Biomedical & Pharmacology Journal, December 2024. Vol. **17**(4), p. 2455-2462

Yoga Improves Vascular stiffness in COVID-19 Survivors of Vijayapur, Karnataka, India

Jyoti Paramanand Khodnapur[1], Gireesh Paramanand Khodnapur[2], Ishwar Veerabhadrappa Basavaraddi[3], Amrit Podder[4]*, Rameshwar Pal[5], Sumangala Mahesh Patil[1] and Madivalappa Parasappa Doddamani[1]

[1]Centre for Yoga and Exercise Science, Department of Physiology, BLDE (Deemed to be) University's, Shri. B. M. Patil Medical College Hospital and Research Centre, Vijayapur, Karnataka, India.
[2]Department of Orthopedics, BLDE (Deemed to be) University's, Shri. B. M. Patil Medical College Hospital and Research Centre, Vijayapur, Karnataka, India.
[3]Morarji Desai National Institute of Yoga, Ministry of AYUSH, Government of India, India.
[4]Department of Physiology, Teerthanker Mahaveer Medical College and Research Centre, Teerthanker Mahaveer University, Moradabad, Uttar Pradesh, India.
[5]Department of Physiology, Morarji Desai National Institute of Yoga, Ministry of AYUSH, Government of India, India.
*Corresponding Author E-mail:amritpodder0@gmail.com

https://dx.doi.org/10.13005/bpj/3038

(Received: 07 August 2024; accepted: 28 October 2024)

The protective effect of yoga and other mind-body practices on cardiovascular health and stress reduction has been proven. However, the specific influence of common yoga protocol (CYP) on rate pressure product (RPP) and vascular stiffness in COVID-19 survivors requires rigorous scientific investigation. The purpose of the current study was to assess how a standard yoga program affected the vascular stiffness and RPP of COVID-19 survivors who had mild illness. This prospective observational research included seventy-two people who sought care at our hospital and had their COVID-19 diagnosis. Study participants were split up into a Yoga group and a control group, age and gender-matched. Physical anthropometry, physiological parameters and vascular stiffness indicators like brachial-ankle and carotid-femoral Pulse Wave Velocity (b-a PWV and c-f PWV) and brachial and ankle Arterial stiffness Index (bASI and aASI) were also assessed compared the effect of CYP at baseline and after three-month. Using SPSS software, a post hoc test and analysis of variance (ANOVA) were used for the statistical study. On day ninety of CYP practice, the yoga group displayed a notable decrease ($p<0.05$) in heart rate (HR), systolic blood pressure (SBP), diastolic blood pressure (DBP), mean arterial pressure (MAP), pulse pressure (PP), b-a PWV, c-f PWV, bASI and aASI compared to baseline values observed at the time of enrollment. Similarly, the control group showed no significant alteration in physiological and vascular stiffness parameters at day ninety. The current study unequivocally demonstrated the influence of CYP on HR, SBP, DBP, MAP, PWV and ASI in the yoga group of COVID-19 survivors.

Keywords: Arterial Stiffness Index; Common Yoga Protocol; COVID-19 survivors; Pulse Wave Velocity; Vascular Stiffness.

The COVID-19 pandemic has indeed had significant global effects, impacting populations worldwide with substantial numbers of cases and fatalities [1]. Various research studies showed that COVID-19 is associated with multi-systemic disease apart from respiratory conditions [2, 3, 4].

The link between COVID-19 and cardiovascular complications has been a significant concern since the early stages of the pandemic [5]. COVID-19 can modify the functions of the cardiovascular system in various ways, such as myocarditis, myocardial infarction, arrhythmias, and thromboembolic events (blood clots) [6, 7].

Several mechanisms may contribute to the cardiovascular complications associated with COVID-19, including direct viral damage to the heart and blood vessels, systemic inflammation and cytokine release, destabilization of underlying cardiovascular conditions, and endothelial dysfunction [8].

