

Research article

A doppler ultrasonographic observation of interventional postural alterations on shear rates in peripheral arteriesVinay Kumar N.¹, Gugapriya T.S.², Guru Thangiah Arun³, Balaji P.K.⁴¹Department of Anatomy, Government Medical College, Palakkad, 678013, Kerala, India²Department of Anatomy, All India Institute of Medical Sciences, Nagpur, 441108, Maharashtra, India³Specialist Radiologist, Hamad Medical Corporation, 60789, Qatar⁴Department of General Medicine, SRM Trichy Medical College Hospital & Research Centre, Trichy, 621105 Tamil Nadu, India

(Received: September 2021

Revised: March 2022

Accepted: April 2022)

Corresponding author: T. S. Gugapriya. Email: guga.tarun@gmail.com

ABSTRACT

Introduction and Aim: Drastic life style changes had resulted in increased reports of morbid atherosclerosis in young adults which is potentially a serious inflammatory condition which causes arteries to become harder and blocked with lipid accumulation known as plaques or atheroma. In the present study, effect of changes in posture on the resting shear rate (SR) was studied in arteries of both extremities.

Materials and Methods: A cross sectional observational doppler ultrasound study was done in 30 healthy subjects, who satisfied a pre-set inclusion and exclusion criteria. The mean blood flow velocity (BV) and diameter were measured for both brachial arteries and femoral arteries in supine, sitting with leg fully extended, sitting with leg flexed at 90°, standing with and without slight head tilting of 10° postures after resting the subjects for 10 minutes in between each posture. The SR in various postures were calculated and tabulated. The data was statistically analysed using independent 't' test and one-way ANOVA. Post Hoc test was applied for analysing statistical significance of SR in between postures.

Results: The femoral artery showed significantly lower SR ($P < 0.001$) in all the postures studied when compared to brachial artery. On comparing posture within brachial and femoral artery by applying one-way ANOVA with Post Hoc test, only femoral showed significant difference in SR between postures.

Conclusion: The postural effect in SR of arteries in lower limb may lead to alterations in the endothelium of arteries resulting in increased atherogenicity as compared to upper limb arteries.

Keywords: Shear rate; blood flow velocity; peripheral artery diameter; atherosclerosis; haemodynamic shear stress.

INTRODUCTION

Drastic life style changes in recent years have resulted in increased reports of morbid atherosclerosis in young adults (1-3). Dyslipidaemia is reported to be 37.5% and 62% among 15–64-year-old and young industrial workers respectively (4). Studies compared the susceptibility of vessels of extremities and coronary vessels to atherosclerosis. Among them, few studies claimed higher predisposition of lower limbs for atherosclerotic lesion when compared to upper extremities (5). On the contrary; studies also reported that the brachial artery is equally susceptible to atherosclerosis in comparison to coronary arteries (6). Inquiry into factors making these vessels prone for atherosclerosis, focused shear stress as the prime phenomenon contributing to occurrence of this condition.

Haemodynamic Shear stress is defined as a force of biomechanical origin. It can be obtained by using models of fluid dynamics wherein the flow of blood,

the dimensions of the vessel and viscosity of the blood are used to derive it. It is calculated as product of viscosity of blood and shear rate (SR) in vessel wall and expressed in units of dynes/cm². This frictional force of blood on endothelium of arteries plays a crucial role in controlling blood flow and maintenance of quality of blood vessels (7). Blood flowing through blood vessels is considered to be expressing non-Newtonian fluid characters. Also, the blood viscosity was proved to depend on haemodynamic SR or duration of vessel deformation. Blood undergoes shear thinning phenomena when exposed to high SR. Nevertheless, haemodynamic SR exhibits non-linear relation to shear stress (8). This haemodynamic alteration especially low SR has been proposed by many studies as an important determinant of endothelial function that stimulates an atherogenic phenotype especially in non-coronary atherosclerosis (7, 9-12).

Different points of arterial tree exhibit variation in the SR depending on the anatomy or geometry of the

vessel. Few studies claimed SR to be limb specific by showing difference between SR of arteries present in both limbs (13-16). Studies exists that showed variation in SR due to stimulatory occlusion by inflated cuff, exercise or incremental activity within or between arteries of both upper and lower limbs (17,18). Even though minimal data was available on the effects of different postures like supine, sitting and standing on SR and its influence on atherogenesis in the peripheral arteries (19, 20). There is still lack of clear data on the impact of postures in changing the SR between upper and lower limb arteries.

