Effects of Hatha Yoga Practice on the Health-Related Aspects of Physical Fitness

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Ten healthy, untrained volunteers (nine females and one male), ranging in age from 18–27 years, were studied to determine the effects of hatha yoga practice on the health-related aspects of physical fitness, including muscular strength and endurance, flexibility, cardiorespiratory fitness, body composition, and pulmonary function. Subjects were required to attend a minimum of two yoga classes per week for a total of 8 weeks. Each yoga session consisted of 10 minutes of* pranayamas *(breath-control exercises), 15 minutes of dynamic warm-up exercises, 50 minutes of* asanas *(yoga postures), and 10 minutes of supine relaxation in* savasana *(corpse pose). The subjects were evaluated before and after the 8-week training program. Isokinetic muscular strength for elbow extension, elbow flexion, and knee extension increased by 31%, 19%, and 28% (p<0.05), respectively, whereas isometric muscular endurance for knee flexion increased 57% (p<0.01). Ankle flexibility, shoulder elevation, trunk extension, and trunk flexion increased by 13% (p<0.01), 155% (p<0.001), 188% (p<0.001), and 14% (p<0.05), respectively. Absolute and relative maximal oxygen uptake increased by 7% and 6%, respectively (p<0.01). These findings indicate that regular hatha yoga practice can elicit improvements in the health-related aspects of physical fitness.
(Prev Cardiol. 2001;4:165–170) *©2001 CHF, Inc.*

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Manuscript received May 9, 2000; accepted June 28, 2000

Yoga is an ancient Indian practice, first described in Vedic scriptures around 2500 B.C., which utilizes mental and physical exercises to attain *samadhi*, or the union of the individual self with the infinite.[1] According to the first comprehensive textual description of yoga, the *Yoga Sutras*, written in the third century B.C., yoga is the cessation of thought waves in the mind.[2] Hatha yoga, one of the many forms or paths of yoga, focuses on overall fitness through *pranayamas* (breath-control exercises), *asanas* (yoga postures), and *chanda* (meditation). Like other forms of yoga, hatha yoga is purported to quiet the mind and focus the concentration; however, of all the yoga traditions, the importance of physical fitness is emphasized most in hatha yoga.[3,4]

Studies have shown that yoga practice can lead to improvements in hand-grip strength,[5] muscular endurance,[6] flexibility,[7] and maximal oxygen uptake (VO_{2max}).[8] In addition, decreases in percent body fat[9,10] and increases in forced vital capacity (FVC) and forced expiratory volume in 1 second ($FEV_{1.0}$)[11–13] have also been observed. However, no research to date has addressed the effects of hatha yoga on all the health-related aspects of physical fitness, which are defined as muscular strength and endurance, flexibility, cardiorespiratory endurance, and body composition,[14] in the same subjects. Furthermore, most yoga studies conducted to date have derived their results from indirect measurements and estimates. For example, muscular strength was often solely evaluated using the hand-grip dynamometer,[3,15] cardiorespiratory endurance was estimated from the Astrand-Rhyming[8] or Harvard step tests,[7,9] and body composition was assessed from skinfold thickness.[7,9,10] We report the results of a pilot study intended to evaluate the effects of hatha yoga practice on health-related physical fitness variables (including pulmonary function) using direct measurements.

METHODS AND PROCEDURES

Subjects

Healthy, young subjects were recruited by flyer from our local campus community. No incentives were offered other than the yoga classes and physiologic testing. Following approval of our institutional Human Subjects Review Committee, written informed consent was obtained from 14 subjects (11 females and three males) who volunteered to participate. The age range was 18–27 years (means±SEM, 22.1±0.8). Subjects were expected to attend a minimum of 50% of the 32 classes offered. One male and nine female subjects completed the study, with an average attendance of 21.5 classes. Three subjects dropped out during the first 2 weeks of the study and declined to perform post-study testing. One other regular attendee also declined to perform post-study testing. Subjects were required to be sedentary, having engaged in no regular physical activity, including yoga, for the previous 6 months. Subjects were instructed to refrain from all other forms of exercise while participating in the training program. Additionally, no subject had known heart disease or significant recent joint or muscular injury, as determined by written medical history.

