

## Original Research

# The efficacy of isometric handgrip training on arterial stiffness and blood pressure in elevated and stage 1 hypertensive individuals – An interventional study

Deepika Velusami\*, Soundariya Krishnamurthy, Shivayogappa S. Teli, Senthamil Selvi S., Mangani Mangalavalli S.

Department of Physiology, Sri Manakula Vinayagar Medical College and Hospital, Madagadipet, Puducherry, India-605107

\*Correspondence to: Deepika Velusami, Associate Professor, Department of Physiology, Sri Manakula Vinayagar Medical College and Hospital, Madagadipet, Puducherry, India-605107, E-mail id: deepy843@gmail.com

Received: 27 November 2021 / Accepted: 11 January 2022

### Abstract

**Objectives:** Hypertension is considered a risk factor for cardiovascular diseases. Various forms of exercise are recommended for the pre-hypertensive stage as a prevention measure. The objective of the study was to evaluate the effect of isometric handgrip resistance exercise on blood pressure (BP) and arterial stiffness in elevated and stage 1 hypertensive individual. **Materials and Methods:** In this interventional study, 50 pre-screened pre-hypertensive individuals participated in the isometric handgrip exercise training. Participants were instructed to follow 40% maximum voluntary contraction (MVC) with three sessions per week for 8 weeks. BP and vascular indices namely reflection and stiffness indices were measured and compared before and after the exercise. **Results:** Forty individuals participated in the program and were divided into two groups: Group I (n=21) with elevated BP and Group II (n=19) with stage 1 hypertension. Our study report indicates that the systolic BP was significantly decreased in both the groups ( $p < 0.001$ ) while diastolic BP decreased only among the elevated BP group ( $p = 0.01$ ). Vascular indices did not report any significant change in both groups. Systolic ( $p = 0.001$ ), diastolic ( $p = 0.03$ ), pulse pressure ( $p = 0.001$ ) and mean arterial pressure ( $p < 0.001$ ) were significantly reduced when both the groups were taken together for the analysis. Heart rate was a significantly positive correlation with the vascular indices ( $p < 0.001$ ), similarly, diastolic BP was significantly positively correlated with stiffness index ( $p < 0.001$ ). **Conclusion:** Isometric handgrip exercise with 40% MVC with three sessions per week for 8 weeks is effective in reducing the BP levels but has no effect on arterial stiffness. Thus, this form of exercise can be recommended for the young pre-hypertensive.

**Keywords:** isometric handgrip exercise, elevated blood pressure, stage 1 hypertension, pre-hypertension.

### Introduction

Hypertension is referred to as a “silent killer” since it may not produce any warning signs and symptoms and is the major cause of premature deaths globally and is also associated with cardiovascular diseases. The precursor stage was named by the Joint National Committee on prevention, detection and treatment of

high blood pressure as ‘pre-hypertension’ [1] in 2003, which has been further re-classified as “elevated” and “stage 1” hypertension in 2018, by the American Heart Association Task Force in 2017. In view of the increasing trends in hypertension in young individuals, blood pressure assessment in all young individuals at every opportunity is both prudent and justified. Non-pharmacological therapies are recommended for elevated and



stage 1 hypertension as treatment and prevention strategies for hypertension [2].

The American College of Sports Medicine (ACSM) and other health organizations [3] advocate increasing physical activity with various types and forms of exercise as the first-line intervention. Exercises like aerobic, dynamic resistance, and isometric resistance exercises are all proven best non-pharmacological approaches in reducing the blood pressure in hypertension individuals.

Arterial stiffness is proved as an emerging biomarker reflecting vascular damage in young individuals [4]. Arterial stiffness measured using digital volume pulse (DVP) has been proved to be validated, simple, non-invasive, and a reproducible technique with minimal intra-observer variation [5]. Increased arterial stiffness in normal individuals is associated with accelerated blood pressure progression [6]. Hypertension and arterial stiffness are closely associated with each other, and whether hypertension is a cause or consequence for arterial stiffness is a debatable issue [7].

Aerobic exercise and dynamic resistance exercises of 90–150 min/week have proved to decrease the blood pressure in hypertensive by 5/8 mmHg and 4 mmHg, respectively. Isometric resistance exercise 4×2min (handgrip), 1-minute rest between exercises, 30–40% maximum voluntary contraction with 3 sessions per week for 8–10 weeks is found to decrease the blood pressure by 5 mmHg in hypertensive and 4 mmHg in normotensives [2].

Vast literature persists exploring the effects of aerobic exercises and blood pressure reductions [8, 9] in various age groups individuals but the effect of isometric handgrip exercise in apparently healthy individuals with elevated and stage 1 hypertension is least explored. Moreover, our previous studies [4, 10] in young individuals reported a significant increase in blood pressure and increased prevalence of pre-hypertension. With the interventional strategies in mind and to aid the young individuals, the present study was planned to evaluate the effect of isometric handgrip resistance exercise on blood pressure and arterial stiffness in elevated and stage 1 hypertensive individuals.

