Effect of Age and Sex on Heart Rate Variability in Healthy Subjects

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Abstract

Objective: The study aimed to investigate the effect of age and sex on the heart rate variability (HRV) analysis and to explore the normal range of HRV in different age and sex groups for potential health care applications.

Method: Baseline HRV, age, and sex data were collected from 470 subjects without cardiovascular conditions. Short-term HRV was recorded using Biocom Active ECG units (Biocom, Seattle, Wash). Subjects were divided by age into 10-year intervals and by sex for HRV analysis.

Results: Total power, representing the overall autonomic activity, decreased consistently from the age groups 10+ to 80+ years ($P < .001$). Both the low frequency (sympathetic activity) and high frequency (parasympathetic activity) declined ($P < .05$) as age increased. Sex had a significant effect on heart rate, R-R interval, high frequency, normalized low frequency, normalized high frequency, and low frequency–high frequency ratio. Sex did not seem to affect the SD of the normal-to-normal heartbeats and total power ($P > .05$) despite the significant heart rate changes ($P < .05$).

Conclusion: This study demonstrated that age had a greater impact on HRV than sex. The older age group had consistently lower HRV than younger people. The values generated in this study may be useful in health care settings to determine abnormal ranges of HRV under different clinical and experimental conditions. (J Manipulative Physiol Ther 2007;30:374-379)

Key Indexing Terms: *Heart Rate; Age Factors; Sex*

The chiropractic profession has become increasingly aware of the value of heart rate variability (HRV) analysis with increased research activities in recent years.[1,2] Some research evidence has suggested that autonomic nervous system activities may be affected by normal and diseased conditions.[3,4] Modern physiologic investigations of the impact of somatosensory input on autonomic functions have been reviewed by Sato et al[3] with 750 basic scientific articles cited. There is a growing need for a clearly defined normal range of HRV in different age and sex groups to make HRV a useful clinical assessment tool in chiropractic and other health care professions.

Heart rate variability analysis has been used for many years to measure autonomic nervous system activities for its simplicity, accuracy, and noninvasive application.[3,4] However, a normal range of HRV in the healthy asymptomatic population has still not been identified. When HRV is compared to blood pressure measurements in perceived normal or abnormal readings, even untrained people recognize a blood pressure reading of more than 140/90 mm Hg as higher than normal (120/80 mm Hg). Similarly, a heart rate measurement of 110 beats per minute suggests an increased heart rate (tachycardia). However, the perceived normal range is not clear for HRV measurements. Without a normal range, changes in HRV are difficult to interpret and use in evaluating chiropractic adjustments.

Recent studies on the effect of age and sex on HRV focused on certain stimulations to change the short-term HRV. Sato and Miyake[4] found that the male subjects were more sympathetic dominant than the female subjects. Carter et al[5] reported an increase in total power in all age groups after endurance training programs. Bonnemeier et al[6] investigated the circadian profile of cardiac autonomic nervous modulation in healthy subjects and concluded that normal aging was associated with a constant decline of cardiac vagal modulation due to a significant decrease in nocturnal parasympathetic activity. The significant sex-related difference of HRV decreased with aging. These findings emphasize the need to determine age- and sex-dependent normal ranges for HRV assessment. Normal HRV in the healthy population is

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Table 1. *Relationship of sex to HRV*

	Sex	n	Mean	SD	Minimum	Maximum	*t*	*P*
Mean RR	Male	167	825.379	126.588	511.6	1162	6.957	.009
	Female	303	799.368	121.98	525.2	1221		
RM-SSD	Male	167	38.598	28.558	4.7	186	2.225	.136
	Female	303	43.46	45.311	4.7	550.3		
Total power	Male	167	697.117	847.911	14.9	6918.6	0.066	.798
	Female	303	706.263	883.162	10.4	7665.8		
VLF	Male	167	274.23	350.867	8.8	2749.9	0.596	.44
	Female	303	254.688	425.437	2.1	5872.3		
LF	Male	167	291.263	472.27	2.2	4741.8	0.377	.539
	Female	303	258.919	339.015	3.5	2557.5		
HF	Male	167	132.08	225.481	1.3	2266	6.461	.011
	Female	303	191.372	333.216	1.6	3176.1		
LF NORM	Male	167	68.308	19.946	14.3	98.2	17.204	.0001
	Female	303	60.867	19.947	13	96.8		
HF NORM	Male	167	31.604	19.907	1.8	85.7	16.525	.0001
	Female	303	38.469	20.031	3.2	87		
LF/HF ratio	Male	167	4.37	5.86	0	53	16.542	.0001
	Female	303	2.77	3.33	3	30		

