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A comparative study of arterial stiffness indices between smokers & non smokers

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Abstract: *Background & Objective:* Arterial stiffening is recognized as a *critical precursor* of cardiovascular disease (CVD). CVD is the leading cause of mortality and morbidity worldwide. Smoking is one of the modifiable risk factor for CVD. Lifestyle modification is clinical efficacious therapeutic interventions for preventing and treating arterial stiffening. Arterial stiffness can be measured from Digital Volume Pulse which is economical, easier, non-invasive & less time consuming method (Finger Photoplethysmography). Hence, the current study is designed to compare the Arterial Stiffness Indices between smokers & non smokers. *Materials & Methods:* The study involved fifty five non smokers & fifty five smokers within the age group of 30-50 years. Subjects' height, weight and baseline value of Blood pressure, Pulse rate and Peripheral Pulse Wave were recorded in both non smokers & smokers. From Peripheral pulse wave, arterial stiffness indices were calculated.

Arterial Stiffness Index (SI) = Patients Height (h)/ Transit time (ΔT_{DVP})

[Transit time (ΔT_{DVP}) → Time delay between systolic peak & Diastolic peak]

Reflection Index (RI) = Magnitude of Diastolic peak / Magnitude of Systolic Peak × 100

Results: Arterial Stiffness Index & Reflection Index were highly significantly in smoker than non smokers, $p<0.001$. *Conclusion:* The increased arterial stiffness indices in smoker suggests that the cigarette smoke damages vascular endothelium, which can lead to increased arterial stiffness and consequently to overall deterioration of the cardiovascular system condition. Non invasive measurements of arterial stiffness will aid the optimal stratification of CVD risk in an apparently healthy population.

Keywords: Arterial stiffness; Cardiovascular diseases; Digital Volume Pulse; Smoking.

Introduction

Cardiovascular disease (CVD) is the leading cause of mortality and morbidity worldwide [1]. Arterial stiffness and wave reflection exerts adverse effects on cardiovascular function. Arterial stiffening is recognized as a *critical precursor* of CVD and is independent predictors of cardiovascular events. Arterial stiffening is a major factor in cardiovascular disease because of the reduced capacity in blood vessels and the concomitant rise in pulse pressure and fall in shear stress [2]. Therefore, assessment of arterial stiffness is believed to be useful in the prevention of cardiovascular disease.

Smoking is one of the modifiable risk factor for CVD [3]. Tobacco, especially cigarette smoking is a major cause of CVD, responsible for about one third of CVD deaths. Chronic cigarette smoking has been shown to be associated with increased arterial stiffness [4-5]. The risk of CVD deaths increases with increasing exposure to cigarette smoke, as measured by number of cigarette smoked daily, the duration of smoking & the degree of inhalation & the age of initiation. The relative risk for CVD is substantially greater in early adult life than in old age & is associated more strongly with the cigarette smoke than other forms of tobacco. The pathophysiological changes in smoking are due to the changes in vascular endothelium, induction of coronary vasoconstriction and changes in basal nitric oxide (NO) or endothelial nitric oxide synthase production. Lifestyle modification, aerobic exercise and sodium restriction appear to be clinical efficacious therapeutic interventions for preventing and treating arterial stiffening.

Arterial stiffness can be measured using invasive and non-invasive methods. Pulse

wave analysis is one of the methods used to assess arterial stiffness. The most popular non-invasive methods are based on pletysmographic principles [6]. Others include computer oscilometry, ultrasonography and applied tonometry. Large artery stiffness can be determined by Pulse wave velocity which is a standard method [7]. But it is difficult, time consuming and expensive. These factors have fostered the development of simple methods to record arterial stiffness. These techniques are much simpler, non-invasive, economical and easier to apply. We can also measure Arterial stiffness Indices from Digital Volume Pulse (DVP) which is economical, easier, less time consuming, non-invasive method. So the present study is designed to record Arterial Stiffness Index, Reflection Index by using Finger Photoplethysmography & to compare it with smokers and non smokers.

Material and Methods

The study was conducted in a sample of one ten subjects in Salem. They had been divided into fifty five non smokers (control group) & fifty five smokers (study group) within the age group of 30-50 years. Subjects were selected based on inclusion and exclusion criteria.

Inclusion criteria [control group]: Fifty five normal healthy non smokers between 30 and 50 years were included.

Inclusion criteria [study group]: Fifty five smokers between the ages 30 and 50 years were included.