## Materials and Methods

This was an interventional study carried out in the Department of Physiology, Sri Manakula Vinayagar Medical College and Hospital, Puducherry, India. All the 50 pre-screened pre-hypertensive individuals, of age group 17–20 years, screened during medical health check-ups organized by the institution at the time of joining the course were included in the study. These subjects were further classified based on the blood pressure values as two groups: Group I (n=21): Elevated blood pressure (systolic blood pressure ranging from 120–129 mmHg and diastolic blood pressure <80 mmHg); Group II (n=19): Stage 1 Hypertension (systolic blood pressure ranging from 130–139 mmHg or diastolic blood pressure ranging from 80–89 mmHg) [2]. The study was initiated after obtaining the institutional ethical committee approval. A written assent and consent form was obtained from all the study participants.

## Methodology

A counseling session was conducted to all participants included in the study addressing the ill effects of increased blood pressure and the effectiveness of resistance training programs. No diet alteration or any other forms of new exercise should be introduced during the six weeks training program. All the 50 pre-hypertensive individuals were instructed to perform isometric handgrip exercise 4 times for 2 minutes with 1 minute rest between exercises. Out of 50 subjects, six students were not willing to participate and four didn't complete the 8 weeks exercise training program.

## Isometric resistance training protocol

The exercise training was done using the handgrip spring dynamometer and monitored in the Department of Physiology. Participants were instructed to adopt 40% maximum voluntary contraction (MVC) with three sessions per week for 8 weeks [11]. The handgrip dynamometer

was held in the dominant hand and compressed for a brief duration of 4–5 seconds and isometric contraction was recorded. Three attempts were given with a pause of 10 seconds between each attempt. The average of the three recordings was taken as MVC. After rest, the subjects were instructed to perform 40% of MVC for a maximum of 3 minutes. The exercise was repeated five times with 5 minutes rest after each contraction.

### Recording of blood pressure

Blood pressure was measured in the right arm in sitting posture using a standardized aneroid sphygmomanometer after a 10-minute rest period. Three measurements were taken with 5 minutes intervals and the average of the three values was considered for the analysis. The blood pressure was recorded 4 weeks and 8 weeks after the exercise and compared with the pre-exercise recorded levels. Pulse pressure was calculated as the difference between systolic and diastolic blood pressure. Mean arterial pressure was calculated as pulse pressure + (Diastolic blood pressure/3).

### Principle and Recording of arterial stiffness

DVP technique of measuring arterial stiffness is based on transmitting the infrared light through the finger with a wavelength of 940 nm (Photoplethysmography). The principle involves the usage of a pressure transducer that converts the pressure changes to voltage changes. It measures the vascular measures namely: Stiffness Index (SI) and Reflection Index (RI). DVP records two peaks, the systolic and the diastolic peak. The systolic peak represents the pulse wave transmitted from the left ventricle to the finger directly and the diastolic peak is from the pulse wave transmitted along the aorta to the small arteries in the lower parts, from where they are reflected along the aorta as a reflected wave. The path length is directly proportional to the subject's height (h). Vascular indices are calculated using the formulas as given:

$$SI = \text{Subject's height (h)} / \text{Pulse transit time (PTT)}$$

$$RI = \text{Magnitude of diastolic peak (b)} / \text{Magnitude of the systolic peak (a)} \times 100$$

Subjects were requested to report to the physiology lab and DVP was measured in a temperature-controlled room ( $22 \pm 2^\circ\text{C}$ ), in the right index finger for 5 minutes using the Digital Polyrite (RMS vital module LF201308, India). Pulse wave contour analysis was done using the Polyrite D software that gave the PTT, SI, and RI. RI and SI were recorded 4 weeks and on the 8th week after the exercise training period and compared.

### Statistical analysis

Data entry and statistical analysis were performed using Microsoft excel and IBM SPSS statistics 26, respectively. Frequency for all variables was obtained. Continuous variables were expressed as means and standard deviations. The student's paired t-test was used to assess differences between the means. The level of significance is fixed at 0.05. The confidence interval is set as 95%. Correlation between the variable was evaluated using Pearson's Correlation.

### Results

The basal characteristic clinical features of the study participants are represented in Table 1. Of the 40 participants, 24 were males and 16 were females. Blood pressure and vascular indices among the elevated and stage 1 hypertension before and after 8 weeks of exercise are represented in Table 2. Systolic blood pressure reported a significant decrease in both the groups ( $p < 0.001$ ) while diastolic blood pressure decreased only among the elevated blood pressure group ( $p = 0.01$ ) but did not show any significant decrease among the stage 1 hypertensive group ( $p = 0.49$ ) after 8 weeks of exercise. Also, pulse pressure and mean arterial pressure were significantly reduced in Group I with  $p = 0.001$  and  $p < 0.001$ , respectively.