A study suggested that COVID-19 may affect the cardiovascular system, resembling vascular ageing. A study examining the vascular stiffness among COVID-19-survivors showed increased PWV compared to controls [9]. For example, COVID-19 has been connected with endothelial dysfunction and vascular damage, which lead to vascular stiffness [10]. Vascular stiffening refers to a reduction in arteries' capacity to dilate and constrict in reaction to modifications in blood pressure. The reduced ability to stretch the artery wall is frequently linked to anatomical and functional alterations in the blood vessel walls. An elevated chance of cardiovascular incidents, like heart attacks, strokes, and heart failure, is linked to vascular stiffness. It can also exacerbate the workload on the heart and contribute to left ventricular hypertrophy and impaired cardiac function [11].

A good diet, regular exercise, yoga, and managing cardiovascular risk factors are modifications to one's way of living that can help stop or slow the progression of vascular stiffness. In some studies, regular participation in yoga, which usually combines breathing techniques, meditation, and physical postures, has been associated with lower vascular stiffness. Yoga is considered a low-intensity exercise that focuses on flexibility, strength, and relaxation, and it can provide several cardiovascular and overall health benefits. Studies examining the effects of yoga on vascular stiffness have shown promising results, with some demonstrating significant reductions in vascular stiffness measures among individuals who practice yoga regularly [12].

The research aimed to determine whether vascular stiffness is lower in individuals who regularly practice yoga than those who do not participate among COVID-19 survivors. The present study can provide insightful information about the possible consequences of regular yoga on vascular stiffness and contribute to our understanding of yoga as a lifestyle intervention for promoting vascular health among COVID-19 survivors.

MATERIALS AND METHODS

The current observational investigation was carried out based on the guidelines of the Declaration of Helsinki. All participants were given written informed permission, and the Institutional Ethics Committee approved the protocol. (Reference BLDE(DU)/IEC/581/2021-22).

Study Design and Overview

The present observational cohort study was conducted at the Centre for Yoga and Exercise Science, Department of Physiology, between December 2021 and December 2022. Participants reported for a basal recording from 9:00 am until 11:00 am, and physical, physiological and vascular stiffness parameters of participants were measured. The participants performed three months of CYP training, including prayer, loosening practices, asanas, pranayama and meditation [13]. Following three months, physical, physiological and vascular stiffness parameters were measured.

Sample size

The total sample size for the study was 72, with each group containing 36, to reach an 80% power level. A two-sided 5% significance threshold is required to identify a real difference in test means and the reference group of 301.1 (i.e., 580.1–279) units, assuming a pooled standard deviation of 216.4 units p-value of less than 0.05 [14, 15].

Participants

Using online forms and multiple emails regarding COVID-19 disease confirmed at the current hospital in the past; we could enlist 72 participants age ranging from 20 and 24 who had mild COVID-19 disease for this study. Individuals with known smokers, alcoholics, uncontrolled cardiometabolic illness or those on medication to regulate blood pressure, cholesterol, or blood sugar were not allowed to participate. Depending upon

their willingness to be included in the yoga group, participants were divided into two groups: control (had not done yoga) and yoga (practiced at least five days per week for at least twelve weeks).

Intervention

The participants received 60 minutes of yoga instruction (the Common Yoga Protocol) five days a week for three months. The Common Yoga Protocol was employed, which consists of pranayama, meditation, asanas (standing, sitting, prone, and supine), and loosening techniques [13]. We noted the participants' daily attendance.

Outcome measures

Primary outcome: Vascular stiffness

Vascular parameters were measured using a device known as a Periscope (Periscope, Genesis Medical Systems, and India) [16]. Every recording was done while lying flat. The brachial-ankle and carotid-femoral pulse wave velocity (b-a PWV and c-f PWV) and arterial stiffness index (ASI) (brachial and ankle) were recorded by the periscope [17, 18].

Covariates: Demographic

Participants were asked to self-report their biological sex (male or female) and age (years/ months).

