Short Communication

Changes in Heart Rate Variability after Yoga are Dependent on Heart Rate Variability at Baseline and during Yoga: A Study Showing Autonomic Normalization Effect in Yoga-Naïve and Experienced Subjects

Abstract

Background: Yoga therapy is widely applied to the maintenance of health and to treatment of various illnesses. Previous researches indicate the involvement of autonomic control in its effects, although the general agreement has not been reached regarding the acute modulation of autonomic function. **Aim:** The present study aimed at revealing the acute effect of yoga on the autonomic activity using heart rate variability (HRV) measurement. **Methods:** Twenty-seven healthy controls participated in the present study. Fifteen of them (39.5 ± 8.5 years old) were naïve and 12 (45.1 ± 7.0 years old) were experienced in yoga. Yoga skills included breath awareness, two types of asana, and two types of pranayama. HRV was measured at the baseline, during yoga, and at the resting state after yoga. **Results:** In both yoga-naïve and experienced participants, the changes in low-frequency (LF) component of HRV and its ratio to high-frequency (HF) component (LF/HF) after yoga were found to be correlated negatively with the baseline data. The changes in LF after yoga were also correlated with LF during yoga. The changes in HF as well as the raw HRV data after yoga were not related to the baseline HRV or the HRV during yoga. **Conclusion:** The results indicate that yoga leads to an increase in LF when LF is low and leads to a decrease in LF when it is high at the baseline. This normalization of LF is dependent on the autonomic modulation during yoga and may underlie the clinical effectiveness of yoga therapy both in yoga-naïve and experienced subjects.

Keywords: *Autonomic activity, heart rate variability, low-frequency component, normalization effect, yoga therapy*

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Introduction

Yoga therapy is a behavioral practice based on the ancient Indian discipline, and now, is widely used over the world for maintaining health and treating illnesses.[1] It employs various skills of traditional yoga, which have been utilized in treating psychosomatic and psychiatric disorders by objectively perceiving the physical signs of the subject and promoting the self-control ability.

The underlying biological mechanisms of yoga therapy have been studied to further advance its use, and the involvement of autonomic modulation is suggested.[2,3] In addition to heart rate (HR) and blood pressure,[4,5] HR variability (HRV) has been frequently used as a physiological parameter to estimate the influence of yoga on autonomic activity.[6-9]

Among various methods to analyze HRV, frequency-domain power-spectrum analysis is commonly used and calculates the high-frequency (HF) variation corresponding to respiration-related parasympathetic activity and the low-frequency (LF) variation corresponding to blood pressure-related activity.[10,11] Using these HRV variables, yoga practitioners were found to have an increased parasympathetic activity at rest.[12,13]

The effects of yoga therapy have also been studied by measuring the HRV changes after 1 to several months of practices. Eight weeks of hatha yoga led to an increased parasympathetic tone.[14] The autonomic balance tilted toward parasympathetic predominance after a 1-month practice of yoga including asana, pranayama, and dhyana.[15] It has been reviewed that yoga can affect cardiac autonomic regulation with vagal dominance.[2]

On the other hand, some studies concluded that no changes in HRV were found after

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yoga.[16-18] A meta-analysis also indicates no convincing evidence for the effectiveness of yoga in modulating HRV.[19]

The effects of yoga therapy are also dependent on the skills that are employed in the yoga practice. HRV measurement during dhyana suggested a reduced sympathetic activity and/or increased vagal modulation but showed no conclusive changes during ekagrata and cancalata.[20] A decrease of parasympathetic activity has also been shown following kapalabhati but no significant changes after Nadi Shuddhi.[21]

