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RESEARCH ARTICLE

NONINVASIVE CARDIOVASCULAR RESPONSES TO INTEGRATED APPROACH OF YOGA THERAPY (IAYT): STUDY ON YOUNG AND OLDER MALES

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ABSTRACT

Background/Aims: Arterial stiffness index (ASI) is significantly reduced after physical exercise or after Yoga activities. However, the effect of integrated yoga therapy (IAYT) for longer duration, using PC based cardiovascular analyzer & PPG analysis system on non-invasive cardiovascular responses such as arterial stiffness index or ankle brachial index (ABI) are not yet reported. The aim of the study was to investigate the effect of IAYT for a longer duration on noninvasive cardiovascular responses including arterial stiffness index in both young and older males residing in rural areas. **Methodology:** A total of 20 male subjects were included in the study. All healthy participants were divided into two groups (A&B) based on their age. There were 10 participants in group A considered as young aged below 40 years, 10 old adults aged above 60 years were included in group B. All participants in group A & B were accepted and recorded all non-invasive cardiovascular parameters as experimental control (group C). A 6-weeks 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 cardiovascular parameters signifying the status of arterial stiffness index and ankle brachial 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 ($P < 0.05$) and no significant alterations ($P > 0.05$) on ABI after IAYT for 6-weeks of IAYT 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 ($P < 0.01$) in young adults. There were no significant changes in Systolic Blood Pressure (SBP), Diastolic Blood Pressure (DBP) and Pulse Pressure (PP) after IAYT for 6 weeks. **Conclusion:** Our findings suggest that IAYT offered was more effective than Yoga or brisk-walk separately in reducing ASI. This could be due to reducing sympathetic activity and improved endothelial function with enhancement in bioavailability of NO, which would be less effective in aged individuals. 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 to reduce cardiovascular diseases (CVD).

INTRODUCTION

The integrated approach of yoga therapy (IAYT) is an important and essential approach to get positive health which includes taking a healthy life with nourishing diet, a healthy and natural environment, a holistic lifestyle, adequate bodywork through yoga asanas, invigorating breath work using pranayama, kriyas and the production of a healthy thought process through the higher practices of Jnana and Raja Yoga (Table-1).

IAYT slows down the loops of uncontrolled speed of thoughts (stress). In this we provide successive stimulations followed by progressive relaxations and the rest to correct the imbalances and promote mastery over the mind and can harmonize the disturbances at each level. IAYT was developed by S-VYASA is a holistic approach to treat cardiovascular diseases (CVD) and diseases like diabetes, hypertension, obesity (1-4). The studies based on IAYT have shown significant results on health by reducing arterial stiffness, which

emphasizes the importance of holistic treatment rather than focused treatment (Yoga). Yoga therapy is supported by medical physiologists, psychologist and neuroscientist. IAYT provides a sound, evidence-based items 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 and can be designed according to the client's need (5-7).

Table 1. Schedule based on IAYT for all subjects come under group A & B for group A and B

Program	Description
Loosening exercises	Toe, ankle, knee, waist, wrist, shoulder, neck rotation and bending (12 round each) & stretching exercises.
Asana (15-20 min)	Adho Mukha Shvnanasana, Adho Mukha Vrikshasana, Dhanurasana, Anantasana, Ardha chandrasana, Ardha cakrasana, Pada hastasana, Bhujangasana, Salabhasana, Sarvangasana, Matsyasana, Mayurasana, Viparitararani, Halasana, Vakrasana, Ardha matsyendrasana, Utrasana, Relaxation technique both instant and quick (3 min each), Deep relaxation technique (3 min)
Pranayama & Kriyas	Kapalbhati (40-120 strokes/min), Sectional breathing (5 rounds), Dhauti (Vamana dhauti), Trataka kriya, Cooling & bhramari pranayama (9 rounds), Anuloma viloma pranayama (21 rounds),
Meditation (10 min)	Spiritual meditation, Mindfulness meditation, Focused meditation, Mantra Meditation
Maitri Milan	Gita chanting & Main lecture of the day in yogic principles & Bhagavat Gita
Breakfast & Lunch	Sattvic food

