DIASTOLIC BLOOD PRESSURE RESPONSE TO EXERCISE IN PATIENTS WITH CORONARY ARTERY DISEASE.

Thesis

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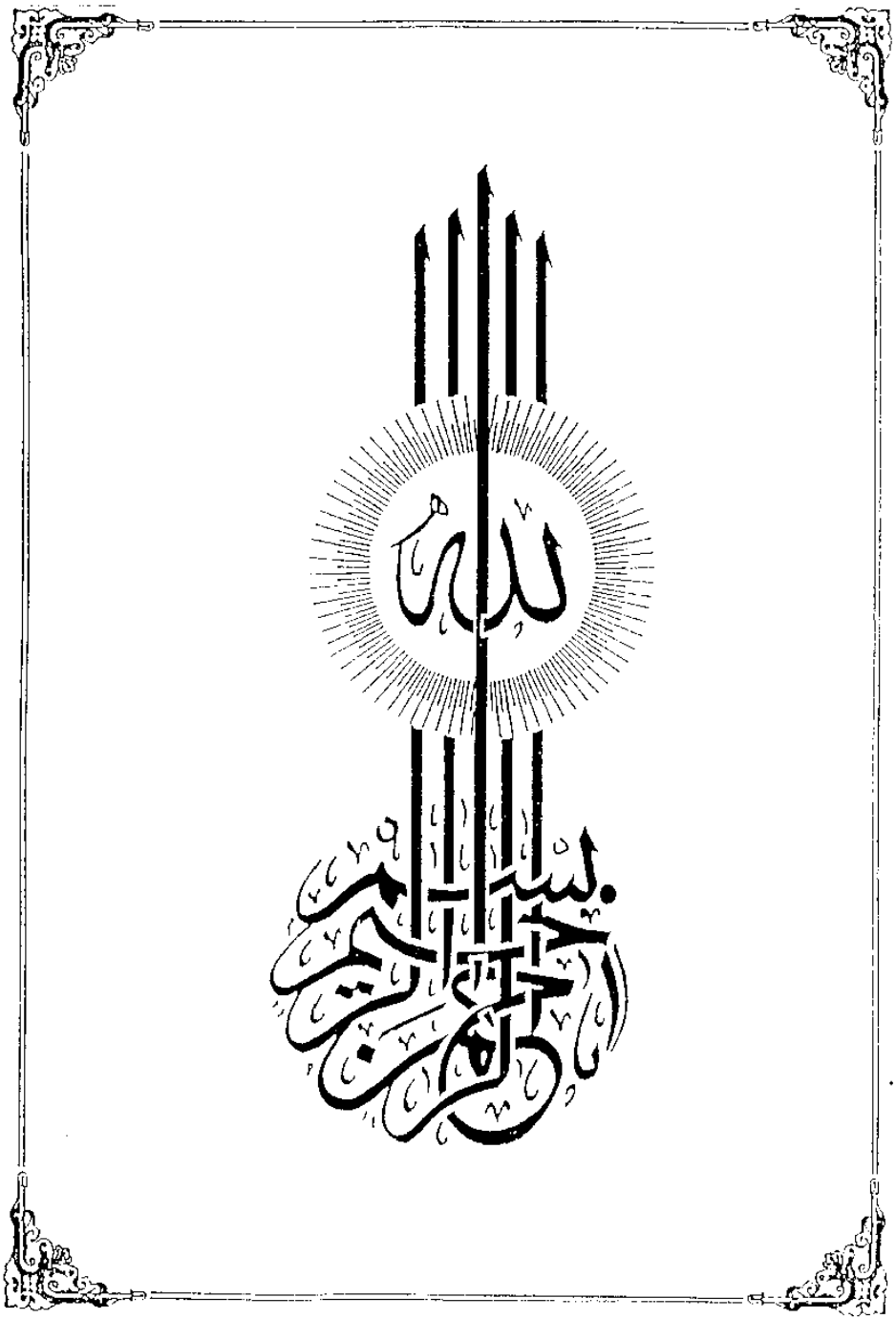