Most of the effects of yoga therapy introduced above were analyzed after the yoga practices for more than a month.[14,15,20,21] HRV data are known to be affected by psychological and physical conditions.[22] The data separated by more than a month could be influenced by differences in these conditions at the time of measurement. Considering these limitations of previous researches, recent studies examined the acute effect of yoga therapy by measuring HRV before and after yoga. Following long Sudarshan Kriya Yoga, Bhaskar *et al*.[23] reported that LF decreased and HF increased. On the other hand, Telles *et al*.[24] examined the acute effects of several yoga skills and reported an increase of LF and a decrease of HF, indicating reduced parasympathetic activity. The acute effects of yoga on HRV shown in previous reports were not consistent. The results may depend on the yoga techniques that the study employs.[25]

Considering the complexed relation between yoga and autonomic function introduced above, it would be interesting not only to compare the data before and after yoga but also to examine the relation of these data to the data during yoga. Bhagat *et al*.[26] have reported that HRV indices are significantly altered during yoga in relation to the respiratory rhythm. It the present study, we recorded HRV at the resting baseline state, during yoga, and at the resting state immediately after yoga and further analyzed the relationships among them.

Methods

Subjects

Twenty-seven healthy controls participated in this study, who had no history of cardiac, neurological, and mental disorders. Fifteen of them were naïve in yoga (age: 39.5 ± 8.5 years, mean ± standard deviation (SD), range: 22–54 years, 11 males, and 4 females). Twelve were experienced in yoga (age: 45.1 ± 7.0 years, mean ± SD, range: 32–54 years, 12 females), and the mean length of yoga experience was 11.6 ± 8.1 years. Written informed consent was obtained from each of the participants before starting the measurement. The average age of yoga-naïve participants was not different from that of experienced participants' (*t*-test, $P > 0.05$). The discrepancy in the male-to-female ratio between the groups came from consecutive assignments.

Yoga protocol

The participants participated in one session of the yoga of about 20 min. They were seated on a chair during yoga. The protocol included breath awareness, asana, and pranayama. The details are found in the publication by Kimura [Figure 1].[1]

In brief, during the breath awareness skill, the participant put hands on the chest or the abdomen to feel the respiratory movement.

Asana is the isometric yogic breathing skill, and two types were employed in the present study. In the first one (hand-to-hand, asana 1), the participant pressed the hands together, and in the second (hand-to-head, asana 2), the participant pressed a side of the head with one hand. The pressure was generated between the hands (asana 1) or between the hand and head (asana 2), without movement for several seconds accompanied by inspiration. Then, the pressure was released for several seconds accompanied by expiration. The participant was instructed to perform this pressure/release for six times. The length of each pressure/release performance was monitored by an experimenter and was confirmed to be longer than 7 s in the present study (<0.15 Hz). The vocalization of sound "*a*" accompanied the pressure/release.

Pranayama in the present study consisted of two kinds of breathing skill, bhramari pranayama (pranayama 1) and 1:2 breathing (pranayama 2). In bhramari pranayama, the participants took a breath out slowly, accompanying vocalization of sound "*n*." In the 1:2 breathing, the ratio of inspiration and expiration was instructed to be 1:2. The total length of each cycle was longer than 7 s (<0.15 Hz). The participants conducted bhramari pranayama breathing nine times and 1:2 breathing five times.

Each yoga skill was followed by a rest period of about 30 s before the next started.

The experimental protocol was approved by the Institutional Review Board of the Tokyo Metropolitan Institute of Medical Science.

Heart rate variability measurement

HRV was measured with the same method as that used in our previous study.[27] At least 5 min of adaptation period was introduced before the start of the yoga protocol. During the experiment, the participant was seated on a chair with electrocardiogram (ECG) electrodes attached to the chest. ECG was measured conventionally with a gain of 10,000 and a time constant of 0.1 s. The signals were sampled at the frequency of 200 Hz and were stored in a computer for off-line analysis (Bonaly Light, GMS, Tokyo, Japan). R–R interval trend data were obtained using R-peaks of ECG, and their fluctuation was analyzed using maximum entropy method (MemCalc, GMS, Tokyo, Japan). The maximum entropy method was selected for the power spectrum