Arterial stiffness is an important part in the determination of cardiovascular risk. Non-invasive technique usually in the form of pulse wave velocity (PWV) is a safe, simple method to learn and has good inter- and intraoperation reproducibility, to find out cardiovascular diseases. We must know the status of our arterial stiffness like knowing the status of our blood pressure and blood sugar. Due to the paucity of instruments as well as trainers, we generally avoid knowing the status of our cardiovascular system. Physicians also confused on importance of knowing the status of arterial stiffness (9-10). The standard techniques used for measuring arterial stiffness are carotid-femoral pulse wave velocity (c-f PWV), brachial-ankle pulse wave velocity (ba PWV), through PC based cardiovascular analyzer (PARISCOPE, Genesis Medical System, Hyderabad) 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 tells us the endothelial function (11-14). The effect of integrated approach of yoga therapy with longer duration on almost all noninvasive cardiovascular parameters signifying the status of arterial stiffness in healthy conditions is not yet reported. 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 male adults. We have reported several reports on the effect of physical fitness but the effect of IAYT was not reported by us.

MATERIALS AND METHODS

The study protocol and informed consent were duly permitted by the Institutional Ethical Committee (IEC) of the Institute. Normal healthy 10 male subjects, aged 30-35 years (32.57 ± 11.74) were included in group A and 10 old healthy male subjects aged 60 years or above (61.80 ± 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 (Table-2) for one week using both PC based cardiovascular analyzer 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. It used ECG as a marker. Periscope thus facilitates use in epidemiological studies which has been accepted 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) (9-10). 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 same operator in the morning hours between 7 and 10 a.m. with the 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 recordings were done as per earlier methods developed by us (9). SBP, DBP, PP, Heart rate or Pulse Rate (PR), brachial ankle (ba) PWV of both right (R baPWV) and left (L ba PWV), carotid femoral pulse wave velocity (c-f PWV) were recorded both before and after following IAYT (Figure-2 & 3) in all subjects included in both group A & B. Ankle brachial index (ABI) on both right and left were also recorded both before and after following IAYT (Figure-2 & 3) in all subjects included in both group A & B (9-10). PC based PPG analysis system (Dicrowin) was used for collecting pulse data which must 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 consists of time and amplitudes of the pulse.

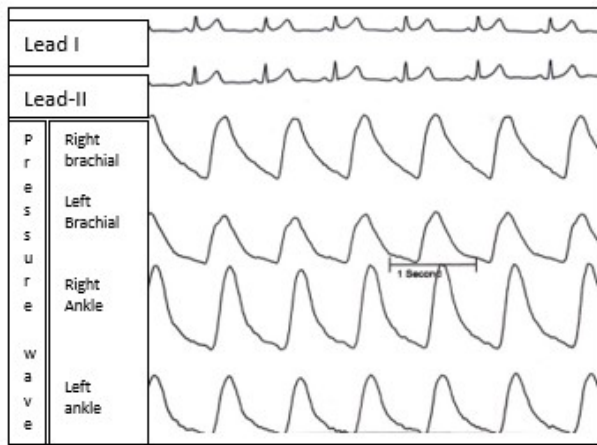


Figure 2. A piece of original record showing ECG tracing (Lead I & II) and pressure wave form obtained from the PC based cardiovascular analyzer

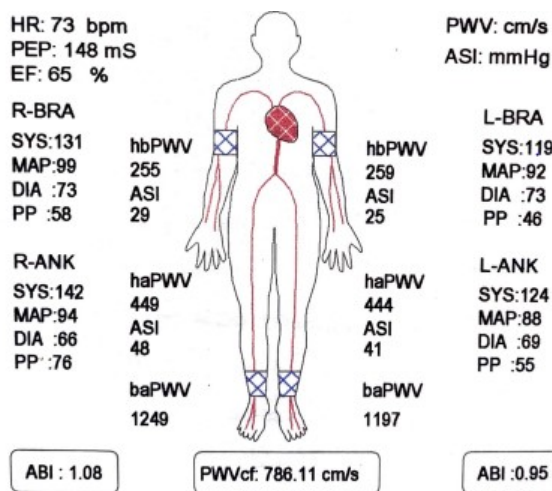


Figure 3. A piece of original record obtained from the PC based cardiovascular analyzer

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 (10-11).