So, this research using doppler ultrasound was planned to increase our understanding and knowledge about the possible reason for difference in the incidence of atherosclerosis between upper and lower limb arteries, by way of measuring the effect of changes in posture on the resting SR by determining the blood flow velocity (BV), diameter of brachial arteries and femoral arteries in supine, sitting and standing postures in healthy normal volunteers.

MATERIALS AND METHODS

The present study is a cross sectional observational one conducted with a sample size of 30 healthy volunteers in the age group of 20-30 years of both genders attending outpatient department. The sampling method used for determining the sample size based on pervious study data was that of convenient sampling process (19). The enrolled subjects for the study were normotensive, non-obese, non-smoker and not on antihypertensive, anti-lipidemic medications. They were screened by measuring blood pressure, calculating BMI and evaluating a general clinical history questionnaire with physical examination.

Each day only two participants were studied. One day prior to the scheduled intervention the participants were informed to abstain from taking caffeine and doing any exercise. Just before examination, participants were asked to rest for 15 minutes followed by recording heart rate and blood pressure.

An Ultrasound doppler machine (GE Voluson S8) was

utilised to record measurements. Anatomical landmarks for placing the transducer of Doppler ultrasound were marked in the nondominant limb between anterior axillary fold and cubital fossa for brachial and 8 to 10 cm distal to branching of femoral artery in femoral triangle for femoral. Both the arteries were measured at a point without branches and tortuosity. The BV was measured using a transducer of 7 - 10 MHz frequency range and diameter of arteries at an insonation angle of $\leq 60^\circ$ in spectral doppler mode. In both arteries, BV in cm/sec was measured first for a duration of 60 seconds followed by diameter in mm for the next 15 seconds (Fig. 1). The measurements were done in supine, sitting with leg fully extended (Sitting A), sitting with leg flexed at 90° (Sitting B), standing with slight head tilting of 10° (Standing C) and standing without slight head tilting of 10° (Standing D) (weight bearing tilt) postures after resting the subjects for 10 minutes in between each postural intervention. The shear rate was calculated by using the formula,

$SR = 4 \times BV / \text{Diameter in centimetre scale.}$

The study was done conferring to the regulations laid down by ethical committee and the declaration of Helsinki after obtaining permission from the Institutional Ethical Committee. Enrolled participants were explained about the study in their vernacular language and a written informed consent was taken. The data were tabulated and analysed by SPSS software. Independent 'T' test was applied for analysing SR by comparing relation to each posture in both arteries. One-way ANOVA was used for analysing SR of brachial arteries and femoral arteries in five postures individually for their statistical significance. As the SR of femoral artery was statistically significant in all the postures in comparison with that of brachial artery, Post Hoc test was used for analysing significance of SR in between postures for femoral artery. The statistical significance was set at $P < 0.001$ for independent 'T' test and one-way ANOVA and $P < 0.05$ for Post Hoc test.

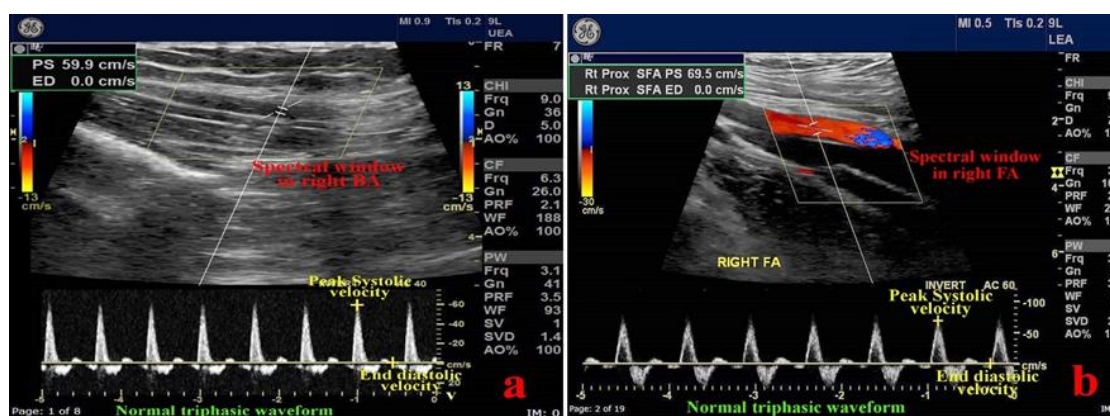


Fig. 1: Showing blood velocity (BV) and diameter of a) Brachial artery and b) Femoral artery measured by doppler ultrasound