RR, R-R interval; *RM-SSD*, square root of the mean squared differences of successive normal-to-normal intervals; *VLF*, very low frequency; *NORM*, normalized.

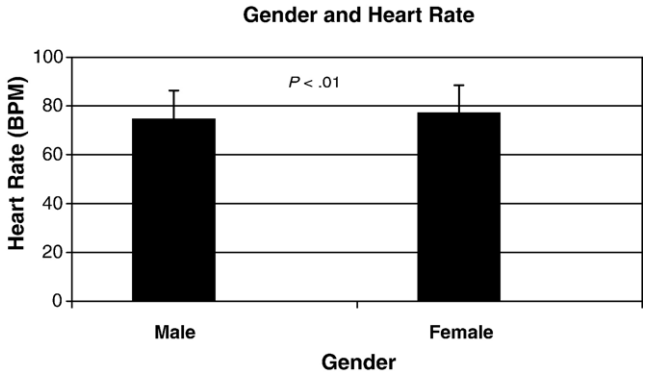

Fig 1. *Relationship of sex to heart rate.*

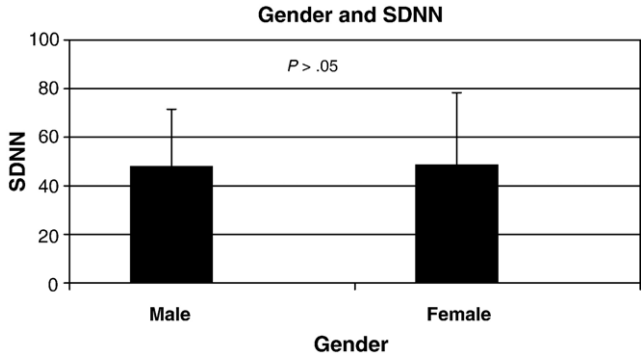

Fig 2. *Relationship of sex to SDNN.*

strongly affected by 2 factors: age and exercise. Young people (<30 years) tend to have higher HRV because of active autonomic modulations. With aging, the heart rate changes less because of increasingly sedentary lifestyle. The only proven method for older people (>50 years) to increase their HRV is engaging in regular exercise.

Decreased HRV is caused by disease processes such as stress, anxiety, diabetes, heart disease, hypertension, and many other conditions.[7,8] However, the normal range of HRV is one of the most important factors in the application of HRV analysis to any medical condition. To observe a treatment effect on HRV, an overlooked factor is the "set point" of the normal HRV, regulated by the body's negative feedback mechanism to maintain homeostasis. The set point is not changed by short-term heart rate fluctuations except by trauma. The set point is established and modulated by lifestyle and physiologic processes of the internal organs over the years.[9,10] Attempts to change the set point in the short term are unlikely to be effective. For example, by asking an individual to run for 10 minutes, a temporary increase in heart rate will be observed; when the individual rests, his heart rate will return to the resting level. This is true with HRV recording. Exercise and sympathomimetic drugs can change short-term HRV, but once drug and exercise effects are gone, HRV returns to the set point.[9] However, if drug and exercise are applied daily over a period, the HRV set point becomes reset at higher or lower levels. Therefore, studies of short-term HRV changes should take into account these limitations. This is the reason why long-term HRV changes are more reliable than short-term HRV changes.[11]

It is important that normative HRV data are collected for studying the effects of chiropractic manipulation on HRV. This study gathered HRV data from many studies to generate baseline HRV readings evaluating effects of age and sex on HRV.

