**Original Article**

# Differences in Heart Stroke Volume between Han and Korean-Chinese Nationalities and Correlative Factors*

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**Abstract**

**Objective** To compare the differences in stroke volume (SV) and stroke volume index (SI) between Han and Korean-Chinese and to investigate the correlated risk factors.

**Methods** A total of 1 647 Han and 876 Korean-Chinese aged 10-80 years were investigated. SV, SI, cardiac output, cardiac output index, heart rate (HR), systemic vascular resistance (SVR), systemic vascular resistance index (SVRI), and blood pressure were measured.

**Results** SV/SI values in Korean-Chinese were lower than those in the Han of the same sex and age. Covariance analysis showed that, apart from the effect of sex, age and body mass index (BMI), the differences in SV and SI between the two cohorts were still significant ($P$<0.001). Multiple regression analysis revealed that the SV difference between the two ethnicities was affected (in descending order from a strong to weak correlation) by SVR, SVRI, HR, diastolic blood pressure, mean arterial pressure, BMI, and systolic blood pressure, while the SI difference was affected by SVR, SVRI, HR, mean arterial pressure, diastolic and systolic blood pressure, and BMI.

**Conclusion** The Fact that SV and SI in Korean-Chinese are lower than those in Han is related with higher SVR, HR and blood pressure in the Korean-Chinese.

**Key words**: Heart stroke volume; Heart stroke volume index; Systemic vascular resistance; Blood pressure; Korean-Chinese; Han

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## INTRODUCTION

Some reports have show that the prevalence of hypertension and mortality of cerebral-cardiovascular diseases is higher in Korean-Chinese than that in the Han nationality[1-2]. The mean systolic blood pressure is 145.60±22.47 mmHg in Korean-Chinese males and 139.40±23.39 mmHg in Korean-Chinese females, which is higher than that of Han males (131.86±20.35 mmHg) and females (130.23±22.32 mmHg) in the Yanbian area. These numbers indicate that there is a difference in blood pressure between Korean-Chinese and Han cohorts[3]. In our project investigating human physiological

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parameters supported by the Ministry of Science and Technology of China in the Mudanjiang and Hailin area, Heilongjiang province, we found that blood pressure and systemic vascular resistance (SVR) were higher in Korean-Chinese than those in Han. These results are consistent with other reports[4]. The presence of SVR is one of the basic factors that is involved in blood pressure, and SVR is also the most important factor that affects cardiac post load. There is a close relation between changes in SVR and changes in blood pressure. SVR augmentation may result in a change in blood pressure, which induces hemodynamic changes. Therefore, SVR is an important parameter to explain cardiac function. However, there are few reports on SVR and cardiac ejective function. It is unknown if a change in SVR and blood pressure induces a change in cardiac ejective function in Korean-Chinese. Therefore, to determine the relationship between cardiac ejective function and SVR and blood pressure, cardiac ejective function was compared between Korean-Chinese and Han of the Mudanjiang and Hailin area of China and related factors were also investigated.

## METHODS

### *Subjects*

We collected data from subjects in Heilongjiang province. We randomly took samples according to people's living area, race and economic characteristics. To ensure that samples were representative, they had sufficient statistical power, and they were accurate, the least number of samples studied was 15 000. Ages ranged from 10 to 80 years old in both nationalities. Han subjects were mainly from Mudanjiang and Hailin, while Korean-Chinese subjects were mainly from Xinan town (Korean-Chinese perch area) in the Hailin area. Differences in physiological function between the two ethnicities were less affected by the natural surroundings except for living style since these two areas are close to each other. As a result, it was convenient to compare the two ethnicities. People who participated in the investigation were asked to fill out questionnaire forms about their personal health status, family history, living habits, and environmental factors. 94.0% of the forms were returned from the Korean-Chinese and 95.4% were returned from the Han, with no statistical difference between the two groups. Subjects with major systemic disorders such as diseases of the heart, kidney, liver, thyroid, parathyroid, adrenal glands, diabetes mellitus, hematological disease and a history of malignant tumor were excluded after medical and hematology examinations. We performed statistical analysis on stroke volume (SV) and stroke index (SI) of 2 523 people among whom the numbers of Han males and females were 736 and 911, respectively, while the numbers of Korean-Chinese males and females were 389 and 487, respectively. The tested people were divided into eight groups, numbered from one to eight with people aged between 10–14, 15–18, 19–30, 31–40, 41–50, 51–60, 61–70, and above 71 years. The study was approved by the Ethics Committee and the Institutional Review Board of the Institute of Basic Medical sciences, Chinese Academy of Medical Sciences. Informed consent was obtained from each participant before data collection. The study procedures followed were in accordance with our institutional guidelines.

