

THE EFFECTS OF BIKRAM YOGA ON SELECTED CARDIOPULMONARY
MEASURES AND PSYCHOLOGICAL CONSTRUCTS

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ABSTRACT

THE EFFECTS OF BIKRAM YOGA ON SELECTED CARDIOPULMONARY AND PSYCHOLOGICAL PARAMETERS

by

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This study examined the effects of 60-days of Bikram yoga on measures of pulmonary function, cardiovascular health and psychological parameters. Twenty-two subjects (17 females and 5 males) participated in a 60-day Bikram yoga challenge. Measurements were taken before and immediately after the challenge. The psychological measures of core self-evaluation (CSE), intrinsic motivation and life satisfaction increased significantly by 8.34%, 3.84%, and 8.18%, respectively. In addition, the pulmonary function parameters of Forced Vital Capacity (FVC), % pred. FVC, and

forced expiratory volume in the first second (FEV_{1.0}) significantly decreased by 4.47%, 4.43% and 4.46%, respectively. Resting heart rate (HR) significantly decreased by 5.70% and diastolic blood pressure (DBP) significantly decreased by 7.23%. None of the cardiovascular measures during exercise showed a significant difference. In conclusion, 60-days of Bikram yoga will improve CSE, intrinsic motivation, life satisfaction and resting cardiovascular function, but will not improve resting pulmonary function or cardiopulmonary function during exercise.

CHAPTER I

THE EFFECTS OF REGULAR YOGA PRACTICE ON PULMONARY FUNCTION:

A LITERATURE REVIEW

Abstract

Objectives: Yoga is a popular form of exercise in the Western world and its effects on pulmonary function have been investigated. The purpose of this article is to systematically review this research and determine whether regular yoga training improves pulmonary function in apparently healthy individuals. **Methods:** Using the Alternative Health Watch, the Physical Education Index, Medline, and the SPORTdiscus databases and the keywords of “yoga,” “respiration,” and “pulmonary function,” a comprehensive search was conducted that yielded 57 studies. The experimental studies were included in this review if they included healthy individuals participating in regular yoga training that involved at least one *asana* and/or one *pranayama*. **Results:** Yoga improved pulmonary function, as measured by Maximum Inspiratory Pressure, Maximum Expiratory Pressure, Maximum Voluntary Ventilation, Forced Vital Capacity, Forced Expiratory Volume in the first second, and Peak Expiratory Flow Rate, in all, but one, study. **Conclusions:** Overall, pulmonary function appears to improve with a minimum of 10 weeks of regular

yoga practice and the magnitude of this improvement is related to fitness level and/or the length of time the subjects spend in *pranayama*. In other words, greater improvements in pulmonary function are more likely to be seen in lesser fit individuals and/or those that engage in longer periods of *pranayama*. Additional studies examining specific yoga practices such as Bikram yoga, *Iyengar* yoga and *vinyasa* yoga are warranted to gain a more comprehensive view of the effects of regular yoga practice on pulmonary function.

Introduction

The Sanskrit term “yoga” literally means “union,” and it is interpreted as the joining of the individual self with the supernatural “Self.”¹ Over the centuries, numerous schools of yoga, representing distinct traditions, have arisen from the original teachings of yoga, with Hatha yoga being one of them. Practitioners of the early teachings of Hatha yoga viewed the body as a temple and attempted to regulate the life force in the body using an 8-limb system of spiritual practice to balance, strengthen, and heal it.^{1,2} At present, the style of Hatha yoga that is practiced by Westerners minimizes several of the practices of this 8-limb system, including but not limited to *dhyana* (meditation) and *dhauti* (cleansing), and primarily focuses on *asanas* (physical postures) and *pranayama* (breathing exercises) to enhance health, fitness, and well-being.³ Originally, an *asana* was a seated posture required for meditation.¹ Today, *asanas* practiced during Hatha yoga have evolved into physical exercises consisting of supine, seated, and standing postures held for a period of time.⁴ *Pranayama* practiced during Hatha Yoga, on the other hand, has not changed over the centuries, as it remains a breathing exercise intended to consciously utilize the full lung and is practiced to develop mental, physical, and spiritual strength.⁴

There are many different styles of Hatha yoga, including Bikram, Iyengar, and *Vinyasa* yoga, currently practiced in the West. With more than 15 million Americans practicing yoga,⁵ there is a need for a systematic review of the relevant literature to discern whether regular yoga practice is indeed beneficial to one's health. Therefore, in this review, the most recent research studies investigating the effects of yoga training on pulmonary function of healthy individuals are examined and specific evidence-based pulmonary training adaptations are identified.

Methods

The research articles for this review were identified by accessing the Alternative Health Watch, the Physical Education Index, Medline, and the SPORTdiscus databases, as well as through reference lists of relevant journal articles. Each of these databases were searched frequently using the key words “yoga,” “pulmonary function,” and “respiration.” For inclusion in this review, studies had to be written in English, and published in peer-reviewed journals after 1980, and available through the university's library database or as an interlibrary loan. Articles were excluded if they were anecdotal, a single case study, or an editorial. Studies were included in the review if they involved at least one *asana* and/or one *pranayama*.

Using the aforementioned techniques, 57 studies were identified and considered for the initial evaluation. These studies were separated into two categories: experimental and non-experimental studies. Among these, only experimental studies involving clinical trials using yoga as the independent variable were included in this review. The clinical trials were subsequently broken down by health status (apparently healthy versus

diseased populations) and only those involving healthy individuals were selected for this review.

Results

The literature search identified nine studies on pulmonary function in healthy subjects. Among these, 2 investigated the effects of regular yoga practice on respiratory muscular strength,^{6,7} 3 on ventilatory capacity,⁸⁻¹⁰ and 7 on overall pulmonary function.⁷⁻¹³ The specific yoga interventions are included in Table 1. Though only one study described the specific style of yoga practiced, all provided the exact duration of each specific yoga technique (e.g., *pranayama*, *asana*, *dhyana*, or *dhauti*), thereby allowing the reader to make a fairly educated assumption about the style of yoga utilized in the intervention. Finally, all, but one¹⁸ yoga intervention, elicited positive changes in pulmonary function.

Discussion

Regular yoga training has consistently been shown to improve respiratory muscular strength and overall pulmonary function.⁶⁻¹³ This discussion examines the effects of yoga on: 1) respiratory muscular strength, as measured by maximum inspiratory pressure (MIP) and maximum expiratory pressure (MEP),¹⁴ 2) ventilatory capacity, as measured by maximum voluntary ventilation (MVV),¹⁵ and 3) overall pulmonary function, as measured by forced expiratory volume in the first second (FEV_{1.0}), forced vital capacity (FVC), peak expiratory flow rate (PEFR), and vital capacity (VC).¹⁵ Table 1 summarizes the results from studies investigating the effects of regular yoga training on these measures of pulmonary function in healthy individuals.

Respiratory Muscular Strength

Research findings involving different populations (e.g., 8th grade students to male medical students) have reported improvements in respiratory muscular strength following 3 to 6 months of regular yoga training.^{6,7} For example, Madanmohan et al.⁶ observed an average increase of 37% and 26% in MEP and MIP, respectively, in 27 male medical students who performed 30 minutes of yoga 6 days per week for 12 weeks. Though results of this study should be interpreted with caution as no comparison group was utilized, in a later study, Madanmohan et al.⁷ showed positive results even when a control group was used. In that study, greater volumes of training over a longer period of time resulted in even greater improvements. Specifically, 45 minutes of yoga practiced 6 days per week for 6 months improved MEP and MIP by 57% and 117%, respectively, in 40 eighth grade male and female students. In contrast, the sedentary control group did not show any improvement in either of these parameters. These positive findings may be attributed, in part, to the breathing technique practiced during the yoga sessions. For instance, the students practiced *mukh bhastrika*, a breathing technique purported to strengthen the inspiratory and expiratory muscles through forceful and rapid breathing.¹⁶ Furthermore, the practice of *nouli*⁶ may have helped improve respiratory muscular strength as it is purported that yoga *pranayama* techniques such as *nouli* and *uddhayana bandha* impart better neuromuscular control and enhance rectus abdominal and transverse abdominal strength and stability.^{6,17}

In reference to these two studies, the dramatic improvements observed in the latter study may be due to the increased length of the intervention (6 versus 3 months) and/or the increased duration of practice (45 versus 30 minutes). Nevertheless, the results

of the latter study are not generalizable to most adolescent males and females, as the researchers reported that the subjects may have been malnourished and underweight. Thus, to better able to discern the effects of yoga training on respiratory muscular strength in adolescents, more research using adolescents of more typical body weights and dietary habits is warranted. From the limited data, it can be surmised, however, that yoga practice is likely to increase respiratory muscular strength in healthy populations of varying ages and the degree of improvement appears to be related to the length of the intervention, as a longer intervention will likely elicit greater improvements.

