A Comparative Study of the Cardiac Response to Bhastrika: A Yogic Breathing Exercise and the Exercise Tolerance Test

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Yogic breathing exercises form a spectrum from simple, diaphragmatic breathing to complex exercises involving breath retention and visualization. Many of the advanced exercises are potentially harmful if not taught and practiced systematically.

Just as a novice climber does not attempt to scale Mount McKinley on his or her second climb, so a beginning student would not practice the advanced exercises until after he or she has practiced and mastered the simple exercises which regulate, strengthen, and coordinate the respiratory apparatus. One advanced respiratory exercise is bhastrika, which includes both a rapid, forceful inhalation and exhalation. The book, Science of Breath, by Swami Rama, explains bhastrika as follows:

The word bhastrika means "bellows" and in this pranayama the abdominal muscles work like bellows. . . In this exercise, the diaphragm and abdominal muscles are employed...both inhalation and exhalation are vigorous and forceful. Between seven and twenty one cycles should follow each other in quick succession.[1]

A wide range of benefits from the practice of Bhastrika are described in The Complete Book of Yoga, by Hewitt, drawing from ancient commentaries:

The benefits of bhastrika are to clear the nasal passages, purify the blood, cleanse the sinuses, remove phlegm, improve circulation, generate pranic vitality, tone the nervous system, stimulate the liver, spleen and pancreas, improve digestion, facilitate evacuation, strengthen and tone the abdominal muscles, and massage the abdominal organs (viscera).[2]

Van Lysebeth further articulates the benefits derived from the practice of bhastrika, suggesting that it stimulates the sympathetic nervous system in particular.[3]

The effects of bhastrika have also been compared to the effects of aerobic exercise upon the body. This is an interesting comparison because aerobic exercise typically involves vigorous body activity such as that found during swimming, jogging, or tennis, while bhastrika is performed sitting motionless. In aerobic exercise, the respiration rate increases both in depth and frequency, and heart rate

(HR) increases secondary to the activation of the sympathetic nervous system in response to the body's increased need for blood flow and oxygen. Bhastrika consists of rapid, relatively shallow breathing in a very regular sequence. This technique has been shown to induce a decrease in finger pulse volume, a decrease in finger temperature, and in one study, an increase in HR . These findings are consistent with an increase in sympathetic arousal. HR responses, however, are relatively small, especially compared to HR changes during aerobic exercise. In one study of five yoga students, no significant change in HR occurred.[4]

This response of HR during bhastrika is the focus of this study because it is an easily quantifiable index of at least one facet of autonomic nervous system function, because it allows for a direct comparison with aerobic exercise, and finally because of the ambiguity in the literature about the nature of HR response during this exercise. Also, the previous studies of HR changes during bhastrika are limited in their findings as they discuss only the average change in HR and do not take into account the time course of the changes or the possible training effects that occur over a period of regular practice. These studies also do not observe the more subtle aspects of the beat-to-beat variability of HR, and because of the discordant findings concerning the overall response of the heart, do not clearly address the issue of the direction and intensity of autonomic nervous system (ANS) activation.

The current protocol was also designed to permit observation of HR response to the gradual increase in repetitions of the bhastrika practice during a three-month training period of one of the subjects.

Method

The present study is based upon data collected during the practice of bhastrika from three subjects with varying levels of experience with the exercise. All three subjects were healthy males between 25 and 35 years of age. Subject 1 had approximately one year of experience of intermittent practice of bhastrika. Subject 2 had an intermediate level of experience with bhastrika. Subject 3 had practiced bhastrika regularly for more than four years.