### *Methods*

SV and SI and other indicators were tested on people lying on their back by the BIOZ.com™ Cardio Dynamics Monitor (BioMed company product, USA). The following steps were carried out: (1) Eight electrodes connected to the BIOZ.comTM Cardio Dynamics Monitor were placed on the neck and chest after cleaning the skin; (2) The sleeve above the elbow of the right arm was tied up; (3) The body height and weight of the tested person were input into the BIOZ.com™ Cardio Dynamics Monitor; (4) Results were recorded; and (5) SV and SI values were automatically shown on the BIOZ.com™ Cardio Dynamics Monitor according to the impedance theory[5-6].

### *Data Processing*

All data were analyzed and processed by SPSS 15.0. The physiological parameters are represented as mean value±standard deviation and they were compared by *t*-test between Han and Korean-Chinese. To explain the SV and SI differences between the two nationalities, analysis of covariance was used to exclude the effect of sex, age and BMI. To study the effect of each single factor on the SV/SI difference between Han and Korean-Chinese, first, the coefficients of SV/SI difference of the two nationalities were obtained by multiple linear regression analysis, to account for sex and age (model 1), or sex, age,

and BMI (model 2) into consideration. Factors other than sex, age, and BMI were then added one by one in model 2 and analyzed. The percentage of effect for each factor was calculated by the formula: (coefficient of model 2 plus added factor — coefficient of model 2)/coefficient of model 2 ×100%[7]. The testing level was 0.05.

## RESULTS

### *Mean Values and Standard Deviations of SV and SI in Han and Korean-Chinese Populations*

Tables 1 and 2 show the mean values and standard deviations of SV and SI of males and females in Han and Korean-Chinese populations.

**Table 1.** The Values of SV and SI of Male Residents in Different Age Groups

| Age | Han | | | Korean-Chinese | | |
|---|---|---|---|---|---|---|
| | *n* | SV(mL) | SI(mL/m$^2$) | *n* | SV(mL) | SI(mL/m$^2$) |
| 10-14 | 79 | 51.88±16.30 | 37.11±6.09 | 61 | 53.38±12.57 | 36.76±4.85 |
| 15-18 | 107 | 72.22±14.74$^{**}$ | 41.99±7.12$^{**}$ | 46 | 64.76±12.79$^{**}$ | 38.65±6.38$^{**}$ |
| 19-30 | 123 | 78.23±13.43$^{*}$ | 43.21±6.69 | 30 | 70.83±17.19$^{*}$ | 40.59±8.31 |
| 31-40 | 139 | 77.95±14.06$^{*}$ | 41.44±6.37 | 52 | 72.53±10.97$^{*}$ | 41.33±5.98 |
| 41-50 | 121 | 77.84±14.15$^{***}$ | 41.64±6.21$^{**}$ | 40 | 66.73±12.34$^{***}$ | 38.36±6.04$^{**}$ |
| 51-60 | 94 | 73.72±12.51$^{***}$ | 39.91±6.21$^{*}$ | 56 | 64.64±14.19$^{***}$ | 37.43±6.68$^{*}$ |
| 61-70 | 42 | 68.62±17.17$^{*}$ | 37.24±8.06 | 62 | 61.42±11.65$^{*}$ | 36.45±6.06 |
| 71- | 32 | 62.63±11.46$^{*}$ | 36.19±6.48 | 42 | 55.78±12.94$^{*}$ | 33.62±6.24 |
| Total | 736 | 72.62±16.36$^{***}$ | 40.72±6.88$^{***}$ | 389 | 63.16±14.28$^{***}$ | 37.76±6.55$^{***}$ |