Treatment

Yoga classes were offered four times per week, from 7:30–9:00 a.m., for 8 weeks. A certified yoga instructor led all classes. Each yoga session consisted of 10 minutes of *pranayamas*, (breath-control exercises), 15 minutes of warm-up exercises, 50 minutes of *asanas*, (yoga postures), and 10 minutes of relaxation in *savasana*, (the corpse pose).

The *pranayamas* consisted of alternate nostril breathing *(nadi sodhana)*[16] while maintaining the thunderbolt *(vajrasasa)*[2] or half-lotus *(ardha padmasana)*[1] position. Nostril-regulated breathing *(ujjayi)*[1] was practiced throughout the warm-up and *asana* portions of the exercise program. The warm-up program focused on slow, dynamic muscular movements, which consisted of the frog pose,[17] dynamic lunges, shoulder/arm circles, neck rolls, standing forward bend *(parsva uttanasana)*,[16] and two to three cycles of the "sun salutation" *(surya namaskar)*.[1] The *asanas* introduced in this study included the following poses: spinal twist *(vakrasana)*,[1] cat *(vidalasana)*,[17] forward bend *(pascimottanasana)*,[2] head to knee *(maha mudra)*,[2] tree *(vrksasana)*,[18] warrior *(virabhadrasana)*,[19] triangular *(trikonasana)* variations one and two,[19] superman,[17] partner bridge, and pigeon *(eka pada rajakapotasana)*.[19] The *asanas* focused on the quality and ease of breath, isometric muscular contractions, flexibility, balance, and concentration. Each yoga session ended with 10 minutes of *savasana* to relax and cool down.

Although individual yoga techniques are universally documented, the various exercises, sequences, and duration of each movement are dependent on individual instructors. Whereas the *pranayamas* and warm-up protocols were practiced in their entirety, only a limited number of *asanas* were completed at each yoga session. Because our subjects were novices in the practice of yoga, only fundamental techniques were introduced in this study. Because many of the *asanas* are difficult, even for the experienced yoga practitioner, subjects were encouraged to do all exercises as accurately as possible, but to maintain their concentration and breath control with comfortable positions at all times.

Evaluation

Measurements were made during the weeks prior to and immediately following the 8-week training program. All procedures were demonstrated prior to testing. Testing was divided into two sessions, with each session separated by 1 day of rest. Maximal strength and $\dot{V}O_{2max}$ were evaluated on day 1, and muscular endurance, flexibility, body composition, and pulmonary function were measured on day 3.

Muscular strength was evaluated using the LIDO Multi-Joint II™ (Loredan Biomedical, Inc., Sacramento, CA).[20] Isokinetic strength at 30^{o} sec^{-1} was measured for elbow extension, elbow flexion, knee extension, and knee flexion. The range of motion for elbow extension was 90^{o}–10^{o}, elbow flexion was 10^{o}–90^{o}, knee extension was 125^{o}–55^{o}, and knee flexion was 30^{o}–100^{o} (with 0^{o} designating full extension), as determined by pilot tests to maximize torque. For each movement, five trials were completed, and the average of the top two torques was taken to represent maximal strength.

Muscular endurance was also measured with the LIDO Multi-Joint II. Isometric contractions at 50^{o} elbow extension, 50^{o} elbow flexion, 85^{o} knee extension, and 90^{o} knee flexion were measured. Subjects performed five maximal isometric efforts within 2 minutes. The average of the top two trials represented peak torque for that movement. Subjects were then instructed to maintain an isometric contraction at 80% of their peak torque. Muscular endurance was measured as the time until subjects were no longer able to maintain at least 70% of their maximal torque.

Flexibility was measured at the ankle, shoulder, and hip joints. Three submaximal trials preceded three test trials for each movement. The average of the top two scores was used to represent maximal flexibility for that movement. To reduce subjective variability, the same two researchers performed all flexibility measurements.

