



Original Research

A Comparison of Blood Viscosity and Hematocrit Levels between Yoga Practitioners and Sedentary Adults

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ABSTRACT

International Journal of Exercise Science 12(2): 425-432, 2019. Elevations in whole blood viscosity (WBV) and hematocrit (Hct), have been linked with increased risk of cardiovascular disease (CVD). Endurance training has been demonstrated to lower WBV and Hct; however, evidence supporting the efficacy of yoga on these measures is sparse. A cross-sectional study was conducted examining WBV and Hct levels between yoga practitioners with a minimum of 3 years of consistent practice and sedentary, healthy adults. Blood samples were collected from a total of 42 participants: 23 sedentary adults and 19 regular yoga practitioners. Brachial arterial blood pressure (BP) was measured and the averages of 3 measures were reported. The yoga practitioner group had significantly lower WBV at 45 s⁻¹ ($p < 0.01$), 90 s⁻¹ ($p < 0.01$), 220 s⁻¹ ($p < 0.05$), and 450 s⁻¹ ($p < 0.05$) than sedentary participants. No significant group differences in Hct ($p = 0.38$) were found. A tendency toward lower systolic BP ($p = 0.06$) was observed in the yoga practitioner group; however, no significant group differences in BP were exhibited. A consistent yoga practice was associated with lower WBV, a health indicator related to CVD risk. These findings support a regular yoga practice as a valid form of exercise for improving rheological indicators of cardiovascular health.

KEY WORDS: Cardiovascular disease, alternative exercise, rheological factors, biomarkers, cross-sectional

INTRODUCTION

Elevations in whole blood viscosity (WBV) and hematocrit (Hct) are associated with cardiovascular disease (CVD) risk and mortality (9, 11). WBV is a prognostic indicator of short-

and long-term cardiovascular events in post-myocardial infarction patients (5) and Hct, a determinant of WBV (24), has been linked with many cardiometabolic risk indicators, (e.g., insulin resistance, obesity, dyslipidemia and hypertension) (24). Given these correlations, lifestyle interventions aimed at improving these rheological measures could translate into the improvements in cardiometabolic risk profile.

Hatha yoga is the physical practice of yoga incorporating postures, breathing, meditation and focus. Although yoga has been associated with improvements in lipid profile (16), blood pressure (BP) (7), and glucose tolerance (15), its effects on rheological markers remain elusive. One investigation demonstrated significantly reduced blood viscosity after one Hatha yoga session in yoga naïve women (3) and higher Hct levels have been found among practitioners of yoga compared with nonpractitioners of yoga (4). To our knowledge, no studies have examined the effects of a regular yoga practice on WBV and Hct. Thus, the purpose of this investigation was to compare WBV and Hct between regular yoga practitioners and sedentary adults. Our working hypothesis was that yoga practitioners would have higher hematocrit and lower blood viscosity than their sedentary peers.

Methods

Participants

A power analysis conducted with G*Power 3.1.9.3 (Heinrich Heine University, Universität Düsseldorf, Germany) determined a total sample size of 30 participants was needed in the present study to achieve a power of 0.80, with an effect size (f) of 0.4 and an $\alpha = 0.05$. Yoga practitioners who practiced Hatha yoga (inclusive of various styles) for at least one hour, three times per week for three years and sedentary individuals participating in less than one hour per week of moderate-to-vigorous physical activity for the prior 6 months were recruited for this investigation. Potential participants who responded to study flyers were screened via health history questionnaires to assess eligibility. Exclusion criteria were as follows: pregnancy; smoking within the past six months; uncontrolled hypertension or diabetes; and other chronic diseases. No cardiovascular medications were being taken by any participants at the time of the study. A total of 42 (19 yoga practitioners and 23 sedentary individuals) individuals were recruited. The study procedures were approved by the local institutional review board, and all the participants provided their written informed consent prior to any data collection.

Protocol

All subjects fasted for a minimum of 12 hours prior to all testing sessions, which were all conducted in the mornings to avoid diurnal changes in dependent variables. All subjects abstained from physical activity for 24 hours and premenopausal females were tested during the early follicular stage of the menstrual cycle. Three brachial blood pressure measurements were completed using an Omron Colin VP-1000 cuff (Omron Healthcare Co., Ltd. 53, Kyoto, Japan) after the subject had rested for a minimum of 5 minutes. After blood samples were obtained from an antecubital vein, Hct was assessed using a Micro Capillary Reader No. 2201 (Damon/IEC Boston 35, Massachusetts) and WBV was assessed using the Brookfield DV-1 Viscometer (Brookfield Engineering, 11 Commerce Boulevard, Middleboro, MA 02345).