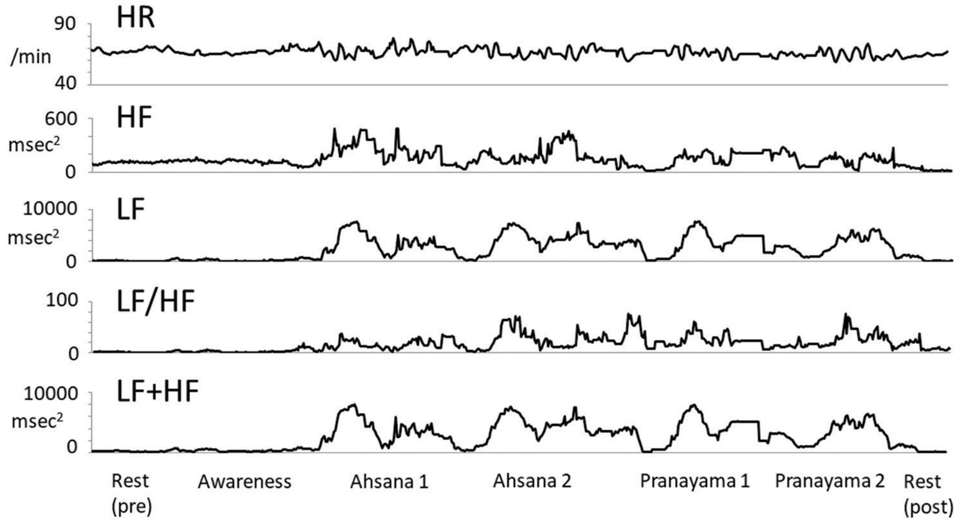

Figure 1: A sample data of heart rate (HR) and heart rate variability parameters (high-frequency HF, low-frequency LF, low-frequency/high-frequency LF/HF, and low-frequency + high-frequency LF+HF) in a participant during a yoga session with multiple skills. The details of yoga skills are found in the text. The data during the rest periods were recorded both before (pre) and after (post) yoga. During yoga, heart rate and heart rate variability parameters show fluctuations

analysis because it has been successfully applied to trend data with a minimum duration of 30 s[28] and is useful for studies incorporating measurements of multiple behavioral states.[22] R–R intervals between the range of 273 and 1500 ms were used for the analysis to exclude paroxysmal heart beats. When a R–R interval was omitted, it was replaced by the average of the preceding and the following intervals. These R–R intervals were resampled at the mean HR. MemCalc[29] calculated LF and HF components of the spectrum every 2 s by integrating the power at the corresponding frequency intervals (LF: 0.04–0.15 Hz and HF: 0.15–0.4 Hz)[10] for the preceding 30 s period. R–R intervals were also converted to HR (/min).

Pharmacological studies have shown that HF reflects parasympathetic activity related to respiratory frequency.[30] LF reflects baroreceptor activity controlling blood pressure under the normal respiratory frequency and is related to both sympathetic and parasympathetic activities.[11] In the present study, respiration was monitored, and its frequency was confirmed to be within the range of 0.15–0.4 Hz at the baseline and at the resting state after yoga.[10,31,32] However, in the slow-breathing states during yoga skills, asana, and pranayama, the respiratory frequency was below 0.15 Hz, and the parasympathetic activity corresponds to HRV in the range of LF. During slow breathing, LF reflects both parasympathetic and baroreceptor activities.[11] In the present study, the differences between the HF and LF scores during yoga and those scores at the baseline (yoga-pre) were calculated to quantify the autonomic modulation during yoga. It should be noted that during asana and pranayama with slow breathing, respiration-related parasympathetic activation was included in LF.

HF, LF, the sum of LF and HF (LF + HF), LF/HF, and HR were averaged in the interval from 30 s to the end of each yoga skill to exclude any data at the beginning of each new period that may still reflect the previous condition [Table 1].[33] The average of the data during all yoga skills was also calculated. HRV parameters and HR were measured at the baseline resting state (pre: 1 min), during yoga, and at the resting state after yoga (post: 1 min).