Covariates: anthropometry and physiological parameters

Anthropometric parameters like height, weight and Body Mass Index (BMI) were measured by using standard procedures. Physiological parameters like Heart rate, diastolic blood pressure (DBP) and systolic blood pressure (SBP) were measured by following standard procedures. All the parameters were recorded three times for each participant, and the average value was used. The average blood pressure of SBP and DBP was used to calculate mean arterial pressure or MAP. The difference between SBP and DBP was considered as pulse pressure (PP). The rate pressure product derived from the heart rate and systolic blood pressure serves as a proxy for the amount of oxygen that the heart consumes (MVO_2) [19, 20].

Statistical Analysis

We used SPSS version 20.0 to perform statistical analysis. Standard deviations and means are used to illustrate descriptive statistics. The study employed one-way ANOVA and a post-hoc test (Least Significant Difference) to assess the differences in mean values of parameters between the Control group before the yoga intervention (Group 1), the Yoga group before the yoga intervention (Group 2), the Control group following the yoga intervention (Group 3), and the Yoga group following the yoga intervention (Group 4).

RESULTS

Participant Demographics

The study screened 250 COVID-19 survivors, of whom 72 were eligible for participation. The final analysis included 36 participants in each group (yoga and control) with a balanced gender distribution (50% male, 50% female). The yoga group practiced yoga an average of five times per week.

Anthropometric parameters

ANOVA did not demonstrate a noteworthy change in height, weight, and BMI among the yoga and control groups before and after the yoga intervention, ensuring that the groups were comparable to the intervention (Table 1).

Table 1. Anthropometric characteristics among both Control group and Yoga group before and after yoga intervention

Parameters	Group 1 20-24 years (n=36, M:F=1:1)	Group 2 20-24 years (n=36, M:F=1:1)	Group 3 20-24 years (n=36, M:F=1:1)	Group 4 20-24 years (n=36, M:F=1:1)	ANOVA F value	ANOVA p Value
Weight in Kg	61.05±10.86	62.55±6.88	62.75±9.75	58.86±6.20[1,2,3]	1.554	0.203
Height in cm	164.40±6.06	163.39±6.26	164.40±6.06	163.39±6.26	0.136	0.814
BMI in kg/m^2	22.64±4.08	23.46±2.52	23.32±2.61	21.93±1.93[1,2,3]	2.027	0.113

Following ANOVA using the LSD method, post-hoc comparisons were performed between each group. Significance level: 'p' value <0.05. Male: M, female: F, and body mass index: BMI

Table 2. Physiological characteristics among both Control group and Yoga group before and after yoga intervention

Parameters	Group 1 20-24 years (n=36, M:F=1:1)	Group 2 20-24 years (n=36, M:F=1:1)	Group 3 20-24 years (n=36, M:F=1:1)	Group 4 20-24 years (n=36, M:F=1:1)	ANOVA F value	ANOVA p Value
Heart Rate in bpm	78.24±4.52[4]	75.87±6.81[4]	79.08±3.5[4]	72.91±5.11[1,2,3]	8.427	0.0001
Systolic blood pressure in mmHg	127.81±15.03[4]	134.0±17.19[4]	128.25±16.15[4]	116.64±9.1[1,2,3]	8.632	0.0001
Diastolic blood pressure in mmHg	74.44±11.82[4]	74.72±10.4[4]	75.44±12.41[4]	67.72±5.84[1,2,3]	3.639	0.014
Pulse pressure in mmHg	53.36+11.31[4]	59.27+13.60[4]	52.81.+11.31[4]	48.916+7.9[1,2,3]	5.128	0.0002
Mean arterial pressure in mmHg	92.23±11.85[4]	94.46±11.40[4]	93.04±12.71[4]	84.02±6.03[1,2,3]	6.332	0.0001
Rate pressure product in mmHg/min	9992±1237.18[4]	10164±1580.18[4]	10142.01±1322.36[4]	8502±860.06[1,2,3]	13.11	0.0001

