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EFFECT OF SHORT DURATION AEROBIC EXERCISE TRAINING ON REFLECTION INDEX, STIFFNESS INDEX AND PULSE WAVE VELOCITY

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Abstract : The study was aimed to establish the effect of aerobic exercise on reflection index (RI), stiffness index (SI) and brachial finger pulse wave velocity (BFPWV) in healthy subjects of Bangalore, India. Students of 18 to 25 years (males) were recruited according to the inclusion criteria. The subjects were trained on treadmill for a period of 8 weeks, and the above parameters were measured using BIOPAC software and doppler machine. ANOVA of repeated measures was done to see the effect of training on RI, SI and BFPWV with bonferroni correction. There was a significant decrease in above parameters (P< 0.0001) compared to basal levels. There was significant correlation between BFPWV and SI (P<0.001). 8 weeks of training showed beneficial effect by reducing BFPWV, SI, and RI and it returned towards baseline after subsequent 4 weeks of detraining. We conclude that changes are because of the effect of aerobic exercise and are reversible.

Key words : arterial stiffness aerobic exercise BFPWV

INTRODUCTION

Arterial stiffness in simple terms describes the rigidity of arterial walls. There are several methods to assess the arterial stiffness example pulse wave velocity (PWV), reflection index (RI), stiffness index (SI), ultrasound derived indices and magnetic resonance imaging (MRI) derived indices (1). Vascular stiffness develops from a complex interaction between stable and dynamic changes involving structural and cellular elements of the vessel wall. These vascular alterations are influenced by heamodynamic forces as well by extrinsic factors such as hormones, salt and glucose regulation. Simple aging and common diseases like hypertension, diabetes mellitus will also amplify the vascular changes that results in arterial stiffness number of life style changes and therapies that can reduce arterial stiffness including weight loss, exercise, salt reduction, neuroendocrine directed therapies such as targeting the renin angiotensin aldosterone system, natriuretic peptides, insulin modulators (2). The non invasive

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assessment of cardiovascular function by means of the peripheral pulse has gained substantial interest in recent year. The peripheral pulse provides a signal that establishes the presence of a beating heart and quantifies the cardiac rhythm and its variability with time (3), (4). Peripheral arterial pulse wave forms are obtained by different variety of instruments for example photoplethysmography (PPG) (3), digital volume pulse (5), applanation tonometry or arterial ton meter (4, 6, 7, 8), fidelity micro manometer (Millers instrument) (9, 10).

The present study was aimed to see the effect of aerobic exercise on all the parameters of peripheral arterial stiffness like RI, SI and brachial finger pulse wave velocity (BFPWV).

METHODS

Subjects

Male subjects in the age group of 18-25 years were recruited from the student and staff population of St John's medical college and hospital Bangalore. A brief history, general and systemic examination was performed and healthy subjects were recruited according to the inclusion criteria. All the procedures were approved by the ethical committee of St John's medical college Bangalore. To the subjects detailed description of protocol was explained and written informed consent was obtained. Weight was measured using digital scale (OEHNLE-WAAGEN GmbH & CO, Murrhardt, Germany) and height was measured to the nearest 0.1 cm using stadiometer (Holtain limited, CRYMYCH, DYFED, made in Britain). Forearm length was measured from point of appearance of the brachial pulse through doppler and photo-plethysmograph sensor on the finger.

Preparation of volunteers and procedure

Subjects came early morning in the post absorptive state, entire procedure was explained to the volunteers to allay their apprehension. Then the subjects underwent moderate intensity aerobic exercise training for half an hour thrice weekly alternate day over a period of 8 weeks. Bruce 3rd grade of treadmill exercise (treadmill speed of 4.8 kph and inclination of 10 degree) was adopted. This 3rd grade of exercise corresponded to 55% to 69% of target heart rate (THR) which represents the moderate degree exercise. Continuous monitoring of heart rate was done during the treadmill exercise with the help of an instrument called Welch Allyn.