Ventilatory Capacity

Research findings have also demonstrated that yoga improves MVV, an index of ventilatory capacity.⁸⁻¹⁰ Makwana et al.¹⁰ observed positive training effects on MVV in 25 experienced male yoga participants practicing yoga for 90 minutes each day for 10 weeks. Significant improvements in MVV were observed in the treatment group, but not in the sedentary control group (32% versus 2%). Surprisingly, in a study devoting more time each day to yoga practice and involving a longer intervention, less substantial improvements in MVV were reported.⁸ In that study, 30 male army soldiers, 25 to 35 years of age, performed 60 minutes of *asanas and pranayama* every morning as well as 60 minutes of *asanas, pranayama and dhyana* every evening for 3 months. Results were compared to a control group that engaged in heavy physical activity for 3 hours each day. Though the average MVV for the control group remained unchanged, the average MVV for the treatment group increased by 10%. These results are quite surprising for two reasons. First, the control group engaged each day in intense physical activity for a longer period of time than the treatment group and did not show any improvement in MVV, and

secondly, the treatment group experienced only modest changes in MVV. Although yoga training resulted in improvements in MVV in both studies, the former study reported much greater improvements in MVV than the latter even though it involved less time engaged in yoga practice each day (90 versus 120 minutes accumulated per day) as well as a shorter intervention (10 weeks versus 3 months). Though the cause of this wide difference requires further investigation, it appears, based on the very limited findings, that regular yoga training will increase ventilatory capacity and that the magnitude of this increase may be affected by the fitness level of the participant.

Overall Pulmonary Function

Yoga has also been consistently shown to improve results of overall pulmonary function tests in males and females of varying ages.⁷⁻¹³ In addition to the improvements in MVV, Harinath et al.⁸ also observed increases in FVC, FEV_{1.0}, and PEFR by 33%, 18.75%, and 6%, respectively, in a yoga group, but no change in any of these measures in a physically active control group. These results support the findings of an earlier study that used the same length of time (i.e., 3 months) and subjects with similar characteristics, (i.e., physically fit and active males).¹² In that study, 40 males, who had a history of being physically active, participated each day in 90 minutes of *asanas*, 60 minutes of *pranayama*, 15 minutes of *dhyana*, and 60 minutes of devotion per day, as well as attended two 60-minute yoga lectures per day. Twice each week, they also practiced *kriyas* (i.e., cleansing practices). Three months of intensive yoga training increased FEV_{1.0} by 18% and PEFR by 60%. Not surprisingly, with respect to these two studies, the latter study reported much greater increases in PEFR than the former study. These differences are likely due to the greater number of minutes devoted each day to yoga

practice, in general (225 versus 90 minutes), or to *pranayama*, specifically (60 versus 30 minutes) in the latter study compared to the former study. Nevertheless, the results of both studies should be interpreted with caution, as they both used fit men and required the subjects to practice yoga for at least 90 minutes each day of the week, a duration that may not be feasible for most Westerners.

It appears that shorter training sessions and intervention periods may also be effective in promoting positive results on pulmonary function tests. For instance, Yadav and Das¹³ investigated the effects of yoga using a shorter, more realistic training duration. Sixty women practiced yoga 5 days per week for 12 weeks. Each 1-hour session consisted of 15 minutes of *pranayama* and 45 minutes of prayer, *asanas*, and meditation. After 6 weeks of yoga training, FVC and FEV_{1.0} improved by 13%, while PEFR did not change. After 12 weeks of yoga training, however, improvements in all three pulmonary function tests were seen. Specifically, FVC and FEV_{1.0} each increased by 26% and PEFR increased by 10%.

The effects of yoga training on overall pulmonary function in other populations, including adolescents,⁷ college-age individuals¹⁸ and smokers,¹¹ have also been investigated, though to a very limited extent. Mandamohan et al.⁷ observed that FEV, FEV_{1.0}, and PEFR improved by 20%, 15%, and 24%, respectively, in adolescents practicing yoga for 6 months and remained unchanged in a sedentary control group. Furthermore, Birkel and Edgren¹¹ reported positive effects of yoga on VC in 287 college students of varying health status. After completing a variety of yoga styles and *pranayama* for 50 minutes per session, two times a week for 15 weeks, the VC improved in students who smoked by 9%, and in non-smoking students by 10%. Although the non-

smoking students experienced the greatest gains in VC, it is important to note that regular yoga training enhanced the VC of both groups investigated. Unlike previous studies, this study included subjects of varying fitness and activity levels (i.e., athletes as well as active and sedentary non-athletes) and, thus, the improvements in VC may be due, at least in part, to physical activity that the subjects may have engaged in outside of the yoga class. Despite this threat to external validity, this particular study used a sample, ranging in physical activity level, health status, and age (18 to 45 years), that is fairly indicative of a normal sample population as well as employed a reasonable training volume in terms of minutes of yoga practiced per session over a fairly typical investigation period.

To the best of our knowledge, only one study reported no improvements in pulmonary function.¹⁸ Ten healthy, untrained college-aged students volunteered to participate in 90 minutes of yoga four days per week. Each session consisted of 10 minutes of *pranayama*, 15 minutes of warm-up poses, 50 minutes of *asanas* and 10 minutes of *savasana* (relaxation in corpse pose). Interestingly, FVC and FEV_{1.0} did not change as a result of the eight-week Hatha yoga practice. One explanation for the lack of improvement in pulmonary function may be due to the small number of participants (n=10). Nevertheless, based on the other seven studies discussed in this review, regular yoga training appears to improve overall pulmonary function of adolescents as well as young to middle-aged adults.

The positive performances on pulmonary function tests, such as FVC and VC, may be due to a number of physiological adaptations. First, specific yoga *asanas* may help increase the flexibility of the shoulders, rib cage and back.¹¹ Furthermore, by

focusing on one's breath during *pranayama*, one consciously overrides the stimulus to the respiratory centers leading to more conscious control over respiration.⁶ During focused breathing, the lungs are emptied and filled more completely which has been suggested to cause an increase in FVC and VC.¹³ Specifically, the more often the lungs are completely filled and emptied, a greater improvement in FVC and VC is expected to be observed. This logic may help explain why the studies that employed longer and more intense training sessions, specifically those that devoted more time to *pranayama*, reported greater improvements in FVC. Lastly, yogic cleansing procedures (*kiryas*) help cleanse the nasal and sinus passages which may improve pulmonary function.¹³ These physiological adaptations may help explain how yoga significantly improves measures of pulmonary function in healthy individuals as well as some special populations.

Conclusion

Western versions of yoga, most notably Hatha yoga, have evolved from ancient Hindu teachings and focus on the physical aspect of yoga rather than the spiritual aspect. As illustrated in Table 1, all but one of the studies investigating the effects of yoga training on pulmonary function have reported positive findings despite using different methodology and employing different populations. The duration of training (i.e., 10 weeks to 6 months), the volume of training in terms of time (i.e., 30 minutes to greater than 2 hours per day) and frequency (i.e., 2 to 7 days per week), the type of yoga practiced (breathing exercises and yoga postures), and the study population used (trained versus sedentary, children versus adults, and healthy versus those who smoked) resulted in varying degrees of improvement. Therefore, it is difficult to ascertain the specific training volume and duration as well as the style of yoga required to produce maximal

pulmonary training adaptations. Based on the relevant literature, it appears that yoga training will improve various aspects of pulmonary function and the magnitude of this improvement is due, in part, to the total volume of training in terms of minutes per session, days practiced per week, and overall duration of the training program. At a minimum, 10 weeks of yoga training performed at least 2 days per week for one hour is likely to elicit some improvements in pulmonary function and that longer individual sessions, greater frequency of training sessions per week, and/or longer intervention duration will elicit even greater results.

This review, however, identified several conflicting results, especially when examining the different styles of yoga practiced. Two studies employed a Westernized version of yoga practice,^{11,18} whereas other studies examined a more traditional or classical version of yoga.^{6-10,12,13} Classical yoga teaches that the *asanas* are the least important part and that *pranayama* and lifestyle changes (e.g., stress management, cleansing practices and meditation) provide the most benefit.¹ Overall, it appears that Hatha yoga can provide pulmonary benefits to healthy populations and it should be included as part of a regular fitness program. Research is lacking, however, on the effects of different styles of yoga on pulmonary function. Future studies should examine the effects of various yoga practices on pulmonary function including but not limited to, Bikram yoga, *ashtanga* yoga, and *vinyasa* yoga.

