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ORIGINAL ARTICLE

Yoga and Psychophysiological Determinants of Cardiovascular Health: Comparing Yoga Practitioners, Runners, and Sedentary Individuals

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Abstract
Background The evidence of cardiovascular benefits of yoga is promising, but lacks demonstrations of specificity compared to other interventions.
Purpose The present cross-sectional study examined cardiovascular health markers in long-term practitioners of yoga (yogis), runners, and sedentary individuals.
Methods We compared physiological, psychological, and lifestyle variables associated with cardiovascular health across groups.
Results Yogis (n =47) and runners (n =46) showed favorable profiles compared to sedentary individuals (n =52) on heart rate, heart rate variability, depression, perceived stress, and cigarette smoking. Runners and male yogis showed superior aerobic fitness compared to the sedentary group. Runners reported greater social support compared to other groups. Yogis demonstrated a lower respiration rate compared to sedentary individuals and were more likely to refrain from eating meat compared to other groups.
Conclusions Yogis and runners demonstrated several cardiovascular health advantages over sedentary individuals. Our findings raise the possibility that yoga may improve aerobic fitness in men but not women.

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Introduction

Yoga, an ancient practice developed to connect the mind and body, has gained both popularity and scientific attention for its promising effects on health [1]. *Hatha yoga*, the most common branch in North America, combines the practice of *asana* (physical postures), *pranayama* (breathing techniques), meditation, and philosophical teachings, which may influence both physiological and psychological factors that have been linked with improved health.

Several systematic reviews exist on the effects of yoga practice on cardiovascular health, all of which conclude that yoga is potentially protective against cardiovascular disease in healthy adults and individuals with diabetes or heart disease [1–4]. Positive findings have been reported for several indices of cardiovascular disease risk, most commonly blood pressure (BP) and heart rate (HR). These reviewers point to yoga's promise in cardiovascular health, but also stress that conclusions remain tentative due to a lack of methodologically rigorous research. Identified methodological weaknesses include poorly described research methods, small sample sizes, inadequate statistical analysis, lack of control group, and inclusion of multiple interventions [1]. Additionally, Innes et al. [1] found that over 70 % of the clinical trials had been conducted in India, which limits generalizability to Western populations due to the differences in yoga practice and cultural meaning. Finally, a major difficulty in determining the specific cardiovascular health benefits of yoga is the paucity of studies that examine the effects of yoga relative to practices of other physical and/or self-regulatory activities.

The present study aimed at identifying the potential specificity of yoga on cardiovascular health markers by comparing long-term regular yoga practitioners, referred to as yogis, to long-term regular runners, and to sedentary individuals. Our design highlights the unique differences between those who practice yoga and those who do not, as opposed to differences accounted for by engaging regularly in physical activity more generally. We chose to measure noninvasive physiological markers of cardiovascular health including BP and HR, which have most commonly been studied in the yoga and cardiovascular health literature [1], as well as heart rate variability (HRV; HRV indices are described under "Physiological Measures"). It was considered critical for this study to recruit participants who had long-standing patterns of running or yoga to maximize the likelihood of finding activity-specific benefits which might have developed over time.

HRV is an index of autonomic nervous system functioning and has been associated with a range of cardiovascular health outcomes including incidence of hypertension [5]. Few studies have measured resting HRV in long-term yogis, though several have shown immediate increases in HRV during acute yoga practice in healthy adults [6] and in pregnant women [7].

Two recent cross-sectional studies compared yogis and non-yogis, but did not include a comparison group that practiced another physical activity. One study found no difference in BP or HR between female yogis (*yoginis*) who had practiced yoga one to two times per week for at least 2 years and female yoga novices who had practiced yoga for between 6 and 12 sessions [8]. Another study found no difference in resting HR, but showed significantly lower systolic and diastolic BP and significantly higher HRV in yogis of at least 6 months compared to individuals who had never practiced yoga [9].

Given the various components of yoga practice, we examined a range of other factors associated with cardiovascular health in order to highlight potential pathways by which yoga could exert cardiovascular effects. These included respiration rate, waist circumference and aerobic fitness, lifestyle factors, and psychological factors. We chose to measure lifestyle factors that have been shown prospectively to affect cardiovascular disease risk including cigarette smoking [10], sleep [11], and meat consumption [12]. We also chose to measure the psychological factors that have accrued the most empirical support for good cardiovascular health, which include depression, perceived stress, hostility, and low social support [13].

The most extensively studied psychological factor in relation to yoga has been depression. A review of the literature concludes that each of the five published randomized-controlled trials (RCTs) targeting depressive symptoms in response to yoga intervention had shown positive results [14]. However, conclusions are tentative because the trials differed greatly in depression severity and intervention type, and study methodology was often not thoroughly reported. Pilkington et al. [14] also concluded that it would be helpful for future research to compare yoga intervention with other forms of physical activity. A meta-analysis of the associated psychological benefits of exercise treatment in cardiac patients concluded that exercise rehabilitation without any specific targeting of depression still produced significant reductions in reported depression symptoms ($d = -0.46$) [15]. While exercise may improve depressive symptoms in individuals with depressive disorders, recommendations for optimal exercise, such as aerobic versus non-aerobic exercise, remain unclear [16]. Therefore, it would be beneficial to determine whether the association between yoga and psychological factors, such as depression, is specific.

Although trait mindfulness, the tendency to attend to the present moment without judgment, has not yet been studied in relation to cardiovascular health, we chose to measure mindfulness because it has been shown to be greater in advanced yogis compared to novice yogis [17] and to predict lower rates of psychopathology [18]. We expected that mindfulness would be uniquely superior in yogis, and not runners, compared to sedentary individuals.