Study protocol: 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 having breakfast & lunch. The yoga practices were rigorous for participants in group A & B when compared to the participants in groups C who had not followed IAYT. The details of yoga practices (IAYT) for both groups are explained in Table 1. 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 had joined the center to undergo a 6-weeks of IAYT. As the aim of the study was to investigate the effect of integrated yoga therapy 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 normal and healthy. We included both young and old participants in group A & B respectively. Group C (Experimental control) were the same participants of group A & B. 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 2. Height, weight, blood pressure, and pulse rate were measured at the beginning and end of the yoga program with the help of a 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 ischemia, peripheral ischemic 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 23. The pulse data was 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

- All non-invasive cardiovascular parameters in group A & B (Experimental control) were not significantly different ($P>0.05$) except age (Table-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).
- HR, SBP, DBP & PP were not altered significantly ($P>0.05$) after following IAYT in both the groups A & B (Table-3).
- 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).
- 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).
- ABI at right and left were not altered significantly ($P>0.05$) after following IAYT (Table-3) in both the groups.
- 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 ($P>0.05$).
- 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).
- 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).
- Mean arterial blood pressure was also insignificant in both the groups (A & B) when tested before and

Table 2. Details (non- invasive & other cardiovascular responses) of the male subjects (Experimental control group) or Group C). Data were represented as mean \pm 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 \pm 11.74	60.80 \pm 11.72	0.003*
Height(cm)	164.891 \pm 8.45	165.20 \pm 3.34	0.815
Weight (kg)	76.071 \pm 20.72	74.236 \pm 10.05	0.732
BMI (Kg/m ²)	26.15 \pm 7.85	22.31 \pm 3.14	0.779
SBP (mm Hg)	113.60 \pm 5.37	121.20 \pm 11.45	0.821
DBP (mm Hg)	76.67 \pm 13.48	77.60 \pm 5.36	0.212
PR (beats/min)	81.33 \pm 12.04	84.40 \pm 8.25	0.512
PP (mmHg)	41.12 \pm 06.04	43.22 \pm 10.04	0.634
Right ba PWV (cm/s)	1249.7 \pm 21.74	1209.4 \pm 27.71	0.923
Left ba PWV (cm/s)	1197.1 \pm 31.70	1207.9 \pm 27.04	0.524
C-F PWV (cm/s)	677.2 \pm 21.74	607.2 \pm 21.24	0.751
R Bra ASI (mmHg)	29.8 \pm 06.01	39.8 \pm 06.04	0.488
L Bra ASI (mmHg)	25.3 \pm 06.14	35.3 \pm 05.04	0.211
R Ank ASI (mmHg)	48.5 \pm 04.04	58.5 \pm 05.01	0.502
L Ank ASI (mmHg)	41.4 \pm 06.08	52.4 \pm 06.06	0.604
ABI (Right)	1.08 \pm 01.01	0.95 \pm 02.04	0.823
ABI(Left)	1.01 \pm 01.14	0.87 \pm 01.09	0.514
RI (%)	14.71 \pm 03.14	21.11 \pm 02.11	0.432
SI (meter/sec)	5.05 \pm 01.12	5.21 \pm 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 \pm 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	P value n=10	Group B	P value n=10
Age (Yrs)	32.57 \pm 11.74	51.80 \pm 09.72	32.57 \pm 11.74	0.7	51.80 \pm 10.72	0.4
Height(cm)	164.891 \pm 18.45	165.20 \pm 23.34	164.89 \pm 8.45	0.8	165.20 \pm 3.34	0.6
Weight (kg)	76.07 \pm 10.72	76.08 \pm 10.72	75.23 \pm 10.05	0.6	76.09 \pm 6.08	0.8
SI(m/s)	5.08 \pm 01.12	5.71 \pm 01.18	4.48 \pm 01.12	0.05*	4.21 \pm 01.18	0.05*
RI (%)	14.41 \pm 03.11	22.11 \pm 02.18	10.31 \pm 03.11	0.05*	20.11 \pm 02.11	0.2
BMI	23.01 \pm 3.14	28.31 \pm 3.14	20.99 \pm 2.903	0.7	21.99 \pm 2.90	0.8
SBP (mmHg)	113.20 \pm 11.45	123.20 \pm 11.45	1012 \pm 11.22	0.01*	112 \pm 11.22	0.05*
DBP (mmHg)	77.60 \pm 5.36	84.60 \pm 5.36	75.60 \pm 6.06	0.4	81.05 \pm 09.22	0.8
PP (mmHg)	42.12 \pm 06.04	47.33 \pm 07.14	40.33 \pm 07.14	0.7	41.33 \pm 07.14	0.8
PR beats/min	74.40 \pm 8.29	84.40 \pm 8.29	71.20 \pm 7.43	0.8	81.40 \pm 6.22	0.6
Right ba PWV (cm/s)	1140.7 \pm 38.29	1240.7 \pm 31.29	1012.7 \pm 28.29	0.03*	1010.7 \pm 28.29	0.01*
Left ba PWV (cm/s)	1197.1 \pm 28.29	1217.1 \pm 28.29	1017.1 \pm 28.29	0.03*	1091.1 \pm 28.29	0.02*
C-F PWV (cm/s)	608.2 \pm 11.45	698.2 \pm 11.45	602.2 \pm 11.45	0.02*	604.2 \pm 11.45	0.01*
R Bra ASI (mmHg)	65.3 \pm 3.14	58.3 \pm 3.14	25.3 \pm 3.14	0.01*	25.3 \pm 3.14	0.01*
L Bra ASI (mmHg)	48.5 \pm 2.90	58.5 \pm 2.90	34.5 \pm 2.90	0.01*	49.5 \pm 2.90	0.02*
R Ank ASI mmHg	44.4 \pm 2.90	41.4 \pm 2.90	30.4 \pm 2.90	0.02*	31.4 \pm 2.90	0.02*
L Ank ASI mmHg	53.4 \pm 6.0	63.4 \pm 6.0	33.4 \pm 6.0	0.03*	51.4 \pm 6.0	0.02*
ABI (Right)	0.96 \pm 0.02	1.06 \pm 0.02	1.01 \pm 0.09	0.7	0.97 \pm 0.029	0.3
ABI (Left)	0.71 \pm 0.06	0.91 \pm 0.02	1.07 \pm 0.02	0.01*	1.17 \pm 0.02	0.4