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REVIEW OF LITERATURE

BLOOD PRESSURE RESPONSE TO EXERCISE IN HEALTHY MEN

Physical exercise is one of the most stressful conditions imposed on the cardiovascular system of man. Full participation and adaptability of the various neural, humoral and hydraulic components of the circulation are of paramount importance in enabling man to meet the demands for oxygen and substrate delivery, in addition to carbon dioxide and metabolite removal. In heavy physical exercise, the cardiac output may reach six to eight times the resting value. While the responses of the cardiovascular system during exercise involve virtually every circulatory component, these responses fall basically into three categories. The first of these is the large reduction in resistance in the working musculature produced by local vasodilatation[1]. The second group of responses are mediated by the sympathetic nervous system and directed toward maintaining an arterial perfusion pressure sufficient to insure adequate blood flow to the working musculature[2]. The third major response pattern is maintenance of an acceptable body temperature, which becomes an important consideration in the regulation of the circulation if exercise continues until body temperature begins to rise significantly[3].

Before exertion begins, cortical signals may excite the vasomotor center, resulting in increased heart rate, vasomotor tone, cardiac output and arterial pressure[4].

Immediately upon initiation of muscular contraction, the local vasodilator mechanism reduces resistance to flow in the working muscle. Venous return and cardiac output are enhanced. Because of the competition between sympathetic discharge and the local vasodilator mechanism, increased sympathetic outflow has little direct effect on working muscle. However, increased sympathetic outflow does redistribute blood volume and flow from the skin, viscera, kidney and nonworking muscle to working muscle. Thus in short-term exercise, all of the increased cardiac output is directed toward working muscle. As exercise continues and body temperature rises, skin blood flow increases as a result of sympathetic vasodilatation. Blood volume and flow are directed to the skin from the visceral and nonworking muscle area[5].

With maximal exercise, cardiac output may rise to 25 liters per minute. Vasodilatation in the skeletal muscular bed helps this increase in flow to take place, but in addition an increase in mean arterial pressure occurs. The principal mechanism of increasing cardiac output is that of increasing heart rate. With an increasing heart rate, the duration of systolic ejection per beat diminishes. Attainment of normal systolic emptying in shorter and shorter periods requires increasing the rate of tension development in the myocardial fibers. This causes increase in the oxygen consumption with each contraction[6].

The normal blood pressure response to exercise is a progressive rise in systolic pressure with increase in exercise intensity and very little change in the diastolic pressure. Heart rate and systolic blood pressure increase with time and workload, with the increase tapering off as maximum effort is approached. Any rise or fall of diastolic pressure in normal persons is not likely to exceed 10 mmHg. The resultant rise in mean blood pressure with exercise reflects the fact that fall of the systemic resistance with exercise is insufficient in itself to allow for the rise in cardiac output. In most exercise protocols the systolic blood pressure rises about 8 to 10 mmHg per stage. Although in the interest of safety it is common to specify a level of resting blood pressure, such as 180/110 mmHg, over which exercise testing will not be carried out, in fact there are no reported instances of stroke or other hypertensive complications during diagnostic exercise testing[7].

With increasing age a drop in maximal heart rate, maximal oxygen consumption, and maximal exercise time is noted. Maximal systolic blood pressure and pressure-rate product change little with increasing age, while diastolic blood pressure increases slightly. As expected, heart rate and systolic blood pressure show a gradual fall after stoppage of exercise[8].