The present study's cross-sectional design allowed for examination of differences between long-term yogis, long-term runners, and sedentary individuals on physiological indices of cardiovascular health (i.e., HR, BP, and HRV), as well as psychological factors (i.e., depression, perceived stress, hostility, social support, and mindfulness), respiration rate, waist circumference, aerobic fitness level, and lifestyle factors (i.e., sleep quality, meat consumption, and cigarette smoking). By examining these group differences, the study identified potential mechanisms through which yoga may improve cardiovascular health. This study was intentionally not conceived as a RCT because it was meant to describe what happens when individuals choose a health practice and stick to it consistently over time.

Methods

Participants

Participants were recruited through advertisements in a newspaper, public posting boards, fitness stores, yoga studios, a yoga event, running group mailing lists, and the Craigslist website. They were offered an honorarium of $50.00. A total of 145 individuals were included in the study (yoga, $n = 47$; running, $n = 46$; sedentary, $n = 52$). Figure 1 depicts the number of individuals who expressed interest in participating, their recruitment source, and the reasons for exclusions by group. Nine individuals were eligible by telephone screening interview and therefore participated in the study, but were ultimately excluded. Although they had reported sufficient participation in yoga or running (three times per week, 30 min

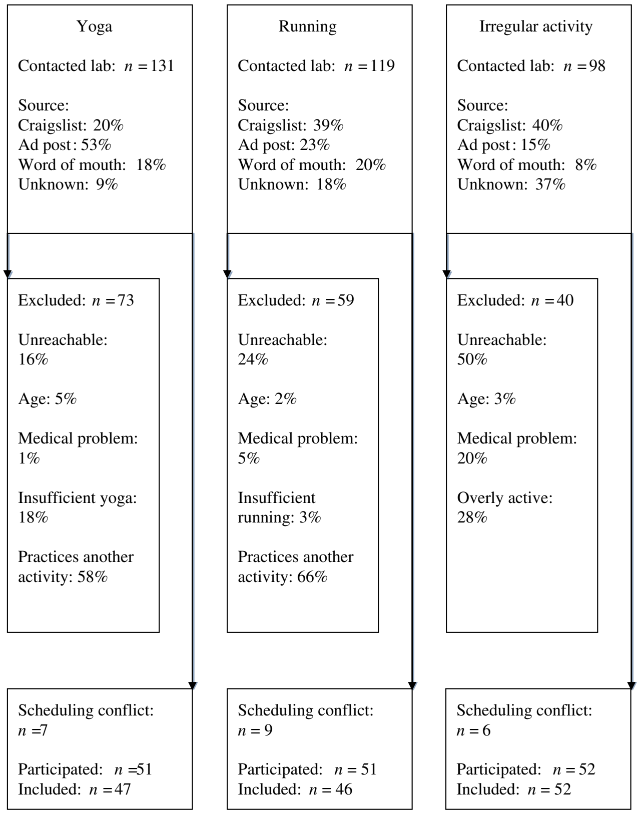

Fig. 1 Flowchart of exclusion and inclusion of study participants

each session, for 2 years) in the screening interview, they reported insufficient total minutes per week, times per week, or years of experience in the self-report questionnaire completed in the laboratory (yoga, $n = 4$; running, $n = 5$). Cases in which individuals reported "2–3" times of participation per week with total minutes of participation per week of ≥90 were retained in the sample (yoga, $n = 2$; running, $n = 1$).

Three groups were included in the present study comprising yogis, runners, and sedentary individuals. The yoga group consisted of individuals who reported practicing yoga that included asana (physical postures) and a meditative component (whether on or off the yoga mat) for at least 30 min per session, at least three times per week, for a minimum of 2 years. The study included practitioners of all types of Hatha yoga except Bikram yoga or other types of yoga performed in hot temperatures, because of confounding of regular exertion in temperatures around 105° Fahrenheit. The running group consisted of individuals reporting regularly running for at least 30 min per session, at least three times per week, for the past 2 years at minimum. The sedentary group was comprised of individuals who reported that they did not regularly participate in any activity intended to reduce perceived stress or improve aerobic fitness. Regularity of activities was defined as lasting at least 30 min, one time per week or more, for any 6-month period within the last 2 years.

Individuals were excluded if they were not proficient in the English language, if they had a history of any heart disease or hypertension, or if they used anxiolytic medication. Individuals who endorsed a history of panic attacks were excluded due to a laboratory stress induction not discussed here. Individuals were excluded if they were under the age of 20 or over the age of 59 to meet the requirements of the modified Canadian Aerobic Fitness Test used in our study. To assure non-overlapping groups, individuals who identified as yogis or runners were excluded if they also participated in any other activity intended for stress reduction or aerobic fitness that lasted at least 30 min, one time per week, for any 6-month period within the last 2 years.

Procedures

This study had received appropriate ethics approval. The study took place in the Behavioural Cardiology Laboratory in the Psychology Department at the University of British Columbia between March 2010 and October 2010. To increase the accuracy of physiological measures, participants were asked to abstain from meditation, yoga, running or vigorous exercise, and to abstain from consuming alcohol or caffeine for 12 h prior to participation. We were not concerned that caffeine withdrawal would affect our findings as the majority of studies on short-term caffeine abstinence have not demonstrated any effects on BP or on HR [19]. Participants completed the consent form and a battery of questionnaires. Waist circumference was measured. A standard occlusion cuff, electrodes, and strain gauge were attached and participants were asked to rest for 10 min while BP, HR, HRV, and respiration rate were measured. Participants were subsequently exposed to two 5-min laboratory stressors, an arithmetic task, and a handgrip strength task, as part of analyses not included in this study. At the end of a 5-min recovery period after the stressors, HR (which is what is measured by the modified Canadian Aerobic Fitness Test) was not significantly different from baseline, $t(142) = -0.42$, $p = 0.68$. Participants then completed the modified Canadian Aerobic Fitness Test followed by debriefing and remuneration.