For Hct measures, blood samples were spun and tested using two micro capillary reader tubes. The average Hct from the two tubes was recorded. For WBV, blood samples were run at a constant temperature of 37 degrees Celsius and speed, torque, and temperature readings were recorded. Blood is a non-Newtonian fluid, demonstrating fluctuations in viscosity under various levels of shear (10). Therefore, WBV is tested at multiple shear rates (45 s^{-1} , 90 s^{-1} , 220 s^{-1} , 450 s^{-1}). Shear rate units are expressed in reciprocal seconds (s^{-1}).

Statistical Analysis

Data normality was assessed using a Shapiro-Wilk test. All data were normally distributed except Hct and WBV at 220 s^{-1} . Analysis of covariance was used to compare WBV at shear rates of 45, 90 and 450 s^{-1} between the yoga practitioner group and sedentary group. Body mass index (BMI) was entered as a covariate based on significant group differences in this measure and the association between high WBV and BMI (13). Whole blood viscosity at 220 s^{-1} was analyzed using Quade's test while controlling for BMI. Hematocrit was analyzed using the Mann-Whitney U test. Statistical significance was set *a priori* at $p < 0.05$ for all comparisons. Three participants in the yoga practitioner group engaged in endurance exercise more than two days per week. Thus, in order to isolate the effects of yoga on study outcomes, we also completed the statistical analysis without these subjects. Upon excluding these participants, the results remained the same. Thus, all group participants are displayed in the table and figures below. All statistical analysis and computation were done using SPSS Statistics for Windows, Version 24.0 (IBM Corp, Armonk, NY).

RESULTS

Selected subject characteristics are displayed in Table 1. Body mass and BMI were significantly higher in the sedentary versus the yoga practitioner group ($p < 0.05$ for both). Systolic BP and diastolic BP were not significantly different between groups though SBP tended to be lower in the yoga practitioner group ($p = 0.06$). Significant differences were found between the sedentary and yoga practitioner groups in WBV at 45 s^{-1} ($p < 0.01$), 90 s^{-1} ($p < 0.01$), 220 s^{-1} ($p < 0.05$), and 450 s^{-1} ($p < 0.05$) with lower mean values among yoga practitioners (Figure 1). No significant group differences were observed in Hct readings ($p = 0.38$) (Figure 2).

Table 1. Selected Subject Characteristics

	Sedentary (n=23)	Yoga Practitioner (n = 19)
Male/Female (n)	4/19	4/15
Age (yr)	47 ± 8	48 ± 8
Height (cm)	167.5 ± 7.1	163.9 ± 8.0
Body mass (kg)	78.9 ± 17.6	$58.0 \pm 8.8^*$
BMI	28.1 ± 6.4	$21.5 \pm 2.2^*$
Systolic BP	118 ± 12	110 ± 15
Diastolic BP	70 ± 9	66 ± 10

Values are means \pm SD. * $P < 0.05$ vs. sedentary. BMI = body mass index; BP = blood pressure