The reflection index did not report any significant change among elevated ( $p = 0.15$ ) and stage 1 hypertensive group ( $p = 0.73$ ) after the

Table 1: Basal clinical characteristics of the study participants.

Parameters	Mean $\pm$ SD
Age (years)	18.00 $\pm$ 0.78
Height (meters)	1.65 $\pm$ 0.09
Weight (kilograms)	76.53 $\pm$ 21.54
BMI (kg/m <sup>2</sup> )	27.63 $\pm$ 5.98
SBP (mmHg)	128.35 $\pm$ 6.37
DBP (mmHg)	75.62 $\pm$ 8.38
PP (mmHg)	52.75 $\pm$ 8.16
MAP (mmHg)	77.93 $\pm$ 6.50
Heart rate (beats/minute)	89.62 $\pm$ 8.17
RI (%)	50.1 $\pm$ 12.96
SI (m/seconds)	5.28 $\pm$ 1.39

SBP, systolic blood pressure; DBP, diastolic blood pressure; PP, pulse pressure; MAP, mean arterial pressure; RI, reflection index; SI, stiffness index.

Table 2: Blood pressure and vascular indices among the elevated and stage 1 hypertension before and after 8 weeks of exercise.

	Pre-exercise levels	8 weeks after exercise	p-Value
Group 1: Elevated (n=21)			
SBP	124 $\pm$ 2.82	119.85 $\pm$ 3.08	<0.001
DBP	78.81 $\pm$ 5.76	70.33 $\pm$ 5.87	0.01
PP	52.19 $\pm$ 6.49	49.52 $\pm$ 6.07	0.001
MAP	76.13 $\pm$ 4.84	72.97 $\pm$ 4.48	<0.001
HR	85.24 $\pm$ 4.43	84.57 $\pm$ 4.46	0.003
RI	49.57 $\pm$ 11.32	48.09 $\pm$ 10.61	0.15
SI	5.57 $\pm$ 1.27	5.52 $\pm$ 1.35	0.39
Group 2: Stage 1 hypertension (n=19)			
SBP	133.15 $\pm$ 5.72	131.94 $\pm$ 6.07	<0.001
DBP	79.84 $\pm$ 8.92	79.26 $\pm$ 10.59	0.49
PP	52.57 $\pm$ 9.70	52.33 $\pm$ 10.45	0.24
MAP	79.87 $\pm$ 7.40	78.49 $\pm$ 8.02	0.09
HR	94.47 $\pm$ 8.69	77.42 $\pm$ 25.74	0.01
RI	51.28 $\pm$ 14.64	51.67 $\pm$ 14.30	0.73
SI	4.96 $\pm$ 1.39	5.24 $\pm$ 1.50	0.02

SBP, systolic blood pressure; DBP, diastolic blood pressure; PP, pulse pressure; MAP, mean arterial pressure; HR, heart rate; RI, reflection index; SI, stiffness index.  $p < 0.05$  was considered to be statistically significant.

8-week exercise training. Similarly, the stiffness index also didn't report producing a significant change among the elevated group ( $p=0.39$ ) whereas in the stage 1 hypertensive group it showed a significant increase ( $p=0.02$ ) before and after exercise.

Graphs 1–6 represent the graphical presentation of the blood pressure and vascular indices parameters in individuals reporting increased blood pressure levels (elevated and stage 1 hypertension), before and after 8-week exercise training. Systolic and diastolic blood pressure showed a significant decrease ( $p < 0.001$ ) and ( $p=0.03$ ), respectively. Similarly, pulse pressure and mean arterial pressure also showed significant changes before and after exercise, ( $p=0.001$ ) and ( $p < 0.001$ ), respectively. Vascular indices didn't report any significant changes ( $p=0.99$  and  $p=0.1$ ).

Table 3 represents the correlation between blood pressure and vascular indices among the two groups. Heart rate was a significantly positive correlation with the vascular indices ( $p < 0.001$ ), similarly, diastolic blood pressure was significantly positively correlated with stiffness index ( $p < 0.001$ ).

