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Effect of Age on Circulatory Response to Postural and Valsalva Tests[1] (39884)

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The functional testing of the human circulatory system by means of dynamic exercise has been widely used as a cardiovascular screening procedure. Recently, nonexercise stresses such as the valsalva maneuver and head-up tilt also have been employed to assess circulatory performance in valvular disorders (1), hypertension (2), and coronary heart disease (3, 4). There is some evidence to indicate that age may have an effect on responses to this type of stress (5), but relatively little attention has been given to this factor. Because of the increasing use of stress tests, the present study was planned for the purpose of (i) comparing and correlating the responses of different age groups of normal males to 70° head-up tilt and the valsalva and (ii) analyzing the responses from the standpoint of the mechanisms involved.

Procedure and methods. The study was conducted on two groups of white male subjects, one group 40 to 49 years of age and a second group 47 to 56 years of age. All were paid volunteers who underwent medical history, physical examination, and chest X ray within the previous year. All findings were within normal limits and the subjects were free of hypertension, hyperglycemia, diabetes, or any other serious systemic disease. Before the test, each subject was interviewed and a 12-lead ECG was recorded; the purposes of the study and technique to be used were carefully explained to minimize apprehension. Throughout the test, effort was made to maintain a quiet atmosphere and to approximate baseline conditions as closely as possible.

Blood pressure was estimated with an indirect method using a crystal microphone (E for M) located just over the brachial artery, which sensed the arterial impulse over approximately the range of sounds heard stethoscopically. Heart rate was monitored with bipolar ECG chest leads; for short-term changes (e.g., valsalva), the fastest or slowest instantaneous rates were determined for that period or phase. Recordings were made on a Grass Polygraph Model 5P4. After a control period of 10 min, a 20-min, 70° head-up tilt test was performed using a tilt table with a footboard for weight-bearing and techniques previously described (6). The heart rate and blood pressure were taken every 2 min.

For the valsalva test, the subject was asked to take a deep breath and then to maintain an airway pressure of 40 mm Hg for 15 sec by blowing into a tube connected to a manometer; the system was designed to force the subject to maintain an open glottis. Heart rate readings were taken before, during, and after the maneuver, and the rate responses were analyzed using the criteria described by Elisberg (7); this involves determination of the maximum (or minimum) heart rate occurring in each of the four classical stages of the valsalva as well as the heart rate increments (or decrements) between successive stages.

Data were collected and stored on magnetic disks. Analyses were made visually via graphs and tables and also with the aid of an IBM 370 Model 135 computer. Differences between mean responses were determined with Student's t test; in order to assess interrelationships, degrees of linear correlation were calculated using Pearsons product-moment correlation coefficient (8).

Results. The responses to tilt obtained in the two groups are summarized in Table I (Groups B and C) and compared with those obtained in a previous investigation in our

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TABLE I. HEMODYNAMIC RESPONSES OF NORMAL MALES TO 70° HEAD-UP TILT (MEANS ± SEM).

	Group A 19-26 Years (10 subjects; N = 20)[a]	Group B 40-49 Years (19 subjects; N = 36)[a]	Group C 47-56 Years (N = 10)[a]
Heart rate (beats/min)			
Control	72.0 ± 2.6**	61.9 ± 1.6	60.2 ± 2.2
Δ Values[b]	27.2 ± 2.6**	13.2 ± 1.1	13.3 ± 1.8
Systolic pressure (mm Hg)			
Control	116.1 ± 2.5	129.0 ± 1.9**	112.9 ± 3.7
Δ Values	−1.1 ± 2.2	−2.1 ± 1.4	−2.7 ± 3.6
Diastolic pressure (mm Hg)			
Control	60.7 ± 1.7****	80.5 ± 1.3	73.0 ± 2.5***
Δ Values	12.7 ± 1.2**	5.2 ± 0.8	2.8 ± 1.9
MABP (mm Hg)			
Control	79.2 ± 1.7	96.7 ± 1.4	86.2 ± 2.7
Δ Values	8.1 ± 1.3*	2.7 ± 0.9	1.3 ± 2.3

[a] Because in some cases the test was repeated in the same subject, the N's in those series exceeded the number of subjects.
[b] Δ = Difference between control and mean value during tilt.
* Different from other two groups at 0.01 level.
** Different from other two groups at 0.001 level.
*** Different from 40- to 49-year-old group- at 0.05 level.
**** Different from 40- to 49-year-old group at 0.001 level.