Exclusion criteria [control group]:

1. History of Smoking
2. History of Hypertension
3. History of Diabetes Mellitus
4. History of Cardio vascular disease
5. History of Peripheral vascular disease
6. History of Other drug treatment

Exclusion criteria [study group]:

1. History of Hypertension
2. History of Diabetes Mellitus
3. History of Cardio vascular disease
4. History of Peripheral vascular disease
5. History of Other drug treatment

Methodology: The subjects were selected by a detailed history & thorough physical examination. They were asked to fill a questionnaire to assess their smoking habits. The experimental protocol was fully explained to the participants to allay apprehension. They were refrained from smoking for 12hours before the test. Informed consent was taken from all the subjects. The study was approved by Institutional Ethical Committee.

Experimental design: Data was collected by recording the DVP. Subject's weight was measured using calibrated weighing machine in light clothing and bare feet. Height was measured in meters. All experiments were performed at room temperature. Baseline pulse rate, Systolic, Diastolic & pulse pressure were measured in sitting position after 5 min of rest by using mercury sphygmomanometer.

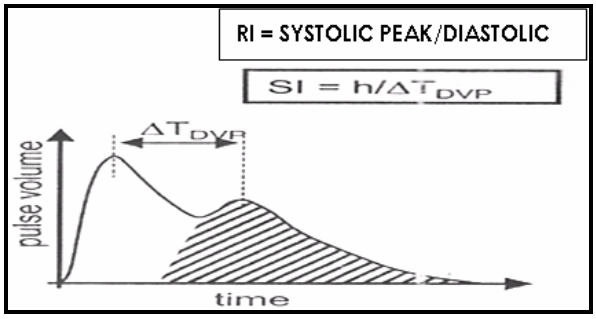
Finger Photoplethysmography: Digital Volume Pulse was measured by an instrument known as Finger Photoplethysmography, using Infra-red light with wave length of 940 nm; placed on the right index finger of the subject. The signal from the instrument was digitalized by digital converter with a frequency of 100 Hz; which was connected to the computer. The main principle of this device is conversion of pressure changes to voltage changes by means of differential pressure transducer with two inputs, positive and negative. Volume changes generated by pulse waves are transformed into pressure changes and are brought to a positive input [6].

Subject is initially acquainted with the instrument and a trial is given before performing for the study. DVP recording was done with the help of software virtual oscilloscope which was provided by national instrument which can be freely distributed for academic purpose. Pulse wave contour consists of two main components: the first is caused by systolic pressure wave that results from blood ejection from the left cardiac chamber to aorta and its consequent distribution to peripheral sites. The second component is formed by pressure wave reflected back to the aorta from the lower body continuing to the upper limbs.

The shape of the pulse wave is determined by a number of factors, age, sex, body height, pulse and physical fitness [8]. Length of this travelling wave is usually proportional to the subject's height (h). The time delay between systolic peak & diastolic peak is called Pulse transit time (PTT or ΔT), is inversely proportional to arterial stiffness. To correct for the size of the subject, the reflection time is divided by the height of the subject. The resultant value is SI, which is expressed in meters/second. SI is comparable to the definitive measure of arterial stiffness, the pulse wave velocity (PWV). RI is a measure of vascular tone. It is calculated by dividing the amplitude of the systolic component by the amplitude of the diastolic component. This ratio is expressed as a percentage.

The parameters and their definitions are shown in Figure 1. These parameters were measured by software Image tool.

Fig-1: Pulse wave contour and definitions of evaluated parameters



Arterial Stiffness Index (SI) = Patients Height (h)/ Transit time (ΔT_{DVP})
[Transit time (ΔT_{DVP}) → Time delay between systolic peak & Diastolic peak]

Reflection Index (RI) = Magnitude of Diastolic peak / Magnitude of Systolic Peak × 100

Statistical analysis: The results were expressed as mean ± standard deviation (SD). A p value of <0.05 was considered statistically significant. Statistical analysis was performed using the statistical package for social & sciences. Students unpaired't' test was applied to compare between the parameters.

Results

Fifty five normal healthy non smokers in the age group of 30 and 50 (36.85 ± 4.99) years and Fifty five smokers in the age group of 30 and 50 (37.29 ± 4.76) years were subjected to DVP recording. Arterial stiffness was estimated from the pulse wave analysis. Both SI (11.74 ± 4.12) meters/second & RI (75.64 ± 12.35) % in smokers were significantly higher at 95% confidence interval than non-smokers SI (5.72 ± 0.28) meters/second & RI (48.19 ± 9.51) %, p< 0.001. The results are shown in the table 1.