Physiological Measures

To measure systolic BP (SBP), diastolic BP (DBP), and HR for resting measures, we used the VSM-100 BpTRU automatic BP device, a reliable and noninvasive tool [20]. The instrument has demonstrated 89 % agreement with standard auscultatory mercury sphygmomanometer measurements, within 5 mmHg, as well as 96 and 99 % agreement, within 10 and 15 mmHg, respectively [20]. The BpTRU cuff was attached to the participants' nondominant arm and measurements were taken every 2 min for 10 min. The first two readings were not included in the resting average to allow the participant to acclimatize to the procedure.

For short-term measurement, it is recommended to use frequency domain methods, which uncover the source of HRV, derived through fast Fourier transformation and spectral analysis of the electrocardiogram recordings [21]. We chose to measure high frequency (HF) power, found between 0.15 and 0.4 Hz, both in absolute and normalized units, as they are the most well-understood spectral components. Absolute power (in square millisecond) of the HF component represents power in the high-frequency range, primarily resulting from efferent vagal activity. Normalized units (n.u.) represent the relative value of the HF power component in proportion to the total power minus the power of the very low frequency component. In other words, normalized units represent the balance of sympathetic and parasympathetic nervous systems [21].

HF power was measured using the CardioPro Version 1.0 (Thought Technology; Montreal, Canada) for the ProComp+ system, with three electrodes attached to the chest in standard three-lead configuration. Measurements were taken continuously during a 10-min period of seated rest and data from the second 5-min interval were used to derive the HF index.

Respiration rate was also recorded with the CardioPro Version 1.0 for the ProComp+ system using a PS-I strain gauge filled with conduction fluid attached by Velcro strap at the level of the umbilicus. Test–retest reliability is moderately high [22]. Respiration rate was calculated as the average breaths per minute based on the second 5-min of a 10-min measurement period.

Waist circumference was measured because it is accepted as the best anthropometric measure to identify individuals at risk for cardiovascular disease [23]. Waist circumference was measured in accordance with the Canadian Society for Exercise Physiology [24] using a fabric measuring tape, placed mid-way between the bottom of the rib cage and the iliac crest, with measurements rounded to the nearest 0.5 cm.

Aerobic fitness was measured using the modified Canadian Aerobic Fitness Test, a submaximal (85 % of maximum HR) protocol to determine aerobic fitness [24], which strongly predicts maximal oxygen uptake [25]. Aerobic fitness zone scores (five levels) were derived, which account for sex, age, and weight. Participants wore a portable HR monitor (Polar FS2c) placed at chest level. Participants completed a minimum of one and a maximum of six 3-min sessions of stepping on a two-step (each 20.3 cm) bench at predetermined speeds based on age and sex, guided by audio instructions. The test was complete when participants reached or exceeded their predicted 85 % maximal HR based on age and sex.

Self-report Measures

Depressive symptoms were assessed by the Beck Depression Inventory-II (BDI-II) [26], based on the Diagnostic and Statistical Manual of Mental Disorders-Fourth Edition criteria. The BDI-II is a 21-item multiple-choice questionnaire used to measure the severity of depressive symptoms, which has shown to be a reliable, internally consistent, and valid measure in nonpsychiatric samples including college students [27] and primary care patients [28].

Trait hostility was assessed by the 29-item hostility subscale of the Buss–Perry Aggression Questionnaire [29]. The subscale has shown adequate internal consistency and test–retest reliability as well as convergent validity with a number of measures of aggression in a Canadian sample [30].

Perceived stress was measured by the Perceived Stress Scale-10 [31], which is a measure of perceived nonspecific stress. Although it is a briefer version than the original 14-item scale, the Perceived Stress Scale-10 is improved in terms of factor structure and internal consistency [31].

The 40-item Interpersonal Support Evaluation List was used to assess the perceived availability of social resources. The questionnaire captures four subscales of social support: tangible, appraisal, self-esteem, and belonging. The instrument shows strong reliability and convergent validity with psychological symptomatology in the general population [32].

We administered the Mindful Attention Awareness Scale [33] to measure trait mindfulness. The Mindful Attention Awareness Scale has shown very good internal reliability [34], strong convergent validity with measures of psychological well-being, and the ability to differentiate between inexperienced meditators and experienced Zen Buddhist practitioners, whose practice would presumably increase mindfulness [33].

The Pittsburgh Sleep Quality Index [35] was used as a global measure of sleep over a 1-month period. It has good internal consistency, test–retest reliability, and diagnostic sensitivity and specificity in distinguishing between good and poor sleepers [35].

To assess meat consumption, participants were asked to specify their dietary preferences out of a choice of nonvegetarian (no dietary restriction), vegan (no meat, seafood, dairy products, or eggs), lacto-ovo vegetarian (no meat or seafood), and pescetarians (no meat). We categorized participants into meat eaters and non-meat eaters which included vegans, lacto-ovo vegetarians, and semivegetarians.

Cigarette smoking was assessed with the face-valid question “On average, how many cigarettes do you smoke per day?” with choices of 0, 1–5, 6–10, 11–20, 21–29, and over 30. Due to the lack of variability in cigarette smoking frequency, participants were categorized into nonsmokers (0 per day) and smokers (one or more per day).