Table 2. *Relationship of age to HRV*

	Age	n	Mean	SD	Minimum	Maximum	F	*P*
Mean RR	10+	15	793.753	117.979	647.6	1075.2	3.955	0
	20+	63	760.975	132.274	511.6	1125		
	30+	83	799.894	123.606	527.6	1147.1		
	40+	115	809.617	116.823	540	1163.1		
	50+	92	811.529	119.539	562.8	1221		
	60+	68	854.382	123.774	614.8	1162		
	70+	27	813.526	126.171	583.8	1058.1		
	80+	7	853.986	120.001	595.5	942.5		
RM-SSD	10+	15	49.06	28.639	19.2	98.3	1.34	.229
	20+	63	43.825	26.802	9.2	147.1		
	30+	83	45.454	30.699	6.4	179.4		
	40+	115	35.988	24.975	5.4	162.7		
	50+	92	48.895	70.896	4.7	550.3		
	60+	68	35.266	25.264	7.4	186		
	70+	27	41.474	36.578	8.3	136.9		
	80+	7	27.129	24.318	4.7	79.1		
Total power	10+	15	1627.073	1796.028	240.5	6918.6	7.561	.000
	20+	63	872.468	695.091	56.2	3317.3		
	30+	83	913.537	950.546	43	5330.1		
	40+	115	688.602	900.373	32.8	7665.8		
	50+	92	676.824	884.743	10.4	6262.7		
	60+	68	344.572	310.673	30.9	1624.3		
	70+	27	308.87	272.382	46.1	1112.3		
	80+	7	284.814	432	14.9	1240.4		
VLF	10+	15	532.347	586.369	120.5	2293.1	3.37	.002
	20+	63	313.632	252.518	31.4	1310.6		
	30+	83	321.453	435.591	15.2	2749.9		
	40+	115	278.683	572.404	12.7	5872.3		
	50+	92	245.017	299.597	5	1637.4		
	60+	68	149.713	164.68	2.1	951.9		
	70+	27	116.581	87.156	16.6	364.7		
	80+	7	89.129	63.616	11.4	169.1		
LF	10+	15	809.2	1250.543	36.7	4741.8	10.049	0
	20+	63	346.77	305.004	10.7	1445.4		
	30+	83	371.096	460.525	13.5	2557.5		
	40+	115	257.496	277.373	10.3	1352.2		
	50+	92	241.704	302.285	3.8	1490.6		
	60+	68	110.119	108.97	3.5	502.9		
	70+	27	87.722	92.576	8.5	456.5		
	80+	7	86.071	155.614	2.2	431.6		
HF	10+	15	285.5	272.219	36.4	828.7	2.312	.025
	20+	63	216.022	300.328	5.5	1717.6		
	30+	83	218.568	246.408	3	997		
	40+	115	150.475	262.752	1.7	1915.6		
	50+	92	191.24	458.585	1.6	3176.1		
	60+	68	81.459	135.945	1.3	961.9		
	70+	27	104.015	183.424	1.6	758.2		
	80+	7	109.071	234.448	1.3	639.7		
LF NORM	10+	15	66.267	20.417	26.4	85.6	1.177	.314
	20+	63	64.967	17.265	16.6	92.5		
	30+	83	63.576	19.808	13	93.1		
	40+	115	65.247	18.735	14.3	96		
	50+	92	64.082	22.234	13.1	96.9		
	60+	68	59.641	21.212	15.7	98.2		
	70+	27	61.907	24.619	15.7	94.4		
	80+	7	51.5	18.474	15	65.8		
HF NORM	10+	15	33.733	20.417	14.4	73.6	1.108	.357
	20+	63	34.594	17.448	7.5	83.4		
	30+	83	36.249	19.794	6.9	87		
	40+	115	34.447	18.581	4	85.7		
	50+	92	35.075	21.927	3.1	86.9		