ABNORMAL SYSTOLIC BLOOD PRESSURE RESPONSE TO EXERCISE IN PATIENTS WITH CORONARY ARTERY DISEASE

During exercise testing, most attention is paid to the electrocardiographic changes to the neglect of other available physiologic variables. In the pioneer days of exercise cardiology, Master[9] pointed out the importance of changes in arterial pressure during the step test. More recently, multivariant analysis in men with coronary heart disease[10] has shown that the maximal systolic pressure achieved is among the best predictors of cardiovascular mortality. It is appropriate therefore to investigate more fully the variations and significance of systolic pressure changes during symptom - limited maximal exercise testing. Although one can question the accuracy of brachial arterial cuff pressure measurements taken during exercise, the reproducibility of an exercise-induced decrease in systolic blood pressure in all subjects undergoing a second exercise test and the absence of this finding in normal men during maximal treadmill testing confirms that the blood pressure can be recorded during exercise with a high degree of reliability.

In normal subjects exercise produces an increase in systolic blood pressure, and this increase is usually accompanied by a decrease in the diastolic blood pressure with a widening of the pulse pressure[7]. A decrease in systolic blood pressure below resting levels has been

observed during treadmill exercise testing in some patients with severe valvular, hypertensive or coronary heart disease[11]. A decrease in systolic pressure below resting levels at the onset of treadmill exercise-induced angina has been reported as a reliable sign of severe multiple vessel coronary artery disease[12]. However, Baker et al.[13] [1976] reported that a decreasing systolic blood pressure may be observed during graded exercise in the absence of significant coronary artery disease, especially in women[14]. Smith et al.[15] [1976] suggested that a reduction in systolic pressure may be a normal physiologic response during prolonged strenuous exercise. Irving et al.[16] [1977] plotted the relations of the systolic pressure values during symptom-limited maximal exercise according to the number of coronary arteries having 70 percent or more stenosis. As this number increased, the maximal systolic pressure observed was lower. A similar trend was found when the maximal systolic pressures during exercise were plotted according to arbitrary ranges of the ejection fraction at rest but, overall, the correlation was poor. There was a significant trend toward a lower rate of subsequent mortality in men with higher systolic pressure during this exercise test. However, the reported diastolic pressures were not related to mortality. The mortality rates by univariable analysis for these pressure ranges demonstrate the superiority of the systolic pressure level over the ST segment change in predicting mortality from

coronary heart disease[10]. The superiority of systolic over diastolic pressures in this context is even greater. If one takes a maximal systolic pressure of less than 140 mmHg as a cut-off point, the specificity for subsequent mortality from coronary heart disease is 89 percent, the sensitivity 39 percent and the predictive risk ratio 3.9:1[16]. Similar analysis using clinical interpretation of ST segment depression as the predictive variable did not achieve statistical significance. Morris et al.[17] [1978] observed no significant differences between those with and without a decrease in systolic blood pressure in the frequency of computer-quantitated ST segment abnormalities with exercise, the presence of ventricular premature complexes, the prevalence of previous myocardial infarction, evidence of akinesia or dyskinesia in the left ventriculogram or the level of mean left ventricular end-diastolic pressure. The rate for sudden cardiac death (defined as death occurring within 24 hours of the onset of symptoms) for subjects with a maximal systolic pressure below 140 mmHg was 4.6 times that for the group with values of 140 mmHg or higher. For nonsudden deaths from coronary heart disease, the rate in the group with values below 140 mmHg was 2.67 times greater than that for the group with higher pressures. There was no apparent trend for noncardiac deaths in relation to maximal systolic pressure[16].

With regard to the angiographic variables, 70 percent of the men with a maximal systolic pressure of less than 140

mmHg had coronary arteries with at least 70 percent stenosis and 38 percent had an ejection fraction at rest of less than 40 percent. The specificity for disease of this severity in two or more vessels was 92 percent, whereas sensitivity was only 28 percent. The predictive risk ratio was 2.1:1[16]. The relation of exertional pressure values to the arteriographic and ventriculographic variables indicates that the poorer prognosis of persons with lower pressures is a consequence of their severe coronary vascular disease and abnormal left ventricular function due to severe ischemia or previous infarction. Because it is not feasible to undertake coronary angiography in all persons with coronary heart disease, the high specificity of the small systolic pressure changes for future mortality and for two and three vessels stenosis means that maximal treadmill exercise testing is valuable in defining the persons at the greatest mortality risk.

