Effect of Integrated Approach of Yoga Therapy on Noninvasive Cardiovascular Responses: Study on Young and Older Healthy Males.

Abstract:

Background/Aims: The studies on the effect of integrated approach of yoga therapy (IAYT) have shown significant results in improving the overall health. Arterial stiffness index is significantly reduced after physical exercise or after Yoga activities. However, the effect of integrated yoga therapy using PC based cardiovascular analyzer & PPG analysis system on non- invasive arterial stiffness index is not yet established. The aim of the study was to investigate the effect of IAYT on noninvasive cardiovascular responses including arterial stiffness in both young and older healthy males.

Methodology: A total of 20 participants were included in the study. The participants were divided into two groups (A&B) based on their age. There were 10 participants in group A who were considered as young healthy, 10 old healthy adults were included in group B. All participants in group A & B were accepted and recorded all invasive cardiovascular parameters as experimental control (group C). A 6-week integrated approach of yoga therapy (IAYT) was given as an intervention to the participants come under group A & B. The PC based cardiovascular analyzer and PC based PPG analysis system were used to record almost all parameters signifying the status of arterial stiffness index at the beginning and end of the yoga program. The arterial stiffness index (ASI) and reflection index (RI) were computed from the pulse data. The data were analyzed using the paired-samples t test.

Results: There was a significant reduction in Pulse Wave Velocity (PWV), ASI ($P < 0.05$) after IAYT for 6 weeks in young and old participants. There was non-significant reduction in BMI after IAYT in healthy young and older adults, but the ASI was more significantly low in young adults. There were no significant changes in Systolic Blood Pressure (SBP), Diastolic Blood Pressure (DBP) and Pulse Pressure (PP). after IAYT.

Conclusion: Our findings suggest that IAYT offered was more effective than Yoga or brisk-walk separately in reducing arterial stiffness. This would be due to reduce sympathetic activity and improve endothelial function with enhancement in bioavailability of NO and would be less effective in elderly individuals with increased PP. The age-related endothelial dysfunction associated with decreased bioavailability of nitric oxide (NO), a potent vasodilator, contributes to vascular stiffness would not be ruled out. The life-style modalities in IAYT must be considered as a prime candidate.

Keywords:

Arterial stiffness index (SI). Pulse wave velocity (PWV). Reflection Index (RI)

Introduction:

The integrated approach of yoga therapy (IAYT) includes a healthy life nourishing diet, a healthy and natural environment, a holistic lifestyle, adequate bodywork through yoga asanas, invigorating breath work using pranayama and the production of a healthy thought process through the higher practices of Jnana and Raja Yoga (Table-1). IAYT was developed by S-VYASA is a holistic approach to treat the diseases like diabetes, hypertension, obesity and the

studies based on IAYT have shown significant result on health by reducing arterial stiffness, which emphasizes the importance of holistic treatment rather than focused treatment (Yoga).

Table 1. Integrated yoga program schedule for group A and B.

Program	Description
Loosening exercises (10 round each)	toe, ankle, knee, waist, wrist , shoulder, neck rotation and bending sakti vikasaka sukshma yayama for wrists, palms, fingers, elbows, arms, back, thighs and calf muscles.
Yogasanas (15–20min)	ardhakati cakrasana, ardha cakrasana, pada hastasana, bhujangasana,salabhasana, dhanurasana, sarvangasana, matsyasana, viparitakarani, halasana,cakrasana, sasankasana, vakrasana, ardha matsyendrasana, ustrasana, instant relaxation technique (1 min), quick relaxation technique (3 min), deep relaxation technique (3 min)
Pranayama & Kriyas	kapalbhati (40–120 strokes/min), sectional breathing (5 rounds), surya and candra anuloma viloma pranayama (21 rounds),cooling& bhramari pranayama (9 rounds)
Meditation (10 min)	Cyclic meditation (3 min), Nadanusandhana (3 min), OM meditation (3 min).
Maitri Milan	Gita chanting & main lecture of the day in yogic principles from the Bhagavat Gita
Breakfast & Lunch	Sattvic food

While yoga is a healthy pursuit that can benefit its practitioners in its general form, yoga therapy is an evolving field which focuses on using evidence-based yogic practices in the treatment of specific health conditions. Yoga therapy is highly informed by medical physiology, psychology and neuroscience. This provides a sound, evidence-based rationale for using yoga as an adjunct therapy in a variety of mental and physical health conditions and gives yoga therapists the

knowledge needed to safely tailor a yoga program to the needs of their client, designed according to the client's need [1–7].