Determination of arterial stiffness

Finger photo pulse plethysmography, lead II ECG and doppler recording was done and the waves obtained were acquired by the BIOPAC PRO software. A pulse transducer was wrapped around the left index finger to record the finger pulse wave by photo pulse plethysmography. The pulse plethysmograph measures the density of blood in the fingertip. Doppler probe was used to record the left brachial artery wave. Both waves were recorded simultaneously for 5 minutes. This recording was done every 2 weeks during the training period and after 4 weeks of detraining.

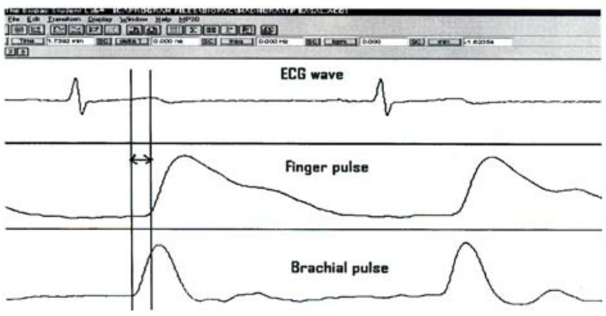

Fig. 1 : Recording of wave.

Calculation of RI, SI and BFPWV using pulse wave.

$$RI = \frac{\text{Amplitude of 2th peak (diastolic)}}{\text{Amplitude of 1st peak (systolic)}}$$

$$SI = \frac{\text{Height of the subject in meters (Ht)}}{\text{Time difference between the systolic and diastolic peak (PTT)}}$$

$$BFPWV = \frac{\text{Distance between the two points (finger tip to cubital fossa)}}{\text{Time interval between the foot points of finger pulse and pulse of the brachial artery } (\Delta T)}$$

RESULTS

The basal recordings of different parameters of 18 healthy male subjects are given in the Table I.

TABLE I : Subject characteristics (age group 18 to 25 years).

Variables	*Mean N=18*	*SD*
Age	20.44	±2.24
Height (meters)	1.70	±0.06
Weight (kgs)	61.49	±7.99
BMI	21.65	±2.22
SBP (mm Hg)	115.77	±4.46
DBF (mm Hg)	74.77	±5.16
HR (beats/min)	78.44	±4.79
RI (%)	62	±0.08
SI (m/s)	8.79	±0.68
BFPWV (m/s)	9.27	±0.36

TABLE II : Repeated measures ANOVA of different parameters at different time interval during the exercise training period including detraining period.

Variables	*Baseline*	*15 days*	*30 days*	*45 days*	*60 days*	*1 month detraining*	*P value*
RI	0.62(0.08)	0.60(0.05)	0.53(0.04)	0.48(0.04)	0.45(0.03)	0.50(0.06)	0.0001
SI	8.79(0.68)	8.15(0.45)	7.73(0.36)	7.40(0.37)	7.27(0.34)	7.70(0.56)	0.0001
BFPWV	9.27(0.36)	8.73(0.49)	8.10(0.43)	7.70(0.4)	7.51(0.35)	8.21(0.75)	0.0001

TABLE III : Repeated measures ANOVA of different parameters at different time interval during the exercise training period excluding detraining period with Bonferroni correction.

Variables	*Baseline*	*15 days*	*30 days*	*45 days*	*60 days*	*P value*
RI[1,2]	0.62(0.08)	0.60(0.05)	0.53(0.04)	0.48(0.04)	0.45(0.03)	0.0001
SI[1,2]	8.79(0.68)	8.15(0.45)	7.73(0.36)	7.40(0.37)	7.27(0.34)	0.0001
BFPWV[1,2]	9.27(0.36)	8.73(0.49)	8.10(0.43)	7.70(0.4)	7.51(0.35)	0.0001

-Values are Mean (S.D)
[1]Significant difference across 5 group using an ANOVA of repeated measures (P<0.05)
[2]Significantly different between the group's using a post-hoc Bonferroni-corrected pair-wise t-test