RESULTS

The doppler ultrasound study on the effect of different postures on the SR in brachial arteries and femoral arteries was analysed in 29 healthy individuals in the age group of 20 to 30 years. One of the enrolled study participants discontinued in the midcourse due to personal reasons. Among the selected subjects, 14 were female and 15 males. The age of females ranged from 20 to 30 years with a mean age of 24.35 years and of the males from 21 to 29 years with a mean of 24.46 years. The blood pressure of the enrolled subjects was within normal limits. The Body Mass Index (BMI) in females ranged from 18 to 26.2 with an average of 22.6 and in males it ranged from 17.6 to 24.8 with an average of 21.2. The maximum, minimum BV in both arteries was measured and mean BV in different postures were calculated. The mean BV of the brachial artery was higher than femoral artery in all postures studied (Table 1)

The diameter of both arteries was also measured and mean diameter for various postures was calculated. The comparison of mean arterial diameter showed that

femoral artery is wider than brachial in all postures studied (Table 1).

The SR was calculated using the formula $SR = 4 \times BV/\text{arterial diameter}$ for both the arteries. On comparing the SR between both arteries in each posture it was observed that brachial artery exhibited higher SR (Figure 2).

Independent t-test was used for statistically comparing SR between brachial and femoral artery in each posture. The values were significant statistically at P value <0.001 . Comparison of SR between different posture within brachial and femoral artery was further done by one-way ANOVA. In the brachial, the difference in SR between the postures was not significant but significant difference was seen in femoral artery between postures. Post Hoc test (Tukey HSD) was done to confirm the statistical significance observed by ANOVA and it showed significant changes in femoral artery between supine and sitting A ($P = 0.034$), supine and standing C ($P = 0.001$), supine and standing D ($P = 0.003$) (significance in mean difference is at 0.05 level).

Table 1: Mean blood velocity, mean diameter of both arteries in different postures

Posture of the participant	Brachial artery		Femoral artery	
	Mean blood velocity (cm/sec)	Mean diameter (cm)	Mean blood velocity (cm/sec)	Mean diameter (cm)
Supine	21.23	0.41	17.53	0.48
Sitting with leg fully extended (Sitting A)	18.47	0.39	13.50	0.5
Sitting with leg flexed at 90° (Sitting B)	17.11	0.39	14.6	0.49
Standing with slight head tilting of 10° (Standing C)	16.45	0.40	12.09	0.50
Standing without slight head tilting of 10° (Standing D)	17.38	0.39	12.33	0.50

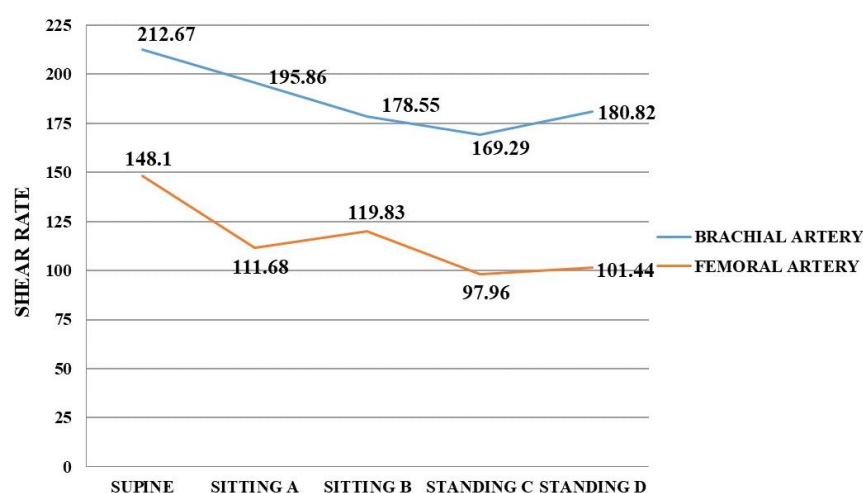


Fig. 2: Comparison of effect of changes in posture on shear rate in both arteries

DISCUSSION

Life-style factors are significant components in the aetiology of atherosclerotic cardiovascular disease (ACVD), which is one of the leading causes of death (21, 22). In fact, it is estimated that 50% of deaths attributable to ACVD are preventable through life-style modifications (22).

