimens from subjects 20 to 99 years old. Mayo Clin Proc 1988; 63: 137-46.*
12. 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 Clin Proc 1988; 63: 126-36.*
13. Gray H. *The heart. In: Gray's Anatomy, descriptive and applied. 33rd ed. New York: Longman, 1962; 731-50.*
14. Ludwig J. *Current methods of autopsy practice. 2nd ed. Philadelphia: Saunders, 1979; 668-89.*