Table 2. *continued*

	Age	n	Mean	SD	Minimum	Maximum	F	*P*
HF NORM	60+	68	39.663	21.659	1.8	84.3		
	70+	27	37.689	24.764	5.6	84.3		
	80+	7	48.129	18.823	32	85		
LF/HF ratio	10+	15	2.95	1.92	0	6	0.88	.522
	20+	63	2.78	2.3	0	12		
	30+	83	2.91	2.66	0	14		
	40+	115	3.27	3.6	0	24		
	50+	92	4.27	5.9	0	31		
	60+	68	3.5	6.91	0	53		
	70+	27	3.44	3.82	0	17		
	80+	7	1.29	0.66	0	2		

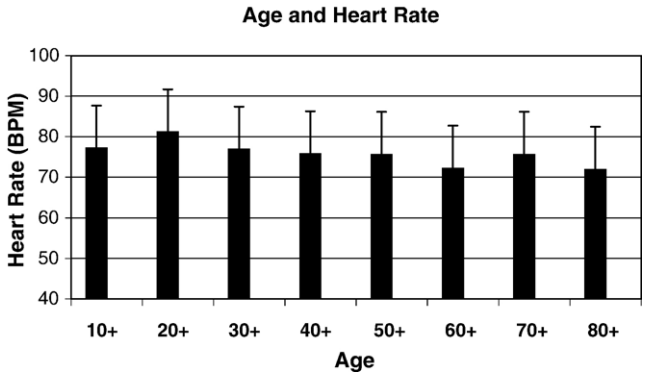

Fig 3. *Relationship of age to heart rate (N = 470).*

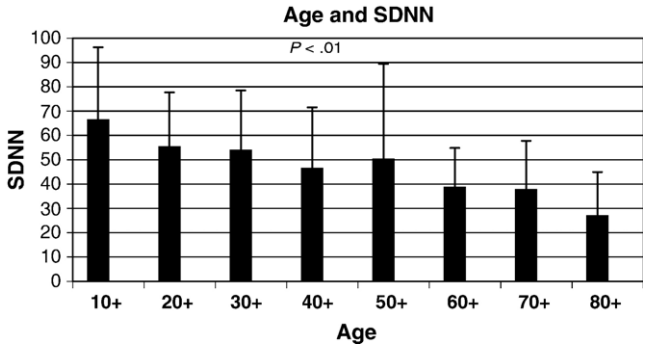

Fig 4. *Relationship of age to SDNN.*

Materials and Methods

Design

This retrospective study gathered baseline HRV data from studies in the past 4 years that involved HRV data. Subjects in the original studies were required to read and sign institutional review board–approved informed consent documents before undergoing any study-related procedures. All study data collections were approved by an institutional review board. From existing studies, only baseline HRV, age, and sex were used.

Inclusion Criteria

Subjects were selected from different racial, sex, and age groups.

Exclusion Criteria

Individuals with coronary heart diseases, serious and uncontrolled hypertension, or other overt diseases were excluded from the study.

Measurement

Biocom's Heart Rhythm Scanner (Active ECG, Biocom, Seattle, Wash) was used in the HRV data collection with digital signal-processing software. This scanner records electrocardiographic (ECG) signals, computing the instantaneous changes of HRV after each session. A Biocom Active ECG unit connected the unit to the subjects through 3 small electrodes that attach to the left arm, right arm, and left leg. No additional gels were needed. If the ECG signal was weak, the skin surface was cleaned to improve skin conductance.

Statistical Analysis

Subjects were divided by age and sex for final data analysis. Age groups were divided by 10-year intervals, producing a total of 8 age groups from 10+ to 80+ years old. All continuous data were expressed in mean values $\pm$ SD. The paired *t* test was used for comparisons of continuous variables measured in the study. Analysis of variance was used for comparison of 3 or more groups. Correlation was analyzed using SPSS 12 (SPSS Inc, Chicago, Ill). $P < .05$ was considered significant.