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Table 1
Pulmonary Effects of Yoga Training

First author (year)	Population (N)	Yoga format	Control exercise	Duration	Outcomes for yoga	Outcomes for control
Birkel (2000)	University students (287)	Hatha yoga; <i>Ujjayi</i> breathing; Alternate Nostril Breathing; <i>Ashtanga</i> Yoga		50 min, 2d/wk, 15 wk	Smokers: ↑ VC (S) Non-Smokers: ↑ VC (S)	
Harinath (2004)	Army soldiers (30)	Morning: 45 min <i>asanas</i> , 15 min <i>pranayama</i> ; Evening: 15 min <i>asanas</i> , 15 min <i>pranayama</i> ; 30 min meditation	Morning: 40 min stretching, 20 min slow running; Evening: 1 hr physical activity games	7 d/wk, 3 months	↑ FVC (S)* ↑ FEV _{1.0} (S)* ↑ PEFR (S)** ↑ MVV (S)**	FVC (NS) FEV _{1.0} (NS) PEFR (NS) MVV (NS)
Joshi (1992)	Male and female medical students (75)	20 min <i>pranayama</i>		2 times/d on week days, 1 time/d on Saturday, 6 wks	↑ FVC (S) ^a ↑ MVV (S) ^a ↑ PEFR (S) ^a	
Madanmohan (1992)	Male medical students (27)	2 min <i>pranayama</i> ; 13 min <i>asanas</i> ; 15 min <i>shavasana</i>		6 d/wk, 12 wks	↑ MEP (S)* ↑ MIP (S)*	
Makwana (1988)	Males; yoga grp had previous yoga practice (25) vs. sedentary controls (15)	63 min <i>asanas</i> ; 25 min <i>pranayama</i> ; 2 min prayer	Remained sedentary	7 d/wk, 10 wks	↑ VC (S) ^b ↑ FEV _{1.0} (S) ^b ↑ MVV (S) ^b	VC (NS) FEV _{1.0} (NS) MVV (NS)
Mandanmohan (2003)	8 th grade students (40)	45 min class; <i>asanas</i> , <i>pranayama</i> , 10 min <i>shavasana</i>	Remained sedentary	6 d/wk, 6 months	↑ MEP (S) ^a ↑ MIP (S) ^a ↑ FEV (S) ^a ↑ FEV _{1.0} (S) ^a ↑ PEFR (S) ^a	MEP (NS) MIP (NS) FEV (NS) FEV _{1.0} (NS) PEFR (NS)

Table 1-Continued¹

Telles (1993)	Males previously engaged in PA for 8.9 yrs (40)	90 min <i>asanas</i> ; 1 hr <i>pranayama</i> ; 20 min ocular exercises; 15 min meditation; 60 min devotions; 2, 60 min lectures	7 d/wk, 3 months; cleansing practices: 2 d/week	↑ PFR (S) ^a ↑ FEV _{1.0} (S)** ↑ FVC (S) ^a
Tran (2001)	Sedentary male and female adults (10)	10 min <i>pranayama</i> ; 15 min warm-up; 50 min <i>asanas</i> ; 10 min <i>savasana</i>	90 min, 4 d/wk, 8 wk	FVC (NS) FEV _{1.0} (NS) FEV _{1.0} /FVC (%) (NS)
Yadav (2001)	Adult females (60)	10-15 min <i>pranayama</i> ; <i>asanas</i> , prayer, and meditation	1 hr, 5 d/week, 12 wk	Week 1 and 6: ↑ FVC (S) ^a ↑ FEV _{1.0} (S) ^a PEFr (NS) Week 1 and 12: ↑ FVC (S) ^a ↑ FEV _{1.0} (S) ^a ↑ PEFr (S)*

¹ *p<0.05; **p<0.01; ^ap<0.001; ^bp<0.005; NS=not significant; S=significant; FVC=forced vital capacity; FEV_{1.0}=forced expiratory volume in the 1st second; PEFr=peak expiratory flow rate; MVV=maximum voluntary ventilation; VC=vital capacity; MEP=maximum expiratory pressure; MIP=maximum inspiratory pressure

CHAPTER II

THE EFFECTS OF BIKRAM YOGA ON SELECTED CARDIOPULMONARY AND PSYCHOLOGICAL PARAMETERS

An abundance of research has consistently shown that regular yoga training improves pulmonary function (Birkel & Edgren, 2000; Harinath et al., 2004; Joshi, Joshi, & Gokhale, 1992; Makwana, Khirwadkar, & Gupta, 1987; Mandanmohan, Jatiya, Udupa, & Bhavanani, 2003; Telles, Nagarathna, Nagendra, & Desiraju, 1993; Yadav & Das, 2001). Though the magnitude of change varies considerably, research has demonstrated that yoga improves maximum voluntary ventilation (MVV), an index of ventilatory capacity, by 10 to 32% (Harinath et al., 2004; Joshi et al., 1992; Makwana et al., 1987).

Yoga has also been consistently shown to improve results of specific pulmonary function tests (Harinath et al., 2004; Makwana et al., 1988; Telles et al., 1993; Yadav & Das, 2001). Yoga training studies have reported increases in forced vital capacity (FVC) by 33% (Harinath et al., 2004), in forced expiratory volume in the first second (FEV_{1.0}) by 18 to 19% (Harinath et al., 2004; Makwana et al., 1988), in peak expiratory flow rate (PEFR) by 6 to 60% (Harinath et al., 2004; Telles et al., 1993), and vital capacity (VC) by 18% (Makwana et al., 1988). These positive findings have been attributed, in part, to

pranayama (i.e., breathing exercises) as greater results are seen when more time is devoted to this practice during a session.

Because of yoga's slow-paced movements separated by rather long periods of static stretching, it is not considered an aerobic activity, and thus, unlikely to be beneficial to the cardiovascular system (Clay, Lloyd, Walker, Sharp, & Pankey, 2005; DiCarlo, Sparling, Hinson, Snow, & Roskopf, 1995; Prasad, Ramana, Raju, Reddy, & Murthy, 2001). Nevertheless, the effects of yoga on measures of cardiovascular health such as maximal oxygen consumption ($VO_2\text{max}$), resting systolic and diastolic blood pressures, and resting heart rate have been investigated and findings have been mixed (Bowman et al., 1997; Harinath et al., 2004; Murugesan, Govindarajulu, & Bera, 2000; Raju et al., 1985; Raju et al., 1994; Raju, Prasad, Venkata, Murthy, & Reddy, 1997; Ray et al., 2001; Selvamurthy, Nayar, Joseph & Joseph, 1983; Telles et al., 1993; Tran, Holly, Lashbrook & Amsterdam, 2001). Specifically, yoga training has been reported to result in slight increases in $VO_2\text{max}$ (4 to 6%, Bowman et al., 1997; Raju et al., 1997; Tran et al., 2001), a wide range of improvements in movement economy (9 to 60%, Raju et al., 1985; Raju et al., 1994; Raju et al., 1997; Selvamurthy et al., 1983), slight reductions in exercise heart rate (7%, Raju et al., 1997; Selvamurthy et al., 1983), and varying reductions in both resting blood pressure (7 to 24%) and resting heart rate (4 to 30%, Bowman et al., 1997; Harinath et al., 2004; Murugesan et al., 2000; Ray et al., 2001; Telles et al., 1993).

Though yet to be investigated, yoga is likely to provide some psychological benefits as various forms of exercise appear to improve psychological constructs including satisfaction with life, intrinsic motivation, and core self-evaluation (CSE), as

measured by locus of control, self-esteem, self-efficacy, and neuroticism (Judge, Locke, & Durham, 1997). Specifically, studies have shown improvements in self-esteem (McAuley, Blissmer, Katula, Duncan, & Mihalko, 2000; Sonstroem, Harlow, & Josephs, 1994; Stewart et al., 1997) and self-efficacy (Elavsky et al., 2005; McAuley, & Blissmer, 2000) as a result of physical activity. Furthermore, the CSE scale has been shown to significantly correlate with life satisfaction (Judge, Erez, Bono, & Thoresen, 2003). Therefore, as CSE increases (specifically self-esteem and self-efficacy), life satisfaction will also increase (Elavsky et al., 2005; Lachman & Weaver, 1998; McAuley, & Blissmer, 2000). Improvements in CSE and life satisfaction, through positive engagement in physical activity, will help improve intrinsic motivation (McAuley et al., 1999). In addition, as participants increase their intrinsic motivation, they are more likely to adhere to an exercise program (Ryan, Frederick, Lipes, Rubio, & Sheldon, 1997). For example, if a subject engages in an activity for six months yet fails to enjoy the activity (e.g., due to a lack of intrinsic motivation) or see any positive results, the subject may not improve their CSE or satisfaction with life, thereby demonstrating the importance that one engages in an activity that is rewarding both physically and mentally.