Following ANOVA using the LSD method, post-hoc comparisons were performed between each group. Significance level: 'p' value <0.05. Male: M, female: F

Table 3. Vascular stiffness parameters among both Control group and Yoga group before and after yoga intervention

Parameters	Group 1 20-24 years (n=36, M:F=1:1)	Group 2 20-24 years (n=36, M:F=1:1)	Group 3 20-24 years (n=36, M:F=1:1)	Group 4 20-24 years (n=36, M:F=1:1)	ANOVA F value	ANOVA p Value
b-a PWV in cm/sec	1033.6±520.87[4]	1471.3±625.3[4]	1509.9±636.63[4]	913.79±412.6[1,2,3]7	10.05	0.0001
c-f PWV in cm/sec	922.91±309.57[4]	1033.6±359.94[4]	1033.5±354.97[4]	579.76±160.21[1,2,3]	18.65	0.0001
bASI in %	4.58±5.44[4]	24.97±8.38[4]	25.04±5.25[4]	17.47±4.11[1,2,3]	13.66	0.0001
aASI in %	38.78±7.84[4]	40.52±7.97[4]	39.03±6.15[4]	23.04±3.68[1,2,3]	47.43	0.0001

Following ANOVA using the LSD method, post-hoc comparisons were performed between each group. Significance level: 'p' value <0.05. Male: M, female: F, and b-a PWV: pulse wave velocity, c-f, brachial-ankle Ankle vascular stiffness index (aASI), brachial vascular stiffness index (bASI), and carotid femoral pulse wave velocity (PWV)

Physiological parameters

Following the intervention, the yoga group demonstrated significant improvements ($p < 0.05$) in several indicators when compared to the control group (Table 2). Heart rate, systolic and diastolic blood pressure, mean arterial blood pressure, pulse pressure, and rate pressure product all significantly decreased in the yoga intervention group, according to an ANOVA (Table 2).

Vascular stiffness parameters

When compared to the control group, the brachial-ankle pulse wave velocity, carotid-femoral pulse wave velocity, brachial arterial stiffness index, and ankle arterial stiffness index all revealed a significant ($p<0.05$) decrease in the yoga group (Table 3).

DISCUSSION

The current research investigated the effects of a CYP intervention on anthropometric, physiological and vascular stiffness parameters in young adults who survived COVID-19 disease. The main finding was that, after adjusting for age and sex, participants who regularly practiced yoga had far lower HR, BP, RPP, PWV and ASI than non-yoga participants.

Baseline Characteristics and Group Equivalence

We specifically recruited participants who had recovered from COVID-19 disease. We recruited 250 participants who were confirmed (RTPCR) diagnosed with COVID-19 disease, and 72 met the inclusion criteria. The final analysis included 36 participants each in the yoga and control groups, with a balanced gender distribution (50% male, 50% female) in both groups. The yoga group practiced yoga an average of five times per week. Importantly, baseline characteristics (weight, height and BMI) revealed that there were no significant differences ($p > 0.05$) between the control and yoga groups before the yoga intervention (Table 1). This balanced enrollment strengthens the study's internal validity, as any observed changes after the intervention can be more confidently attributed to the yoga program.

Effects of Yoga Intervention on physiological parameters

The yoga intervention resulted in significant improvements ($p < 0.05$) in multiple parameters when compared to the control group (Table 2). Among these improvements were decreases in blood pressure, heart rate, and rate pressure product. The parameters did not significantly improve in the control groups.

The present research demonstrated a significant decrease in heart rate after three months of yoga intervention among the yoga group. Numerous research investigations have demonstrated that consistent pranayama lowers resting heart rate [21, 22]. The relaxation response, which is parasympathetic dominance brought on by deep breathing and breath control techniques, is assumed to cause this [21, 22]. Improved cardiovascular health and a lower risk of heart disease are linked to lower resting heart rates.