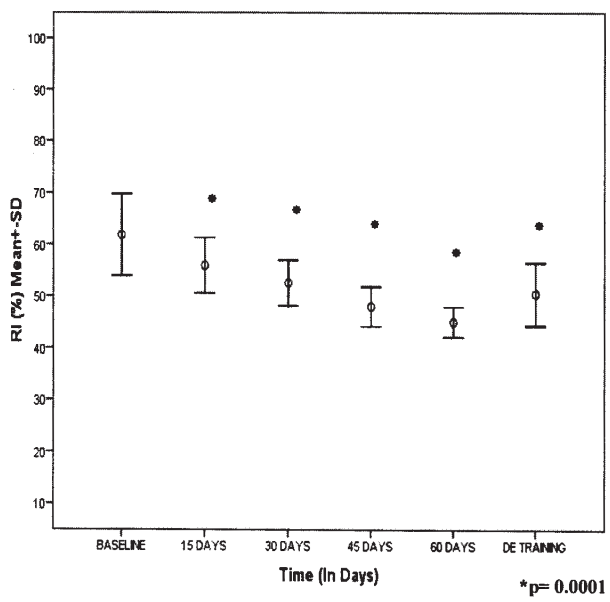

Fig. 2: Repeated measures ANOVA of RI.

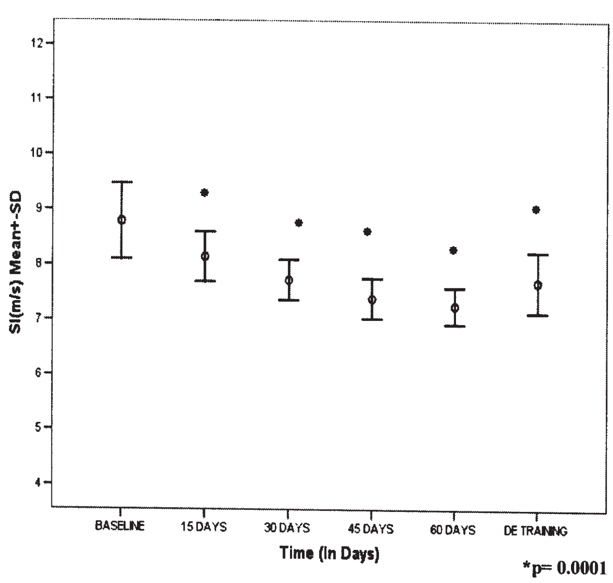

Fig. 3: Repeated measures ANOVA of SI.

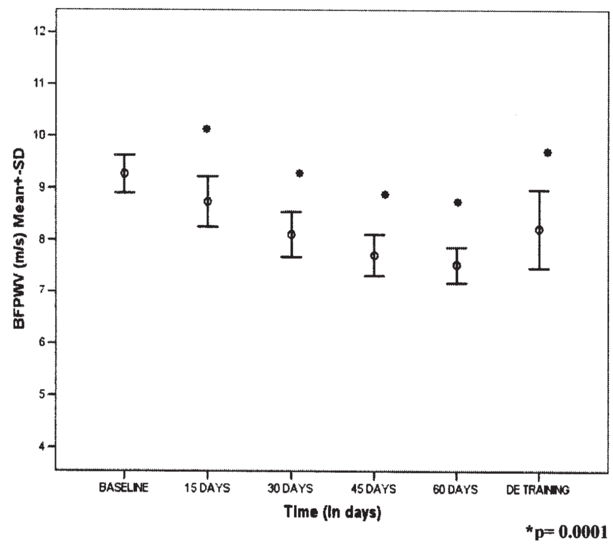

Fig. 4: Repeated measures ANOVA of BFPWV.

TABLE IV: Pearson Correlation between BFPWV and SI.