Data Handling and Statistical Analyses

Data were entered twice into SPSS 17.0 by two research assistants, and compared to ensure accuracy. We visually inspected each participant's HRV data to identify technical errors, and errors and outlier effects were corrected according to guidelines of the Cardiopro, Version 1.0 User's Manual (Thought Technology, Montreal, Canada).

Statistical analyses were conducted using SPSS version 17.0. Group differences were analyzed by analysis of variance (ANOVA), analysis of covariance (ANCOVA), multivariate analysis of variance (MANOVA), and chi-square test.

We took the following steps to reduce type I error: (1) MANOVA was chosen over separate ANOVAs when the assumptions of MANOVA were met, (2) the conservative Sheffé's post hoc test was chosen, and (3) a family-wise alpha of 0.05/number of comparisons was used when performing multiple analyses on the same set of data.

Results

Statistical Assumption Testing

The assumptions of ANOVA and MANOVA were tested, and violations were addressed when identified. Absolute HF and normalized HF were positively skewed, and therefore the data were natural log transformed (ln). Correlations for perceived stress and depression were in the 0.70 range, indicating risk of multicollinearity, but were nonetheless both analyzed, because the two variables are known to be distinct yet related in the literature and the potential for conservative bias was accepted. The Box's M Test of Equality of Covariance Matrices yielded a significant value of 61.62 ($p=0.001$). To address this violation, we used Pillai's trace in multivariate analyses. Levene's test was used to test the assumption of homoscedasticity, evaluated at $p<0.01$, and one violation was identified for waist circumference ($F(2, 142)=8.64$, $p<0.001$).

Participants

Descriptive statistics for demographic and other variables of interest are provided in Table 1. Using ANOVA, a significant group difference was found for age ($F(2, 142)=4.88$, $p=0.03$). Post hoc analysis (Scheffé) revealed that yogis were older than runners ($p=0.04$). The chi-square test was used to determine that groups did not differ significantly by sex ($\chi^2(2)=0.01$, $p=0.99$).

Differences were present for ethnicity/race, when dividing the sample into individuals who identified themselves as White (65 %) and as Asian (26 %). Nine percent of participants identified with other ethnicities: Black (2 %), First Nations (3 %), Hispanic (1 %), Middle Eastern (1 %), and South Asian (2 %). When comparing White and Asian ethnicity by group using a chi-square test, yogis and sedentary individuals differed ($\chi^2(1)=14.70$, $p<0.001$), such that the yogis were comprised of fewer Asian individuals and more White individuals than the sedentary group. Yogis and runners also differed ($\chi^2(1)=4.16$, $p=0.04$), such that the yogis were comprised of fewer Asian individuals and more White individuals than the running group. Runners and sedentary individuals did not differ ($\chi^2(1)=3.79$, $p>0.05$). Differences in ethnicity and age could not be reasonably controlled for in this study, and this limitation is discussed further in our discussion.

Description of the Yoga Group

The yoga group was comprised of individuals with clear variability in yoga practice and experience. Yogis reported primarily practicing Hatha (20 %), Ashtanga (15 %), Power (15 %), Flow/Vinyasa Flow (6 %), Kundalini (6 %), Iyengar (6 %), Yin, (11 %), mixed styles (9 %), and "other" (10 %). They had been practicing yoga regularly for a mean of 6.49 years (SD=3.67), ranging from 2 to 18 years. They reported practicing yoga at a mean of 5.1 times per week (SD=4.12), ranging from 2.5 to 30 times per week. Two participants indicated that they practiced yoga "two to three" times per week in the questionnaire. The yoga group reported a mean of 277.45 min per week of yoga including asana (SD=153.97), ranging from 90 to 840 min per week. The yoga group indicated practicing meditation, accompanying and independent of their yoga practice, a mean of 127.21 min per week (SD=215.51), ranging from 0–1,260 min. Seventy percent of the yoga group reported practicing *Ujjayi* breathing. This breathing technique involves inhaling and exhaling through the nose, while constricting the throat, which produces a hissing sound. Participants indicated that they practiced other breathing techniques a mean of 6.9 times per week (SD=18.73), ranging from 0 to 125 times. Forty-nine percent of the yoga group identified themselves as yoga instructors, whether or not they were currently teaching. Eighty-seven percent reported that yogic philosophy is part of their daily life.

Description of the Running Group

The running group reported running regularly for a mean of 8.30 years (SD=6.99) ranging from 2 to 43 years. They reported running a mean of 3.96 times per week (SD=1.18) ranging from 2.5–8 times per week. One participant endorsed running "two to three times per week" by questionnaire, though the participant had endorsed running a minimum of three times per week in the telephone screening interview. Runners reported running for 218.8 min per week (SD=116.40) ranging from 90–600 min per week. Fifty-six percent of the running group had participated in a marathon or half marathon in the previous 2 years. Of these runners, 39 % considered the goal of marathon participation to be competitive.