***Note.*** Mean±SD. $^{*}P$<0.05, $^{**}P$<0.01, $^{***}P$<0.001 Han *vs.* Korean-Chinese.

**Table 2.** The Values of SV and SI of Female Residents in different Age Groups

| Age | Han | | | Korean-Chinese | | |
|---|---|---|---|---|---|---|
| | *n* | SV (mL) | SI(mL/m$^2$) | *n* | SV(mL) | SI(mL/m$^2$) |
| 10-14 | 90 | 48.58±11.03 | 35.68±5.55 | 35 | 50.29±10.10 | 34.81±5.12 |
| 15-18 | 126 | 59.97±12.50$^{***}$ | 38.93±7.23$^{**}$ | 58 | 53.68±11.18$^{***}$ | 35.86±6.21$^{**}$ |
| 19-30 | 154 | 61.01±12.07 | 39.00±6.49 | 36 | 59.42±10.36 | 38.93±5.36 |
| 31-40 | 137 | 62.13±9.77$^{**}$ | 38.94±5.34$^{*}$ | 71 | 57.76±11.69$^{**}$ | 36.92±6.74$^{*}$ |
| 41-50 | 151 | 60.00±10.81$^{***}$ | 37.20±5.75$^{*}$ | 71 | 54.58±10.54$^{***}$ | 35.35±5.90$^{*}$ |
| 51-60 | 161 | 57.20±9.97$^{***}$ | 35.15±5.36$^{***}$ | 63 | 48.94±8.93$^{***}$ | 31.61±5.10$^{***}$ |
| 61-70 | 66 | 52.14±9.39$^{***}$ | 32.51±5.02 | 88 | 46.75±9.97$^{***}$ | 31.12±5.43 |
| 71- | 29 | 45.99±9.19 | 30.33±5.20 | 64 | 44.06±9.63 | 29.67±4.89 |
| Total | 911 | 57.86±11.77$^{***}$ | 36.94±6.32$^{***}$ | 487 | 51.45±11.41$^{***}$ | 33.87±6.34$^{***}$ |

***Note.*** Mean±SD. $^{*}P$<0.05 , $^{**}P$<0.01 , $^{***}P\leqslant$0.001 Han vs. Korean-Chinese

Among males, the highest SV value was in 31–40-year-old Korean-Chinese and 19–30-year-old Han nationalities, and the SV value decreased as age increased or decreased. SV was lower in Korean-Chinese males than that in Han males of the same age in almost all age groups except for 10–14-year-olds, in which SV was higher in Korean-Chinese than in Han [41–50, 51–60 ($P$<0.001), 15–18 ($P$<0.01), 19–30, 31–40, 61–70, and >71 years old ($P$<0.05)].

SI was calculated by the SV value divided by body surface area. The highest value of SI of males was also in 31–40-year-old Korean-Chinese and 19–30-year-old Han, and SI decreased when age increased or decreased. The SI in Korean-Chinese males in other age groups was also lower than that in Han males of the same age groups [15–18 and 41–50 ($P$<0.01), and 51–60 years old ($P$<0.05)].

Among females, the highest SV value was in 31–40-year-old Han and 19–30-year-old Korean-Chinese, and SV values decreased when age increased or decreased. SV in Korean-Chinese females was lower in the same age groups except for 10–14-year-olds compared with Han females [51–60 ($P$<0.001),

15–18, 41–50, 61–70 ($P$=0.001), and 31–40 years old ($P$<0.01)].

The highest SI was in the 19–30-year-old age group in both nationalities in females and SI values decreased when age increased or decreased. SI in Korean-Chinese females was also lower than that in Han females in the same age group [51–60 ($P$<0.001), 15–18 ($P$<0.01), 31–40 and 41–50 years old ($P$<0.05)].

### *SV/SI Difference between Korean-Chinese and Han by Analysis of Covariance.*

Analysis of covariance showed that SV in Korean-Chinese was lower than that in Han ($F$=150.519, $P$<0.001) after controlling for sex, age and BMI. The revised mean value and standard error was 57.317±0.444 mL in Korean-Chinese (95% confidence interval, 56.447–58.188 mL) and 64.104±0.322 mL in Han (95% confidence interval, 63.474–64.735 mL).

Analysis of covariance showed that SI in Korean-Chinese was lower than that in Han ($F$=80.872, $P$<0.001) after controlling for sex, age and BMI. The revised mean value and standard error was 35.982±0.218 mL/m$^2$ in Korean-Chinese (95% confidence interval, 35.555–36.409 mL/m$^2$) and 38.422±0.158 mL/m$^2$ in Han (95% confidence interval, 38.112–38.731 mL/m$^2$).