Arterial stiffness measured using the pulse wave velocity is considered as a potential indicator for cardiovascular risks and has gained significant clinical and research importance in the recent past [8]. The standard techniques used for measuring arterial stiffness are carotid-femoral pulse wave velocity (c-f PWV), brachial-ankle pulse wave velocity (ba PWV), and large artery stiffness index (SI) & reflection index (RI) through photoplethysmography (PPG analysis system). Arterial stiffness measured using the carotid-femoral pulse wave velocity technique is considered as the gold standard [9] and as per this technique, it is measured as the ratio of the distance between two arteries (carotid and femoral) to the time taken for the pulse to travel from the carotid to the femoral artery. The other technique, i.e., ba PWV, is like c-f PWV except for the pulse location and the clinical utility of arterial stiffness measured at the brachial artery has shown significant results in identifying cardiovascular risks [10]. The time interval between systolic and diastolic peaks depends on the stiffness of the arteries and height of the person. The ratio of the height of the person to the time interval between systolic and diastolic peaks is termed stiffness index (SI) which represents the arterial stiffness. The ratio of the diastolic peak amplitude to the systolic peak amplitude is termed reflection index (RI) which represents the endothelial function [11-14].

The effect of integrated approach of Yoga therapy on changes in arterial stiffness is not yet established. As IAYT has shown larger clinical interest, we wanted to investigate the effect of a 6-weeks IAYT program on arterial stiffness in young and older healthy adults.

Materials & Methods: The study protocol and informed consent were duly permitted by the Institutional Ethical Committee (IEC) of the Institute. Normal healthy10 male subjects aged 30-35 years (32.57±11.74) were included in group A and 10 old healthy male subjects aged 51 years or above (51.80±11.72) were included in group B in this study. All subjects both healthy young (Group A) and aged (Group B) male subjects were accepted as experimental control (Group C). All noninvasive cardiovascular parameters including arterial stiffness were recorded for one week using both PC based cardiovascular analyzer (Periscope) as per description reported earlier and PPG analysis system (Dicrowin). Study was performed in the surrounding areas of the University.

Measurement of noninvasive parameters: Periscope (Figure-1) is a PC based low-cost instrument hence used with a computer (Fig-1). It used ECG as a marker. Periscope thus facilitates use in epidemiological studies which has been validated and has good intraday and inner observer reproducibility for various estimated central and peripheral arterial velocities. In brief, PWV was determined by a non-invasive pulse wave analyzing device (Periscope). All participants, Group A & B, were asked to have vegetarian diet, asked to refrain from smoking and drinking caffeine-containing beverages 12 hours before the test. Procedure was performed always by the sale operator in the morning hours between 7 and 10 a.m. with subject resting in supine position at

least 10 min before the recording. Electrodes for electrocardiogram were placed in ventral surface of both wrists and medial side of ankles and BP cuffs were wrapped on both upper arm brachial artery and tibial artery above ankles. The cuff was connected to a plethysmography sensor which determines volume pulse form and an oscillometer pressure sensor, which measures blood pressure volume waveform from the brachial and tibial arteries (Figure 1).

Figure-1: Elements to record non-invasive cardiovascular parameters (PC based cardiovascular analyzer).

All the pressure recording were done as per earlier methods [9]. SBP, DBP, PP, Hear rate or Pulse Rate (PR), Heart brachial (hb) PWV, heart ankle (ha) PWV, brachial ankle(ba) PWV, carotid femoral (c-f) PWV and right and left heart brachial pulse wave velocity (right hb PWV & left hb PWV) were recorded both before and after following IAYT (Figure-2 &3).

Figure-2: Figure: A record showing ECG tracing (Lead I & II) and pressure wave form obtained from the PC based cardiovascular analyzer.