After three months of yoga intervention, the yoga group's systolic, diastolic, mean arterial, and pulse pressures all significantly decreased, according to the current study. It has been demonstrated that pranayama techniques reduce blood pressure, such as alternating nostril breathing (Nadi Shodhana) and slow, deep breathing. By encouraging relaxation and lowering sympathetic nervous system activity, these methods lower BP and cause vasodilation [23].

The rate pressure product (RPP) in the present study decreased after yoga intervention in the yoga group. The heart's workload and oxygen intake are measured by the rate pressure product. It is calculated by multiplying the heart rate (HR) by the systolic blood pressure (SBP) [24]. Research has demonstrated that yoga can decrease RPP by lowering cardiac workload and improving cardiovascular efficiency and pranayama decreases the RPP after six weeks of training among hypertensive patients [24].

Effects of Yoga Intervention on Vascular Stiffness Parameters

Brachial-ankle and carotid-femoral pulse wave velocity (b-a PWV and c-f PWV) and brachial and ankle arterial stiffness index (bASI and aASI) are decreased in the present study after yoga training in the yoga group. Higher levels of PWV and ASI are measures of vascular stiffness and are associated with stiffer arteries and a higher risk of cardiovascular disease. It is proven that yoga intervention reduces vascular stiffness by lowering sympathetic activity, promoting NO bioavailability, and improving endothelial function [25] and regular yoga practice is linked to a 0.3 ms decrease in

central vascular stiffness compared to non-yoga individuals [26].

According to researchers, a brief Bikram yoga intervention significantly lowered the insulin resistance index in older but not younger persons and decreased vascular stiffness in young but not older adults. An 8-week Bikram yoga intervention was completed by twenty-four young individuals and eighteen middle-aged and older adults. In younger persons ($p<0.05$), there was a drop in the â-stiffness index and an elevation in carotid artery stretch ability ($p<0.05$), but not in older adults [27].

The role of deficiency of vitamin D in the development of vascular stiffness has been demonstrated in various studies which may result in various cardiovascular diseases such as hypertension [28]. Yoga might be helpful in the reversal of these mechanisms as demonstrated in various studies [29, 30].

The present study's findings support other studies showing yoga's positive impact on blood pressure, heart rate, and vascular stiffness. These results imply that yoga can be an effective method for improving cardiovascular health in young adults who have recovered from COVID.

This study suggests that yoga is a safe and effective non-pharmaceutical approach to improving vascular health in young adults, especially those recovering from mild COVID-19. It may be a good option for individuals who cannot participate in high-intensity exercise routines.

CONCLUSION

To conclude, regular yoga practice can be a valuable strategy for promoting cardiovascular health in young adults, including those recovering from COVID-19 disease. Future research with larger samples and longer durations is warranted to confirm these findings and elucidate the underlying mechanisms.

ACKNOWLEDGEMENT

Authors acknowledge Morarji Desai National Institute of Yoga, Ministry of AYUSH and BLDE (Deemed to be) University's Shri. B. M. Patil Medical College Hospital and Research Centre for the continuous supports and coordination.

Funding Sources

The author(s) received no financial support for the research, authorship, and/or publication of this article.

Conflict of Interest

The author(s) do not have any conflict of interest.

Data Availability Statement

This statement does not apply to this article.

Ethics Statement

Institutional ethical clearance was obtained from Institutional Ethical Committee of BLDE University (Ref. No.: BLDE(DU)/ IEC/581/2021-22).