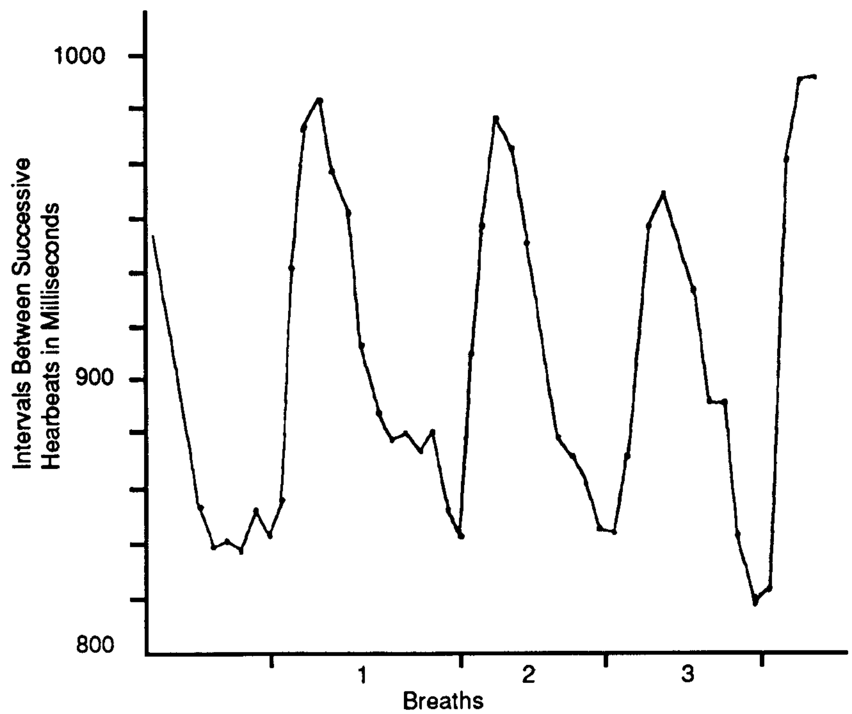


Figure 1. A typical example of the phasic change in HR or sinus arrhythmia in a relaxed subject.

In an attempt to evaluate the effect of an intense period of training on the performance of bhastrika, Subject 2 ceased practice for a four month period prior to the beginning of testing. Practice of bhastrika was resumed at the beginning of the testing and continued during a three month period, twice daily for three to five minutes gradually increasing duration according to comfortable capacity. The repetitions of the breathing exercise were limited to the number that most intermediate yoga students commonly practice so that the results would be of interest to most students practicing these techniques. This subject (S2) underwent additional evaluations of HR response to bhastrika in the laboratory periodically during the three months of training. Data drawn from pre-training, mid-training, and end-training testing sessions are presented here. For this subject (S2), the change in sympathetic activation due to the breathing exercise was also calibrated by comparing it to similar changes which occurred during a maximal exercise tolerance test on a treadmill.

Each testing session was conducted at the same time in the early morning, and the subject was instructed not to eat prior to the sessions. At the beginning of each session, the resting respiration rate of the subject was recorded while he was seated in a comfortable position. The subject was instructed to practice breath awareness. During the practice of breath awareness, the subject observed his breath and attempted to regulate the flow so that it became smooth and even with no jerks, pauses, or noise. This respiration rate and simultaneous beat-to-beat HR was the baseline for that session. (See Figure 1.)

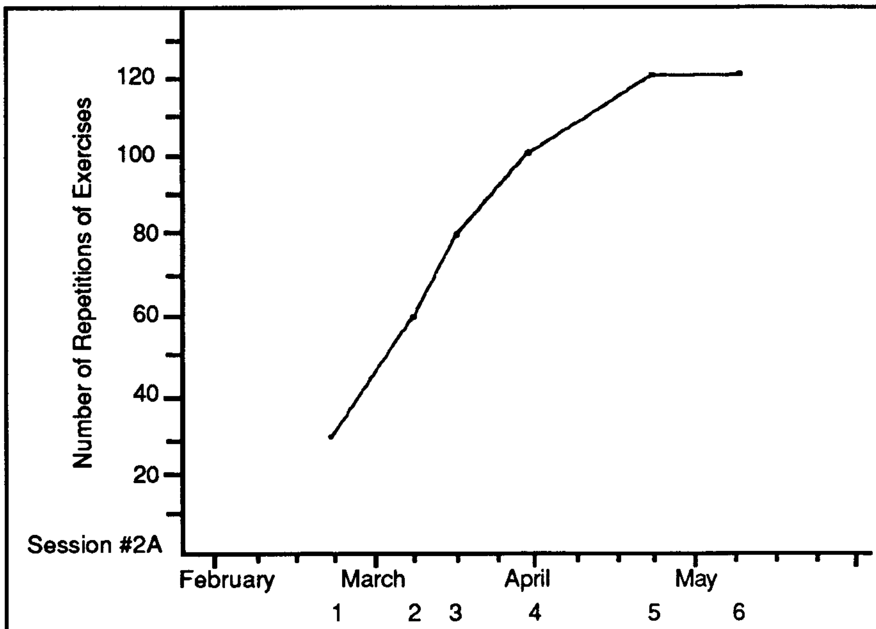


Figure 2a. Rate of increase in the number of repetitions of bhastrika in successive recording sessions for Subject 2.

After relaxation and breath awareness were practiced for one to two minutes, or until HR fluctuations stabilized, the subject was asked to perform a series of rounds of gentle bhastrika. After the exercise series was completed, the recovery phase was recorded, usually for one to two minutes, until HR again stabilized. Once the baseline level of respiration rate and HR had been reestablished (usually within two minutes), a series of rounds of vigorous bhastrika were performed. In this second round, bhastrika was performed as vigorously as possible.