### *Factors that Affected SV/SI Differences between Han and Korean-Chinese by Linear Regression*

To determine the effect of every factor on SV and SI, sex and age should be excluded. Therefore, we used model 1 to analyze the effect of age and sex on SV/SI between the two nationalities by multiple linear regression. Model 2 was set up by model 1 plus BMI to analyze the effect of BMI on SV/SI. SVR, SVRI, MAP(mean artery pressure), SBP(systolic blood pressure), DBP (diastolic blood pressure), and HR were introduced one by one on the basis of model 2 to investigate the contribution of every factor on the differences in SV and SI between the two nationalities. After controlling for the effect of sex and age, the results showed that SV in Korean-Chinese was lower than that in Han ($P$<0.001; Table 3; Model 1). The SV difference between the two nationalities was 9.60% ($P$<0.001, Table 3; model 2) lower when BMI was added to the model. Other single factors were introduced on the basis of model 2 and they reduced the difference in SV between the two nationalities as follows: SVR reduced by 61.32% ($P$<0.001); SVRI reduced by 36.14% ($P$<0.001); MAP reduced by 12.4% ($P$<0.001); SBP reduced by 10.75% ($P$<0.001); DBP reduced by 12.13% ($P$<0.001); and HR reduced by 27.53% ($P$<0.001, Table 3).

**Table 3.** Relation of Various Variables to the Differences in SV and SI between Han and Korean-Chinese

| Row | Variables in multiple linear regressions model | ΔSV (mL) Mean±SE | ΔSI (mL/m$^2$) Mean±SE |
|---|---|---|---|
| A | Model 1 | -7.508±0.578$^{***}$ | -2.436±0.270$^{***}$ |
| B | Model 2: Model 1+BMI | -6.787±0.553$^{***}$ | -2.440±0.271$^{***}$ |
| C | Model 2+SVR | -2.904±0.462$^{***}$ | -0.613±0.231$^{**}$ |
| D | Model 2+SVRI | -4.795±0.503$^{***}$ | -1.356±0.240$^{***}$ |
| E | Model 2+MAP | -6.577±0.559$^{***}$ | - 2..208±0.273$^{***}$ |
| F | Model 2+SBP | -6.701±0.559$^{***}$ | -2.310±0.273$^{***}$ |
| G | Model 2+DBP | -6.597±0.558$^{***}$ | -2..216±0.272$^{***}$ |
| H | Model 2+ HR | -5.441±0.485$^{***}$ | -1.685±0.226$^{***}$ |

***Note.*** Model 1: population (Korean-Chinese/Han), age, gender. Model 2: Model 1+BMI. ΔSV and ΔSI represent the coefficients for SV and SI differences between Han and Korean-Chinese, respectively. BMI, body mass index; SVR: systemic vascular resistance; SVRI: systemic vascular resistance index; SBP, systolic blood pressure; DBP, diastolic blood pressure; HR, heart rate: MAP, mean artery pressure. $^{***}P$<0.001 vs model 2 (row B vs model 1), $^{**}P$<0.01 vs model 2.

SI in Korean-Chinese was lower than that in Han ($P$<0.001; Table 3; model 1) when sex and age were excluded. The SI difference between the two nationalities was 0.16% ($P$<0.001) lower when BMI was added to the model. Other single factors were introduced on the basis of model 2 and they reduced the difference in SI between the two nationalities as follows: SVR reduced by 74.84% ($P$<0.01); SVRI reduced by 44.43% ($P$<0.001); MAP reduced by 9.36% ($P$<0.001); SBP reduced by 5.17% ($P$<0.001); DBP reduced by 9.03% ($P$<0.001); and HR reduced by 30.83% ($P$<0.001, Table 3).

## DISCUSSION

It has previously been reported that the mean values of physiological parameters such as height, body weight, BMI, SBP, DBP, HR, CO, CI(cardiac output index), SVR, and SVRI are different between

the Han and the Korean-Chinese, and the mean age of Korean-Chinese is older than that of Han in both sexes ($P$<0.001)[4]. Therefore, in the present study, we compared SV and SI between these two races taking into account age and sex. The results of $t$-tests showed that both cardiac SV and SI in Korean-Chinese were lower than those in Han of the same age and sex. Since SV and SI were affected by sex, age and BMI, analysis of covariance was used to compare the two nationalities more accurately. We found that SV and SI were different between the two nationalities after the effect of sex, age and BMI were excluded. Therefore this led to the question—what other factors were involved? Other related factors that may have affected SV and SI were analyzed by multiple linear regression. The results showed that the coefficients of SV and SI in Korean-Chinese were lower than those in Han (Table 3, model 1). The coefficient difference of SV between the two nationalities was decreased when BMI was introduced on the basis of model 1. The coefficient difference of SI between the two nationalities was also decreased (Table 3, model 2), indicating that BMI affects SV and SI.