Informed Consent statement

The informed consent was obtained for experimentation and that it conforms to the standards currently applied in the country of origin

Clinical Trial Registration

This research does not involve any clinical trials

Authors Contribution

Each author mentioned has significantly and directly contributed intellectually to the project and has given their approval for its publication; Jyoti P Khodnapur: Conceptualization, Methodology, Writing – Original Draft, Supervision, Project Administration, Resources, Supervision; Gireesh P Khodnapur: Conceptualization, Methodology, Writing – Original Draft; Ishwar V Basavaraddi: Data Collection, Analysis, Writing – Review & Editing; Amrit Podder: Conceptualization, Methodology, Writing – Original Draft, Visualization; Rameshwar Pal: Supervision, Project Administration, Visualization; Sumangala M Patil: Data Collection, Analysis, Writing – Review & Editing; Madivalappa P Doddamani: Data Collection, Analysis, Writing – Review & Editing.

REFERENCES

1. World Health Organisation. (n.d.). *WHO coronavirus disease dashboard*. Retrieved June 12, 2023, from https://data.who.int/dashboards/covid19/cases?n=c
2. Smereka J., Szarpak L., Filipiak K. J. Modern medicine in the COVID-19 era. *Disaster and Emergency Medicine Journal.* 2020;5(2):103–105.

3. Berry C., Mangion K. Multisystem involvement is common in post-COVID-19 syndrome. *Nature Medicine.* 2022;28(6):1139–1140.
4. Gasecka A., Pruc M., Kukula K., Gilis-Malinowska N., Filipiak K. J., Jaguszewski M. J., Szarpak L. Post-COVID-19 heart syndrome. *Cardiology Journal.* 2021;28(3):353–354.
5. Guzik T. J., Mohiddin S. A., Dimarco A., Patel V., Savvatis K., Marelli-Berg F. M., Kotecha D. COVID-19 and the cardiovascular system: Implications for risk assessment, diagnosis, and treatment options. *Cardiovascular Research.* 2020;116(8):1666–1687.
6. Wang W., Wang C. Y., Wang S. I., Wei J. C. Long-term cardiovascular outcomes in COVID-19 survivors among non-vaccinated population: A retrospective cohort study from the TriNetX US collaborative networks. *EClinicalMedicine.* 2022;53:101619.
7. Szarpak L., Pruc M., Filipiak K. J., Popieluch J., Bielski A., Jaguszewski M. J., Kotecha D. Myocarditis: A complication of COVID-19 and long-COVID-19 syndrome as a serious threat in modern cardiology. *Cardiology Journal.* 2022;29(2):178–179.
8. Zanoli L., Gaudio A., Mikhailidis D. P., Katsiki N., Castellino N., Lo-Cicero L., Ferrucci L. Vascular dysfunction of COVID-19 is partially reverted in the long-term. *Circulation Research.* 2022;130(12):1276–1285.
9. Dashoundhi V., Khodnapur G. P., Podder A., Patil S. M., Khodnapur J. P. Assessment of arterial stiffness in patients recovered from mild COVID-19 disease using pulse wave velocity: A cross-sectional study. *Journal of Clinical and Diagnostic Research.* 2023;17(8):CC05–CC08.
10. Çiftel M., Ateþ N., Yýlmaz O. Investigation of endothelial dysfunction and vascular stiffness in multisystem inflammatory syndrome in children. *European Journal of Pediatrics.* 2022;181(1):91–97.
11. Sharma A., Patil S. M., Dasgupta A., Podder A., Kumar J., Sindwani, P. Unravelling the intricate relationship between oxidative stress and endothelial dysfunction in hypertension. *Cureus.* 2024;16(5):e61245.
12. Patil, S. G., Dhanakshirur, G. B., Aithala, M. R., Naregal, G., & Das, K. K. Effect of yoga on oxidative stress in elderly with grade-I hypertension: A randomized controlled study. *Journal of Clinical and Diagnostic Research.* 2014;8(7):BC04.
13. Ministry of AYUSH, Government of India. (n.d.). *International day of yoga, common yoga protocol*. Retrieved December 16, 2021. from https://yoga.ayush.gov.in/public/assets/front/pdf/CYPEnglishLeaflet.pdf