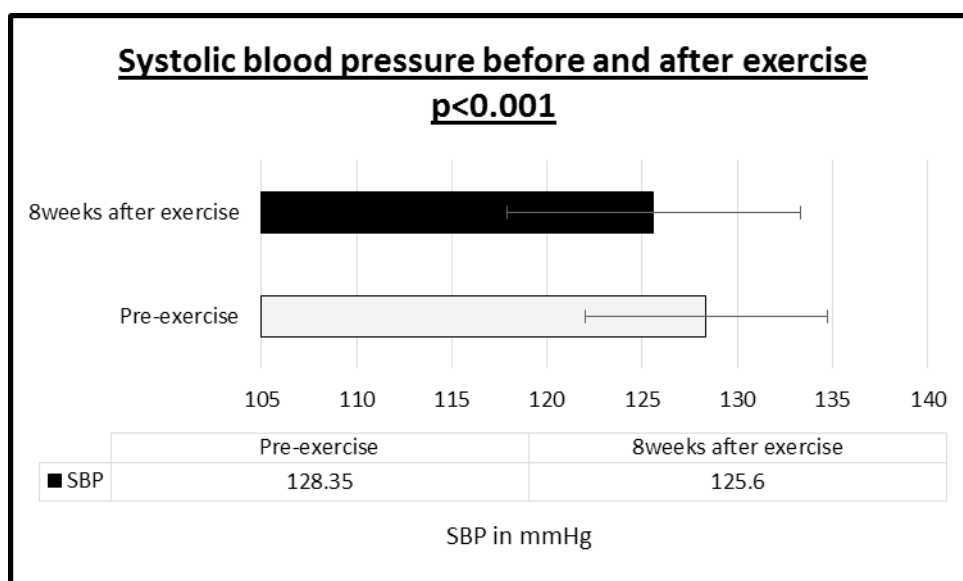
## Discussion

In the present study, out of 40 participants; 21 reported elevated blood pressure while 19 individuals had stage 1 hypertension. Both the groups reported a significant decrease in the systolic blood pressure whereas diastolic blood pressure was decreased only in the elevated blood pressure group after 8 weeks of isometric handgrip exercise training. Heart rate was significantly reduced in stage 1 hypertensive group. Mean arterial pressure was significantly reduced in the elevated blood pressure group. Reflection and stiffness indices didn't report any significant changes after the training program. When both the groups were taken together and analyzed systolic blood pressure, diastolic blood pressure, pulse pressure, and mean arterial blood pressure were significantly reduced but vascular indices showed no significant changes after exercise. Mean arterial pressure was significantly correlated with diastolic blood pressure and

Table 3: Pearson’s correlation between blood pressure and vascular indices.

	SBP		DBP		MAP		RI		SI	
	r	p	r	p	r	P	r	p	R	p
<b>SBP</b>	–	–	0.46	<0.001	0.09	0.44	0.12	0.31	–0.07	0.54
<b>DBP</b>	0.46	<0.001	–	–	–0.38	<0.001	–0.18	0.11	0.05	0.6
<b>MAP</b>	0.64	<0.001	–0.38	<0.001	–	–	0.27	<b>0.01</b>	–0.11	0.3
<b>RI</b>	0.12	0.3	–0.17	0.12	0.27	<b>0.01</b>	–	–	0.35	<b>0.001</b>
<b>SI</b>	–0.07	0.54	0.05	0.6	–0.11	0.3	0.35	<b>0.001</b>	–	–

p<0.05 was considered to be statistically significant. SBP, systolic blood pressure; DBP, diastolic blood pressure; MAP, mean arterial pressure; RI, reflection index; SI, stiffness index. p<0.05 was considered to be statistically significant.