For Subject 2, the protocol used for the additional sessions, during his three-month training period, was as follows:

A total of six recording sessions was conducted, one every other week. All the recording sessions were conducted at the same time (7:30 a.m.) to avoid any inherent physiological variations due to time of day. The number of repetitions of the exercises was gradually increased in each recording session according to the subject's comfortable capacity. The increase in repetitions was as follows: first session: 30 repetitions, second session: 60 repetitions, third session: 80 repetitions, fourth session: 100 repetitions, fifth and sixth sessions: 120 repetitions.

The order in which each exercise was performed was varied to avoid habituation. The maximal exercise tolerance test was conducted on a Quinton treadmill, with continuous monitoring of EKG and respiration; blood pressure was monitored each minute. The speed and inclination of the treadmill was increased every three minutes according to the Bruce protocol until maximum exercise capacity was reached.[5]

Abdominal and chest excursions were recorded using a Respitrace® vest, recorded on a Siemans Mingograph EM 34 polygraph. HR intervals were timed using a Coulbourn Micro-Processor and recorded by a Gultan NP-7 digital printer. EKG for the exercise tolerance test was recorded on a Hewlett-Packard EKG with a bipolar electrode placement in the CV-5 electrode configuration. An analog printout of the HR intervals and an EKG were also recorded by the Mingograph.

Results: Baseline Period

The respiratory arrhythmia (the normal wave-like rise and fall of HR during a single respiratory cycle) during the baseline determinations was consistent, measuring 140 to 160 milliseconds (See Figure 1). The degree

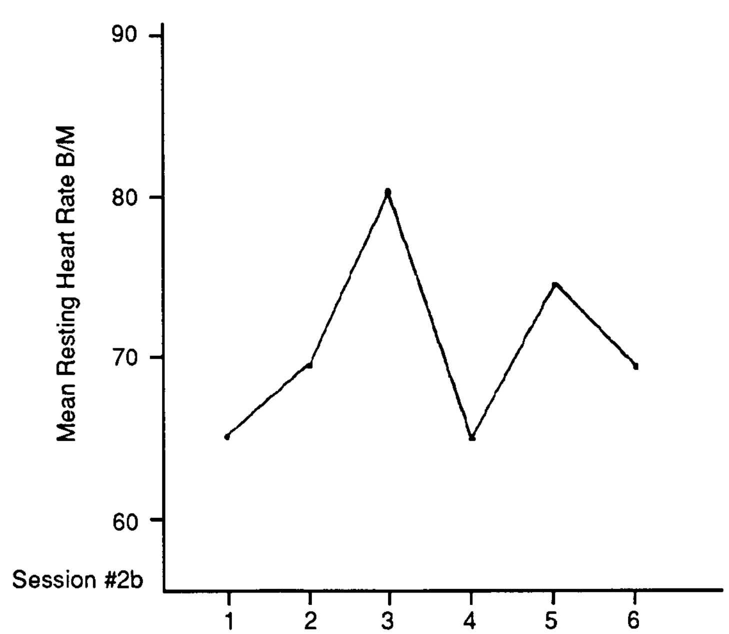
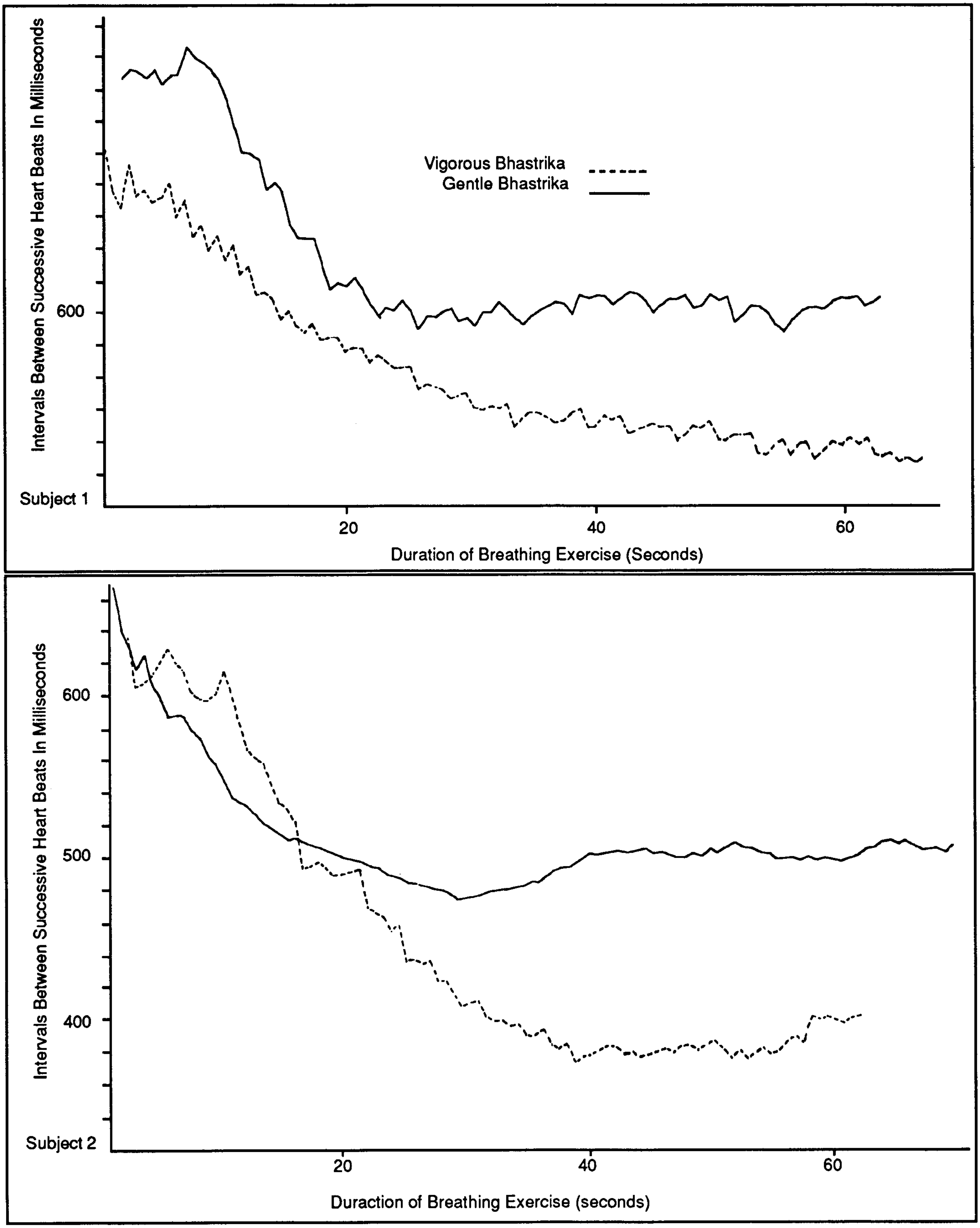