Results

Data on HRV from 470 subjects (303 females) were included. The average patient age was 44 $\pm$ 16 years. Sex had a significant effect on heart rate, R-R interval, high frequency (HF, represents some parasympathetic activity), normalized low frequency (LF, represents some sympathetic

activity), normalized HF, and LF/HF ratio (Table 1, Fig 1). Sex did not seem to affect the SD of the normal-to-normal heartbeats (SDNN, Fig 2), total power ($P > .05$), or the LF component despite the significant heart rate changes ($P < .05$). Both the SDNN and the total power were higher in females than in males but did not reach statistically significant levels. Age groups from 10+ to 80+ years showed significant differences on HRV response (Table 2, Figs 3 and 4). Total power, representing the overall autonomic activity, decreased consistently in age groups 10+ to 80+ years ($P < .001$). The age groups 20+ to 50+ years had narrow ranges of total power readings. The biggest change of total power was found between the age groups 10+ to 20+ and 50+ to 80+ years. The SDNN also decreased ($P < .05$) as age increased (Fig 4). Both the LF and HF declined ($P < .05$) as age increased (Table 2).

Discussion

Since the first study on the effect of mechanical stimulation on the autonomic nervous system activities,[12] many studies have investigated the effects of spinal stimulation on autonomic or visceral function.[13-19] A recent study by Budgell and Polus[20] demonstrated improvement of HRV after thoracic chiropractic adjustments. Our own studies also showed a positive effect of chiropractic adjustment on HRV.[21,22] These efforts affect the long-term use of HRV in the chiropractic profession. There is a great need for establishing the normal HRV ranges in age and sex groups to provide guidance in the clinical application of HRV analysis.

Two important issues were addressed in the current study: the influence of sex on subjects' HRV and the effect of age on subjects' HRV. This study demonstrated that age had a greater impact on the HRV than sex. Interestingly, the mean values of the female subjects' heart rate (76.9 beats per minute) was slightly higher than that of male subjects (74.5 beats per minute), but the total power was also higher in the female subjects.

The heart rate sex differences were significant, whereas the total power difference was not statistically significant. Women throughout the world enjoy higher life expectancy compared to men for varying reasons. Could higher total power, an increased parasympathetic activity, play a role in their longevity? Because the total power in this study was not significantly higher in the female sex, no conclusion could be drawn on the effect of sex on the HRV.

The effect of age on HRV demonstrates the most striking differences. Subjects in the 10+ age group had much higher total power of 1627 compared with 284 in the 80+ age group. The other age groups presented themselves in descending order (Table 2). Total power was lower from the 10+ to the 20+ age groups and stayed fairly flat from the 20+ to 50+ age groups. The HRV total power of the 60+ age group showed another marked drop before continuing a gradual decline to the 80+ age group. The reason for this large drop at 2 critical ages was not clear. It was postulated that the significant decrease in HRV resulted from the transition from postpubertal growth spurt to adulthood and the overall decline in physical activities and possibly health in the 60+ age group. Further study may include neonates to extend the range of the age groups. It has been reported that increasing postnatal age was accompanied by a significant ($P < .05$) elevation of HRV parameters.[11]

This study is significant because it used a relatively large database to determine the distribution of HRV in varying age and sex groups. The numbers in Tables 1 and 2 may be helpful in determining normal ranges for HRV comparisons under different clinical and experimental conditions. However, the database needs to expand to cover wider age groups and include more subjects.

Although it was known that long-term exercise exerts significant effects on the HRV, it was not part of the study because of the limitation of the study design. The effect of exercise on HRV needs to be investigated and compared to the data in the current study.

Conclusion

Age was the most considerable factor affecting HRV in this study. Sex did not seem to significantly affect the resting HRV. Further studies will compare this normal range of HRV with the HRV in patients with a variety of illnesses and physical conditions. Final establishment of reference HRV ranges based on patient age could be used to evaluate the effect of chiropractic manipulation on the autonomic nervous system.

Practical Applications

- Heart rate variability decreases with advancing age in healthy subjects.
- Heart rate variability is less affected by sex.
- Heart rate variability may be useful in health care settings to determine abnormal ranges of HRV under different clinical and experimental conditions.

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