Table 1 Summary of demographic, physiological, and self-reported data

	Yoga (Y) (n=47)	Running (R) (n=46)	Sedentary (S) (n=52)	Significant group differences
Demographics				
Age (M, SD)	39.51 (11.02)	33.59 (9.8)	34.58 (12.55)	Y>R*
Female (%)	57	57	54	None
White (%)	79	67	50	Y>S**, Y>R*
Asian (%)	9	24	44	Y<S**, Y<R*
Other (%)	12	9	6	Not examined
Physiological				
SBP	106.88 (11.61)	108.7 (12.12)	105.38 (11.39)	None
DBP	72.25 (8.34)	71.87 (9.01)	67.03 (11.8)	None
HR	60.23 (8.08)	56.18 (9.58)	70.66 (8.59)	Y<S**, R<S***
Respiration rate	12.44 (2.5)	13.43 (2.35)	14.07 (2.0)	Y<S**
lnHF n.u.	6.29 (1.13)	6.3 (1.0)	5.38 (1.21)	Y>S**, R>S***
lnHF power	13.16 (2.18)	13.42 (2.03)	11.46 (2.31)	Y>S**, R>S***
Waist circumference	81.2 (8.58)	77.64 (7.88)	82.23 (15.62)	None
Aerobic fitness zone	2.04 (1.19)	1.44 (0.79)	2.7 (1.02)	Y>S**, R>S***, R>Y*
Psychological				
Depression	4.98 (5.23)	4.73 (5.26)	9.64 (7.68)	Y<S***, R<S***
Perceived stress	11.02 (6.11)	11.84 (6.94)	16.94 (7.23)	Y<S***, R<S**
Hostility	15.69 (5.51)	16.2 (5.73)	19.54 (6.35)	Y<S**, R<S**
Social support	40.07 (6.39)	42.55 (3.7)	37.1 (7.84)	R>S***
Mindfulness	4.62 (0.73)	4.18 (0.93)	4.23 (0.73)	None
Lifestyle				
Global sleep	7.82 (2.3)	7.2 (3.15)	9.08 (3.45)	R<S**
Smoker (%)	2	2	33	S>Y**, S>R**
Meat eaters (%)	62	89	94	Y<S***, Y<R**
Pescetarian (%)	15	7	4	Not examined
Lacto-ovo vegetarian (%)	15	2	2	Not examined
Vegan (%)	9	2	0	Not examined

*$p \leq .05$, **$p \leq .01$, ***$p \leq 0.001$

Physiological Measures

Descriptive statistics for our variables of interest are provided in Table 1. Separate ANOVAs were run for SBP, DBP, and HR. When group and sex were entered as fixed factors, no group differences were found for SBP ($F(2, 137)=1.61$, $p=0.21$, $\eta p^2=0.023$). Sex was associated with SBP ($F(1, 137)=35.49$, $p<0.001$, $\eta p^2=0.206$), where males had higher SBP than females. Sex did not interact with group membership on SBP ($F(2, 137)=0.25$, $p=0.78$, $\eta p^2=0.002$).

No group differences were found for DBP ($F(2, 136)=0.60$, $p=0.55$, $\eta p^2=0.009$). Sex was associated with DBP by two-way ANOVA ($F(1, 137)=18.89$, $p<0.001$, $\eta p^2=0.121$), whereby males had higher DBP than females. Sex did not interact with group membership on DBP ($F(2, 137)=0.14$, $p=0.87$, $\eta p^2=0.002$).

A significant group difference was found for resting HR ($F(2, 137)=15.45$, $p<0.001$, $\eta p^2=0.184$). Post hoc analyses (Scheffé) revealed that yogis had significantly lower resting HR than sedentary individuals ($p<0.01$, $d=-1.25$), runners had significantly lower resting HR than sedentary individuals ($p<0.001$, $d=-1.59$), and yogis and runners did not significantly differ from each other ($p=0.16$, $d=0.46$). Sex was not related to HR ($F(1, 137)=2.96$, $p=0.09$, $\eta p^2=0.021$) nor did it interact with group membership ($F(2, 137)=0.59$, $p=0.56$, $\eta p^2=0.009$).

Respiration rate was not correlated with heart rate in this sample ($r(137)=0.05$, $p=0.56$) and was analyzed separately. No significant sex difference was found in respiration rate ($F(1, 133)=0.11$, $p=0.74$, $\eta p^2<0.001$) and there was no interaction between sex and group membership ($F(2, 133)=1.59$, $p=0.21$, $\eta p^2=0.023$). However, there was a significant group difference in respiration rate ($F(2, 133)=5.66$, $p<0.01$, $\eta p^2=0.078$). Specifically, post hoc (Scheffé) tests revealed that yogis had significantly lower respiration rate than sedentary individuals ($p<0.01$, $d=-0.72$) but did not differ from runners ($p=0.14$, $d=-0.41$). When only yogis who practiced Ujjayi breathing (70 % of the yoga sample) were included, the overall group difference strengthened ($F(2, 119)=7.21$, $p=0.001$, $\eta p^2=0.108$). Yogis who practiced Ujjayi demonstrated marginally significantly fewer breaths per minute ($M=12.11$, SD=2.48) compared to runners ($p=0.05$, $d=0.55$) and significantly fewer breaths per minute compared to sedentary individuals ($p=0.001$, $d=0.87$). Runners and sedentary individuals did not differ on respiration rate ($p=0.39$, $d=0.29$).

For lnHF absolute power, ANCOVA was used to analyze group differences, covarying for respiration rate, which significantly predicted lnHF absolute power ($\beta=-0.33$, $t(137)=4.00$, $p<0.001$, $R^2=0.33$, $F(1, 137)=16.03$, $p<0.001$). With respiration rate entered as a covariate, and group and sex entered as fixed factors, sex was not related to lnHF absolute power ($F(1, 132)=0.62$, $p=0.43$, $\eta p^2=0.005$) and sex did not interact with group ($F(2, 132)=0.75$, $p=0.47$, $\eta p^2=0.011$). There was a significant group difference on lnHF absolute power ($F(2, 132)=9.29$, $p<0.001$, $\eta p^2=0.123$), such that sedentary individuals had significantly lower lnHF absolute power compared to yogis ($p=0.004$, $d=0.76$) and compared to runners ($p<0.001$, corrected alpha for multiple comparisons of $p=0.03$; $d=0.90$). Yogis and runners did not significantly differ from each other ($p=0.24$, $d=0.12$).