Figure 2b. Changes in the baseline HR during the sessions as in Figure 2a.



Figures 3a and 3b show the change in heart beat intervals during the vigorous and gentle practice of bhastrika. Note the regularity and small beat-to-beat change, especially in Subject 3, Figure 3b.

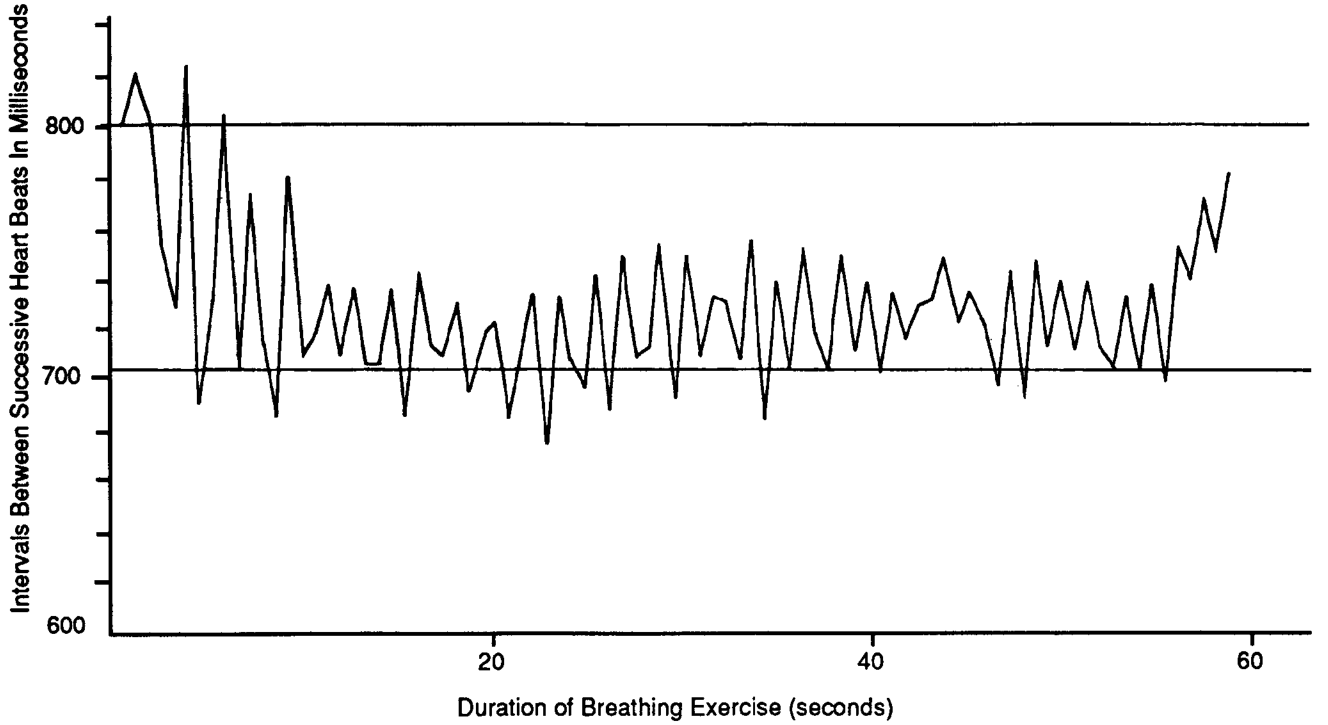


Figure 4a. Gentle Bhastrika. This is an example of gentle bhastrika by Subject 2.

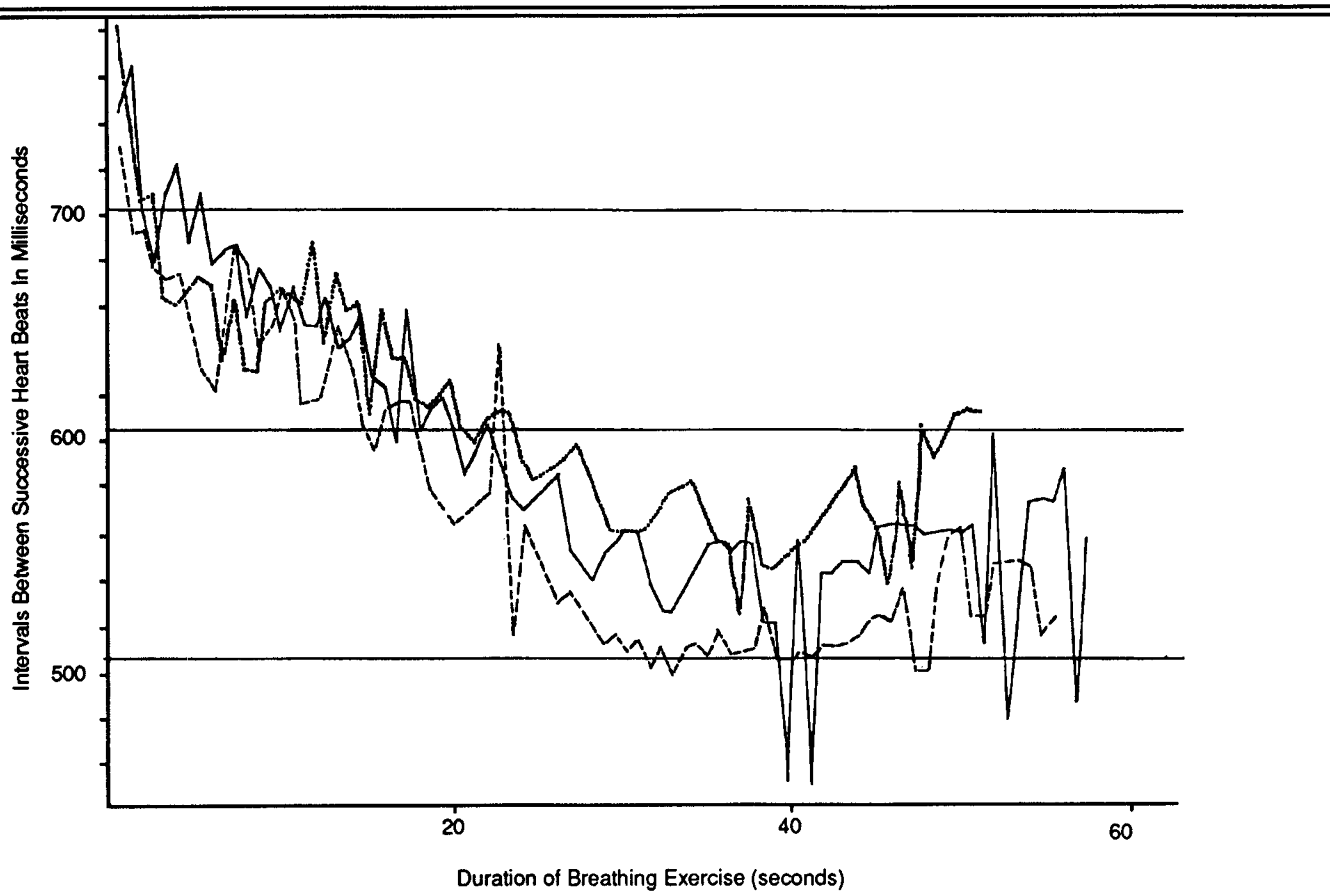


Figure 4b. Vigorous Bhastrika. Three different sessions of recording vigorous bhastrika in Subject 2 are shown here.