14. Dhand N. K., Khatkar, M. S. 2014. Statulator: An online statistical calculator. Sample size calculator for comparing two independent means. Retrieved December 16, 2021. from http://statulator.com/SampleSize/ss2M.html
15. Rosner, B. 2015. *Fundamentals of biostatistics.* 8th ed. Cengage Learning.
16. Patil S. G., Aithala M., Das, K. K. Evaluation of vascular stiffness in elderly with prehypertension. *Indian Journal of Physiology and Pharmacology.* 2015;59(1):16–22.
17. Podder A., Patil S. M., Kanthe P. S., Patil S. M., Khodnapur J. P., Badiger S., Sorganvi V., Das K. K. Physical anthropometry influences arterial stiffness in hypertensive patients of North Karnataka. *Biomedical and Pharmacology Journal.* 2023;16(4):2439–2442.
18. Patil S. M., Khodnapur J. P., Das K. K., Podder A. The role of serum erythropoietin (EPO) and vascular endothelial growth factor (VEGF) in pulse wave velocity (PWV) among hypertensive patients: A cross-sectional study. *Cureus.* 2024;16(6):e62416.
19. McArdle W. D., Katch F. I., Katch, V. L. 2006. *Essentials of exercise physiology.* 3rd ed. Lippincott Williams & Wilkins.
20. Nagpal S., Walia L., Lata H., Sood N., Ahuja, G. K. Effect of exercise on rate pressure product in premenopausal and postmenopausal women with coronary artery disease. *Indian Journal of Physiology and Pharmacology.* 2007;51(3):279–283.
21. Pal G. K. Effects of pranayama on cardiovascular health. *International Journal of Clinical and Experimental Physiology.* 2016;3(3):57–58.
22. Kuppusamy M., Kamaldeen D., Pitani R., Amaldas J. Immediate effects of Bhramari pranayama on resting cardiovascular parameters in healthy adolescents. *Journal of Clinical and Diagnostic Research.* 2016;10(5):CC17–CC19.
23. Pramanik T., Pudasaini B., Prajapati R. Immediate effect of a slow pace breathing exercise Bhramari pranayama on blood pressure and heart rate. *Nepal Medical College Journal.* 2010;12(3):154–157.
24. Goyal R., Lata H., Walia L., Narula M. K. Effect of pranayama on rate pressure product in mild hypertensives. *International Journal of Applied and Basic Medical Research.* 2014;4(2):67–71.
25. Patil S. G., Aithala M. R., Das, K. K. Effect of yoga on vascular stiffness in elderly subjects with increased pulse pressure: A randomized controlled study. *Complementary Therapies in Medicine.* 2015;23(4):562–569.
26. Raj T., Elliot C. A., Stoner L., Higgins S.,

Paterson C., Hamlin M. J. Association between yoga participation and vascular stiffness: A cross-sectional study. *International Journal of Environmental Research and Public Health.* 2023;20(10):5852.

27. Hunter S. D., Dhindsa M. S., Cunningham E., Tarumi K., Alkatan M., Nualnim N., Tanaka, H. The effect of Bikram yoga on vascular stiffness in young and older adults. *The Journal of Alternative and Complementary Medicine.* 2013;19(12):930–934.
28. Sharma, A., Banthia, P., Naidu, A., Podder, A., & Kumar, J. Dissecting the arterial stiffness in hypertensive individuals and its intricate relationship with vitamin D: A cross-sectional study. *African Journal of Biological Sciences. 2024;6*(12):170–173.
29. Khodnapur J. P., Podder A., Basavaraddi I. V., Patil, S. M. Unraveling the interplay between oxidative stress and vascular aging with yoga: A cross-sectional study. *African Journal of Biological Sciences. 2024;6*(13):232–237.
30. Kumar, J., Sharma, A., Dasgupta, A., Podder, A., Naregal, G., Iqbal, M. K., & Patil, S. M. Unraveling the relationship between vitamin D and oxidative stress: A cross-sectional study. *Cureus. 2024;16*(8), e67818.