		Mean	*SD*	*Pearson correlation*	*P value*
Baseline	SI BFPWV	8.79 9.27	.68 .36	.38	0.116
After 15 days	SI BFPWV	8.15 8.73	.45 .49	.32	0.196
After 30 days	SI BFPWV	7.73 8.10	.36 .43	.55	†0.02
After 45 days	SI BFPWV	7.40 7.70	.37 .40	.85	*0.00
After 60 days	SI BFPWV	7.27 7.51	.34 .35	.86	*0.00
1 month detraining	SI BFPWV	7.70 8.21	.56 .75	.79	*0.00

DISCUSSION

The salient finding of our study was as follows: first, within one month of endurance training the BFPWV and SI significantly reduced indicating that arterial compliance increased which in our study we measured by brachial artery doppler waveform and finger pulse plethysmography. BFPWV measurements are comparable with those of aortic PWV or carotid femoral PWV (11) and brachial ankle PWV (BAPWV) (12).

Second, the increase in arterial compliance which was significant starting from 4 weeks of training ($P<0.0001$) continued till 8 weeks with a significant increase ($P<0.0001$). Arterial compliance is reflected by the decrease in BFPWV. There is significant correlation between BFPWV and stiffness index ($P<0.001$), our results are consistent with other study. (13) Third, the increase arterial compliance showed a trend to reverse at the end of one month after detraining, indicating a return to the baseline values a few months after cessation of endurance training. This confirms that the change in the arterial compliance was as a result of endurance training (14).

Study by Hayashi et al have shown that aerobic exercise training has more beneficial effect in the central artery by way of reducing stiffness as compared to the peripheral artery, nevertheless reduced compliance is seen in both types of arteries (6). The mechanism would be the increased production of NO (nitric oxide) during and also immediately after the exercise due to shear stress, but with repeated stimulation through regular exercise NO release remain elevated during the period between the exercise bouts and leads to vasodilatation. The study done by Kingwell et al demonstrated that lower limb exercise increased the upper limb blood flow. This suggests that stimulus is not related to local muscular adaptation but it is due to enhanced basal production of NO during the period between the exercise bouts (15). Regular exercise prevents and restores the age related decline in endothelial dependent vasodilatation. Endothelium is important for regulation of vascular tone and cardiovascular homeostasis. To see the affect of regular aerobic exercise study was done by De Souza C A et al in healthy young men, middle and older age group who were either sedentary or exercise trained individuals (tread mill exercise using Balkes protocol for 3 months). Forearm blood flow (FBF) was measured in all of them. Among the sedentary men FBF response to acetylcholine was 25% lower in middle and older age group compared to young group, in contrast, there was no age related difference in the vasodilatory response to acetylcholine among the endurance trained men (16). The elements of the arterial wall that determine its compliance are the composition of elastin and collagen (structural determinants) and the vasoconstrictor tone exerted by its smooth muscle cells (functional determinant). Because biochemical changes in the elastin-collagen composition of the arterial wall are believed to occur over years, it is unlikely that short-term regular aerobic exercise increased arterial compliance by this mechanism. However, it is possible that the increased pulse pressures and mechanical distension during the exercise sessions “stretched” collagen fibers and modified their cross-linking, thereby increasing arterial compliance. In this context, it is possible that regular exercise increased arterial compliance by reducing the chronic suppressive influence exerted by sympathetic-adrenergic tone either directly or by enhancing the sympathoinhibitory effect of NO(17). The vascular benefits of exercise are indirectly related to a decline in the release of neuro hormonal vasoconstrictors and reduced efferent sympathetic tone, and to endothelial mechanical signaling associated with increased pulsatile flow and stretch and consequent enhanced nitric oxide stimulation (18). By finding the indices like RI, SI and BFPWV we can easily identify the peripheral arterial stiffness, which helps in identifying the early cardiovascular diseases and we can advice the patients for the regular aerobic exercise training as it reduces the arterial stiffness and also reduces the incidence of cardiovascular diseases.

Conclusion

Moderate intensity aerobic exercise training has its effects on arterial compliance both in central and peripheral arteries. The reduced arterial stiffness would definitely decrease the incidence of cardiovascular diseases in a given population and at the peripheral level reduce and prevent micro vascular damage.