Manipulation of data and statistical analysis

The data in the yoga-naïve and experienced participants were analyzed separately to examine the effect of yoga experience. In addition to the raw HRV data, the ratio of the data at the resting state after yoga (post) to that at the baseline resting state (pre) was used to evaluate the change after yoga (post/pre). The differences between HRV parameters during yoga and those at the baseline (yoga-pre) were also calculated to quantify the autonomic modulation during yoga, as described in the previous paragraph.

The raw parameters before (pre) and after (post) yoga at the resting states were compared using the Wilcoxon's signed-rank test. The relations between the ratio of the data (post/pre) and the baseline data (pre), between the ratio of the data (post/pre) and the data during yoga, and between the data during yoga and the baseline data (pre) were examined using Spearman's correlation coefficients (Prism 5, GraphPad, San Diego, CA, USA).

Results

The effects of yoga on heart rate and heart rate variability parameters

Figure 1 presents an example of the recorded data in one participant. HR and HRV parameters showed fluctuations in the course of yoga therapy, depending on the behavioral

Table 1: The data in all the participants are presented as mean (standard deviation, SD) at the baseline resting state (pre), during breath awareness (awareness), during two types of asana (asana 1: handtohand, asana 2: handtohead), and during two types of pranayama (pranayana 1: bhramari and pranayama 2: 1:2 breathing), the averaged data during these five yoga skills (average), and the data at the resting state after yoga (post)

Naïve																	
		pre		awareness		asana 1		asana 2		pranayama 1		pranayama 2		average		post	
HR	/min	70.3	(10.3)	68.6	(9.0)	70.3	(8.3)	69.8	(8.1)	67.9	(7.9)	68.7	(6.8)	69.1	(8.2)	68.3	(8.4)
HF	ms^2	332.1	(516.4)	304.3	(187.7)	235.4	(115.3)	310.1	(273.3)	270.1	(199.5)	228.7	(182.7)	269.8	(139.6)	241.7	(302.5)
LF	ms^2	979.2	(1231.6)	639.4	(378.1)	1826.4	(923.0)	1974.2	(1045.4)	2045.4	(1458.5)	2141.6	(1405.8)	1725.4	(811.3)	654.4	(679.0)
LF/HF		5.5	(6.0)	4.3	(5.6)	12.3	(7.6)	19.2	(26.6)	12.9	(9.6)	16.7	(11.6)	13.1	(8.5)	4.4	(3.8)
LF + HF	ms^2	1311.3	(1478.2)	943.8	(421.4)	2061.8	(993.0)	2117.0	(1265.4)	2315.6	(1595.7)	2370.3	(1533.2)	1961.7	(932.2)	896.1	(884.4)
Experienced																	
		pre		awareness		asana 1		asana 2		pranayama 1		pranayama 2		average		post	
HR	/min	65.2	(7.4)	65.8	(7.4)	67.2	(8.1)	66.8	(7.6)	65.7	(7.4)	66.1	(6.8)	66.6	(7.3)	65.3	(8.4)
HF	ms^2	186.2	(188.3)	227.8	(157.2)	234.8	(128.7)	196.0	(129.7)	196.0	(87.7)	130.5	(95.0)	189.6	(84.9)	167.0	(186.5)
LF	ms^2	842.7	(955.6)	1337.0	(1790.0)	2118.0	(1381.0)	2197.0	(1578.0)	2231.0	(1588.0)	2445.0	(2146.0)	2015.0	(1322.0)	645.5	(642.2)
LF/HF		10.1	(13.6)	17.9	(43.8)	14.0	(11.3)	15.4	(10.1)	17.2	(17.5)	29.7	(24.7)	19.5	(14.7)	8.4	(8.2)
LF + HF	ms^2	1029.0	(942.4)	1565.0	(1774.0)	2353.0	(1438.0)	2393.0	(1656.0)	2427.0	(1618.0)	2575.0	(2179.0)	2205.0	(1360.0)	812.6	(684.8)
																mean	(SD)

states. Table 1 summarizes the scores of HRV parameters during yoga protocol.