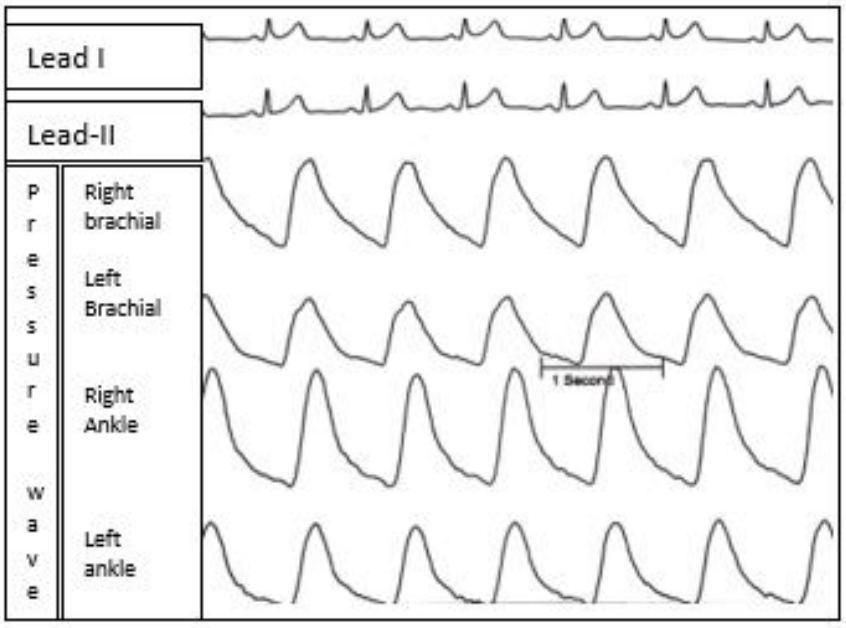
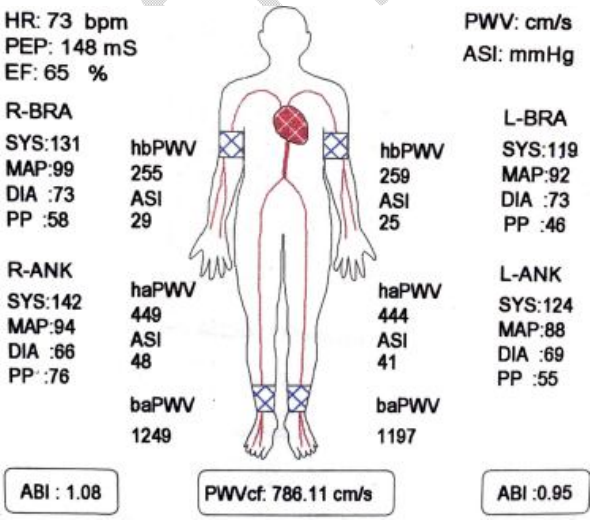


Figure-3: A record obtained from the PC based cardiovascular analyzer



PC based PPG analysis system (Dicrowin) was used for collecting pulse data which has to record SI and RI. The pulse data was collected for 1 min by placing the sensors on the finger. Initially, the pulse was sensed with fingers to identify the exact pulse locations and then the sensors were

placed by closely aligning it with the sensed locations. The pulse was taken from the left finger for males. The pulse data consist of time and amplitudes of the pulse. The pulse data were collected from the participants (Group A & B) at the beginning of the IAYT and later at the end of the IAYT. The systolic, diastolic, mean and pulse pressure were recorded in both the groups of healthy subjects. Vascular parameters such as RI or reflection index (vascular tone) and SI (Large artery stiffness index) were recorded [10].