Table-1: Comparison of stiffness indices between Smokers & Non-smokers

Parameters	Non Smokers	Smokers	'p' value
Stiffness index (m/s) (mean ± sd)	5.72 ± 0.28	11.74 ± 4.12	< 0.001
Reflection index (%) (mean ± sd)	48.19 ± 9.51	75.64 ± 12.35)	< 0.001

Discussion

Measuring arterial stiffness provides good data on the endothelial condition. Cigarette smoke enhances the atherosclerotic changes by several mechanisms. Endothelial damage is a central feature in the evolution of vascular disease induced by cigarette smoking and may act as a precursor for future atherosclerosis. The major health effects of cigarette smoke include: cancer, noncancerous lung diseases; atherosclerotic diseases of the heart and blood vessels; and toxicity to the human reproductive system. Despite the damaging effects of tobacco use; quitting smoking has immediate and long term health effects such as improved circulation and fall in heart rate.

Smoking cessation is an important lifestyle measure for the prevention of cardiovascular disease, and patients with myocardial infarction may experience as much as a 50% reduction in risk of re-infarction, sudden cardiac death [9]. Quitting in late in life also has positive effects. The toxins from cigarette smoke can go everywhere as the blood flows. Chronic tobacco smoking is associated with endothelial dysfunction. Smoking not only accelerates endothelial dysfunction in the large arteries but it is also responsible for changes in the physical properties of arterioles and small arteries [10]. Vascular endothelium

produces a number of mediators including nitric oxide (NO) which regulates arterial wall stiffness owing to smooth muscle tone changes [11]. McWeigh et al showed that cigarette smoking triggers NO production damage [12]. Basic structural factors determining arterial stiffness are predominantly collagen, elastin and transmural pressure.

The mechanisms involved in amelioration in arterial stiffness with smoking cessation may include lipid-soluble smoke particles [13], endothelial dysfunction [14], or vascular inflammation [15], because smoking cessation leads to reduction in levels of inflammatory markers [16]. Although it may take more than a decade to reverse these vascular changes, and the effect is relatively small, smoking cessation helps to reduce cardiovascular events through amelioration in arterial stiffening.

Willett et al reported that cigarette smoking affects cholesterol metabolism, it lower levels of the protective high-density lipoprotein (HDL) cholesterol [17] and Rabkin et al reported smoking cessation raises HDL cholesterol [18]. In animal models, cigarette smoke can damage the inner lining of blood vessels, thus enhancing the transfer of low-density lipoprotein cholesterol particles across the arterial wall and into the developing cholesterol-laden plaque [19]. Cigarette smoking also can affect the blood clotting system, including adherence of blood platelets to the lining of arterial blood vessels [20] and the formation of blood clots that block a narrowed artery. Selley et al reported that Acrolein in cigarette smoke may be partly responsible for its platelet-adhering effects [21].

Cigarette smoke also causes spasm of the coronary arteries. Many chemical components of cigarette smoke have been found to accelerate the development of atherosclerotic disease. Nicotine, the major psychoactive component of smoke, causes powerful changes in heart rate and blood circulation. Nicotine appears to cause injury to the arterial lining [19]. Sheps et al reported that Carbon monoxide in cigarette smoke binds to the hemoglobin in red blood cells, thereby reducing the oxygen-carrying capacity of the blood [22].

Smoking causes tissue injury induced by oxidative stress. Free radicals in cigarette smoke, which are highly reactive oxygen products, are damaging to the heart muscle cells. Studies have reported dermal applications of cigarette smoke in laboratory animals demonstrated chemicals in cigarette smoke underwent covalent binding with heart tissue DNA [23]. Van Schooten et al reported that cigarette smokers showed that the heart tissue contained more DNA adducts than that from nonsmokers and linear relationship between DNA adduct levels and daily cigarette smoking [24]. Furthermore, higher DNA adduct levels were associated with a higher degree of coronary artery disease.

In our study we used SI which substitutes pulse wave velocity (PWV). It has been proved that SI positively correlates with PWV [7]. SI values are mainly influenced by large artery stiffness but they can be also affected by wave reflection from peripheral sites as well as from large arteries [7, 25]. For smokers we detected significant higher values of SI than non smokers, $p < 0.001$, which indicates increased arterial stiffness. To determine vascular tone we used the parameter RI. RI was also significantly higher in smokers compared to non smokers, $p < 0.001$, indicating vascular tone is increased.

Conclusion

1. There is pronounced increase in SI and RI indicating increased arterial stiffness. This suggests that even young smokers have damaged vascular endothelium.
2. Arterial stiffness determined by Digital Volume Pulse is simpler, less time consuming, economical, easier to apply and non-invasive method.
3. Non invasive measurements of arterial stiffness will aid the optimal stratification of CVD risk in an apparently healthy population.
4. Chronic smoking is a leading risk factor in development cardiovascular diseases. DVP can be used to assess how chronic smoking impairs arterial elasticity by evaluating SI and RI.

Scope for the study

Additional study including detailed evaluation of endothelial factors & measurement of

arterial stiffness by Pulse wave velocity is needed to clarify whether initial changes of cardiac impairment exists with early initiation of smoking.

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