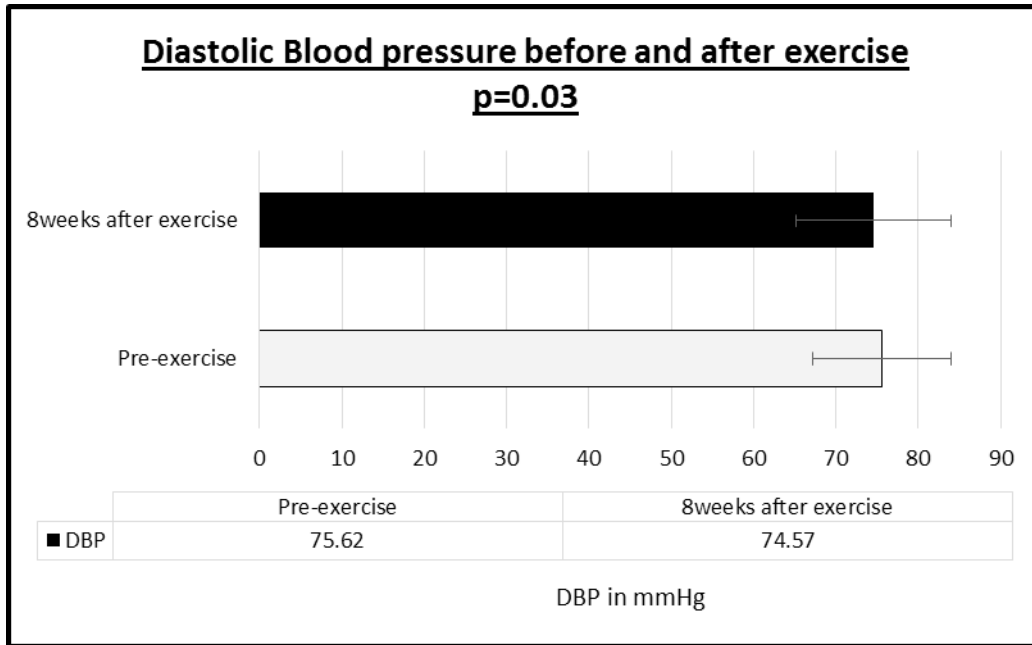


Graph 1: Represents the systolic blood pressure in elevated and stage 1 hypertensive (grouped together) before and after exercise.

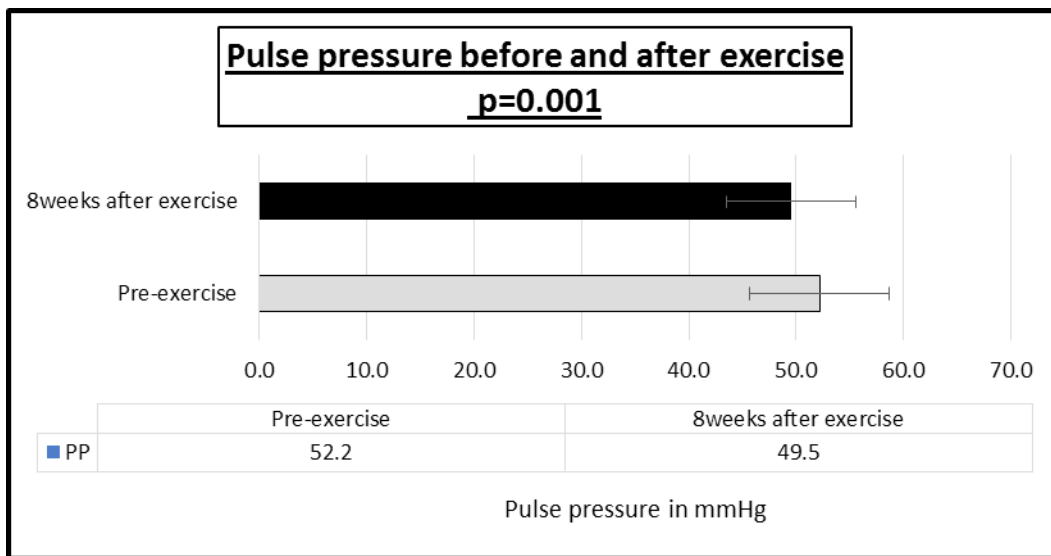
reflection index, whereas stiffness index didn’t show any significant correlation with any blood pressure parameters.

The benefits of exercise training are well documented. A systematic review by Loaiza-Betancur AF in 2020 reports that low-intensity isometric handgrip exercise is efficient in reducing the systolic, diastolic and mean arterial pressure, thus proposing that, this form of exercise can be an alternative in lifestyle blood pressure management [12]. It is established that isometric exercise can reduce blood pressure even in young adult normotensives [13, 14]. A randomized controlled trial involving 400 pre-hypertensive subjects by Ogbutor GU et al., in 2019 reports that the

blood pressure level increased immediately after isometric exercise but returned to pre-exercise levels within 10 minutes of post-exercise. They also reported that isometric handgrip exercise training at 30% maximum voluntary contraction for 2 minutes each day along with combination with lifestyle modification was effective in reducing the blood pressure levels [15]. The acute increase is due to the increased cardiac output, since heart rate and stroke volume both increase while the peripheral resistance shows a slight decrease or no change. The clear mechanism involving a reduction in blood pressure following the isometric exercise training is yet to be fully understood but the possible explanation as



Graph 2: Represents the diastolic blood pressure in elevated and stage 1 hypertensive (grouped together) before and after exercise.