The changes of HR and HRV parameters after yoga are shown in Figure 2. On comparing the raw data at the resting state after yoga (post) and that at the baseline resting state before yoga, no statistical differences were observed for all HRV parameters in the yoga-naïve and experienced participants [yoga-naïve: Figure 2a, upper row, yoga-experienced: Figure 2b, upper row, HR, HF, LF, LF/HF, and LF + HF, $P > 0.05$].

Heart rate variability changes after yoga and the baseline data

Direct comparison of the raw data before and after yoga did not reveal significant effect as shown above. However, on viewing the LF and LF/HF data of both naïve and experienced participants in Figure 2a and b, it was speculated that high baseline score tended to decrease and low baseline score tended to increase after yoga in both the groups. This relation was examined using the ratio of the data at the resting state after yoga to that of before yoga (post/pre) and the data before yoga (pre), and a significant correlation between "post/pre" and "pre" was noted for LF and LF/HF [post/pre vs. pre in Figure 2a and b, lower rows]. The change in LF and LF/HF after yoga was negatively correlated with the baseline data both in the yoga-naïve (LF: $R = -0.595$, $P = 0.019$, LF/HF: $R = -0.796$, $P = 0.0004$), [Figure 2a, lower row] and in the experienced participants (LF: $R = -0.588$, $P = 0.035$, LF/HF: $R = -0.577$, $P = 0.039$), [Figure 2b, lower row]. No correlation was found for HR, HF, and LF + HF ($P > 0.05$).

Heart rate variability changes after yoga and heart rate variability parameters during yoga

The ratio of the data after yoga to that before yoga (post/pre) was also compared to autonomic modulation during yoga. The data in the resting state inserted between yoga skills were omitted from the analysis. The baseline data were subtracted from the HF and LF data during yoga (yoga-pre), and the difference was considered to reflect autonomic modulation during yoga. The average of the data during all yoga skills as well as those during each yoga skill was used for the calculation.

Averaged raw data of HF and LF during yoga showed no statistically significant correlation with the post/pre ratio/ of HRV data ($P > 0.05$). On the other hand, the averaged LF change (yoga-pre) during all yoga skills was significantly correlated with post/pre ratio/of LF in both yoga-naïve ($r = 0.68$, $P = 0.005$) and experienced ($r = 0.60$, $P = 0.038$) participants [Figure 3] but not with that of HF ($P > 0.05$). In the yoga-naïve participants, the LF change during all yoga skills was also correlated with the post/pre ratio of LF/HF [$r = 0.56$, $P = 0.029$, Table 2]. The correlation coefficients for individual yoga skills as well as the average of the data during all yoga skills are presented in Table 2. The LF change during asana was related to the post/pre ratio of LF. In yoga-naïve participants, LF change during breath awareness showed a significant correlation. The averaged HF change during yoga was not related to the post/pre ratio of HRV data [$P > 0.05$, Figure 3].

Baseline heart rate variability parameters and heart rate variability parameters during yoga

The relation of baseline autonomic activity to that during yoga was assessed by comparing the HRV data at the initial resting state and that during yoga. The results are presented in Table 3. In the yoga-naïve participants, the baseline LF scores are related to the LF change during yoga. In the yoga-experienced participants, the baseline HF shows a significant correlation with the LF change during yoga. HF changes during yoga showed no relation to baseline HRV data ($P > 0.05$).