A 6-weeks IAYT program was given as an intervention for the study (Table-1). The program starts in the morning at 6 a.m. and ends at 7 p.m. The IAYT program includes loosening exercises, asanas, pranayama, meditation, advanced yoga techniques, bhajans, and lectures on yoga philosophy. All were asked to take sattvic food at the time of taking breakfast & lunch. The yoga practices were rigorous for participants in group A& B when compared to the participants in groups C who had no Yoga therapy. The details of yoga practices for both groups are explained in Table 2. The other yoga practices were done every day. There were two sessions of loosening exercises and asanas at 6 a.m. and 5 p.m. for a 1-h duration. Pranayama was done for 1 h at 9 a.m. Meditation and advanced yoga techniques were done for 1 h at 3 p.m. and there were lectures on yoga philosophy for 1 h at 12 p.m. and bhajans for 1 h at 6 p.m. The participants have joined the center to undergo a 6-weeks of IAYT. As the aim of the study was to investigate the effect of integrated yoga on arterial stiffness across young and old healthy adults, participants were divided into two groups based on their age. The participants with a BMI <25 was considered as normal and healthy. We included both young and old participants in the group A & B respectively. Group C (Experimental control) were the same participants of group A & B without obesity. The medical history of the participants was examined by a residential doctor at the center. The demographic details of the participants are provided in Table 1. Height, weight, blood pressure, and pulse rate were measured at the beginning and end of the yoga program with the help of PC based analyzer. Blood pressure was measured using a standard mercury sphygmomanometer and pulse rate was measured manually by placing the fingers on the wrist. The BMI was computed as the ratio of weight to the square of height.

Inclusion & Exclusion Criteria

All the presenting subjects were screened clinically as well as were investigated to rule out any comorbidities and persons with history of smoking, history of diabetes mellitus, hypertension, angina, arrhythmia, myocardial ischaemia, peripheral ischaemic disease with documented claudication, respiratory system disease, neurological diseases, persons with hemoglobin less than 10 were excluded from the study. Hence, the participants who were not suffering from any severe cardiovascular diseases and who were not taking any medicines for cardiovascular diseases were included in the study. We have excluded the participants who were suffering from cardiovascular diseases and who were not willing to be part of the study.

Ethics Consideration

The study was approved by the Institutional Ethics Committee. After having explained the aim of the study to the participants, we obtained informed consent from all of them included in group A & B.

Statistical Analysis

The obtained data was expressed in mean and standard deviation. The differences between the post-intervention and the baseline measures were calculated to determine the changes in the outcome measures. The data were analyzed using SPSS Statistics Version 10. The pulse data were assessed for normality using the Kolmogorov Smirnov test. The mean values of stiffness parameters (All cardiovascular parameters including SI and RI) from pre- and post-IAYT were analyzed using the paired samples t test in all three groups. A two-tailed p value <0.05 is considered statistically significant for all comparisons and the data were reported.

Results & Discussion:

1) All non-invasive cardiovascular parameters in group A & B (Experimental control) were not significantly different (P>0.05) except age (Table-2).
2) The body weight, height and age of both the groups were almost same (P>0.05) after following IAYT for 6 weeks(P>0.05) (Table-2).
3) HR, SBP, DBP &PP were not altered significantly(P>0.05) after following IAYT in both the groups A & B(Table-3).
4) Pulse wave velocity (right ba PWV, left ba PWV, & c-f PWV) were significantly reduced (P<0.05) in both the groups (A & B) after following IAYT(Table-3).
5) Arterial stiffness index at four regions (right & left bra, right and left ank) were significantly reduced in both the groups (A & B) after following IAYT for six weeks (Table-3).
6) ABI at right and left were not altered significantly (P>0.05) after following IAYT(Table-3).
7) The mean values of SI and RI for pre- and post-IAYT are shown in Table 3. The young and old groups had shown significant reduction in SI (P < 0.05) after IAYT, whereas there were no significant changes (P>0.05) on RI in the young but non-significant with & older group. The RI was reduced in all the groups but the change in the young group was significant (P>0.05).
8) In all the groups (A & B), the BMI was reduced after IAYT and the reduction in the young and old group was not significant (Table-3).
9) Biochemical parameters such as blood sugar, lipid profile, creatinine was not significantly different in both the groups (A & B) when tested before and after IAYT(Table-3).
10) Mean arterial blood pressure was also insignificant in both the groups (A & B) when tested before and after IAYT(Table-3).