Overall, it appears that Hatha yoga can provide some pulmonary, cardiovascular, and psychological benefits to healthy populations and it should be included in a regular fitness program. Research is lacking, however, on the effects of different styles of yoga on cardiovascular and pulmonary function as well as various psychological constructs. Bikram yoga, also referred to as hot yoga, is a style of Hatha yoga that was developed and popularized by Bikram Choudhury in the early 1970's. A typical Bikram class is 90-minutes in duration, consists of a set series of 26 Hatha yoga postures and 2 breathing

exercises, and is performed in a room heated to 41°C (105° F) with 40% humidity (Choudhury, 2007). To date, however, no research study has investigated the effects of Bikram yoga training on cardiorespiratory function, intrinsic motivation, life satisfaction, or CSE.

Based on the findings of studies investigating the effects of heat on the cardiorespiratory responses to other forms of training (Beaudin, Clegg, Walsh, & White, 2009; Hayashi, Honda, Ogawa, Kondo, & Nishiyasu, 2006; Lorenzo, Halliwill, Sawka, & Minson, 2010; Nadel, Pandolf, Roberts, & Stolwijk, 1974; Sawka, Young, Cadarette, Levine, & Pandolf, 1985; Shvartz et al., 1977), it is fairly accepted that training in the heat improves cardiovascular fitness and pulmonary function. Heat acclimation has been shown to reduce oxygen uptake and blood lactate production at a given power output as well as spare muscle glycogen (Young, Sawka, Levine, Cadarette, & Pandolf, 1985). Studies have also revealed a significant increase in plasma volume following heat acclimation, which was purported to increase $VO_2\text{max}$ (Coyle, Hopper, & Coggan, 1990; Nadel et al., 1974; Sawka et al., 1985). Heart rate has also been suggested to decrease due to the increase in stroke volume that occurs, in part, to an increase in plasma volume resulting from heat acclimation (Senay, Mitchell, & Wyndham, 1976). For instance, following a heat acclimation protocol, Lorenzo et al. (2010) reported increases in plasma volume, and maximal cardiac output in cool and hot conditions, further providing evidence for the decrease in heart rate. Though acclimation to heat will elicit positive adaptations in cardiovascular fitness, these adaptations are attenuated with level of fitness. In other words, a ceiling effect for $VO_2\text{max}$ appears to exist for highly trained individuals

and that highly trained individuals are already partially heat acclimated (Gisolfi & Robinson, 1969; Piwonka, Robinson, Gay, & Manalis, 1965; Shvartz et al., 1977).

Ventilatory adaptations to exercise training in the heat have not been clearly identified. Research has documented that during an acute bout of high intensity exercise (Hayashi et al., 2006; White, 2006; White & Cabanac, 1996) and prolonged low to moderate intensity exercise (Chu, Jay, & White, 2007; Hayashi et al., 2006) as well as rest in a hot environment (Haldane, 1905; White, 1996), increases in pulmonary ventilation are due, in part, to an increase in core body temperature. Data has recently emerged that this relationship between core temperature and ventilation is altered, however, following a passive heat acclimation protocol. It appears that during prolonged exercise, ventilation increases at a lower body temperature following passive heat acclimation (Beaudin et al., 2009). This alteration is strictly related to an improvement in thermoregulation and has no affect on aerobic fitness (Beaudin et al., 2009). Research has not been able to clearly show, however, whether active heat acclimation or prolonged periods of training in the heat enhance ventilatory function independent of an exercise training effect. In other words, it is unclear whether training in the heat will elicit even greater ventilatory adaptations than exercising in a more temperate environment.

Although Bikram Yoga is a rapidly growing fitness trend and booming business in the United States, its effects on psychological constructs and measures of pulmonary function or cardiovascular fitness have not been investigated to the best of our knowledge. Therefore, the purposes of this study were to determine the effects of regular Bikram yoga practice on cardiopulmonary function and psychological constructs including CSE, intrinsic motivation, and life satisfaction in healthy adults. Consistent with previous

research in the heat (Beaudin et al., 2009; Coyle et al., 1990; Hayashi et al., 2006; Lorenzo et al., 2010; Nadel et al., 1974; Sawka et al., 1985; Senay et al., 1976; Shvartz et al., 1977; Young et al., 1985), as well as previous studies on yoga (Birkel & Edgren, 2000; Bowman et al., 1997; Harinath et al., 2004; Joshi et al., 1992; Makwana et al., 1987; Mandanmohan et al., 2003; Murugesan et al., 2000; Raju et al., 1985; Raju et al., 1994; Raju et al., 1997; Ray et al., 2001; Selvamurthy et al., 1983; Telles et al., 1993; Tran et al., 2001; Yadav & Das, 2001), the following hypotheses were offered. 60-days of Bikram Yoga is expected to improve in a sample of men and women: 1) pulmonary function based on measures of FVC, % pred. FVC, FEV_{1.0}, % pred. FEV_{1.0}, FEV_{1.0}/FVC ratio, PEF_R, Forced Expiratory Flow 25-75% (FEF 25-75%), MVV and % pred. MVV; 2) cardiopulmonary function during exercise by having a higher peak VO₂, a higher max HR, higher minute ventilation (V_E), a lower respiratory rate (RR), a higher tidal volume (V_T), a lower resting HR, SBP and DBP; and 3) intrinsic motivation, CSE, and satisfaction with life.

Methods

Participants

Forty-two participants, enrolled in a 60-day Bikram yoga challenge, volunteered to participate in this study. To be included, participants had to be 18 years or older, and participate in at least 80% (i.e., 48 days) of a 60-day challenge. A written consent form outlining the procedures for the laboratory tests was provided to all participants and informed consent was obtained from all participants prior to enrollment into the study. Before this study began, a proposal was submitted to the Institutional Review Board for approval of the procedures.

This study was intended for apparently healthy adults exhibiting no signs or symptoms suggestive of heart, metabolic (diabetes), and pulmonary disease based on the American College of Sports Medicine (ACSM) guidelines (ACSM, 2010). Thus, a comprehensive health-history survey was administered to identify volunteers who: 1) have heart disease, diabetes, chronic obstructive pulmonary disease (including severe asthma), 2) have experienced recent musculoskeletal injuries, 3) are pregnant (or think they are pregnant); and 4) have no more than one risk factor for atherosclerotic cardiovascular disease. This questionnaire was completed and reviewed before the first day of testing.

Based on results from this instrument, 35 participants (seven males and 28 females) were considered low risk and eligible to participate in the full battery of tests. Experience with yoga was not a criterion for inclusion in this study and participants had 1.79 average years of Bikram yoga experience. Table 1 provides descriptive statistics for the 35 subjects. The subjects' physical activity and diet outside of Bikram yoga was not monitored, but each participant was asked to maintain his/her current diet and refrain from participating in any other forms of exercise.

Data Collection Procedures

Subjects were asked to participate in testing on two separate occasions: a) before starting the 60-day program; and b) within one week of completing the 60-day program. Before each test, subjects were asked to: 1) drink plenty of fluids over the 24-hour period preceding the test; 2) avoid food, tobacco, nicotine, alcohol, and caffeine for at least 3 hours prior to the test; 3) avoid strenuous physical activity the day of the test; and 4) get at least 6 hours of sleep the night before the test (ACSM, 2010). During testing, subjects

completed a consent form and a series of questionnaires to gather demographic information as well as data regarding the various psychological constructs.

Measures

Core-Self Evaluations (CSE). CSE is a higher order trait consisting of self-esteem, self-efficacy, neuroticism and locus of control (Judge et al., 2003). This variable was measured with 12 items from Judge et al. (2003) using a seven-point Likert response scale anchored by 1=strongly disagree and 7=strongly agree. Sample items include: "When I try, I generally succeed" and "I am filled with doubts about my competence" (reverse scored). Reverse scored items were corrected before averaging items to create a scale composite. Cronbach's coefficient alpha of internal consistency reliability for scores at time one on this measure was .79. At time two, Cronbach's alpha was .80.

Intrinsic Motivation. Intrinsic motivation refers to motivation from inside an individual rather than external rewards. This variable was measured with four items from Lawler and Hall (1970) using the same seven-point Likert response scale as stated above. Sample items include: "When I do my work well, it gives me a feeling of accomplishment." Cronbach's coefficient alpha of internal consistency reliability for scores at time one on this measure was .91. At time two, Cronbach's alpha was .87.