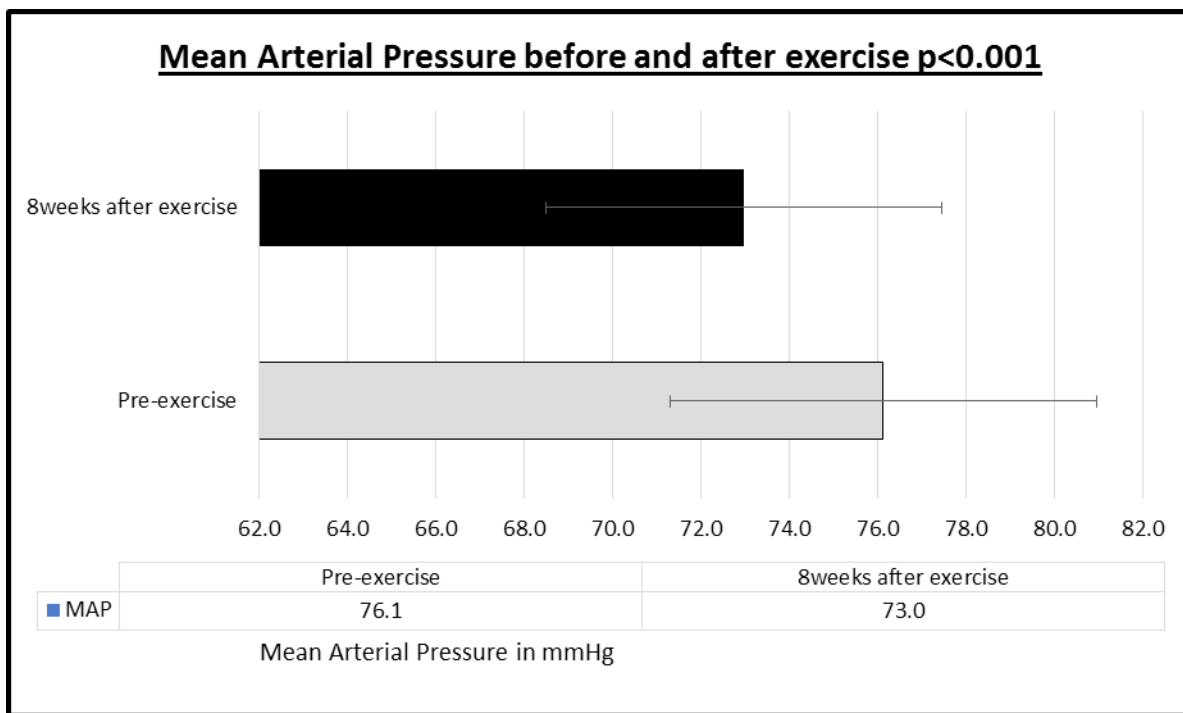


Graph 3: Represents the pulse pressure in elevated and stage 1 hypertensive (grouped together) before and after exercise.

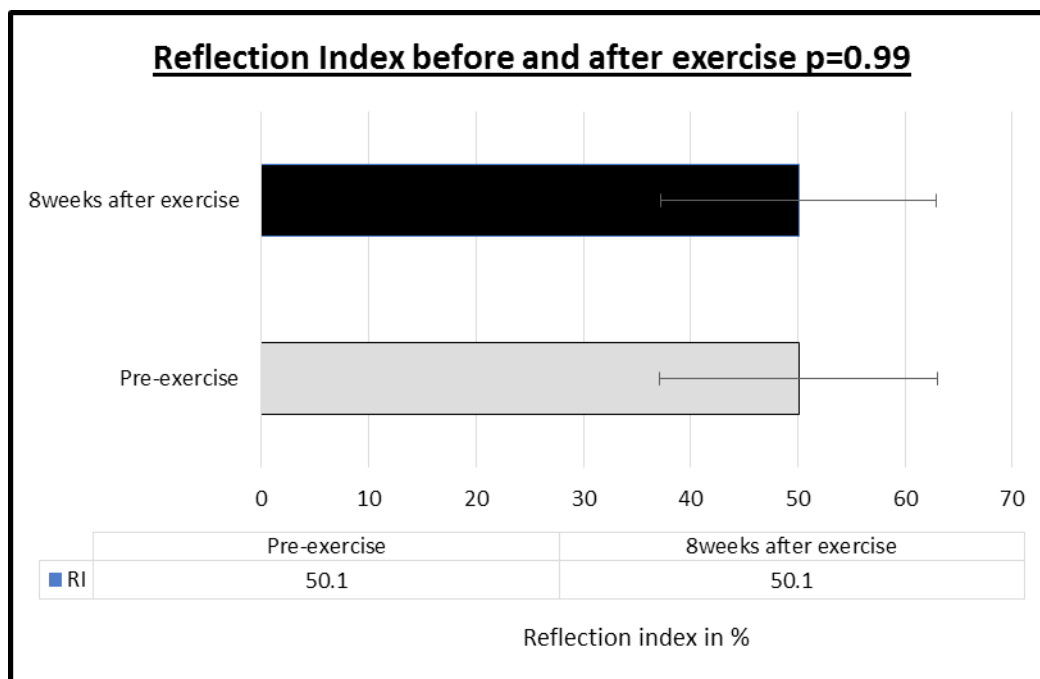
per review by Millar P. J. et al., in 2014 states that these effects include improvement in conduit and resistance vessel endothelium-dependent dilation, oxidative stress and autonomic regulation of the blood pressure and heart rate [16].