of variation remained constant in any one session but varied slightly from session to session for Subject 2. The mean HR during this "breath awareness" phase also varied from session to session. (See Figures 2a and 2b.) The mean resting HR remained consistent in any given session despite the change from session to session. No trend to a lowering of the resting HR was seen, as is noted in aerobic training. There was, however, an obvious increase in endurance for the exercise, consistent with a training effect on the respiratory muscles.

Results: Bhastrika

The beat-to-beat HR responses to bhastrika performed gently and vigorously are shown in Figures 3a and 3b, for the subjects with some practice (S1) and with prolonged practice (S3), respectively.

A consistent two-phase pattern is obvious in both:
1) The first phase was a period of HR acceleration. The slope and duration of this period remained consistent throughout the training, whether 30, 60, 80, 100 or 120 repetitions were performed. This phase lasted for about 45 heart beats in each case, or 20 to 30 seconds.

2) The second phase consisted of a period in which HR leveled off at an accelerated rate. As the beat-to-beat change diminished, a flatter curve resulted. This phase lasted for about 25 heart beats (14 seconds) before larger intervals began. HR began to slow. This second phase grew longer with practice and with increased number of repetitions.

The basic difference between vigorous and gentle performance of bhastrika (terms which were not given a quantified definition) was greater HR response during the plateau phase during vigorous effort. Subject 1 achieved a HR of 100 beats per minute (BPM) with gentle practice and 120 BPM with vigorous practice. Subject 3, the most highly trained of the three, achieved a HR of 120 BPM with gentle practice and 150 BPM with vigorous practice. Subject 2 (Figures 4a and 4b) showed the smallest HR responses, 85 BPM with gentle bhastrika and 115 BPM with vigorous. There was no clear change in response over the training period, although a tendency toward a faster HR with each subsequent session is suggested.

This is clearly a different response than the change with aerobic training, in which HR required for a given activity becomes slower with training. The tendency in this study is that prolonged training over months in Subject 2, and years in Subject 3, lead to progressively faster heart responses, perhaps from an increase in the strength or coordination with which the exercise can be performed. In all subjects, the duration and rate of acceleration of HR in the first phase of the response was similar and did not appear to change over time with training.

An interesting finding is the occurrence of an increased regularity of the HR during the time the breathing exercises were performed. After the stage in which the HR accelerated rapidly, the second phase of the exercise was first distinguished by very small beat-to-beat interval changes. The decreased phasic HR change in both S1 and S3, as well as the fact that this period of regularity grew longer and flatter in the later sessions of S2's training, may indicate that the subject's continued practice influenced this response.

Discussion

During vigorous aerobic exercise, the heart beats at the same relative rate (500 to 650 milliseconds) are irregular and continue in a phasic acceleration/deceleration relative to inhalation/exhalation. But during vigorous Bhastrika, HR stabilizes and sustains brief periods (5 to 30 heart beats) of essentially unchanging HR. This period of sustained constant HR seems to be a physiological response that can be developed by coordinated and consistent practice of this exercise. This appears to be associated with a 1:1 synchrony between HR and respiration rate to the degree that the heart beat occurs at the same point in each respiratory cycle. Whether this coordination of the heart beat and the respiration rate is significant to the achievement of the benefits of bhastrika is still unknown. Exploring the potential for expanding these responses and observing any further development due to increased proficiency and capacity with prolonged practice would be an interesting topic for further study.

The relationship between the actual beating of the heart and the motion of the diaphragm and lungs also deserves additional study. During the periods of greatest HR regularity, the timing between the QRS wave and the torso excursion was consistent, with the heart beat striking at precisely the same phase of each breath cycle. As this timing changed, the interval changes of HR again became larger and more irregular.

A possible explanation for this is that HR and breath rate are approximately in phase, or synchronous at 110 to 115 beats or breaths-per-minute. Thus, the sympathetic reflexes normally initiated to compensate for the drop in blood pressure with each inhalation may be compensated for by the heart beat itself.