Flexibility was assessed as described by Gettman.[21] Briefly, a goniometer was used to measure the absolute range of motion at the ankle (plantar flexion and dorsiflexion). A measuring tape was used to measure shoulder elevation: from a prone position, with arms straight and shoulder-width apart, the subject held a horizontal meter stick and raised it upward as high as possible while keeping the chin on the floor. The distance from the bottom of the meter stick to the floor represented shoulder elevation. In the trunk extension test, the subject lay prone with

Table I. Changes in Muscular Strength, Muscular Endurance, and Flexibility After 8 Weeks of Hatha Yoga Practice (% Change)

Parameter	Before Training	After Training	(% Change)
Muscular strength (Nm)			
Elbow extension	22.9±2.2	27.9±1.9*	31±14
Elbow flexion	29.6±4.9	33.3±4.6*	19±9
Knee extension	139.7±14.5	165.3±10.9*	28±13
Knee flexion	60.7±7.1	64.5±6.0	11±10
Muscular endurance (sec)			
Elbow extension (n=7)	56.5±17.9	58.1±16.7	93±70
Elbow flexion (n=7)	48.7±8.3	53.1±8.9	18±16
Knee extension	49.0±4.0	55.2±6.3	12±8
Knee flexion	53.6±6.9	81.8±13.7**	57±16
Flexibility			
Ankle flexibility (degrees)	64.0±3.9	71.1±3.2**	13±3
Shoulder elevation (cm)	13.6±1.1	34.6±3.8†	155±20
Trunk extension (cm)	8.6±1.4	24.5±3.9†	188±20
Trunk flexion (cm)	36.9±2.8	41.0±2.2*	14±6

Values represent means±SEM. *$p<0.05$; **$p<0.01$; †$p<0.001$; n=10, except where noted

feet and hips held down by researchers: with the hands clasped behind the head, the subject raised the trunk as far upward and backward as possible. Trunk extension was measured as the vertical distance between the mat and the chin. A sit-and-reach box was used to measure trunk flexion: while in the sitting position, with knees straight and in contact with the floor, the subject placed the index fingers of both hands together and reached as far forward as possible on the measuring tape, holding the position for one second. Since each subject served as his/her own control, limb lengths were not expected to change as a result of the 8-week study; therefore, only raw scores were recorded and used for statistical analysis.

All subjects performed a maximal treadmill exercise test following the continuous ramp protocol, as previously described,[22] where treadmill grade increased at the rate of 2.25% min^{-1} at the subject's self-selected running speed (same for both pre- and post-testing) following a 6-minute warm-up. VO_{2max} was determined on-line (Digital Equipment Corporation LSI-11/3, Maynard, MA) and calculated as described by Consolazio et al.[23] Expired gases were passed through a mixing chamber and continuously analyzed by a Perkin Elmer 1100 medical gas analyzer (Pomona, CA). Expired minute ventilation was assessed by the Ventilation Measurement Module (Alpha Technologies Inc., Laguna Hills, CA). Heart rates were measured from a 15-second sample obtained during each minute of exercise and recovery with a Hewlett-Packard 1500A electrocardiograph (Huntington, CA). VO_{2max} was defined as a respiratory exchange ratio greater than 1.0 in the presence of obvious fatigue or as cessation of oxygen consumption increase with increasing work rate.[24]

Body composition was assessed via hydrostatic weighing and calculated with Brozek's equation.[25] Residual lung volume was determined as described by Wilmore et al.[26] with the Jaeger N_2 analyzer (Rockford, IL) and Collins 13.5L respirometer (Boston, MA). Since residual lung volume was not expected to change with 8 weeks of hatha yoga practice, values measured during initial testing were used for both pre- and post-training calculations.

Pulmonary functions were assessed with the 13.5L Collins respirometer. FVC, $FEV_{1.0}$, and percent $FEV_{1.0}$/FVC were recorded from the best of two trials.

Statistics
Data were statistically analyzed by paired *t* tests,[27] with results expressed as means±SEM. Significance was accepted at the $p<0.05$ level.

RESULTS
Muscular strength increased by 31%, 19%, and 28% for elbow extension, elbow flexion, and knee extension, respectively, whereas muscular endurance increased only in knee flexion (57%) (Table I). Three subjects were unable to complete post-training measurements for elbow extension and elbow flexion due to either muscular injuries unrelated to this study (two subjects) or failure to comply with instructions (one subject).

All flexibility measurements increased significantly (Table I). Ankle flexibility, shoulder elevation, trunk extension, and trunk flexion increased by 13%, 155%, 188%, and 14%, respectively.