Life Satisfaction. Life satisfaction refers to the overall attitudes about one's life at a particular point in time. This variable was measured with five items from Diener, Emmons, Larsen & Griffin (1985) using the same seven-point Likert response scale as the other measures. Sample items include: "So far I have gotten the important things I want in life." Cronbach's coefficient alpha of internal consistency reliability for scores at time one on this measure was .87. At time two, Cronbach's alpha was .93.

Physiological Measures. Subjects were measured for height and weight (in light clothing, but without shoes) using a calibrated physician's scale (Detecto Scale Co., Jerico, New York). After 10 minutes of seated rest, blood pressure (Baumanometer Standby Model, W.A. Baum Co, Inc., Copiague, NY) and resting heart rate (Polar FT4 heart rate monitor, Finland) were measured while the subject was in a seated position. Then, participants underwent a battery of pulmonary function tests to measure FVC, FEV_{1.0}, PEFR, FEF 25-75% and MVV. FVC, FEV_{1.0}, FEF 25-75%, and PEFR were administered in the seated position to minimize any risk of fainting according to the American Thoracic Society/European Respiratory Society (ATS/ERS) guidelines (Miller et al., 2005). MVV was administered in the standing position after 3 good FVC, FEV_{1.0}, and PEFR trials were attained (Miller et al., 2005). Prior to both tests, the administrator demonstrated the technique for the subject. A nose clip was then placed on the subject and the subject was instructed to make an airtight seal around the hand-held spirometer and not to block the spirometer with the tongue. The subject performed at least three normal tidal breaths. When ready, the administrator told the subject to begin. For FVC, FEV_{1.0}, and PEFR testing, subjects were instructed to inhale as quickly and deeply as possible followed by a forceful exhalation for at least 6 seconds. The subject was instructed to maintain an upright posture. There were one to two minutes of rest between each trial and the best value from each trial was used for analysis. For the MVV test, subjects were instructed to inhale and exhale as quickly and rapidly as possible for 15 seconds. Data was extrapolated ($V_T \times f_b$) over 12 seconds and expressed in L/min. Participants performed a minimum of three trials and the best value from each trial was used for analysis. Two minutes of rest were given between trials.

Peak VO_2 and HRmax were measured during a graded exercise test on a stationary bike (Monark Ergonomic, 894E). After a 3 to 5 minute warm-up period, the exercise test started at 60 W and the subjects were asked to maintain a 60 revolution $\cdot\text{min}^{-1}$ (rpm) pace. Every two minutes, work increased by 30 W for males and 15 W for females. A Polar FT4 heart rate monitor measured heart rate. Expired air was analyzed on a breath-by-breath basis with a PARVO Medics metabolic analyzer (Salt Lake City, UT). VO_2 , carbon dioxide production (VCO_2), respiratory exchange ratio (RER), and selected ventilatory parameters were determined from 60-second averages. Heart rate was recorded at the end of each minute. Calibration was performed before each test using a certified gas mixture ($\text{O}_2= 16\%$ and $\text{CO}_2= 4\%$, Scott Medical Products, Plumsteadville, PA). Subjects were asked to exercise to their maximum capacity and the highest value of oxygen uptake was considered as peak VO_2 . These procedures were repeated within one week of the end of the 60-day program.

Between tests, subjects participated in a 60-day Bikram Yoga Challenge between the dates of January 1st and March 13th at a yoga studio certified by the Bikram Yoga College of India. Each 90-minute session consisted of a set series of 26 postures performed in a heated (105°F) and humidified (40% relative humidity) studio. Bikram yoga is a standardized, trademarked program that requires all classes, regardless of instructor and studio, be conducted in exactly the same manner (Choudhury, 2000). All classes were taught by a Bikram yoga certified instructor. The first 60 minutes of class consisted of standing and balance poses, and the last 30 minutes involved seated poses. For a detailed description of all poses practiced during Bikram yoga, refer to Bikram's Beginning Yoga Class (Choudhury, 2000). All postures were performed twice.

Attendance was tracked using a sign-in sheet. To be included in final data analysis, subjects attended a minimum of 48 classes (80% attendance).

Statistical Analysis. During pre-testing, demographic data as well as various physical fitness measures were collected. Approximately 60 days later, the same fitness measures were collected. A series of repeated measures (i.e., paired sample) *t*-tests were run on all variables using SPSS. In addition, descriptive data for pre- and post-test subject profiles were assessed and an independent samples *t*-test was run to account for the effect of subject mortality. A Chi Square test was used on the categorical variable of gender to determine differences between time one and time two. Finally, bivariate correlations were calculated for each variable to determine relationships between all variables.

Results

Effect of Subject Mortality

Of the initial 35 participants, nine did not finish at least 48-days of the 60-day challenge and four did not return phone calls for post-testing appointments. Following the 60-day challenge, 22 participants (five males and 17 females) returned for post-testing and the same fitness measures were collected. Of these 22 participants, six were unable to complete a VO₂max test due to muscle complaints and/or fatigue. At the post-test date, the 22 remaining subjects had an average of 2.44 years of previous Bikram yoga experience. Table 1 provides descriptive data for these participants.

Because thirteen participants did not return for post-testing, it is imperative to analyze the effect of subject mortality. Independent sample *t*-tests and one chi-square test were conducted to assess differences between the group of subjects (n=22) who completed the study and the group (n=17) who failed to complete the study. The results

of the chi-square test for gender differences revealed a significant difference ($p < .001$) between the two groups, indicating that men were more likely to drop out of the study versus women. Since there were less than five subjects in one of the two-by-two matrix, Fisher's exact test was used. Additionally, the t -tests revealed that there were no statistically significant differences between the two groups on any continuous demographic or experience-related variable. See Table 1 for these results.

Psychological Variables

Table 2 shows the means and standard deviations for all variables included in the data analysis. Items in each multi-item self-report survey measure were averaged for a scale-level score for each subject. Paired samples t -tests were used to determine whether differences in pre- and post- measures were significant for the 22 subjects who completed the study (i.e., participated in both the pre- and post-testing as well as completed at least 48 days of the 60-day challenge) as tests of the hypotheses. There were significant differences in: 1) CSE ($t(20)=2.26, p < .05$) with mean score improving by 8.34%; 2) Intrinsic motivation ($t(21)=2.15, p < .05$) with mean score improving by 3.84%; and 3) Life satisfaction ($t(21)=2.67, p < .01$) with mean score improving by 8.18%.

Cardiopulmonary and Pulmonary Function Responses

There were three significant differences in variables of pulmonary function. FVC ($t(21)=2.98, p < .05$), % pred. FVC ($t(21)=3.17, p < .05$), and FEV_{1.0} ($t(21)=2.14, p < .05$) all significantly decreased by 4.47%, 4.43%, and 4.46%, respectively, following training. % pred. FEV_{1.0} ($t(21)=2.08, p > .05$), FEV_{1.0}/FVC ratio ($t(21)=.02, p > .05$), PEF_R ($t(21)=.65, p > .05$), FEF 25-75% ($t(21)=1.42, p > .05$), MVV ($t(21)=.33, p > .05$) and % pred. MVV ($t(21)=.29, p > .05$) were not significantly different post-training. Additionally, no pre- and

post-test differences for any measure of cardiovascular function during exercise were observed. Of the three resting variables collected, two were statistically different post-training. Specifically, resting HR ($t(21)=2.35, p<.05$) and resting DBP ($t(21)=3.537, p<.005$) decreased by 5.70% and 7.23%, respectively, while resting SBP ($t(21)=1.93, ns$) did not statistically change between trials.

Discussion

Of the three hypothesis offered, this study found full support for one, partial support for another, and no support for the third. Sixty days of Bikram yoga improved selected psychological constructs and resting measures of cardiovascular function (i.e., resting HR and resting DBP) but not resting pulmonary or cardiopulmonary function during exercise. While there were changes in pulmonary function, these changes were in a direction opposite of that which was hypothesized (e.g., a decrease in FVC, FEV_{1.0}, and % pred. FVC). Although there was a decrease in pulmonary function, it is important to note that the changes were very small and remained within the normal range.