In our study vascular indices, namely reflection and stiffness indices reflecting the arterial stiffness showed no significant change after the exercise training. In contrary to our

results, a study carried out in 33 hypertensives proved that 12 weeks of isometric with 4 x 2min sets alternating the hands at 30% maximum voluntary contraction reduced the arterial stiffness [17]. Another study involving boys and men reported that post-isometric exercise boys report a decrease in arterial stiffness while men showed an increase in stiffness, which may be attributable to quicker recovery in systolic blood pressure in



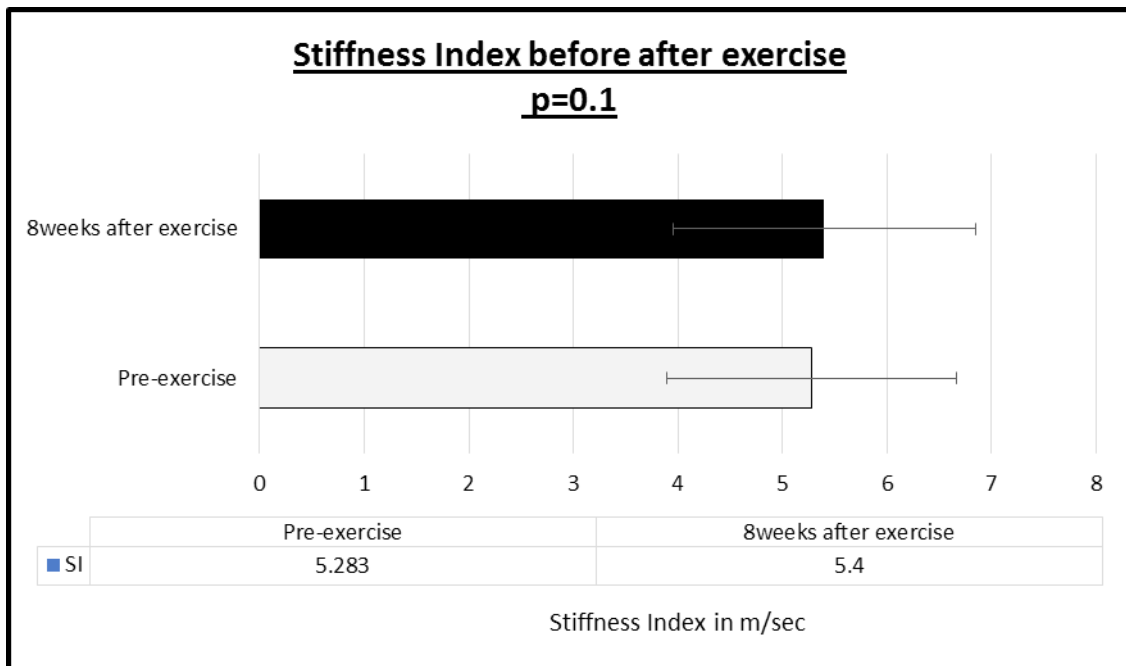
Graph 4: Represents the mean arterial pressure in elevated and stage 1 hypertensive (grouped together) before and after exercise.



Graph 5: Represents the reflection index in elevated and stage 1 hypertensive (grouped together) before and after exercise.

boys in comparison to men [18]. It is also reported that pulse wave velocity which is considered as a reliable index of arterial stiffness is correlated with diastolic blood pressure and mean arterial pressure. It was elevated by 3 minutes supine

non-dominant isometric handgrip exercise performed at 30% MVC [19]. These contrary results indicate that changes in arterial stiffness following the isometric handgrip exercise depend on the maximum voluntary contraction, duration of



Graph 6: Represents the stiffness index in elevated and stage 1 hypertensive (grouped together) before and after exercise.

the training program, minutes of training done, and the technique used to measure arterial stiffness. Another study by Hartog R. et al., in 2018 reports that the vascular indices vary depending on the age factor also [20]. Thus, our study findings could not produce any significant change in arterial stiffness remains justified.

The strength of the study was that it was an intervention-based study that helped the pre-hypertensive individuals to restore their normal blood pressure. The limitation was its small sample size, age, gender-based analysis was not done. Also, other factors like BMI, dietary habits, family history of hypertension, autonomic function tests were not considered for the study. Future research involving large-scale individuals with various intensities and durations of isometric handgrip exercise can be planned to gain better insight.

## Conclusion

Due to the trending focus towards “non-pharmacological” treatment therapies for hypertension, usage of isometric handgrip exercise training remains judicious and acceptable. The study concludes that the handgrip isometric

exercise can be recommended for individuals with elevated and stage 1 hypertension and is effective in lowering blood pressure levels.

## Conflict of interest

The authors declare no conflict of interest.