Table II. Changes in Exercise Respiratory Parameters, Body Composition, and Pulmonary Function After 8 Weeks of Hatha Yoga Practice

Parameter	Before Training	After Training	(% Change)
Cardiorespiratory endurance			
Time (min)	15.5±0.02	16.1±0.02	2±2
Expired ventilation (L•min^{-1})	68.5±6.0	73.4±7.1	7±4
Maximal heart rate (beats•min^{-1})	191.7±3.5	193.2±2.4	1±2
Maximal oxygen uptake (L•min^{-1})	2.0±0.1	2.2±0.1*	7±2
Maximal oxygen uptake (mL•kg^{-1}•min^{-1})	32.3±1.8	34.2±1.8*	6±2
Respiratory exchange ratio	1.2±0.04	1.20±.03	3±2
Body composition			
Weight (kg)	62.5±2.0	62.8± 1.9	1±1
Body fat (%)	28.5±2.3	28.3±2.3	0±2
Fat mass (kg)	18.0±1.8	18.0±1.8	0±2
Fat free mass (kg)	44.6±1.7	44.7±1.5	1±1
Pulmonary function			
FVC (L)	4.0±0.3	4.0±0.3	0±2
$FEV_{1.0}$ (L)	3.4±0.2	3.4±0.2	1±2
$FEV_{1.0}$/FVC (%)	84.3±1.6	85.2±1.2	1±2

Values represent means±SEM. FVC=forced vital capacity; $FEV_{1.0}$=forced expiratory volume in 1 second; $^*p<0.01$

Total time of the treadmill test, expired ventilation, maximal heart rate, and respiratory exchange ratio did not change; however, both absolute and relative $V_{O_{2max}}$ increased by 7% and 6%, respectively (Table II).There were no significant changes in any measure of body composition or pulmonary function (Table II).There were no reported injuries or adverse musculoskeletal effects resulting from this study.

DISCUSSION

This study shows that 8 weeks of regular hatha yoga practice, a tradition that has existed for at least 4500 years and is now becoming increasingly popular in the United States,[28,29] can have significant benefits in improving the health-related aspects of physical fitness.[14] Although previous studies have used indirect measurements and estimates, ours is the first study that has comprehensively, quantitatively, and directly measured muscle strength and endurance, flexibility, cardiorespiratory endurance, body composition, and pulmonary function. We found significant increases in muscle strength and endurance, flexibility, and cardiorespiratory endurance. There were no significant changes in body composition or pulmonary function.

Muscular strength increased significantly in three of the four tests (Table I). Prior yoga investigations that specifically measured isometric muscular strength with the hand dynamometer yeilded conflicting results. Blumenthal et al.[15] showed no changes, whereas Madanmohan et al.[5] reported significant improvements in hand-grip strength resulting from yoga practice. However, since isometric strength is specific to the muscle group and the joint angle being tested,[30] hand-grip strength is a poor measure of general body strength. In the present study, we measured isokinetic muscular strength for elbow extension, elbow flexion, knee extension, and knee flexion. The increases in isokinetic muscular strength in our study most likely derive from holding static postures in the *asanas*. Because static or isometric contractions do not reliably lead to increases in isokinetic strength measurements,[31] the controlled movement from one *asana* to the next should also be considered. Finally, passive stretch in animal models has been associated with increases in muscle and fiber cross-sectional area[32,33] and contractile strength.[34]

Although there was a tendency for muscle endurance to increase in all measurements, only knee flexion endurance increased significantly (Table I). A prior study of muscle fatigue[6] showed improved muscular endurance after 6 months of yoga practice. Electromyographic activity of the biceps and triceps muscles was examined while the subject stretched a spring by hand to a predetermined distance. The authors attributed the increase in muscular endurance to the alternating recruitment of muscle fibers from different motor units to execute the specific task and improved peripheral blood flow to the contracting muscles. However, a close examination of their data indicates a greater decrease in electromyographic activity of the antagonist muscles for the yoga compared with the non-yoga group. Therefore, a more reasonable explanation for the increased muscular endurance is the decrease in neuromuscular activity of the antagonist muscles, suggesting greater neuromuscular efficiency as a result of yoga training. In the present study, the increase in muscular endurance for knee flexion may be attributed to the static or passive stretching nature of the *asanas*. Passive stretch in animal models has been associated with increases in capillarization and oxidative enzymes.[32,33]