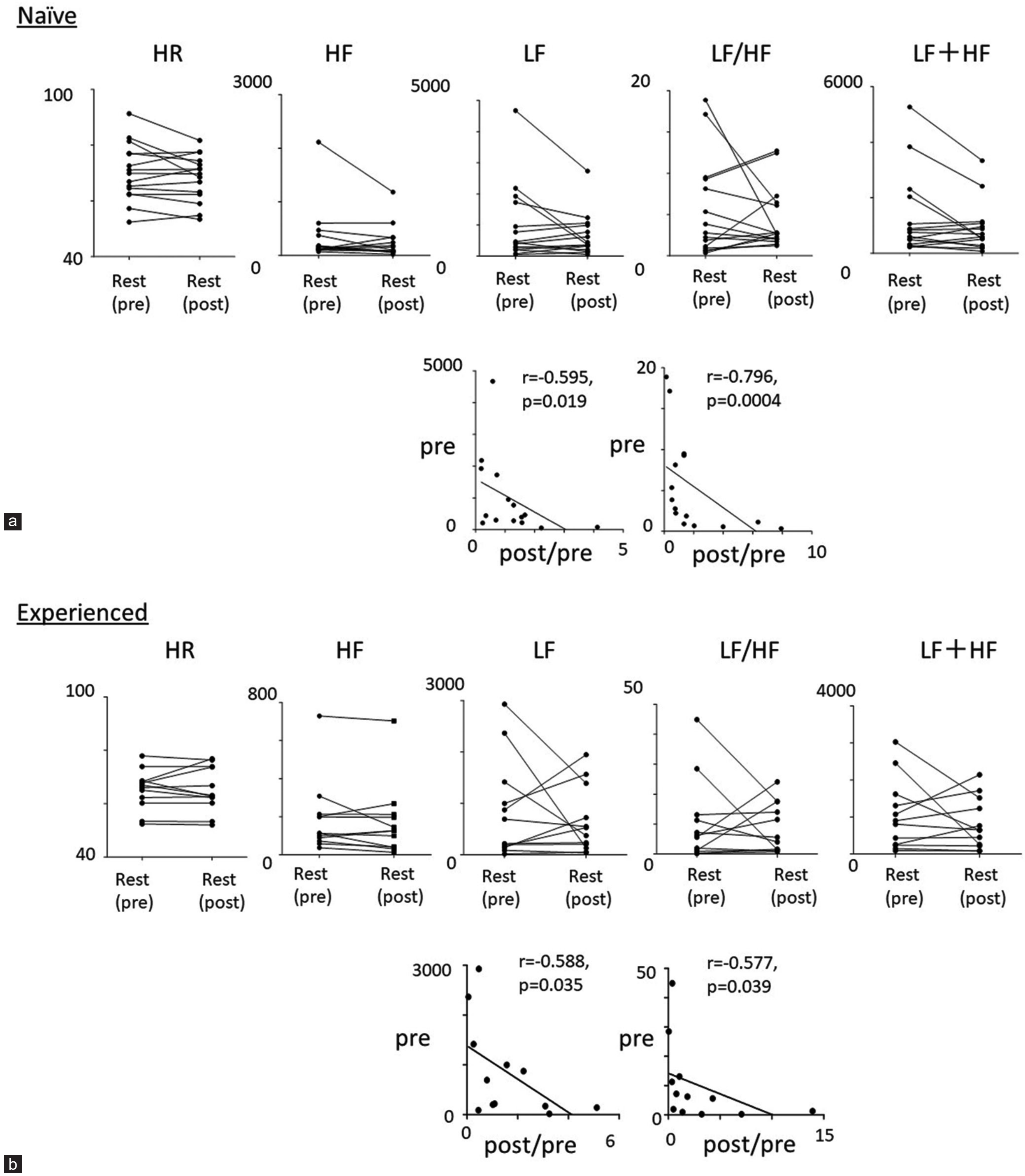

Figure 2: (a and b) The data from naïve and experienced subjects, respectively. Upper row: Changes in heart rate (HR) and heart rate variability parameters (high-frequency HF, low-frequency LF, low-frequency/high-frequency LF/HF, and low-frequency + high-frequency LF+HF) at the resting state after yoga (post) in comparison with that of before yoga (pre). The data from the same participant are connected by a line. No statistically significant differences are observed between the data before and after yoga (Wilcoxon signed-rank test, $P > 0.05$). Lower row: The low-frequency and low-frequency/high-frequency scores at the resting state before yoga (pre) plotted against the changes in these scores after yoga (post/pre). For these two parameters, "post/pre" scores show a correlation with "pre" scores (Spearman's correlation coefficients, $P < 0.05$). When the scores are high before yoga (pre), they tend to decrease, and when low, they tend to increase after yoga, presenting "normalization effect"