Table 2. Demographic details of the male participants (Experimental control group) or Group C). Data were represented as mean ± standard deviation. Group A, young healthy participants; Group B, old healthy male participants; BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure; PR, pulse rate; n, number of participants. * $P<0.05$

Parameter	Group A (n = 10)	Group B (n = 10)	*P* value
Age, (Yrs)	32.57±11.74	51.80±11.72	0.003*
Height(cm)	164.891±8.45	165.20±3.34	0.815
Weight (kg)	76.071±20.72	74.236±10.05	0.732
BMI (Kg/m^2)	26.15±7.85	22.31±3.14	0.779
SBP (mm Hg)	113.60±5.37	121.20±11.45	0.821
DBP (mm Hg)	76.67±13.48	77.60±5.36	0.212
PR (beats/min)	81.33±12.04	84.40±8.25	0.512
PP (mmHg)	41.12±06.04	43.22±10.04	0.634
Right ba PWV (cm/s)_	1249.7±21.74	1209.4±27.71	0.923
Left ba PWV (cm/s)	1197.1±31.70	1207.9±27.04	0.524
C-F PWV (cm/s)	677.2±21.74	607.2±21.24	0.751
R Bra ASI (mmHg)	29.8±06.01	39.8±06.04	0.488
L Bra ASI (mmHg)	25.3±06.14	35.3±05.04	0.211
R Ank ASI (mmHg)	48.5±04.04	58.5±05.01	0.502
L Ank ASI (mmHg)	41.4±06.08	52.4±06.06	0.604
ABI (Right)	1.08±01.01	0.95±02.04	0.823
ABI(Left)	1.01±01.14	0.87±01.09	0.514
RI (%)	14.71±03.14	21.11±02.11	0.432
SI (meter/sec)	5.05±01.12	5.21±01.11	0.612

Table-3: Effect of IAYT for 6 weeks on noninvasive cardiovascular responses in both young and old healthy males. Summary of paired samples 't' test. N= number of participants. Data were represented as mean ± standard deviation. Group A, Young healthy adults; group B, old healthy adult SI, stiffness index; RI, reflection index; IAYT, integrated approach to yoga therapy; BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure; PR, pulse rate. * *p* value comparing pre and post IAYT data, significance at 0.05(* $P<0.05$).

Parameter	Pre IAYT		Post IAYT			
	Group A n=10	Group B n=10	Group A n=10	*P* value	Group B n=10	*P* value
Age (Yrs)	32.57±11.74	51.80±09.72	32.57±11.74	0.7	51.80±10.72	0.4
Height(cm)	164.891±18.45	165.20±23.34	164.89±8.45	0.8	165.20±3.34	0.6
Weight (kg)	76.07±10.72	76.08±10.72	75.23±10.05	0.6	76.09±6.08	0.8
SI(m/s)	5.08±01.12	5.71±01.18	4.48±01.12	0.05*	4.21±01.18	0.05*
RI (%)	14.41±03.11	22.11±02.18	10.31±03.11	0.05*	20.11±02.11	0.2
BMI	23.01±3.14	28.31±3.14	20.99±2.903	0.7	21.99±2.90	0.8
SBP(mmHg)	113.20±11.45	123.20±11.45	1012±11.22	0.01*	112±11.22	0.05*
DBP(mmHg)	77.60±5.36	84.60±5.36	75.60±6.06	0.4	81.05±09.22	0.8
PP (mmHg)	42.12±06.04	47.33±07.14	40.33±07.14	0.7	41.33±07.14	0.8
PR beats/min	74.40±8.29	84.40±8.29	71.20±7.43	0.8	81.40±6.22	0.6
Right ba PWV (cm/s)	1140.7±38.29	1240.7±31.29	1012.7±28.29	0.03*	1010.7±28.29	0.01*
Left ba PWV (cm/s)	1197.1±28.29	1217.1±28.29	1017.1±28.29	0.03*	1091.1±28.29	0.02*
C-F PWV (cm/s)	608.2±11.45	698.2±11.45	602.2±11.45	0.02*	604.2±11.45	0.01*
R Bra ASI (mmHg)	65.3±3.14	58.3±3.14	25.3±3.14	0.01*	25.3±3.14	0.01*
L Bra ASI (mmHg)	48.5±2.90	58.5±2.90	34.5±2.90	0.01*	49.5±2.90	0.02*
R Ank ASI mmHg	44.4±2.90	41.4±2.90	30.4±2.90	0.02*	31.4±2.90	0.02*
L Ank ASI mmHg	53.4±6.0	63.4±6.0	33.4±6.0	0.03*	51.4±6.0	0.02*
ABI (Right)	0.96±0.02	1.06±0.02	1.01±0.09	0.7	0.97±0.029	0.3
ABI (Left)	0.71±0.06	0.91±0.02	1.07±0.02	0.01*	1.17±0.02	0.4