Atherosclerosis sound alarm bells when it involves coronary artery calling for battalion of therapies to fight it, while the damaging lesion runs unabatedly in peripheral arteries. In the mist of lot of studies concentrating on the coronary and carotid artery atherosclerosis (23, 24), this study was proposed to know the effect of posture on the SR in peripheral arteries.

The heart rate, blood pressure, BMI and gender differences even though observed during the study and documented were not taken for analysis because our aim is only to see the variation in SR in peripheral arteries due to altering posture.

The diameter of brachial artery was proclaimed by a study as an independent marker of atherosclerosis (6). The mean brachial artery diameter of 0.39 - 0.41 cm was lower than femoral diameter of 0.48 - 0.5 cm, but the variation in diameter with change in posture coincides with findings of few other studies (25).

Even though the independent values of SR in both arteries varied from previous studies, the difference between the upper limb artery and lower limb artery with respect to SR value ranged between 30 - 40% while it was between 40 - 50% in a previous study (19). The femoral artery SR of 115.8s^{-1} in the present study was lower in comparison to earlier studies with values of 130.3s^{-1} , 134.2s^{-1} (13,14). The SR of brachial artery was 187.44s^{-1} which was higher compared to value of 84.95s^{-1} in another study (14). The SR in this study was higher in brachial compared to femoral artery in all postures studied which was supported and opposed by previous studies (13-16). In the femoral artery the SR was lower in all postures, but it was lowered significantly in supine, sitting A, standing C and D ($p < 0.001$) a finding that needs to be considered as the important inference of our study in the milieu of studies pointing low SR as the basis for atheroma formation in vessels (13-15).

The results of this study that there occurs change in SR with change in posture emphasis the need to further study the association between time duration of each posture to the level of SR change. Non-invasive methodology of this study limits measurement of viscosity and so computation of shear stress on vessel wall could not be done in this study. Yet, dynamics of non-Newtonian fluid might help us to explain the possible alteration of shear stress with changes in the SR as observed in this study. Moreover, the small

sample size in young adults also happens to be a limitation. The study could be extended to include people with predisposing factors for atherosclerosis and advanced age groups.

CONCLUSION

In conclusion, the upper limb brachial artery and lower limb femoral artery were inversely associated with each other with respect to the mean BV and diameter of artery in all the postures studied. Also, the SR of femoral artery was lower than brachial in all postures studied. On comparing between the postures, we found except for sitting with legs flexed 90° (normal sitting postural) in all others, the femoral artery experienced a low SR. These findings add to our knowledge about occurrence of atherogenesis in peripheral arteries and could be the possible explanation for difference in the incidence of atherosclerosis between upper and lower limb arteries. This study might provide the necessary reason to modify the prolonged sitting/standing life style, in order to prevent atherosclerotic complications in peripheral arteries.

ACKNOWLEDGEMENT

We would like to acknowledge Indian Council of Medical Research (ICMR) for their support and funding and Chennai Medical College Hospital and Research Centre, Trichy for the support to complete our project.

CONFLICT OF INTEREST

There are no conflicts of interest.

REFERENCES

1. Allison, M.A., Jensky, N.E., Marshall, S.J., Bertoni, A.G., Cushman, M. Sedentary behavior, and adiposity-associated inflammation: The Multi-Ethnic Study of Atherosclerosis. *Am J Prev Med.* 2012;42(1):8-13.
2. Laufs, U., Wassmann, S., Czech, T., Munzel, T., Eisenhauer, M., Bohm, M., *et al.*, Physical inactivity increases oxidative stress, endothelial dysfunction, and atherosclerosis. *Arter Thromb Vasc Biol.* 2005;25(4):809-814.
3. Navasolava, N.M., Dignat-George, F., Sabatier, F., Larina, I.M., Demiot, C., Fortrat, J.O., *et al.*, Enforced physical inactivity increases endothelial microparticle levels in healthy volunteers. *Am J Physiol-Heart C.* 2010;299(2):248-256.
4. Goyal, A., Yusuf, S. The burden of cardiovascular disease in the Indian subcontinent. *Indian J Med Res.* 2006;124: 235-244.
5. Kroger, K., Kucharczik, A., Hirche, H., Rudofsky, G. Atherosclerotic lesions are more frequent in femoral arteries than in carotid arteries independent of increasing number of risk factors. *Angiology.* 1999;50:649-654.
6. Amato, M., Sansaro, D., Ravani, A.L. Brachial artery diameter enlargement: a new marker of atherosclerosis? *J Am Coll Cardiol.* 2012; 60:1489-1499.
7. Soulis, J.V., Farmakis, T.M., Giannoglou, G.D., Hatzizisis, I.S., Giannakoulas, G.A., Parcharidis, G.E., *et al.*, Molecular viscosity in the normal left coronary arterial tree. Is it related to atherosclerosis? *Angiology.* 2006; 57:33-40.
8. Papaioannou, T.G., Stefanadis, C. Vascular wall shear stress: basic principles and methods. *Hellenic J Cardiol.* 2005;46: 9-15.