ANCOVA was also used to analyze group differences on normalized lnHF (lnHF n.u.), covarying for respiration rate, which was significantly related to lnHF n.u. (r (135)=−0.33, $p<0.001$). With respiration entered as a covariate, and group and sex as fixed factors, sex was not related to lnHF n.u. ($F(1, 128)=0.01$, $p=0.91$, $\eta p^2<0.001$), and sex did not interact with group ($F(2, 128)=1.75$, $p=0.18$, $\eta p^2=0.027$). There was a significant group difference on lnHF n.u. ($F(2, 128)=8.34$, $p<0.001$, $\eta p^2=0.115$). Specifically, correcting for multiple comparisons (the corrected alpha was $p=0.03$), sedentary individuals had significantly lower lnHF n.u. compared to yogis ($p=0.004$, $d=-0.78$) and compared to runners ($p<0.001$, $d=0.83$). Yogis and runners did not significantly differ ($p=0.42$, $d<0.01$).

There was no significant group difference on waist circumference ($F(2, 139)=2.78$, $p=0.07$, $\eta p^2=0.038$). Females had significantly smaller waist circumferences compared to males ($F(1, 139)=38.25$, $p<0.001$, $\eta p^2=0.216$), and there was an interaction with group membership ($F(2, 139)=3.29$, $p=0.04$, $\eta p^2=0.045$). However, there were no significant group differences when groups were analyzed separately for females and males. There appeared to be a trend towards smaller waists in female sedentary participants compared to female yoginis, but larger waists in male sedentary participants compared to male yogis.

The Canadian Society for Exercise Physiology-devised aerobic fitness zone scores were used, which account for age and sex. Group membership was significantly related to aerobic fitness ($F(2, 140)=18.97$, $p<0.001$, $\eta p^2=0.221$). Sex was not related to aerobic fitness zone score ($F(1, 140)=0.03$, $p=0.87$, $\eta p^2<0.001$). There was a significant group by sex interaction ($F(2, 140)=3.86$, $p=0.02$, $\eta p^2=0.054$). Post hoc tests (Scheffé) revealed that male yogis did not differ from male runners ($p=0.96$, $d=0.10$), and both male yogis and male runners showed significantly greater aerobic fitness compared to sedentary males ($p=0.001$, $d=-1.16$ and $p<0.001$, $d=-1.28$, respectively). In contrast, female runners showed superior aerobic fitness to female yoginis ($p=0.002$, $d=-0.96$) and to sedentary females ($p<0.001$, $d=-1.57$) while female yoginis did not differ from sedentary females ($p=0.80$, $d=-0.0.16$).

Self-report Measures

The psychological variables included depression, hostility, perceived stress, social support, and mindfulness. All baseline psychological variables of interest were correlated, and were therefore analyzed together in subsequent analyses using MANOVA to reduce type I error.

There were significant group differences when considering the psychological variables together (Pillai's trace=0.27, $F(10, 266)=4.13$, $p<0.001$, $\eta p^2=0.134$). There was a significant sex difference for the combined psychological variables (Pillai's trace=0.11, $F(5, 132)=3.41$, $p=0.006$). When sex differences on each of the psychological variables were examined, there was only a difference on social support, such that females reported greater social support than males ($F(1, 136)=7.00$, $p=0.01$, $\eta p^2=0.049$). There was no significant interaction between sex and group (Pillai's trace=0.08, $F(10, 266)=1.13$, $p=0.34$).

Post hoc tests (Scheffé) revealed the following group differences. The corrected alpha for multiple comparisons was 0.003. On depression, yogis scored significantly lower than sedentary individuals ($p=0.001$, $d=-0.71$) as did runners ($p=0.001$, $d=-0.75$). Yogis and runners did not differ from each other ($p=0.96$, $d=0.05$). On perceived stress, yogis scored significantly lower than sedentary individuals ($p<0.001$, $d=0.88$) as did runners ($p=0.002$, $d=0.72$). Yogis and runners did not differ from each other ($p=0.92$, $d=-0.13$). On social support, runners scored significantly higher than sedentary individuals ($p<0.001$, $d=0.89$) but did not significantly differ from yogis ($p=0.19$, $d=0.47$). Yogis and sedentary individuals did not differ on social support ($p=0.06$, $d=0.41$).

There were no group differences on hostility using the corrected alpha of $p=0.003$. Yogis did not differ from sedentary individuals ($p=0.01$, $d=-0.65$) nor did runners ($p=0.02$, $d=-0.55$) and yogis and runners differ significantly from each other on hostility ($p=0.98$, $d=0.09$).

There were also no group differences on mindfulness using the corrected alpha of $p=0.003$. Yogis did not differ from runners ($p=0.06$, $d=0.53$) or from sedentary individuals ($p=0.05$, $d=0.53$). Runners and sedentary individuals did not differ ($p=0.99$, $d=0.06$). Length of yoga practice history was examined within the yoga group, and mindfulness was not related to length of practice ($r(45)=0.14$, $p=0.36$).

In sum, yogis and runners did not differ from each other on any psychological variables. Both the yoga group and the running group reported less depression and less perceived stress, compared to the sedentary group, and runners, but not yogis, reported greater social support compared to sedentary individuals.

Lifestyle factors measured in the study included a measure of sleep, and categorical measures of cigarette smoking status and meat-eating status. The chi-square test was used to analyze group differences in cigarette smoking status (smoker versus nonsmoker), and meat-eating status (meat eating or non-meat eating).