laboratory (shown in Group A) in which younger normal male subjects, 19 to 26 years of age, were studied using identical methods and conditions (6). As shown in Table I, the mean resting heart rates in the older subjects (Groups B and C) were lower than those in the younger group; this finding is not unusual (9). With upright tilt the two older groups (Groups B and C, Table I) also had distinctly lesser hemodynamic responses; there was a diminution in heart rate response (of about 50%) as well as a decline in diastolic and arterial pressure response (of about 60 to 80%). Comparison of the control hemodynamic values with the mean tilt values revealed a consistent positive correlation for almost all the variables, along with a prevailing tendency toward a negative linear correlation between the control values and the increments between control and tilt.

The maximal (Phases II and III) and minimal (Phase I and IV) heart rates obtained in the different phases of the valsalva test are shown in Table IIA, the heart rate increments from control in Table IIB, and the rate increments between successive valsalva phases in Table IIC. The results indicate lesser heart rate changes from control to Phase I, and from control to Phase IV in the older subjects (Groups B and C), with decreases ranging from about 50 to 85% (Table IIB). Similarly, the heart rate increments between successive phases were always greater in the youngest subjects (Group A) than in the two older groups (Table IIC), but the differences were not statistically significant in all cases.

Further analysis of the valsalva responses indicated a strong tendency toward a positive linear correlation between control heart rates and phase heart rates in the youngest subjects, which tendency was, however, not as marked in the other two groups. There was also a consistent positive correlation between heart rates of successive phases in all three groups (Table III), with the notable exception of the rates between phases III and IV which showed no linear correlation. Plots and further analyses of these data failed to reveal any nonlinear or other evident relationships between the Phase III and Phase IV rates. As was the case with the tilt test, there was a tendency toward a negative correlation between the basic values (phase heart rates) and the increments to the succeeding phases; this was most pronounced in the relationship between the rates of Phase III and the increments from Phase III to Phase IV (Group A, $r = -0.82$*; Group B, $r = -0.94$** and Group C, $r = -0.94$**).[3]

In order to determine whether cross toler-

[3] (*) Significant at 0.05 level; (**) significant at 0.01 level.

TABLE II. HEART RATE RESPONSES OF NORMAL MALES TO THE VALSALVA TEST (MEANS ± SE).

Group	Phases				
	Control	I	II	III	IV
	A. Heart rates during valsalva phases				
Group A (19 to 26 years)	74.3 ± 2.5**	63.1 ± 2.4	92.2 ± 4.7	102.6 ± 3.2	58.6 ± 2.0
Group B (40 to 49 years)	61.8 ± 1.8	67.7 ± 2.3	88.0 ± 3.1	90.8 ± 3.4	59.5 ± 1.3
Group C (47 to 56 years)	60.9 ± 2.0	63.8 ± 2.2	87.9 ± 2.4	94.2 ± 2.1	57.4 ± 1.5
	B. Heart rate increments from control to valsalva phases				
	I-Control	II-Control	III-Control	IV-Control	
Group A (19 to 26 years)	−11.2 ± 2.0**	17.9 ± 3.7	28.4 ± 2.8	−15.7 ± 1.6*	
Group B (40 to 49 years)	5.9 ± 2.3	26.2 ± 2.8	29.2 ± 3.2	−2.3 ± 1.2	
Group C (47 to 56 years)	2.9 ± 1.6	27.0 ± 2.7	33.3 ± 2.2	−3.5 ± 1.8	
	C. Heart rate increments between successive valsalva phases				
	I-Control	II-I	III-II	IV-III	
Group A (19 to 26 years)	−11.2 ± 2.0**	29.1 ± 3.5***	10.4 ± 3.3***	−44.0 ± 3.5****	
Group B (40 to 49 years)	5.9 ± 2.3	20.4 ± 2.4	2.8 ± 0.9	−31.3 ± 3.3	
Group C (47 to 46 years)	2.9 ± 1.6	24.1 ± 2.4	6.3 ± 1.4	−36.8 ± 2.4	

* Different from other two groups at 0.05 level.
** Different from other two groups at 0.01 level.
*** Different from 40- to 49-year-old group at 0.05 level.
**** Different from 40- to 49-year-old group at 0.01 level.