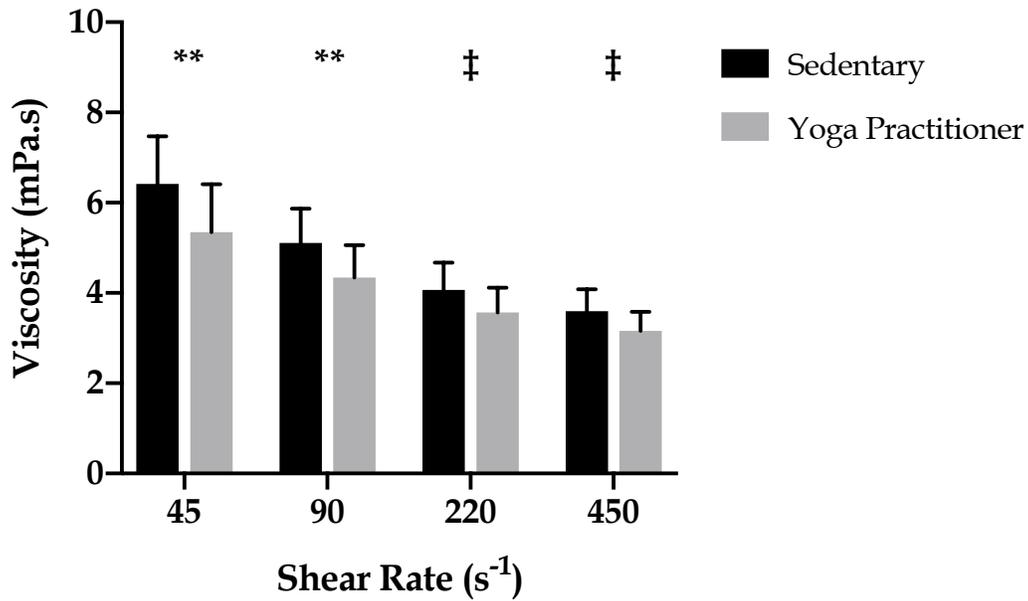


Figure 1. Whole Blood Viscosity in Yoga Practitioners and Sedentary Adults. Whole blood viscosity was significantly lower among yoga practitioners than sedentary adults at shear rates of 45, 90, 220, and 450 s⁻¹. mPa·s= millipascals-second. s⁻¹ = reciprocal seconds. ‡ p<0.05; ** p<0.01.

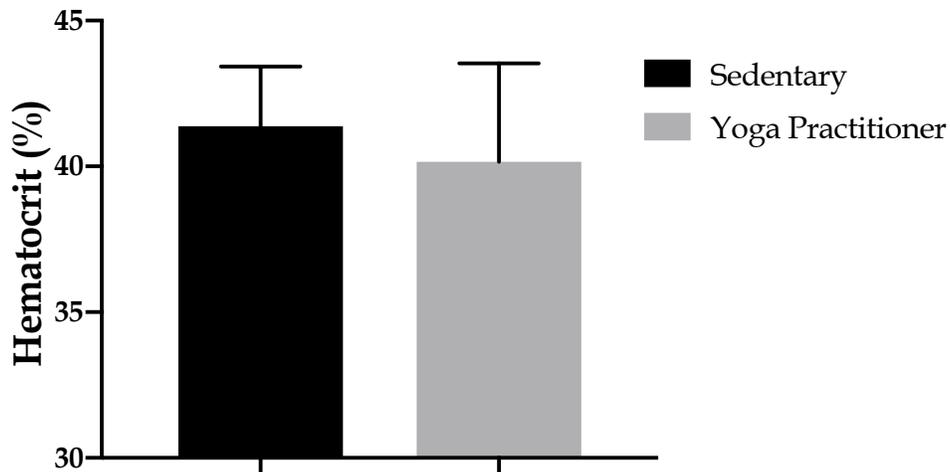


Figure 2. Hematocrit Levels in Yoga Practitioners and Sedentary Adults. No significant difference was observed in hematocrit between the sedentary and yoga practitioner groups.

DISCUSSION

The seminal finding from the current study was that practitioners of yoga demonstrated significantly lower WBV than sedentary adults. We found no effect of a consistent yoga practice on Hct levels.

These findings coincide with previous literature demonstrating an acute lowering effect of yoga on blood viscosity following a single Hatha yoga session (3) and suggest that a chronic adaptation of lower WBV may be evident with a long-term, consistent yoga practice. As WBV is a determinant of peripheral vascular resistance that is positively associated with blood pressure (19), this reduction in WBV with a yoga practice could account for some of yoga's blood pressure lowering effect in adults with hypertension (7). Although we found only a tendency toward lower systolic BP in the yoga practitioner group in the current study, WBV could also have contributed to this marginal group difference.

In addition to blood pressure homeostasis, WBV is also thought to play a role in mediating other cardiometabolic risk factors as evidenced by positive associations between WBV and lipid concentrations (17). Yoga's lowering effect on lipid concentrations (15) may therefore lower WBV through decreases in plasma viscosity. Thus, lower WBV among regular practitioners of yoga could facilitate improvements in cardiovascular disease risk by improving cardiometabolic risk indicators.

Our findings of lower WBV among yoga practitioners are also consistent with results from aerobic exercise interventions. Aerobic exercise has lowered WBV in previously sedentary, middle-aged adults (8) as well as in patients with ischemic heart disease (23). Although rheological adaptations have been demonstrated with yoga and aerobic exercise, it is important to note that the two exercise modes are markedly different with some forms of Hatha yoga being associated with lower oxygen consumption and higher heart rate (2) and blood pressure responses (21) compared with endurance exercise. Our findings highlight the potential of yoga, a complementary and/or alternative exercise mode in modulating CVD risk.