DISCUSSION

Pulsatile decrease in arterial stiffness after taking physical exercise for a period of 30 minutes where pulsatile stretching of collagen fibers during aerobic exercise would 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-3). This observation is also supported by Patil *et al.* (15). In our study, and to endothelial mechanical signaling was associated with increased pulsatile flow and stretch and consequent enhanced nitric oxide stimulation during IAYT in both the groups. 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 was not supporting our observation.

As per others observation 1week 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 (16-20). We suggest that a 6-weeks 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 investigations using more healthy subjects both young and old. 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. 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 showed 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 (SBP & DBP). ABI indicates peripheral artery disease and generally does 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.

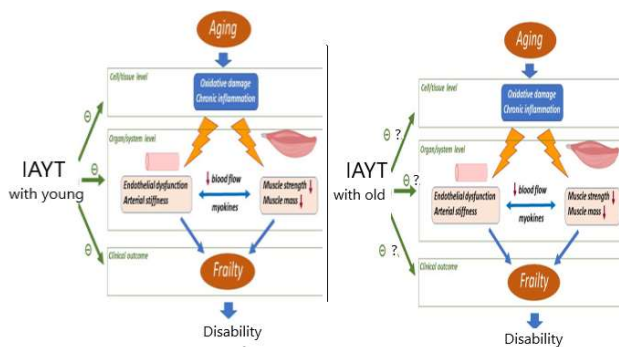


Figure 4. Age related alterations (A &B) and rectification after following IAYT for six weeks

Impairment in skeletal muscle and the cardiovascular system, two interrelated systems, results in compromised functional status in aging (Figure-4). Increased oxidative stress and inflammation in older subjects constitute the background for skeletal muscle and cardiovascular system alterations. Aged skeletal muscle mass and strength impairment are related to anabolic resistance, mitochondrial dysfunction, increased oxidative stress and inflammation as well as a reduced antioxidant response and myokine profile. Arterial stiffness and endothelial function stand out as the main cardiovascular alterations related to aging where increased systemic and vascular oxidative stress and inflammation play a key role. IAYT arises as modifiable determinants of functional outcomes in older persons. Less decrease with pulse wave velocity (PWV) and arterial stiffness in aged subjects as compared to younger (B of figure 4) is not adequately investigated so far. Future investigations are needed using older subjects aged 60 yrs. or above.

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 stiffness in young adults and older adults. 6-weeks IAYT program could be suggested as a most effective program to control the cardiovascular risk or CVD. In older adults, arterial stiffness changes are less as compared to young adults and hence it might take longer in old males to see a similar effect.

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