TABLE III. CORRELATION COEFFICIENTS (r's) BETWEEN HEART RATES OF PHASES IN THE VALSALVA TEST IN NORMAL MALES.

Between heart rates of successive phases	Group A (19–26 Years)	Group B (40–49 Years)	Group C (47–56 Years)
Control vs phase I	0.66*	0.61	0.71
Phase I vs phase II	0.68**	0.91**	0.48
Phase II vs phase III	0.71*	0.97**	0.82**
Phase III vs phase IV	0.20	0.33	0.14

* Significant at 0.05 level.
** Significant at 0.01 level.

ance existed between head-up tilt and the valsalva maneuver, correlation coefficients were determined between the most commonly used indices of tolerance to head-up tilt, viz, Δ values for heart rate, diastolic pressure, and systolic pressure (6) and measures of response to the valsalva test, viz, heart rate increments from control to the different phases and increments between successive phases (4, 6, 7). In Group C there were significant positive correlations between Phases I and IV and II and III of the valsalva; however, there were no other evident intertest correlations in any of the other groups.

Discussion. Previous investigators have reported that, with advancing age, postural stress results in greater decrease and slower recovery of systolic pressure and a lesser increase in heart rate (10) but no marked changes in general tolerance (11); however, in these prior studies, quantitative comparisons between different age groups were not made. Our valsalva results indicate that the two groups of older subjects had lesser heart rate increments than the younger group from control to Phase I and from control to Phase IV (Table IIB); the older groups also had smaller rate increments between the successive phases of the valsalva, but the differences were not always significant.

There was a prevailing tendency toward a positive correlation between the control hemodynamic values and those during stress in both the tilt and valsalva tests. An interesting exception to this was the absence of correlation between the heart rates in Phase III and those of Phase IV in all three groups (Table III), which suggests that, in the valsalva in the normal subject, different (or additional) mechanisms may be operative in regulating heart rate in Phase IV than in the other phases.

Although head-up tilt and the valsalva maneuver are generally similar types of stress since they both reduce cardiac preload, there was very little correlation between the circulatory responses to tilt and valsalva in these groups. However, this is not surprising since a previous study in our

laboratory on normal male subjects 20 to 26 years of age (6) as well as other studies on animals (12) and humans (13) have given little indication of cross tolerance to stresses of this type.

In our study, the valsalva responses were assessed only on the basis of heart rates and rate increments; although blood pressure is the traditional method of analysis, there is increasing evidence that heart rate can be a representative and useful measure of the circulatory response to the valsalva maneuver (7, 14–16).

The reason for the marked diminution of circulatory response in older subjects is not certain. It is possible that, with increasing age, the blood pressure and heart rate changes become attenuated during these maneuvers because of decreased venous compliance or increased central blood volume (17); thoracic aortic pressures were not measured in the current study. A second possibility is that the baroreflexes are less active with advancing age, as suggested by Gribbin *et al.* (18). Whether this loss of sensitivity is due to a greater arteriosclerotic rigidity at the receptor site or a central neural inhibition is not clear (18).

There is also evidence to indicate that essential hypertension may decrease baroceptor sensitivity as a factor independent of age (18, 19) and that even borderline hypertension may importantly affect the hemodynamic response to certain stresses, particularly head-up tilt (2, 20). In view of these findings it seems evident that, when using postural or valsalva tests for clinical evaluation, the age of the subject and presence or absence of hypertension are important factors in test interpretation.

Summary. In order to analyze the effect of age, a study was made of the hemodynamic responses of three groups of normal male subjects (19 to 26, 40 to 49, and 47 to 56 years) to 70° head-up tilt and to the valsalva maneuver. Compared to the youngest group the two older groups showed a marked diminution in heart rate, diastolic pressure, and mean arterial pressure responses to head-up tilt, and lesser heart rate changes in the different phases of the valsalva tests. There was very little intertest correlation between the circulatory responses to the two stresses. These alterations in response with advancing age may be related to altered baroceptor sensitivity or to diminished blood pressure changes associated with decreased venous compliance or increased central blood volume. The results indicate that consideration must be given to the age effect when assessing circulatory responses to the tilt and valsalva in the human.

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