As Hct is a determinant of WBV, it was presumable that lower WBV among yoga practitioners would be accompanied by reductions in Hct. However, we observed no group differences in Hct between yoga practitioners and sedentary adults. This finding is not in agreement with results from another study (27), which found a significant 13% increase in Hct following a 3-month yoga intervention in individuals with end-stage renal disease, a patient population often presenting with anemia. This alludes that yoga could have divergent effects on Hct in healthy and patient populations.

Results from studies on the effects of aerobic exercise on hematocrit have also been incongruous with some finding an increase in Hct with training (1), and others showing a reduction in this measure due to a greater increase in plasma than red blood cell volume with exercise training (20). Based on our current observations of similar Hct levels between yoga practitioners and sedentary adults, it can be theorized that yoga's lowering effect on WBV could be ascribed to a lowering of plasma viscosity as both Hct and plasma viscosity are main determinants of the viscosity of whole blood.

Erythrocyte aggregation and deformability and fibrinogen levels are also determinants of WBV that could explain the lower WBV among yoga practitioners. Yoga has been demonstrated to reduce fibrinogen levels which could facilitate improvements in WBV through reductions in

erythrocyte aggregation (6). Erythrocyte adhesiveness and aggregation are indicative of inflammation (2) and oxidative stress (14), both of which have been significantly altered with the practice of Hatha yoga and yogic techniques in healthy adults (18, 25) and in patients with heart failure (22) and diabetes (12, 26). Thus, it is possible that the lower WBV among the yoga practitioners in our study could be attributed to lower fibrinogen, inflammation and oxidative stress further supporting the role of yoga as an effective CVD risk reduction strategy.

It bears mentioning that despite several styles of yoga not being of adequate intensity to meet the American Heart Association/American College of Sports Medicine recommendations of moderate-intensity exercise, similar cardiovascular, metabolic and rheological alterations have been demonstrated with both aerobic exercise and [various styles of] yoga. Yoga could be a feasible alternative to aerobic exercise for some individuals due to the lower intensity and adaptability of the practice to a variety of individuals.

The current study is not without its limitations. Our participants were predominantly female although similar proportions of males were included in each group. Future studies should attempt to tease out sex specific alterations in rheological measures with yoga. Additional rheological measures, (e.g., red blood cell congregation and deformability and clotting factors) were not obtained. Future investigations should explore these additional measures to obtain a more in depth understanding of yoga's effects on rheology. Finally, hydration status was not accounted for during the data collection process.

In conclusion, a consistent yoga practice appears to be associated with reduced WBV but not Hct alterations. Therefore, regular adherence to yoga could have similar rheological adaptations as those seen with regular endurance exercise. These findings support a regular yoga practice as a valid form of exercise for improving rheological indicators of cardiovascular health.

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REFERENCES

1. Belviranlı M, Okudan N, Kabak B. The effects of acute high-intensity interval training on hematological parameters in sedentary subjects. *Med Sci (Basel)* 5(3), 2017.
2. Boyd CN, Lannan SM, Zuhl MN, Mora-Rodriguez R, Nelson RK. Objective and subjective measures of exercise intensity during thermo-neutral and hot yoga. *Appl Physiol Nutr Metab* 43(4):397-402, 2018.
3. Brown R, Chevalier, G. Grounding the human body during yoga exercise with a grounded yoga mat reduces blood viscosity. *Open Journal of Preventive Medicine* 5:159-168, 2015.
4. Carranquea GA, Maldonadob EF, Verab FM, Manzanequeb JM, Blancab MJ, Sorianoc GM. Hematological and biochemical modulation in regular yoga practitioners. *Biomedical Research* 2(23):176-182, 2012.
5. Cetin EH, Cetin MS, Canpolat U, Aydin S, Aras D, Topaloglu S, Temizhan A, Aydogdu S. Prognostic significance of whole blood viscosity estimated by de simone's formula in st-elevation myocardial infarction. *Biomark Med* 10(5):495-511, 2016.