There was a significant difference between groups on sleep quality ($F(2, 136)=5.09$, $p=0.01$, $\eta p^2=0.070$), where runners had significantly better sleep than sedentary individuals ($p=0.01$, $d=-0.57$), but did not differ from yogis ($p=0.62$, $d=0.22$). Yogis and sedentary individuals did not differ on sleep ($p=0.13$, $d=-0.43$). Sex was not related to sleep ($F(1, 136)=1.42$, $p=0.24$) and did not interact with group membership ($F(2, 136)=1.34$, $p=0.27$).

Cigarette smoking was divided into smoking and nonsmoking status, as there was very little variability in categorizing levels of smoking frequency. There was a low base rate for smoking, with only 13 % of the total sample reporting smoking an average of at least one cigarette per day. Six percent of the total sample reported smoking 1–5 cigarettes per day, 6 % reported smoking 11–20 cigarettes per day, and less than 1 % reported smoking 6–10 cigarettes per day. The majority of the smokers were sedentary individuals, with the exception of one runner and one yogi who each reported smoking 1–5 cigarettes per day. There was no sex difference between smokers and nonsmokers (Yates' $\chi^2(1)=2.38$, $p=0.122$). Yogis were significantly less likely to smoke cigarettes compared to sedentary individuals (Yates' $\chi^2(1)=15.50$, $p<0.001$) as were runners compared to sedentary individuals (Yates' $\chi^2(1)=15.16$, $p<0.001$). Yogis and runners did not differ from each other on smoking status (Yates' $\chi^2(1)<0.001$, $p=0.99$).

Eighty-eight percent of the total sample reported eating meat. Sex was not associated with meat eating ($\chi^2(1)=1.68$, $p=0.20$). Significantly more yogis reported refraining from eating meat compared to runners ($\chi^2(1)=9.40$, $p=0.002$) and compared to sedentary individuals ($\chi^2(1)=15.63$, $p<001$). Runners did not differ from sedentary individuals on meat eating ($\chi^2(1)=0.85$, $p=0.36$).

Discussion

The present study was not a clinical trial but descriptive in nature and it is therefore not possible to attribute group differences in a causal manner to individuals' health practices. Nevertheless, this study demonstrated that long-term, regularly practicing yogis and runners show similar psychological and physiological health advantages compared to sedentary individuals in a sample restricted to healthy adults with no known history of heart disease or hypertension. Compared to sedentary individuals, both yogis and runners showed lower resting HR, higher resting absolute HF power (i.e., an index of greater efferent vagal activity), and higher normalized HF power (i.e., an index of greater parasympathetic activity compared to sympathetic activity). Both yogis and runners reported a lower incidence of cigarette smoking, fewer depressive symptoms, and lower perceived stress compared to sedentary individuals. Runners and male yogis demonstrated superior aerobic fitness levels compared to sedentary individuals. Runners, and not yogis, reported greater sleep quality and greater social support compared to sedentary individuals. Yogis, and not runners, demonstrated a lower resting respiration rate and a greater likelihood of being vegetarian, vegan, or pescetarian compared to sedentary individuals. It is promising that individuals who may be unable to engage in a high-impact practice like running may be able to reap cardiovascular benefits from yoga, though causality cannot be determined in this study.

It was unexpected that we did not find group differences on BP. This finding is at odds with a meta-analysis of RCTs of aerobic exercise versus controls, which concluded that aerobic exercise decreased blood pressure in both hypertensive and normotensive individuals [36]. To understand the lack of difference in BP in our study, it is important to note that our study's sedentary group had quite low resting BPs ($M=105/67$ mmHg) compared to the national average (104/68 for ages 20–39 and 112/74 for ages 40–59) [37]; as such, the control group appears to have been quite healthy. Our null results may therefore be a product of range restriction, which may have arisen from the exclusion of individuals with hypertension, and also due to a potential selection bias due to the participants' prior knowledge that they would be asked to perform an aerobic fitness test. It is furthermore possible that BP differences attributed to exercise or self-regulation practices may not emerge until later in life.

Respiration rate was the only physiological variable in this study in which the yoga group showed an advantage compared to the sedentary group, when the running group did not. The yogis who reported practicing Ujjayi breathing regularly (70 % of the sample) also demonstrated a significantly lower respiration rate than the runners. This adds to the previous finding that male yoga practitioners demonstrate greater lung function compared to male runners and sedentary males as measured by peak expiratory flow rates [38]. There are many breathing techniques that yogis may incorporate into their yoga practice. Respiration indices and techniques are therefore important aspects of yoga that should be explicitly reported and further examined in future yoga research.

We found that considering sex was important when examining the aerobic fitness levels of yoga practitioners. Male yogis performed similarly to male runners on the fitness test, while female yoginis performed similarly to sedentary females. We do not know of an apparent explanation for this sex difference, which has not been previously explored in the literature. A possible explanation may be that male yogis practice more aerobically intense types of yoga styles. We do not have precise data to test this hypothesis. If the sex difference in aerobic fitness of yoga practitioners can be replicated in a randomized controlled trial, this would have major implications for exercise recommendations. Aerobic intensity of different styles of yoga practice is a key variable that has not been adequately studied, and may explain this interesting finding. In general, we do not know to what extent findings in the yoga literature at large generalize to different styles of yoga.

Neither the yoga group nor the running group had significantly smaller waist circumferences than the sedentary group. However, it should be noted that the mean waist circumferences of sedentary females (75 cm) and males (90 cm) were below or at the validated Canadian cutoff scores associated with cardiovascular risk (≥80 cm for females and ≥90 cm for males) [23] which again confirms that our sedentary group was unusually healthy. Therefore, there may have been a floor effect in our study although our findings do not preclude that the uptake of yoga could reduce waist circumference in overweight individuals.