Our results indicate that hatha yoga practice can significantly increase ankle flexibility, shoulder elevation, trunk extension, and trunk flexion (Table I). The increased range of motion can most likely be attributed to the static stretching nature of the *asanas*. Stretching is most commonly advised as a method for increasing flexibility. The increased range of motion resulting from prolonged stretching is most likely due to an increase in length of both connective and muscle tissue.[35] Increased connective tissue length can occur due to its property of plastic elongation,[36] and increased muscle length can occur through the addition of sarcomeres to the ends of muscle fibers.[33,37,38]

Cardiorespiratory endurance, as measured by VO_{2max}, is defined as the ability to perform large-muscle, dynamic, moderate- to high-intensity exercise for prolonged periods of time.[14] In the present study, hatha yoga practice significantly increased VO_{2max}. Balasubramanian and Pansare[8] also reported significant increases in cardiorespiratory endurance after 6 weeks of regular yoga practice. However, the authors estimated VO_{2max} using the Astrand-Rhyming Step Test. Blumenthal et al.[15] and Raju et al.[39] directly measured VO_{2max} by the analysis of expired gases and reported no significant changes resulting from yoga practice. However, the sample population in these two studies consisted of healthy older individuals (ages 60–83) and elite athletes, respectively. The present study is the first to show improvements in cardiorespiratory endurance by direct measurements. Increases in VO_{2max} may be attributed to increased muscular endurance resulting from hatha yoga practice.

Body composition, as measured by hydrostatic weighing, and body weight did not change as a result of hatha yoga practice (Table II). Prior yoga investigations that calculated body composition by measuring skinfold thickness yeilded mixed results. Madhavi et al.[10] showed that 3 months of yoga training led to a significant reduction in percent body fat, thereby resulting in an increase in fat free mass. Conversely, Gharote and Ganguly[7] observed an increase in percent body fat after 9 weeks of yoga practice. The contradictory results may be attributed to differences in yoga training programs, intensity of exercises, duration of yoga studies, and lack of nutritional data from the three reports.

Pulmonary function, as assessed by FVC, $FEV_{1.0}$, and the ratio of $FEV_{1.0}$/FVC did not change as a result of hatha yoga practice. Our findings are consistent with those of prior athletic training studies.[40,41] However, previous yoga studies showed significant increases in FVC and $FEV_{1.0}$,[11–13] whereas the ratio of $FEV_{1.0}$/FVC did not change due to similar increases in both variables. Discrepancies in the results can be attributed to the differences in the treatment programs. In the present study, the subjects practiced nostril-regulated and alternate nostril-breathing exercises. These *pranayamas* focus on slow and deep breathing regulated by manipulations of the nasal passages. In addition to these breathing exercises, prior studies also investigated *kriya pranayama*, which emphasizes fast and shallow rhythmic breathing using the abdominal muscles.

Limitations of this study include a small sample that consisted of a self-selected group of young, healthy, predominantly female subjects; lack of a control group; and the consequent lack of generalizability. Although conceived as a pilot study, the relative magnitude and consistency of the observed changes support their validity and argue for their replication in future research. Ten of the 18 parameters for muscular strength and endurance, flexibility, and cardiorespiratory endurance showed significant improvements, whereas only body composition and pulmonary function were unaltered. In contrast to most prior studies, we used direct measurements to assess the effects of yoga practice on the health-related aspects of fitness. Furthermore, the positive results of this study indicate that hatha yoga is a form of physical activity that would meet the objectives of current recommendations to improve physical fitness and health.[42]

In summary, the results of this investigation indicate that 8 weeks of hatha yoga practice can significantly improve multiple health-related aspects of physical fitness in young, healthy, predominantly female subjects. More specifically, yoga training can increase muscular strength, muscular endurance, flexibility, and cardiorespiratory endurance. However, in the present study, hatha yoga did not have a significant effect on either body composition or pulmonary function.

*Acknowledgments: The authors thank **Lynn Matsuzaki, Megan Stremel, Rich Lee, Cathy Prater, Hanna Shultz,** and **Norm Yamada** for their valuable research assistance. They also acknowledge the subjects for their interest and willingness to participate in this study. Finally, they thank the UC Davis Experimental College for volunteering the time and space for this study.*

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