Discussion

The present study examined the autonomic basis of yoga effectiveness by examining the acute effect of yoga on HRV. In contrast to the previous reports supporting the augmentation of parasympathetic activity reflected in increased HF after long-term yoga therapy, the present study showed no significant acute effect on HF when it compared the data before and immediately after yoga and suggests that parasympathetic activation is not the major biological change for the acute effect.

As the acute effect of yoga therapy, the present results clarified the normalization of autonomic activity reflected in LF. Yoga leads to an increase in LF when LF is low and leads to a decrease when it is high at the baseline. LF/HF behaved in a similar manner. HF did not show such changes. The present study suggests the acute effects of yoga on LF.

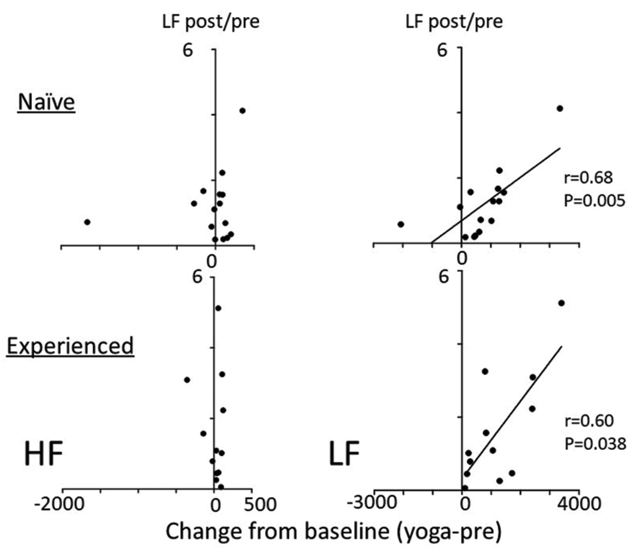

Figure 3: Relation of the changes in low-frequency scores after yoga (low-frequency LF post/pre) with the changes in high-frequency (HF) and low-frequency (LF) scores during yoga (yoga-pre) in naïve and experienced participants. The averaged high-frequency and low-frequency scores during all yoga skills were used for the calculation. The changes in low-frequency score after yoga (post/pre) did not exhibit relation with high-frequency change during yoga but showed significant correlation with low-frequency changes during yoga (Spearman's correlation coefficients, *P* < 0.05)

LF is pharmacologically related to both sympathetic and parasympathetic activities[34] and is known to be related to blood pressure fluctuation called Mayer wave. HR increases when the systolic blood pressure decreases and decreases when the blood pressure increases. This change in HR by baroreceptor activity is reflected in LF and enables a constant supply of blood flow to the body structures.[11]

It is expected that an adequate level of LF is required to maintain the blood flow suitable to the environmental situation. Either excessive or insufficient LF would lead to an inadequate supply of blood flow. The normalization of LF by yoga can lead to suitable control of blood flow in response to behavioral changes. This normalization effect of yoga on the circulatory system may extend to autonomic activity, in general, involving both sympathetic and parasympathetic activities. Optimization of the level of autonomic activity should be important in maintaining a healthy state on facing stress or coping with diseases.

In the present study, asana was related to normalization in both yoga-naïve and experienced participants. Breath awareness was found to be related to normalization only in yoga-naïve participants. Pranayama was not directly related in the present study, although the effect of the order was not ruled out. Future studies are necessary to clarify which components of yoga skills are effective.