The present study is the first to show that yogis and runners report equivalently lower levels of depressive symptoms and perceived stress compared to sedentary individuals. There is debate about whether aerobic exercise and non-aerobic exercise have equivalent effects on depressive symptoms, which requires more research to resolve [16]. Our study is consistent with the position that physical activity may not need to be aerobic to improve depressive symptoms. It should be noted though that yoga comprises more than physical movement, and some yoga practitioners would balk at the characterization of yoga as “just exercise”. Our findings encourage further research into the type, duration, frequency, and components of yoga necessary to impact depressive symptoms, and at which levels of symptom severity.

Our study was also the first to compare yoga practitioners, runners, and sedentary individuals on perceived social support. One hypothesis to explain why only runners reported significantly greater social support is that runners may participate in running clubs or groups. While yogis may practice in a group, socializing with other yogis may be minimal due to the nature of yoga practice, which is typically non-interactive. It has been demonstrated through path analysis that social support can influence exercise adherence by augmenting perceived behavioral control and intention to exercise [39], thereby suggesting that greater social support may have promoted the uptake or maintenance of regular running in the present study sample.

Contrary to predictions, trait mindfulness was not significantly greater in yogis compared to the other groups after correcting for multiple comparisons. However, there was a medium effect size ($d = 0.53$) when examining differences on mindfulness between the yoga group and each of the other groups, and it is likely that increasing the sample size would have revealed significant advantages in the yoga group. It is plausible that the inclusion of individuals with a longer history of yoga practice would have yielded stronger results, as greater trait mindfulness has been demonstrated in yogis who have practiced for more than 5 years compared to yogis who practiced for less than 5 years (($d = 0.62$) by our calculations) [17].

Lifestyle factors, including diet, smoking, and sleep, proved to be important in this study, though often ignored in the yoga literature. The present study found that yogis, but not runners, are more likely to be vegetarian/pescetarian than sedentary individuals. Because the runners generally endorsed a healthy lifestyle relative to sedentary individuals, but not specifically a difference in meat consumption, the difference in diet in the yoga group may be attributed to the yogic value of nonharming as opposed to, or in addition to, a commitment to health. It is unclear whether yoga intervention would promote change in diet or whether such a preference may have preceded yoga practice.

Yogis and runners had lower incidences of smoking compared to the sedentary individuals. The association between group membership and smoking status may be due to factors that precede the uptake of running or yoga, such as a greater commitment to health in the activity groups compared to the sedentary group. It may also be that cigarette smokers are less likely to engage in yoga or running due to greater difficulty exercising. Individuals have been shown to increase exercising after quitting smoking and to decrease exercising after relapsing [40]. Evidence also suggests that exercise can influence smoking cessation in that exercise decreases cravings and withdrawal symptoms in individuals in the process of quitting smoking [41]. Likewise, individuals who engage in mind–body therapies including yoga have proven to be more likely to be successful at quitting smoking [42].

The finding that yogis did not have better sleep quality is inconsistent with the finding of a Spanish cross-sectional study in which yogis reported better sleep compared to controls [43], and there is no obvious explanation for this discrepancy. Our results did show sleep advantages in runners, which is consistent with the American Sleep Disorders Association’s endorsement that physical exercise is a treatment for sleep disorders and this is consistent with known physiology [44].

Like all cross-sectional research, the present study lacks the degree of control one has in a RCT. Our descriptive design was intended to explore the potential long-term benefits of consistently practicing selected health behaviours over time. In a RCT, there is a high probability that some participants would be randomized to practice a health behavior that they do not like and therefore would not continue to practice. If that was the case, the RCT might still be of theoretical interest but results would fail to inform us about long-term effects of health behaviors arising from people making their own choices. A strength of our study is the frequency and the years of yoga and running practice, which are considerably greater than could be expected from participants in a time-limited RCT. The large proportion of yoga instructors and marathon runners in the study indicate a level of immersion in their health practices that would not be expected in a RCT. The other side of this strength is that results may not be generalized to individuals with lower running and yoga practice levels.

As suggested above, our sedentary group was healthier than anticipated, and this may have attenuated the ability to find group differences on variables such as blood pressure and waist circumference. It should be noted that residents of British Columbia have been shown to have the healthiest lifestyles of all Canadians on factors such as physical activity, cigarette smoking, and obesity [45]. Therefore, group differences between regularly practicing yogis or runners and individuals who report sedentary lifestyles may be larger outside of British Columbia. Further research on yoga may be particularly promising in a secondary prevention context with at-risk patients (e.g., patients with metabolic syndrome) or in a tertiary prevention context (e.g., patients enrolled in a cardiac rehabilitation program).

The yoga group was older than the running group by almost 6 years and was comprised of a greater proportion of White participants as opposed to Asian participants compared to both the running and the sedentary group. This ethnic discrepancy between groups could not be resolved because the sample size was too small to conduct adequately powered subgroup analyses, and this may have served as a confound in the current study. Individuals of Chinese origin have demonstrated fewer cardiovascular risk factors compared to individuals of European origin in the UK [46] and in Canada [47]. Differences between the yoga group and the other groups should be seen as over and above the risks posed by differences in age and ethnicity.

As previously described, participants were exposed to two stressors, which are not reported on in the present article. While an effect of prior stressor exposure cannot be excluded, our results make it very clear that stressor exposure did not prevent reaching a relaxed physiological resting state with similar baselines for all three groups.

To summarize, the present study demonstrated that yogis and runners differ from sedentary individuals on various contributors to cardiovascular health. Moving forward, it will be important for researchers to think clearly about what comprises yoga, to adapt a clear and shared language regarding subtypes of yoga, and to consider the mechanisms responsible for potential benefits to cardiovascular health.

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