Increases were seen in all three psychological measures (i.e., CSE, intrinsic motivation, and life satisfaction). These increases in CSE lead to the conclusion that engaging in Bikram yoga will help build self-esteem, self-efficacy, and locus of control while decreasing neuroticism. This is consistent with previous research examining these psychological effects of other forms of physical activity (Elavsky et al., 2005; McAuley, & Blissmer, 2000; McAuley et al., 2000; Sonstroem et al., 1994; Stewart et al., 1997). As previous research suggests, if self-esteem and self-efficacy (two components of CSE) increase then life satisfaction (Elavsky et al., 2005; Lachman & Weaver, 1998; McAuley, & Blissmer, 2000) usually also increases. Overall, enjoyment of the activity and positive

improvements in the activity will enhance CSE and life satisfaction. In addition, if a person enjoys the activity, they are more likely to increase their exercise adherence due to an increase in intrinsic motivation (Ryan et al., 1997). The subjects in the present study finished the exercise program demonstrating excellent exercise adherence, therefore it is not surprising that intrinsic motivation significantly increased. It is important to note however, that the people who dropped out of the study may have done so because they felt no intrinsic motivation to further pursue Bikram yoga, however starting levels of intrinsic motivation were no different for those who dropped out than those who completed the study.

The magnitude of improvement in resting HR (5.7%) and DBP (7.23%) following Bikram yoga training has been observed in previous studies involving other styles of yoga (Harinath et al., 2004, Ray et al., 2001; Telles et al., 1993). While much larger improvements in resting HR have been reported (i.e., 12-30%), those studies used older individuals (average age=68 years) or those with hypertension (Bowman et al., 1997; Murugesan et al., 2000). While resting measures of cardiovascular function were observed in the present study, improvements in cardiovascular function during exercise were not. These findings are supported by previous research examining the metabolic effects of yoga (Clay et al., 2005; DiCarlo et al., 1995; Prasad et al., 2001). For instance, Clay et al. (2005) found that during a Western-style Hatha yoga session, participants exercised at only 15% of VO_2R , and DiCarlo et al. (1995) found that during an Iyengar-style yoga class, participants exercised at only 34% of VO_2max . To date, no studies have examined the metabolic cost of Bikram yoga; thus, it is not possible to determine the intensity of a typical session. However, based on studies involving exercise training in

the heat, it is plausible that regular practice of Bikram yoga may elicit physiological adaptations. Specifically, research involving running and cycling at 40 to 50% of VO_2 max in the heat has observed 4 to 8% improvements in VO_2 max (Lorenzo et al., 2010; Nadel et al., 1974; Sawka et al., 1985). Though performing yoga in the heat may raise exercise intensity to some degree, it clearly does not increase it to the threshold necessary to produce training adaptations. In other words, since no improvements in cardiopulmonary function during exercise were observed in a heated environment, it appears that Bikram yoga does not provide a training intensity of 40-50%.

Since cardiovascular function during exercise showed no improvements, this study cannot suggest that Bikram yoga will improve overall aerobic fitness. Therefore, the improvements in resting HR and DBP may not be due to an increase in heart musculature, rather, the improvements are probably a result of the relaxation and breathing techniques, which have been purported to affect autonomic balance (Khattab, Khattab, Ortak, Richardt & Bonnemeier, 2007).

Although pulmonary function decreased following Bikram yoga training, it is important to note that the changes were very minimal and were most likely due to the high variability of the pulmonary function tests. Pulmonary function tests are very effort dependent, therefore the data may be confounded if subjects did not put forth a valid effort on the tests. In addition, the unexpected results may be due, in part, to the rather short length of the *pranayama* sessions. The participants in the present study engaged in only two *pranayama* (i.e., breathing exercises) techniques lasting a total of about five minutes, a duration much lower than previous studies (Harinath et al., 2004; Joshi et al., 1992; Makwana et al., 1988; Telles et al., 1993; Tran et al., 2001; Yadav & Das, 2001).

In contrast, participants in previous research engaged in *pranayama* for a minimum of 25 minutes and a maximum of one hour. In light of this, the reductions in pulmonary function may be due to the small amount of time devoted to *pranayama* during the Bikram yoga sessions employed in this study. Perhaps engaging in *pranayama* for a longer period of time (i.e., a minimum of 25 minutes, 5 days per week for 10 weeks) will indeed enhance one's lung capacity.

Another possible explanation for the surprising findings specific to pulmonary function is the effect of progesterone on ventilatory response. Progesterone levels are specifically high during the luteal phase of menstruation (i.e., days 15-28). At the end of the luteal phase, progesterone decreases, causing menstruation. Though findings have been slightly mixed (Silva, Viana, & Sousa, 2006), previous research has demonstrated that progesterone increases ventilatory response (Das, 1998; Rajesh, Gupta, & Vaney, 2000; White, Douglas, Pickett, Weil, & Zwillichc, 1983). The majority of participants in the present study were women (n=17 females; n=5 males) and a limitation to this study was the inability to control for women's menstruation. Therefore, changes in progesterone levels throughout the menstrual cycle may have confounded the data and masked any positive effect that yoga may have had on pulmonary function tests thereby leading to insignificant results.

In addition to effecting pulmonary function, previous research suggests that the increase in ventilatory response due to progesterone levels also causes changes in exercise V_E (Schoene, Robertson, Pierson, & Peterson, 1981; Williams & Krahenbuhl, 1997). These studies have shown a higher V_E during the luteal phase (e.g., during high levels of progesterone) versus the follicular phase (e.g., low levels of progesterone). This

may be another reason why there were no significant improvements in measures of cardiopulmonary function during exercise.

Overall, in the present study, the cardiopulmonary findings during exercise and at rest may be due to several physiological reasons. First, these findings may be due to the previous fitness level of the participants. As reported in Table 2, the average peak VO_2 for the subjects at post-testing was $39 \text{ mlO}_2 \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$, placing the subjects at an “above average” classification according to ACSM guidelines (ACSM, 2010). In addition, participants had an average of 2 years of Bikram yoga experience. Based on this descriptive data, it is possible that a ceiling effect may have occurred for Bikram yoga participants as it is widely accepted that adaptations to a training program are influenced by the training status of an individual (McArdle, Katch, & Katch, 2010). Therefore, results from these data may not translate well to less healthy populations or inexperienced yoga participants. In addition, the pulmonary function tests and $\text{VO}_{2\text{max}}$ test are very effort dependent. It is possible that subjects did not put forth a valid effort therefore confounding the data.

It is interesting to note that absolute peak VO_2 was very close to significance ($p=.059$) with an average improvement of 2.9%. Likewise, the average SBP decreased by 2.9%. This trend of increase in absolute peak VO_2 and decrease in SBP suggests that the most logical explanation for the discordant data is due to the small sample size. It is possible that absolute peak VO_2 , SBP, and other variables may have shown significance if a sample size of more than 22 was used.

In conclusion, as Bikram yoga continues to grow in popularity in the United States, so does an increase in the need for further research. To the best of our knowledge,

this is the first study examining the cardiopulmonary and psychological effects of Bikram yoga. Results from this study suggest that 60-days of Bikram yoga will not significantly increase any measure of pulmonary function or cardiovascular function during exercise. However, it does appear that 60-days of Bikram yoga will significantly improve resting HR and DBP as well as intrinsic motivation, life satisfaction, and CSE. Although this study examined the effects of Bikram yoga on participants of varying Bikram experience, the effects of Bikram yoga on untrained individuals would likely be beneficial to the majority of the population. In addition, it would be advantageous to measure the metabolic cost of Bikram yoga in order to understand the proper energy expenditure and provide a more adequate description about the intensity of a typical class.

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Table 2

Descriptive Data for Subjects

Variable	Time 1		Time 2		t-value	df	p-value
	Mean	SD	Mean	SD			
Age	40.91	11.49	41.43	11.55	-.03	33	.98
Weight (kg)	68.78	12.66	66.43	14.14	1.31	33	.09
Previous Bikram experience (years)	1.79	2.63	2.44	2.97	-.81	33	.42
Average days per week attending Bikram	4.54	1.72	6.02	.98	-1.46	33	.15

Table 3
Psychological, Cardiopulmonary and Pulmonary Function Variables

Variable	Time 1 Mean	Time 1 SD	Time 2 Mean	Time 2 SD	T-Value	df	p-value
Psychological Constructs							
Intrinsic Motivation	26.05	3.14	27.05	1.80	2.26	20	.04*
Satisfaction with Life	26.64	5.34	28.82	5.46	3.15	21	.005**
Core Self Evaluation	60.46	9.42	65.50	8.16	2.67	21	.014*
Physiological Variables							
FVC	4.47	1.06	4.27	1.02	2.98	21	.007**
% pred. FVC	116.86	15.73	111.68	15.17	3.17	21	.005**
FEV _{1.0}	3.59	0.85	3.43	0.80	2.14	21	.044*
% pred. FEV _{1.0}	112.77	17.06	108.05	15.17	2.08	21	.050
FEV _{1.0} /FVC	80.63	4.91	80.66	3.70	.02	21	.982
PEFR	7.59	2.30	7.81	2.63	.65	21	.523
FEF 25-75%	3.77	1.41	3.48	0.90	1.42	21	.171
MVV	132.97	27.91	131.87	27.51	.33	21	.741
% pred. MVV	115.36	17.08	116.09	18.53	.29	21	.776