## References

- Chobanian, A. V., Bakris, G. L., Black, H. R., et al. (2003). Seventh report of the Joint National Committee on prevention, detection, evaluation, and treatment of high blood pressure. *Hypertension*. 42:1206–1252.
- Whelton, P. K., Carey, R. M., Aronow, W. S., et al. (2018). 2017 ACC/AHA/AAPA/ABC/ACPM/AGS/APhA/ASH/ASPC/NMA/PCNA Guideline for the prevention, detection, evaluation, and management of high blood pressure in adults: A report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines. *J Am Coll Cardiol*. 2018; 71:e127–248.
- Baster, T., Baster-Brooks, C. (2005). Exercise and hypertension. *Aust Fam Physician*. 34(6):419–424.
- Deepika, V., Vijayakumar, R. (2018). Impact of body mass index on arterial stiffness in young prehypertensives: A cross sectional study. *J Res Health Sci*. 18(1):e00402.
- Gunarathne, A., Patel, J. V., Hughes, E. A., Lip, G. Y. (2008). Measurement of stiffness index by digital volume pulse analysis

- technique: Clinical utility in cardiovascular disease risk stratification. *Am J Hypertens.* 21:866–872.
6. Kaess, B. M., Rong, J., Larson, M. G., et al. (2012). Aortic stiffness, blood pressure progression, and incident hypertension. *J Am Med Assoc.* 308:875–881.
  7. Humphrey, J. D., Harrison, D. G., Figueroa, C. A., Lacolley, P., Laurent, S. (2016). Central artery stiffness in hypertension and aging: a problem with cause and consequence. *Cir Res.* 188:379–381.
  8. Cornelissen, V. A., Smart, N. A. (2013). Exercise training for blood pressure: a systematic review and metaanalysis. *J Am Heart Assoc.* 2:e004473.
  9. Whelton, S. P., Chin, A., Xin, X., He, J. (2002). Effect of aerobic exercise on blood pressure: a meta-analysis of randomized controlled trials. *Ann Intern Med.* 136:493–503.
  10. Deepika, V., Vijayakumar, R. (2018). Evaluation of neutrophil-lymphocyte ratio and arterial stiffness indices among young prehypertensives: A cross sectional study. *Asian J Pharm Clin Res.* 11:154–157.
  11. Inder, J. D., Carlson, D. J., Dieberg, G., McFarlane, J. R., Hess, N. C., Smart, N. A. (2016). Isometric exercise training for blood pressure management: A systematic review and meta-analysis to optimize benefit. *Hypertens Res.* 39:88–94.
  12. Loaiza-Betancur, A. F., Chulvi-Medrano, I. (2020). Is low-intensity isometric handgrip exercise an efficient alternative in lifestyle blood pressure management? A systematic review. *Sports Health.* 12(5):470–477.
  13. Loaiza-Betancur, A. F., Pérez Bedoya, E., Montoya Dávila, J., Chulvi-Medrano, I. (2020). Effect of isometric resistance training on blood pressure values in a group of normotensive participants: A systematic review and meta-analysis. *Sports Health.* 12(3):256–262.
  14. Smart, N. A., Way, D., Carlson, D., et al. (2019). Effects of isometric resistance training on resting blood pressure: Individual participant data meta-analysis. *J Hypertens.* 37(10):1927–1938.
  15. Ogbutor, G. U., Nwangwa, E. K., Uyagu, D. D. (2019). Isometric handgrip exercise training attenuates blood pressure in prehypertensive subjects at 30% maximum voluntary contraction. *Niger J Clin Pract.* 22(12):1765–1771.
  16. Millar, P. J., McGowan, C. L., Cornelissen, V. A., Araujo, C. G., Swaine, I. L. (2014). Evidence for the role of isometric exercise training in reducing blood pressure: Potential mechanisms and future directions. *Sports Med.* 44(3):345–356.
  17. Cahu Rodrigues, S. L., Farah, B. Q., Silva, G., Correia, M., Pedrosa, R., Vianna, L., Ritti-Dias, R. M. (2020). Vascular effects of isometric handgrip training in hypertensive. *Clin Exp Hypertens.* 42(1):24–30.
  18. Schroeder, E. C., Ranadive, S. M., Heffernan, K. S., Jae, Y. S., Fernhall, B. (2017). The acute effect of maximal aerobic and isometric exercise on arterial stiffness parameters in boys and men. *Artery Res.* 19:24–28.
  19. Reid, K. F., Conway, M. A. (2006). Haemodynamic determinants of elevated pulse wave velocity during acute isometric handgrip exercise. *Ir J Med Sci.* 175:13–19.
  20. Hartog, R., Bolignano, D., Sijbrands, E., Pucci, G., Mattace-Raso, F. (2018). Short-term vascular hemodynamic responses to isometric exercise in young adults and in the elderly. *Clin Interv Aging.* 13:509–514.