Other single factors were added one by one based on model 2 to clarify their role on the differences in SV and SI between the two nationalities. SVR followed by SVRI, MAP, SBP, DBP, and finally HR were added to the model, and the coefficients of SV and SI were found to be decreased. Results obtained from linear regression showed that SV was affected by the following (in the order of a strong to weak correlation): SVR, SVRI, HR, DBP, SBP, and MAP; and SI was affected by SVR, SVRI, HR, MAP, DBP, and SBP.

SVR and SVRI were the most important factors that affected SV and SI, and they changed the coefficients of SV and SI differences between the two nationalities by 61.32% and 74.84%, respectively. SVR is a type of resistance (called as “post load”) which exists in blood vessel and obstructs ejection blood from heart to vessels. Augmentation of SVR may result in a decrease in heart ejection. We have previously reported that SVR and SVRI in Korean-Chinese are higher than those in Han, and higher SVR and SVRI may be the main reason for higher blood pressure in Korean-Chinese than that in Han[4]. These results suggest that higher SVR not only increases blood pressure, but also alters cardiac SV and SI. We also investigated cardiac output and CI between the two nationalities. CI was significantly lower in the Korean-Chinese than in the Han ($F$=8.070, $P$=0.005) (data was not shown). Therefore, an increase in SVR is an early sign of potential disease.

There are many factors that affect SVR, some of which are derived from blood vessels such as vasoactive substances released by autosecretion and parasecretion of blood vessels. Endothelial cells can secret a series of vasoactive substances including vasodilators and vasoconstrictors. Smooth muscle of blood vessels contracts and there is an increase in resistance as a result of disturbance of the balance between vasodilators and vasoconstrictors[8]. Pressure may induce structural changes of resistant vessels[9]. Humoral vasoconstrictors can also induce smooth muscle constriction, such as the rennin-angiotensin system and circulating natriuretic substances, which can inhibit the $Na^+$, $K^+$ membrane pump[10-11]. Sympathetic overdrive[12] can also induce smooth muscle constriction. It is unknown which of these factors plays a role on higher SVR in Korean-Chinese. It is also unknown whether it’s affected by genetics or living style and environment. These issues require further investigation.

Another factor that affected the differences in SV and SI between the two nationalities was heart rate. It was the second most important factor apart from SVR/SVRI to affect SV and SI. SV is correlated with ventricular ejection time as well as ventricular diastole time. As the ventricular relaxation phase becomes longer, the filling phase becomes longer. This will result in an increase in filling volume in the ventricular relaxation phase and augmentation of the constrictive ability of cardiac muscle by heterometric autoregulation and cardiac ejection volume increasing. An increase in HR decreases not only cardiac ejection time but also ventricular filling volume because it shortens the cardiac relaxation phase more than the ventricular constriction phase. Both reasons lead to a decrease of cardiac ejection volume. A higher HR in Korean-Chinese (results not shown here) may be one of the reasons that lead to lower SV and SI in Korean-Chinese than those in Han.

The third factor involved in cardiac ejection volume being different between the two nationalities was blood pressure. Postload of the heart increases during the cardiac ejection phase when blood pressure increases, which results in a decrease in SV and SI since the ventricular ejection phase is shortened. The difference in blood pressure between the two nationalities was compared. We found that SBP and DBP in Korean-Chinese were higher than those in Han (data was reported in

another paper[13]), which is consistent with Cui et al's results[1]. Therefore, higher blood pressure in Korean-Chinese may be another reason for the lower SV and SI.

In conclusion, the fact that SV and SI in Korean-Chinese are lower than those in Han is related to a higher SVR, HR and blood pressure in Korean-Chinese. The factors that affect SVR may be released from blood vessel autosecretion or parasecretion, humoral vasoconstrictors, sympathetic overdrive and blood vessel reconstruction by pressure. Further studies are required to determine which factor plays a role on higher SVR of Korean-Chinese. It has been suggested that genetics, living and eating habits, and the environment may contribute to SVR and blood pressure increasing in Korean-Chinese and these possibilities should be investigated in future studies.

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