The significance of the pressure values is quite different in healthy or hypertensive men and in women without stenotic coronary arteries from that in persons with coronary heart disease[18], as indicated by two practical observations: Some persons are hypertensive at rest before testing because of anxiety. At the low levels of exercise, the blood pressure decreases below the resting value and, with increasing work load, it increases again. The net change in pressure attained may therefore be small. Some normal and highly motivated persons, wishing to exercise

very well, exceed the usual limits of exercise through additional energy production from anaerobic metabolism. As the point of collapse rapidly approaches, with metabolic acidosis from excessive lactate production, the blood pressure decreases precipitously and is associated with marked pallor, sweating and incoordination of gait. The pathophysiologic significance of a recorded maximal systolic pressure of 100 mmHg in healthy young men who have performed four or five stages of exercise for 12 to 15 minutes is clearly different from that of the same numerical value recorded in a 60 year old man with a previous myocardial infarction who exercises for less than 3 minutes. Changes in systolic pressure during exercise must be interpreted in light of the clinical findings. The importance of the preliminary clinical evaluation and interpretation of symptoms is therefore emphasized[19].

Causes of Exercise - Induced Fall in Systolic Blood Pressure

The decrease in the peak systolic blood pressure during exercise in patients with multiple vessel coronary artery disease is best explained by acute left ventricular pump failure secondary to extensive myocardial ischemia. This hypothesis is supported by an absence of abnormal blood pressure responses in patients with single vessel coronary artery disease, in whom less myocardium is at risk of ischemic compromise, and by the restoration of a normal blood pressure response to exercise in patients with

multiple vessel disease after coronary artery bypass graft surgery[20]. Because a decline in systolic blood pressure during exercise is primarily dependent upon the area of myocardium rendered ischemic, it is possible that some subjects with single vessel coronary artery disease will eventually be shown to manifest this abnormality. This could especially be the case when a maximal exercise protocol is used because the area of exercise-induced ischemia may be more extensive under these circumstances.

The abnormal blood pressure responses which may be observed in patients with obstructive cardiomyopathy can best be attributed to an accentuation of the left ventricular outflow tract obstruction during treadmill testing. This is most likely due to a combination of an upright posture and the increase in circulating catecholamines that accompanies exercise[21].

Role of Thermoregulatory Mechanisms

Prolonged exhaustive exercise has been shown to cause a decrease in systolic blood pressure even in normal subjects[15]. This response is thought to be mediated through sympathetic vasodilatation of skin vasculature in order to dissipate the heat load generated by the prolonged muscular work. As a larger percentage of the cardiac output is shifted to the skin for cooling purposes, the total peripheral vascular resistance decreases. If cardiac output is already near maximal, both the systolic and mean arterial

blood pressures may decrease. This thermoregulatory or so-called "cardiovascular drift" phase of exercise[15] occurs only with vigorous exertion maintained over a prolonged period.

To sum up, a decrease in systolic blood pressure of 10 mmHg or more below peak values during treadmill exercise is a reliable indicator of multiple vessel coronary artery disease provided the following conditions are met:

1) The decrease in pressure is sustained during one or more repeat determinations obtained at 15 to 20 second intervals after the initial recording.

2) There is no coexistent cardiomyopathy, heart valve disease, hypovolemia, orthostatic hypotension or evidence of congestive heart failure at rest.

3) There are no cardiac arrhythmias at the time of blood pressure recording.

4) The patient is not receiving a combination of pharmacologic agents that would significantly reduce cardiac output or augment the vasodilatation accompanying exercise, or both[22].

5) Exercise is at least 1 minute in duration. This latter condition is designed to exclude "false positive" decreases in systolic blood pressure in very anxious subjects whose pressure may decrease early in the first