At the same time that inhalation occurs and the lungs are filling with blood, potentially lowering the systemic blood pressure by decreasing the blood return to the heart, the heart is contracting and stabilizing the blood pressure. While this respiratory-pulmonary coordination is maintained, autonomic reflexes appear to be held constant, and the heart and respiration rates continue in coordination with little change. Endurance and coordination appear to limit this pheno-

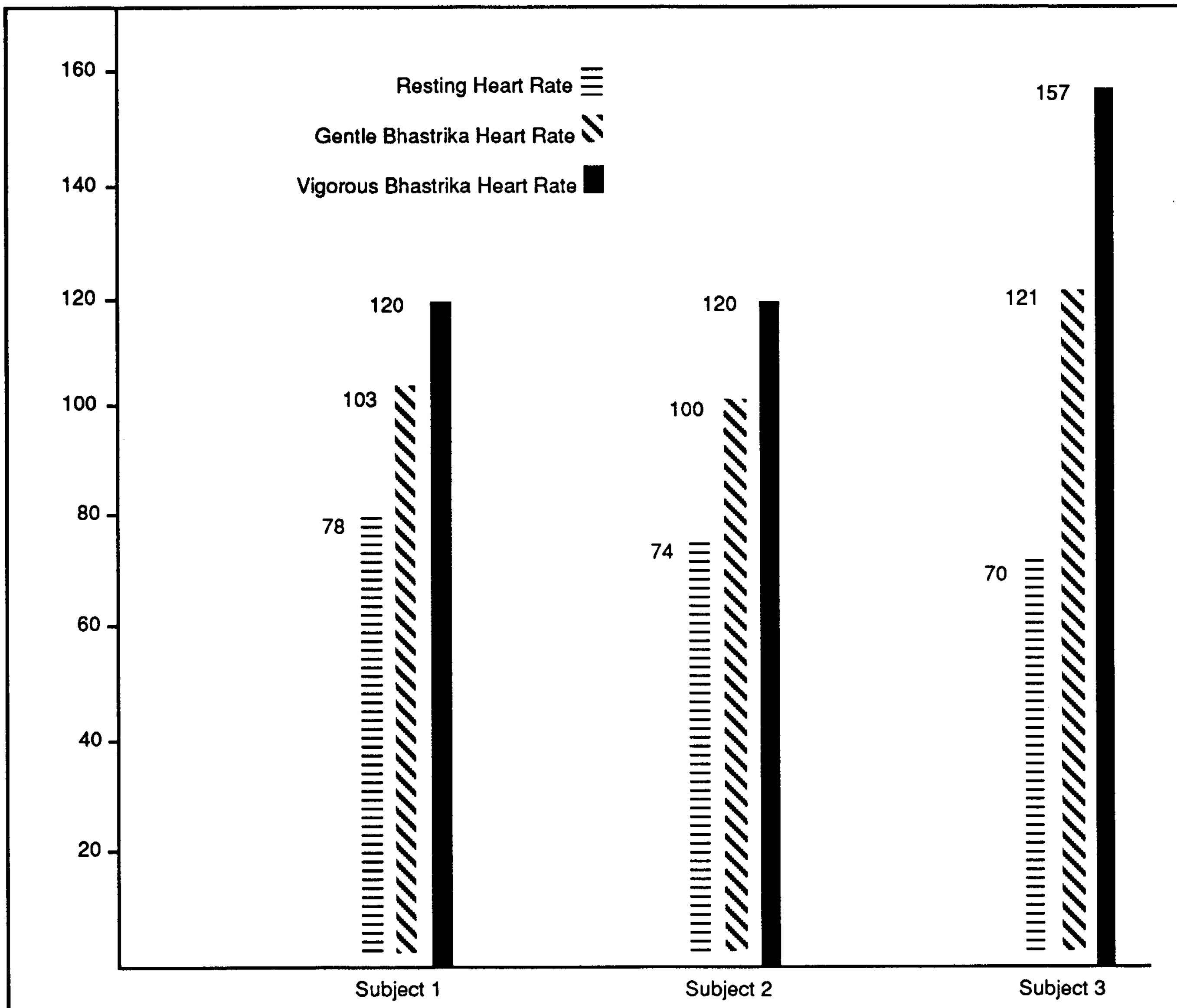


Figure 5. A comparison of the change in HR during vigorous and gentle bhastrika. The subject with the most experience is Subject 3.

menon, since 1) the subject with the longest history of practice showed the longest and most stable regularity and 2) S2 increased the duration of this stabilizing phase as the practice time was increased.

Bhastrika performed both gently and vigorously produced a significant sympathetic nervous system activation. With vigorous practice, HRs increased up to 120 BPM in two subjects and up to 157 BPM in the subject with the most experience, in the absence of any significant physical motion except for breathing. (See Figure 5.) When this HR increase is calibrated in terms of the percentage of maximum HR by comparison with results of the maximal exercise tolerance test, it represents a degree of sympathetic nervous system activation comparable to what occurs at 58 to 78% of maximal exercise.