Table 2-Continued

Peak VO ₂ (LO ₂ •min ⁻¹)	2.39	0.49	2.46	0.51	2.04	15	.059
Peak VO ₂ (mlO ₂ •kg ⁻¹ •min ⁻¹)	37.97	8.06	39.04	8.48	1.83	15	.088
MHR	166.38	46.62	174.81	12.27	.84	15	.414
V _E	83.42	25.54	83.86	24.27	.13	15	.901
RER	1.15	0.09	1.14	0.09	.56	15	.586
RR	45	10.17	46.31	8.40	.53	15	.604
V _T	2.29	0.43	2.22	0.51	.99	15	.336
V _E /VO ₂	42.31	5.07	41.44	6.24	.55	15	.594
V _E /VCO ₂	36.94	3.09	36.31	4.50	.54	15	.597
O ₂ Pulse	13.60	2.75	13.87	2.95	1.00	14	.334
T _I	1.39	0.31	1.33	0.26	.75	15	.467
V _T /T _I	1.72	0.52	1.72	0.50	.05	15	.958
Resting Pulse	66.86	6.30	63.05	8.34	2.35	21	.029*
SBP	117.55	10.82	114.09	9.45	1.93	21	.067
DBP	76.73	7.37	71.18	8.96	3.54	21	.002**

Note: FVC = forced vital capacity, FEV_{1.0} = forced expiratory volume in the 1st second, PEFR = peak expiratory flow rate, FEF 25-75% = forced expiratory flow 25-75%, MVV = maximum voluntary ventilation, peak VO₂ = maximum oxygen consumption, MHR = maximal heart rate, V_E = minute ventilation, RER = respiratory exchange ratio, RR = respiratory rate, V_T = tidal volume, VCO₂ = carbon dioxide production, T_I = inspiratory time, SBP = resting systolic blood pressure, DBP = resting diastolic blood pressure

APPENDIX A

MEDICAL HEALTH APPRAISAL

Medical Health Appraisal

Do you have a physician in town? Name:		
Yes	No	History of Heart Disease – Have you experienced:
<input type="radio"/>	<input type="radio"/>	A heart attack? If so, when?
<input type="radio"/>	<input type="radio"/>	Heart surgery? If so, when?
<input type="radio"/>	<input type="radio"/>	Cardiac catherization? If so, when?
<input type="radio"/>	<input type="radio"/>	Coronary angioplasty (PTCA)? If so, when?
<input type="radio"/>	<input type="radio"/>	Pacemaker/implantable cardiac defibrillator/rhythm disturbance? If so, when?
<input type="radio"/>	<input type="radio"/>	Heart valve disease? If so, when was it diagnosed?
<input type="radio"/>	<input type="radio"/>	Heart failure? If so, when?
<input type="radio"/>	<input type="radio"/>	Heart transplantation? If so, when?
<input type="radio"/>	<input type="radio"/>	Congenital heart disease? If so, when was it diagnosed?
Yes	No	Current Health Status
<input type="radio"/>	<input type="radio"/>	Do you have diabetes? If so, when was it diagnosed?
<input type="radio"/>	<input type="radio"/>	Lung disease? If so, when was it diagnosed?
<input type="radio"/>	<input type="radio"/>	Asthma? If so, when was it diagnosed?
<input type="radio"/>	<input type="radio"/>	Kidney disease? If so, when was it diagnosed?
<input type="radio"/>	<input type="radio"/>	Liver disease? If so, when was it diagnosed?

<input type="radio"/>	<input type="radio"/>	If you are a female, are you pregnant or do you think that you might be pregnant?
Yes	No	Symptoms – Do you:
<input type="radio"/>	<input type="radio"/>	Experience chest discomfort with exertion?
<input type="radio"/>	<input type="radio"/>	Experience unreasonable breathlessness or unusual fatigue at rest, with mild exertion, or during usual activities?
<input type="radio"/>	<input type="radio"/>	Experience dizziness, fainting, or blackouts?
<input type="radio"/>	<input type="radio"/>	Take heart medications? If so, what kind?
<input type="radio"/>	<input type="radio"/>	Experience difficulty breathing when lying flat or when asleep?
<input type="radio"/>	<input type="radio"/>	Experience ankle swelling?
<input type="radio"/>	<input type="radio"/>	Experience forceful or rapid heartbeats?
<input type="radio"/>	<input type="radio"/>	Experience numbness in legs or arms from time to time?
<input type="radio"/>	<input type="radio"/>	Have a known heart murmur?
<p>If you answered “No” to all questions listed above, then proceed to next page. If you answered “yes” to any of the questions listed above, then we recommend that you receive approval from your healthcare provider before participating in the research.</p>		

Yes	No	Cardiovascular risk factors:
<input type="radio"/>	<input type="radio"/>	Do you smoke or have you quit smoking within the last 6 months?
<input type="radio"/>	<input type="radio"/>	Have you been diagnosed with high blood pressure or do you take blood pressure medication? (Mark "Yes" if you do not know your blood pressure).
<input type="radio"/>	<input type="radio"/>	Have you been diagnosed with high cholesterol levels, or do you take cholesterol-lowering medication? (Mark "Yes" if you do not know your cholesterol.)
<input type="radio"/>	<input type="radio"/>	Has a close blood relative experienced a heart attack, heart or blood vessel surgery, or sudden death from a heart attack or stroke before age 55 (father, brother, or son) or age 65 (mother, sister, or daughter)?
<input type="radio"/>	<input type="radio"/>	Have you been diagnosed with high blood sugar, or do you take medicine to control your blood sugar? (Leave blank if you do not know anything about your blood sugar levels.)
<input type="radio"/>	<input type="radio"/>	Are you physically inactive (i.e., do you get less than 30 minutes of physical activity on at least 5 days per the week)?
<input type="radio"/>	<input type="radio"/>	If you are a male, are you 45 years or older? If you are a female, are you 55 years or older (or have you had a hysterectomy or are you postmenopausal)?
<input type="radio"/>	<input type="radio"/>	Is your Body Mass Index 30 kg/m^2 or higher or are you at least 20 pounds overweight? (Mark "Yes" if you <i>think</i> you are overweight/obese.)
Yes	No	Other health issues that may warrant physician approval before engaging in physical activity.
<input type="radio"/>	<input type="radio"/>	Have you ever been told not to exercise by a health care provider?
<input type="radio"/>	<input type="radio"/>	Are you pregnant or think you might be pregnant?
<input type="radio"/>	<input type="radio"/>	Do you have problems with your muscles, bones, or joints?

<input type="radio"/> <input type="radio"/> Are you taking prescription medications? If so, please list:	
Medication	Dosage

I certify that the information included on this form is correct.

Date

Signature of Participant

Date

Signature of Primary Investigator

<p>(Office Use Only) Risk Status: <input type="radio"/> 1. Low <input type="radio"/> 2. Moderate <input type="radio"/> 3. High</p> <p><input type="radio"/> Diabetes <input type="radio"/> Heart Disease <input type="radio"/> Lung Disease <input type="radio"/> Kidney Disease <input type="radio"/> Liver Disease</p> <p><input type="radio"/> Pregnant</p>

APPENDIX B

PRE-TEST INSTRUCTIONS

The Cardiopulmonary Benefits of Bikram Yoga

Research Investigation

Pre-test Instructions

Before you participate in any fitness testing, you need to first be made aware of what to expect, what to do before testing, and what to wear to the test.

What to expect?

When you arrive, you will be introduced to the primary investigator and any questions you may have will be answered. After 10 minutes of seated rest, your heart rate and blood pressure will be measured. Next, you will be taken through a battery of pulmonary tests that will require you to maximally exhale and inhale. Finally, a maximal aerobic exercise test will be administered. You will be asked to ride a stationary bike at an increasing workload until fatigue.

What to wear?

You will need to wear a t-shirt, workout shorts or pants, and comfortable exercise shoes with good support. We also recommend that female clients wear a sports bra.

What to do before testing?

1. You should refrain from consuming food, alcohol, caffeine or using tobacco and nicotine products at least 3 hours before the test.
2. You should be well rested before the test so make sure to get at least 6 hours of sleep the night before the test.
3. Avoid any exercise the day of the test.
4. Drink plenty of fluids during the 24-hour period prior to the test.