REFERENCES

1. Mackenzie IS, Wilkinson IB, Cockcroft JR. Assessment of arterial stiffness in clinical practice. *Q J Med* 2002; 95: 67–74.
2. Zieman SJ, Melenovsky V, Kass DA. Mechanisms, Pathophysiology and Therapy of arterial stiffness. *Arterioscler Thrombo Vase Biol* 2005; 25: 932–943.
3. Avolio A. The finger volume pulse and assessment of arterial Properties. *Journal of Hypertension* 2002; 20: 2341–2343.
4. Oliver JJ, Webb DJ. Non-invasive assessment of Arterial stiffness and Risk of Atherosclerotic Events. *Arterioscler. Thrombo Vase Biol* 2003; 23: 554–566.
5. Wang MC, Tsai WC, Chen JY. A Bio Signal Processing System for Pulse Wave Velocity detection. National Cheng University medical center Taiwan. *9th International Conference on Engineering Education.* 2006; 23–28.
6. Hayashi K, Sugawara J, Komine H, Meadi S, Yokio T. Effect of aerobic exercise training exercise training on the stiffness of central and peripheral arteries in middle aged sedentary men. *Japanese Journal of Physiology* 2005; 55: 235–239.
7. Azhim A, Akioka K, Akutagawa M. Effect of Aging and Exercise Training on the common Carotid Blood velocities in Healthy Men. *Proceedings of the 29nth Annual International Conference of the IEEE EMBS Cite Internationale Lyon, France.* 2007; 23–26.
8. McVeigh GE, Brattli CW, Morgan DJ. Age-related Abnormalities in Arterial Compliance Identified by Pressure Pulse Contour Analysis. *Hypertension* 1999; 33: 1392–1398.
9. McEniery CM, Yasmin, Hall IR, Qasem A, Wilkenson IB, Cockroft JR. Normal Vas cular Aging: Differential Effects on Wave reflection and Aortic Pulse Wave velocity. *J Am Coll Cardiol* 2005; 46: 1753–1760.
10. McEniery CM, Wallace S, Mackenzie IS et al. Endothelial Function is Associated with Pulse Pressure, Pulse Wave Velocity, and Augmenation Index in healthy Humans. *Hypertension* 2006; 48: 602–608.
11. Vaitkevicius PV, Fleg JL, Engel JH et al. Effects of Age and Aerobic Capacity on Arterial Stiffness in Healthy Adults. *Circulation* 1993; 88(11): 1456–1462.
12. Padilla JM, Berjano EJ, Saiz J, Facila L, Diaz P, Merce S. Assessment of relationship between Blood Pressure, Pulse Wave Velocity and Digital volume Pulse. *Computers in Cardiology* 2006; 33: 893–896.
13. Millasseau SC, Kelly RP, Ritter JM, Chowienczyk PJ. Determination of age related increase in large artery stiffness by digital pulse contour analysis. *Clinical Sciences* 2002; 103: 371–377.
14. Cameron JD, Dart AM. Exercise training increases total systemic arterial Compliance in humans. *Am J Physiol* 1994; 266: H693–H701.
15. Kingwell BA, Sherrard B, Jenneings G, Dart AM. Four weeks of cycle traing increases basal production of nitric oxide from the forearm. *Am J Physiol* 1997; 272: H1070–H1077.
16. DeSouza CA, Shapiro LF, Clevenger CM et al. Regular Aerobic Exercise Prevents and Restore Age-Relate Declines in Endothelium Dependent Vasodilation in Healthy Men. *Circulation* 2000; 102: 1351–1357.
17. Tanaka H, Dinenno FA, Monahan KD, Clevenger CM, DeSouza CA, Seals DR. Aging Habitual Exercise, and Dynamic Arterial Compliance. *Circulation* 2000; 102: 1270–1275.
18. Green DJ, Bilsborough W, Naylor LH. Comparison of forearm blood flow responses to incremental handgrip and cycle ergometer exercise relative contribution of nitric oxide. *J Physiol* 2005; 562: 617–628.