9. Cunningham, K.S., Gotlieb, A.I. The role of shear stress in the pathogenesis of atherosclerosis. *Lab Invest.* 2005;85(1):9-23.
10. Stroev, P.V., Hoskins, P.R., Easson, W.J. Distribution of wall shear rate throughout the arterial tree: a case study. *Atheroscler.* 2007;191(2):276-280.
11. Caro, C.G. Discovery of the Role of Wall Shear in Atherosclerosis. *Arterioscler Thromb Vasc Biol.* 2009;29:158-161.
12. Tinken, T.M., Thijssen, D.H., Hopkins, N., Black, M.A., Dawson, E.A., Minson, C.T., *et al.*, Impact of shear rate modulation on vascular function in humans. *Hypertension.* 2009;54: 278-285.
13. Wu, S.P., Ringgaard, S., Oyre, S., Hansen, M.S., Rasmus, S., Pedersen, E.M. Wall shear rates differ between the normal carotid, femoral, and brachial arteries: an in vivo MRI study. *J Magn Reson Imaging.* 2004;19(2):188-193.
14. Nishiyama, S.K., Walter Wray, D., Berkstresser, K., Ramaswamy, M., Richardson, R.S. Limb-specific differences in flow-mediated dilation: the role of shear rate. *J Appl Physiol.* 2007;103: 843-851.
15. Jackson, M., Wood, N.B., Zhao, S., Augst, A., Wolfe, J.H., Gedroyc, W.M., *et al.*, Low wall shear stress predicts subsequent development of wall hypertrophy in lower limb bypass grafts. *Artery Res.* 2009;3: 32-38.
16. Schreuder, T.H., Green, D.J., Hopman, M.T., Thijssen, D.H. Acute impact of retrograde shear rate on brachial and superficial femoral artery flow-mediated dilation in humans. *Physiol Rep.* 2014;2(1):1-8.
17. Ozcan, H., Oztekin, P.S., Zergeroglu, A.M., Ersoz, G., Fiçilar, H., Ustuner, E. Doppler ultrasound evaluation of the structural and hemodynamic changes in the brachial artery following two different exercise protocols. *Diagn Interv Radiol.* 2006;12: 80-84.
18. Johnson, B.D., Wallace, J.P. A comparison of post exercise shear rate patterns following different intensities and durations of running in healthy men. *Clin Physiol Funct Imag.* 2012;32(3):234-240.
19. Newcomer, S.C., Sauder, C.L., Kuipers, N.T., Laughlin, M.H., Ray, C.A. Effects of posture on shear rates in human brachial and superficial femoral arteries. *Am J Physiol Heart Circ Physiol.* 2008;294(4):1833-1839.
20. Thosar, S.S., Johnson, B.D., Johnston, J.D., Wallace, J.P. Sitting and endothelial dysfunction: the role of shear stress. *Med Sci Monit.* 2012;18(12):173-180.
21. Heron, M. National vital statistics reports: from the Centers for Disease Control and Prevention, National Center for Health Statistics, National Vital Statistics System. 2011;59(8):1-96.
22. Mokdad, A.H., Marks, J.S., Stroup, D.F., Gerberding, J.L. Actual causes of death in the United States, 2000. *J Am Med Assoc.* 2004; 291(10):1238-1245.
23. Duivenvoorden, R., VanBavel, E., de Groot, E., Stroes, E.S., Disselhorst, J.A., Hutten, B.A., *et al.*, Endothelial shear stress: a critical determinant of arterial remodeling and arterial stiffness in humans-a carotid 3.0-T MRI study. *Circ Cardiovasc Imag.* 2010; 3:578-585.
24. Mongrain, R., Rodes-Cabau, J. Role of shear stress in atherosclerosis and restenosis after coronary stent implantation. *Rev Esp Cardiol.* 2006;59(1):1-4.
25. Eiken, O., Kolegard, R. Comparison of vascular distensibility in the upper and lower extremity. *Acta Physiol Scand.* 2004;181: 281-287.