We reported decrease in arterial stiffness after taking physical exercise for a period of 30 minutes where pulsatile stretching of collagen fibers during aerobic exercise can break these collagen crosslinks, resulting in a decrease in arterial stiffness [8-10]. In this study, ASI and large artery stiffness index (SI) were reduced after following 6 weeks of IAYT, RI was also reduced in both the groups indicates improvement on endothelial dysfunctions (Table-2). This observation is also supported by Patil et al. [15]. In this study PWV is reduced significantly in both the groups signifying parasympathetic predominance, and inhibition of sympathetic which reduces vascular tone. Load on heart might also be reduced in both the groups which are to be investigated in future. Activation of nitric oxide-dependent pathways, antioxidants, RAAS inhibitors, TGF-β inhibition, 3-hydroxy-3-methylglutaryl–coenzyme might also be involved in subjects following six weeks of IAYT. The vascular benefits of exercise might be indirectly related to a decline in

the release of neurohumoral vasoconstrictors and reduced efferent sympathetic tone, and to endothelial mechanical-signaling associated with increased pulsatile flow and stretch and consequent enhanced nitric oxide stimulation during IAYT.

In older adults and young healthy participants, there was not a significant reduction in BMI, but we did not see a significant reduction in RI and this could be because the average age of the group was just above 50 years. The studies had shown that arterial stiffness increases with age [13] for older adults with obesity as well as BMI, which is not supporting our observation. Results had shown that 1 weeks of IAYT program reduced the BMI of obese participants [16-20]. In this study, both young and older adults had a similar reduction in SI, but significant was observed only in young adults and not in older adults which might be due to age related changes. We suggest that a 6-week duration may not have been sufficient for older adults to see significant changes in RI. There was significant change in RI after 6 weeks of IAYT in young males, which needs further investigation.

We have selected a relatively small sample size for our study. As the results were promising, we think that extensive studies with larger sample sizes would help in establishing the effect of integrated yoga therapy on arterial stiffness. The second limitation was that IAYT was conducted for only 6 weeks and there is a need to study the changes in arterial stiffness by increasing the duration of IAYT. Another limitation of our study was that the yoga practices, diet, Ayurveda, and naturopathy treatments were not the same across the groups. As the study reported a significant effect of IAYT on arterial stiffness, in both younger and old adults, the future investigations should focus on studying the effect by giving the same yoga practices, diet, and treatments across the groups.

Our study shows reduction with SBP, DBP and PP and HR, signifying beneficial modulation in cardiac autonomic nervous system, enhance bioavailability of NO and hence there was a reduction with blood pressure. ABI indicates peripheral artery disease and generally do not change with exercise. In this observation also there was significant increase in young adults might be due to increase peripheral blood supply and no alteration with ABI in older males would be due to age factor, resulting no such improvement on peripheral blood supply.

Conclusion: A 6-weeks IAYT intervention has significantly reduced arterial stiffness in young adults and older adults. Arterial stiffness is considered as one of the potential cardiovascular risk factors and with a significant reduction in arterial stiffness would improve cardiac morbidity and mortality. We can say that a 6-weeks IAYT program could be suggested as an effective program to control the cardiovascular risk. In older adults, arterial stiffness changes are less as compared to young adults and hence it may take longer in old males to see a similar effect. Therefore, the effect of IAYT on arterial stiffness needs to be studied with an extended duration of yoga therapy for older adults. The IAYT is a holistic program and the ability of the patient to cooperate with and integrate the available factors (therapist related and treatment related) could enable best results.

References:

1.Villacres MC, Jagannathan A, Nagarathna R, Ramakrsihna J. Decoding the integrated approach to yoga therapy: qualitative evidence based conceptual framework. Int J Yoga. 2014;7:22–31.