What to bring?

A light snack and/or carbohydrate beverage (such as, Gatorade). Sometimes, clients experience fatigue and/or low blood sugar when performing a battery of fitness tests.

If you have any questions, please call Allison Abel at 281-685-2601 or e-mail her at aa1229@txstate.edu.

APPENDIX C

CONSENT FORM

Consent Form

Project Title: The Cardiopulmonary Effects of Bikram Yoga

IRB Number: 2010Q9888

Principal Investigator: Allison Abel, Graduate Student, 281-685-2601, aa1229@txstate.edu

Professor of Record: Lisa Lloyd, PhD, Associate Professor, 512-245-8358, LisaLloyd@txstate.edu

INTRODUCTION. You are being asked to participate in a research study. This study is being completed as part of my thesis requirements for graduation. This form provides you with information regarding the research being conducted. You have been asked to participate in this study because you have signed up to complete the 60-day Bikram Yoga program at Pure Bikram Yoga in Austin, Texas. Please read this form and ask any questions you may have regarding participation in this study. Participation is entirely voluntary. You will be tested at Pure Bikram Yoga in Austin, Texas. Read the information below and ask questions about anything you do not understand prior to deciding whether or not to participate.

PURPOSE OF THIS RESEARCH STUDY. The purpose of this research is to determine the effects of 60-days of Bikram yoga practice on heart health and lung capacity in healthy adults.

PROCEDURES. If you agree to participate in this study, you will be expected to visit with researchers at 2 different times between December and March.

1. During your first visit, you will meet with a researcher for about 1 hour and you will:
 - Fill out a form asking you some questions about your age, how you feel about exercise, and how much you exercise (*Note.* You can choose not to answer any question on the form).
 - Answer 21 survey questions regarding life satisfaction, and self-esteem. (*Note.* You can choose not to answer any question on the survey.)
 - Be measured for body weight, height. You will not be required to remove any clothing except for your shoes. We ask, however, that you dress in lightweight clothing
 - Rest in a lying position for 5 minutes in a dimly lit room and then have your resting blood pressure and resting heart rate measured.
 - Engage in lung function tests, which require you to inhale and exhale as hard as you can into a mouthpiece.
 - Complete an exercise test on a stationary bicycle to determine your aerobic

endurance capacity (maximal oxygen consumption).

2. During the second visit, which will be within 1 week of the completion of your 60-day yoga training, you will meet with a researcher for about 1 hour and these procedures will be repeated.

POTENTIAL RISKS OR DISCOMFORTS. Injuries to healthy subjects during exercise testing are uncommon. However, the chance for injury is acknowledged and precautions will be taken to prevent injuries. There exists the possibility of adverse changes during the exercise testing. These changes could include abnormal blood pressure, fainting, disorders of heart rhythm, stroke, and very rare instances of heart attack or even death. There is the possibility of dizziness and nausea immediately following the exercise performances. Also, there is the possibility of muscle strain. Muscle soreness may be present for 24-48 hours following the exercise tests. Please note that you are responsible for paying your own medical bills if you seek/receive medical health services due to a complication associated with your participation in this research study.

POSSIBLE BENEFITS. Your participation in this research will help you gain knowledge of your exercise capacity in relation to the general population and a better understanding of your level of fitness for certain sports and recreational activities. This knowledge may aid you in planning a future physical conditioning program or in evaluating the effects of recent physical activity habits. You will also gain a better understanding of your pulmonary ventilation and be able to see whether improvements occurred as a result of the 60-day Bikram yoga training program. If you are interested in learning the results of the study, contact me at 281-685-2601 upon the completion of the study and I will send you a summary of the findings. The results of this study may also help promote Bikram yoga in the medical/exercise community if we find that Bikram yoga significantly improves aerobic fitness and/or pulmonary function.

CONFIDENTIALITY. Your personal information will be kept confidential. Your information will be kept in a locked cabinet in Allison Abel's office at Texas State University-San Marcos and destroyed after three years. The professors and staff will use this information for research, but your name will not be given out in any reports. The information gathered will never be revealed to anyone other than the researchers and will only be reported in aggregate, that is, as part of an average score.

TERMINATION OF RESEARCH STUDY. You are free to decide if you would like to take part in this research. If you choose not to take part, it will not affect your right to seek other services from any agencies, institutions, or entities involved with this research project. You may quit at anytime. If you decide to stop participating in the study, please notify the researchers of your decision. In addition, the researchers may end your participation in the study without your consent if they believe that you may be in danger.

AVAILABLE SOURCES OF INFORMATION

For questions about this study call:

Principal Investigator: Allison Abel

Phone Number: 281-685-2601

For questions you may have about your rights as a research subject call:

Institutional Review Board Chair: Dr. Jon Lasser Phone Number: 512-245-3413

Compliance Specialist: Ms. Becky Northcut Phone Number: 512-245-2102

AUTHORIZATION. “I have read and understand this consent form, and I agree to participate in this research study. I understand that I have received a copy of this form. I voluntarily choose to participate, but I understand that my consent does not take away any legal rights in the case of negligence or other legal fault of anyone who is involved in this study. I further understand that nothing in this consent form is intended to replace any applicable Federal, state, or local laws. I also understand that I may withdraw from this study at any time without penalty.”

Participant Name (Printed):

Participant Signature:

Date:

Principal Investigator (Signature):

Date:

APPENDIX D

SURVEY ITEMS

The Cardiopulmonary Benefits of Bikram Yoga

Part 1

This section is for people who have previously participated in Bikram Yoga

1.	How long have you been practicing Bikram Yoga? _____
2.	On average, how many days per week do you attend Bikram Yoga classes? _____ times per week
3.	Do you engage in any other exercise programs? _____ Yes _____ No (if yes, please complete Part 2; include ONLY the outside activity and NOT Bikram yoga in Part 2)

Part 2

This is for participants who have NEVER previously engaged in Bikram Yoga

4. How many times each week do you do VIGOROUS leisure-time physical activities for AT LEAST 10 MINUTES that cause HEAVY sweating or LARGE increases in breathing or heart rate?
_____ times per week
5. About how long do you do these vigorous leisure-time physical activities each time?
_____ minutes each time
6. How many times each week do you do LIGHT or MODERATE leisure-time physical activities for AT LEAST 10 MINUTES that cause ONLY LIGHT sweating or a SLIGHT to MODERATE increase in breathing or heart rate?
_____ times per week

7. About how long do you do these light or moderate leisure-time physical activities each time?
_____ minutes each time
8. How many times each week do you do leisure-time physical activities specifically designed to **STRENGTHEN** your muscles such as lifting weights or doing calisthenics?
_____ times per week
9. About how long do you do these strengthening leisure-time physical activities each time?
_____ minutes each time

Using the scale below as a guide, write any number from 1 to 7 in the spaces on the right-hand side to indicate the degree to which you agree or disagree.

1	2	3	4	5	6	7
Strongly Disagree						Strongly Agree

1. When I do my work well, it gives me a feeling of accomplishment _____
2. When I perform my job well, it contributes to my personal growth
and development _____
3. I feel a great sense of personal satisfaction when I do my job well _____
4. Doing my job well increases my feeling of self-esteem _____
5. In most ways my life is close to my ideal. _____
6. The conditions of my life are excellent. _____
7. I am satisfied with my life. _____
8. So far I have gotten the important things I want in life. _____
9. If I could live my life over, I would change almost nothing. _____
10. I am confident I get the success I deserve in life. _____
11. Sometimes I feel depressed. _____
12. When I try, I generally succeed. _____
13. Sometimes when I fail I feel worthless. _____
14. I complete tasks successfully. _____
15. Sometimes, I do not feel in control of my work. _____
16. Overall, I am satisfied with myself. _____
17. I am filled with doubts about my competence. _____
18. I determine what will happen in my life. _____

19. I do not feel in control of my success in my career. _____
20. I am capable of coping with most of my problems. _____
21. There are times when things look pretty bleak and hopeless to me. _____

Thanks for helping with the survey. 😊

APPENDIX E

DATA FORM

The Cardiopulmonary Benefits of Bikram Yoga

Contact Information

Name _____

Email _____

Best Contact Number _____

Date of Birth _____/_____/_____ Age _____

Ethnicity (optional) _____

*This will be used only to compare your pulmonary results to national averages.

Standard Measurements

Height _____ft _____in Height _____in

Weight _____lbs Weight _____kg

Resting Pulse _____ Resting BP _____

Pulmonary Function

FVC _____ FEV_{1.0} _____

PEFR _____ MVV _____

Cardiovascular Measurements

VO₂max _____ HR_{max} _____

VITA

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