6. Chohan IS, Nayar HS, Thomas P, Geetha NS. Influence of yoga on blood coagulation. *Thromb Haemost* 51(2):196-197, 1984.
7. Cohen DL, Boudhar S, Bowler A, Townsend RR. Blood pressure effects of yoga, alone or in combination with lifestyle measures: Results of the lifestyle modification and blood pressure study (limbs). *J Clin Hypertens (Greenwich)* 18(8):809-816, 2016.
8. Coppola L, Grassia A, Coppola A, Tondi G, Peluso G, Mordente S, Gombos G. Effects of a moderate-intensity aerobic program on blood viscosity, platelet aggregation and fibrinolytic balance in young and middle-aged sedentary subjects. *Blood Coagul Fibrinolysis* 15(1):31-37, 2004.
9. Danesh J, Collins R, Peto R, Lowe GD. Haematocrit, viscosity, erythrocyte sedimentation rate: Meta-analyses of prospective studies of coronary heart disease. *Eur Heart J* 21(7):515-520, 2000.
10. Ercan M, Koksall C. The relationship between shear rate and vessel diameter. *Anesth Analg* 96(1):307; author reply 307-308, 2003.
11. Gagnon DR, Zhang TJ, Brand FN, Kannel WB. Hematocrit and the risk of cardiovascular disease—the framingham study: A 34-year follow-up. *Am Heart J* 127(3):674-682, 1994.
12. Gordon LA, Morrison EY, McGrowder DA, Young R, Fraser YT, Zamora EM, Alexander-Lindo RL, Irving RR. Effect of exercise therapy on lipid profile and oxidative stress indicators in patients with type 2 diabetes. *BMC Complement Altern Med* 8:21, 2008.
13. Guiraudou M, Varlet-Marie E, Raynaud de Mauverger E, Brun JF. Obesity-related increase in whole blood viscosity includes different profiles according to fat localization. *Clin Hemorheol Microcirc* 55(1):63-73, 2013.
14. Gyawali P, Richards RS, Hughes DL, Tinley P. Erythrocyte aggregation and metabolic syndrome. *Clin Hemorheol Microcirc* 57(1):73-83, 2014.
15. Hunter SD, Dhindsa M, Cunningham E, Tarumi T, Alkatan M, Tanaka H. Improvements in glucose tolerance with bikram yoga in older obese adults: A pilot study. *J Bodyw Mov Ther* 17(4):404-407, 2013.
16. Hunter SD, Dhindsa MS, Cunningham E, Tarumi T, Alkatan M, Nualnim N, Tanaka H. The effect of bikram yoga on arterial stiffness in young and older adults. *J Altern Complement Med* 19(12):930-934, 2013.
17. Kensey KR, Cho YI, Chang M. Effects of whole blood viscosity on atherogenesis. *J Invasive Cardiol* 9(1):17-24, 1997.
18. Kiecolt-Glaser JK, Christian L, Preston H, Houts CR, Malarkey WB, Emery CF, Glaser R. Stress, inflammation, and yoga practice. *Psychosom Med* 72(2):113-121, 2010.
19. Letcher RL, Pickering TG, Chien S, Laragh JH. Effects of exercise on plasma viscosity in athletes and sedentary normal subjects. *Clin Cardiol* 4(4):172-179, 1981.
20. Mairbaurl H. Red blood cells in sports: Effects of exercise and training on oxygen supply by red blood cells. *Front Physiol* 4:332, 2013.
21. Miles SC, Chun-Chung C, Hsin-Fu L, Hunter SD, Dhindsa M, Nualnim N, Tanaka H. Arterial blood pressure and cardiovascular responses to yoga practice. *Altern Ther Health Med* 19(1):38-45, 2013.

22. Pullen PR, Nagamia SH, Mehta PK, Thompson WR, Benardot D, Hammoud R, Parrott JM, Sola S, Khan BV. Effects of yoga on inflammation and exercise capacity in patients with chronic heart failure. *J Card Fail* 14(5):407-413, 2008.
23. Sandor B, Nagy A, Toth A, Rabai M, Mezey B, Csatho A, Czuriga I, Toth K, Szabados E. Effects of moderate aerobic exercise training on hemorheological and laboratory parameters in ischemic heart disease patients. *PLoS One* 9(10):e110751, 2014.
24. Schreijer AJ, Reitsma PH, Cannegieter SC. High hematocrit as a risk factor for venous thrombosis. Cause or innocent bystander? *Haematologica* 95(2):182-184, 2010.
25. Sinha S, Singh SN, Monga YP, Ray US. Improvement of glutathione and total antioxidant status with yoga. *J Altern Complement Med* 13(10):1085-1090, 2007.
26. Yadav RK, Magan D, Mehta N, Sharma R, Mahapatra SC. Efficacy of a short-term yoga-based lifestyle intervention in reducing stress and inflammation: Preliminary results. *J Altern Complement Med* 18(7):662-667, 2012.
27. Yurtkuran M, Alp A, Yurtkuran M, Dilek K. A modified yoga-based exercise program in hemodialysis patients: A randomized controlled study. *Complement Ther Med* 15(3):164-171, 2007.