2. Ebnezar J, Nagarathna R, Yogitha B, Nagendra H. Effect of integrated yoga therapy on pain, morning stiffness and anxiety in osteoarthritis of the knee joint: a randomized control study. Int J Yoga. 2012;5:28–36.

3. Ebnezar J, YogithaBali M, John R, Gupta O. Role of integrated approach of yoga therapy in a failed post-total knee replacement of bilateral knees. Int J Yoga. 2014;7:160–164.

4. Jagannathan A, Hamza A, Thirthalli J, Nagendra H, Nagarathna R, Gangadhar B.Development and feasibility of need-based yoga program for family caregivers of in-patients with schizophrenia in India. Int J Yoga. 2012;5: 42–47.

5. Radhakrishna S: Application of integrated yoga therapy to increase imitation skills in children with autism spectrum disorder. Int J Yoga. 2010;3:26–30.

6. Ranjita R, Badhai S, Hankey A, Nagendra H: A randomized controlled study on assessment of health status, depression, and anxiety in coal miners with chronic obstructive pulmonary disease following yoga training. Int J Yoga. 2016;9:137–144.

7. Tekur P, Chametcha S, Hongasandra R, Raghuram N: Effect of yoga on quality of life of CLBP patients: a randomized control study. Int J Yoga. 2010;3:10–17.

8. Giri PV, Despande S, Joshi A, More P, Singh A, Nagendra HR.Effect of integrated Yoga Therapy on Arterial Stiffness: A pilot study on young and older adults with obesity. Integr Med Int 2017;4:85-93.

9. Bhunia S, Bhunia B, Basavaraj AS, Sant SK. Acute changes after 30 minute of dynamic exercise in arterial stiffness and pulse wave velocity of healthy young and middle aged individuals. Journal of Advance Research in Biological Sciences. 2015; 7(1); 17-23.

10. Bhunia S, Tripathy NK. A comparative analysis of non-invasive cardiovascular functions in proficient and non-proficient healthy subjects. International Journal of Physiology. July-Dec 2013;1(2);22-27.

11. Lumbani QA, Bhunia S, Hyder ANG. A study to assess sympathetic response changes in carotid femoral pulse wave velocity using cold pressor test in normal BMI, overweight and obese subjects.2020; Int J of Basic Appl Physiol. 9(1);75-79.

12. Sugawara J, Tanaka H. Brachial-ankle pulse wave velocity: myths, misconceptions, and realities. Pulse(Base). 2015; 3:106–113.

13. Hertzman AB: The blood supply of various skins areas as estimated by the photoelectric plethysmograph. Am J Physiol. 1938;124:328–340.

14. Millasseau SC, Ritter JM, Takazawa K, Chowienczyk PJ. Contour analysis of the photoplethysmographic pulse measured at the finger. J Hypertension. 2006;24:1449–1456.

15. Patil SG, Aithala MR, Das KK: Effect of yoga on arterial stiffness in elderly subjects with increased pulse pressure: a randomized controlled study. Complement Ther Med. 2016;23:562–569.

16. Richard C Jin, Joseph L. Vascular nitric oxide: formation & function. Journal of Blood Medicine.2010;1:147-162.

17. Wildman RP, Farhat GN, Patel AS, Mackey RH, Brockwell S, Thompson T, et al. Weight change is associated with change in arterial stiffness among healthy young adults. Hypertension. 2005;45:187–192.

18. Wildman RP, Farhat GN, Patel AS, Mackey RH, Brockwell S, Thompson T, et al. Weight change is associated with change in arterial stiffness among healthy young adults. Hypertension .2005;45:187–192.

19. Millasseau SC, Guigui FG, Kelly RP, Prasad K, Cockcroft JR, Ritter JM, et al. Noninvasive assessment of the digital volume pulse. Comparison with the peripheral pressure pulse. Hypertension. 2000;36:952–956.

20. Selvamurthy W, Sridharan K, Ray US, Tiwary RS, Hegde KS, Radhakrishan U, et al. A new physiological approach to control essential hypertension. Indian J Physiol Pharmacol. 1998;42(2):205–13.