The present study further revealed that this normalization effect is related to autonomic modulation during yoga. This finding is based on the relation between the changes in LF after yoga and the LF during yoga. The LF increment (yoga-pre) during yoga was considered to involve breathing-related parasympathetic activity because

Table 2: Correlation coefficient r between LF change during yoga from baseline (yoga-pre) and post/pre ratio of HRV indices

		Awareness	Asana-1	Asana-2	Pranayama-1	Pranayama-2	Average
Naïve							
	HR	-0.30	0.08	0.41	0.28	-0.12	0.09
	LF	0.57*	0.66*	0.46	0.38	0.44	0.68*
	HF	0.18	-0.15	-0.21	-0.14	-0.05	-0.12
	LF/HF	0.44	0.62*	0.46	0.33	0.35	0.56*
	LF + HF	0.61*	0.46	0.20	0.16	0.45	0.51
Experienced							
	HR	0.48	-0.51	-0.20	-0.43	0.07	-0.07
	LF	0.26	0.46	0.80*	0.45	0.40	0.60*
	HF	0.04	0.04	-0.30	0.08	-0.08	-0.03
	LF/HF	0.15	0.26	0.62*	0.22	0.20	0.35
	LF + HF	0.24	0.50*	0.85*	0.55	0.35	0.64*

* *P*<0.05 Spearmen's correlation coefficient

Table 3: Correlation coefficient r between LF change during yoga from baseline (yoga-pre) and HRV indices at baseline rest

		Awareness	Asana-1	Asana-2	Pranayama-1	Pranayama-2	Average
Naïve							
	HR	-0.01	-0.29	-0.58*	-0.21	-0.34	-0.44
	LF	-0.70*	-0.65*	-0.60*	-0.24	-0.36	-0.59*
	HF	-0.17	0.08	0.29	0.21	0.08	0.18
	LF/HF	-0.45*	-0.59*	-0.66*	-0.46	-0.40	-0.64*
	LF + HF	-0.67*	-0.69*	-0.61*	-0.18	-0.38	-0.56*
Experienced							
	HR	-0.43	-0.31	-0.29	-0.03	0.01	-0.30
	LF	-0.01	-0.10	-0.29	0.16	-0.03	0.00
	HF	-0.03	0.22	0.50	0.65*	0.27	0.64*
	LF/HF	0.06	-0.10	-0.41	0.01	-0.02	-0.13
	LF + HF	0.00	0.06	-0.12	0.39	0.01	0.20

* $P<0.05$ Spearmen's correlation coefficient

the respiration rate during yoga skills fell into the range below 0.15 Hz. The present study may suggest that yoga, by adjusting respiration-related parasympathetic activation during yoga skills, normalizes the autonomic balance. It is also possible to assume that blood pressure-related autonomic modulation is controlled by yoga.

This acute normalization of autonomic activity by yoga is not restricted to experienced practitioners but is common to yoga-naïve participants. It is suggested that normalization is brought about without repetitive training of yoga and could be expected from the beginning of yoga therapy. However, the relation between the autonomic activation during yoga and the baseline HF is only found in yoga-experienced participants, suggesting that baseline parasympathetic activation by yoga is produced after long-term practice of yoga.

Yoga is also reported to be effective in neuropsychiatric patients including depression and anxiety.[35-38] It would be interesting to extend the present protocol to psychiatric patients.

Limitation

Future study with a larger sample size containing adequate numbers of male and female is necessary to scientifically verify the present findings, especially with respect to gender.

Conclusion

The present study examined the acute effect of yoga on autonomic activity using HRV measurement during yoga. In both yoga-naïve and experienced participants, yoga leads to an increase in LF when LF is low and leads to a decrease when it is high at the baseline in relation to autonomic modulation during yoga. This normalization effect on autonomic activity may underlie the clinical effectiveness of yoga therapy.

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Conflicts of interest

There are no conflicts of interest.

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