In all the subjects, but particularly Subject 3, the increase in HR represents a significant increase in the level of sympathetic nervous system activation. This level of sympathetic activation is equivalent to the activation usually considered necessary for aerobic training. This essentially represents a very high degree of activation of at least one facet of the sympathetic nervous system, and it has occurred voluntarily through the manipulation of the breath, in the absence of significant physical motion except for the muscles used for breathing.

One way to compare the degree of exercise is to calibrate it in terms of metabolic equivalents or mets (one met is equivalent to the basal metabolic rate). According to this system, Subject 2 doing vigorous bhastrika was inducing a sympathetic response equivalent to that of exercise at seven mets (seven mets is equivalent to walking or jogging at 5.5 mph, playing singles tennis, or water skiing. Of note is that when exercising at seven mets, there is a considerable expenditure of physical energy, i.e.: seven times the resting oxygen requirement).

In bhastrika the work of breathing is the only activity. Because the work of breathing is only a small fraction of the resting oxygen consumption, the overall oxygen need is increased 10 to 20%, comparable to a met level of approximately 1.1 to 1.2, far too small to account for HR response usually seen with exertion levels of seven mets or higher. So a question arises concerning the mechanics of HR response. In the absence of emotional stimuli, HR increases as more blood flow is needed to supply oxygen to the body. If the actual oxygen needs from increased physical exertion have not increased, then other mechanisms must be involved. There are three possible of mechanisms involved:

1) During exercise, the cardiac output is decreased. A more rapid HR is required to maintain adequate circulation. The rapid motion of the lungs may influence the stroke volume of the heart, reducing the volume to the extent that HR must increase.

2) The rapid shallow breathing may reduce the efficiency of the gas exchange in the lungs. With the increase in the body's oxygen requirements by 17 to 20% and the decreased efficiency of the gas exchange, HR would necessarily increase to compensate and maintain metabolic equilibrium.

3) The rapid motion of the lungs may directly (or indirectly) stimulate the sympathetic nervous system which in turn causes HR to increase.

One or all of the above may be involved in the ultimate mechanics of the physical or metabolic changes induced by the practice of bhastrika. For whatever reason, this particular yogic technique clearly creates a major activation of one branch of the ANS that can be achieved voluntarily with minimal physical activity.

The consistent finding of this degree of ANS activation does, however, stand in bold contrast to the previously reported studies, in which minimal heart acceleration occurred. The reasons for this are unclear. The technique used in the studies of Wenger and Bagchi involved interposed periods of breath retention between periods of bhastrika of an unspecified duration, but at least 10 seconds long. The sampling period for HR was also not clearly specified, and a beat-to-beat analysis does not appear to have been undertaken. In this situation, the early acceleration of the heart during the 10 or so seconds of bhastrika may have been overlooked, and the practice was not sustained long enough to elicit the more marked response.

Conclusions

The practice of bhastrika, a standard yogic breathing exercise, induces a sympathetic response, as measured by heart rate, equivalent to significant physical exercise from approximately 58 to 78% of maximal exercise capacity in the three subjects studied. The unique feature of this exercise is that this cardiovascular stimulation is achieved with no physical exertion, except for breathing.

Prolonged performance of this breathing practice leads to a two-phase heart response of initial acceleration followed by a plateau phase of an elevated, relatively constant rate. Prolonged practice over months and years may lead to the achievement of a HR which is faster as well as more regular, the latter characteristic perhaps a result of a precise 1 to 1 synchrony between HR and respiratory rate. A training effect on the cardiovascular system evidenced by a slower resting HR, or progressive slowing over time was not demonstrated. HR response was at a level comparable to that required for aerobic training. The short duration of the practice of Bhastrika used in these subjects (three to five minutes daily) falls short of the customary twenty minutes three to five times a week, associated with aerobic training.

Bhastrika was perceived to have a temporary stimulating, clearing effect on alertness, perhaps in part from ANS activation. The other benefits ascribed to it in the texts of yoga were not measured in this study. Taking into account the data presented, it should also be recommended that people with heart disease undertake this practice under careful guidance, and with a very gradual and gentle approach.

1 Swami Rama, Ballentine, R., and Hymes, A. *Science of Breath*. Himalayan Institute Press, Honesdale, Pa: 1979, p. 118.

2 Hewitt. *The Complete Book of Yoga*, Shocken, 1978, p. 95.

3 Van Lysebeth, A. Pranayama. Unwin, 1979, p. 154.

4 Wenger, M. A., and Bagchi, B. K. Studies of autonomic functions in practitioners of yoga in India. Behavioral Science, 6:312-323, 1961

5 Bruce, R. A. Progress in exercise cardiology. in Ya, P. N., and Goodwin, J. F. (eds.), Progress in Cardiology, Philadelphia: Lea & Febiger, 1974, p. 133.

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