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The Head-Down Tilt and Adaptability for Aerospace Flight

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ALTHOUGH tilt table procedures have been used extensively in the study of the circulatory system, most studies have been with subjects in the feet-down position.[1,2] The tilt table provides a means of studying the influence of g force upon the circulatory system. When an individual is strapped to the tilt table, feet down, in the vertical position, he is exposed to +1 g. When tilted to the recumbent or horizontal position, the subject is exposed to a transverse force of 1 g. If the individual is tilted vertically, head down, he is exposed to negative 1 g. Thus, the tilt table offers a laboratory procedure for evaluating the response of the circulatory system over prolonged periods of time to different types of g force stimulation. It provides certain obvious advantage over more complex procedures. Many centrifuges do not permit sudden change from positive to negative g as can be accomplished on the simple tilt table.

With the advent of the space age, considerable interest has been expressed in circulatory response during weightless conditions.[4] The type of circulatory response to weightlessness will be somewhere between +1 g and —1 g. Whether or not weightlessness has a major influence upon the circulatory system is a moot question. Some concept of its influence can be appreciated by using the tilt table to study individuals passing from +1 g to small amounts of negative g force. The tilt table provides an opportunity for prolonged periods of clinical observation and instrumentation during exposure to small negative g.

It must be appreciated that positive g force is a stimulus to the sympathetic control of the circulatory system. Through sympathetic influences, peripheral resistance is maintained which, in turn, provides for adequate distribution of cardiac output. Without sympathetic control, man would be unable to assume the upright position for any prolonged period of time. In essence, sympathetic control of peripheral resistance is an anti-g reflex. It is an adaptation that man has developed in response to the gravitational field to which he has adapted. Peripheral resistance mediated through the sympathetic control is reflex in nature. When this reflex is delayed in activity, an individual suddenly assuming the upright posture will note momentary faintness. Ablation of the reflex, for example, as a result of sympathectomy, results in postural hypotension. Increased peripheral resistance, as an anti-g reflex, maintains adequate circulatory dynamics. When sympathetic stimulation is dominant, it is common to see cardiac acceleration or an increased heart rate. In the upright posi-

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tion, there is an increase in heart rate and an increase in peripheral vascular resistance. Removal of the sympathetic stimulation as occurs on assuming the recumbent position or bed rest will initially result in cardiac slowing and relaxation of peripheral vascular resistance.

It should be emphasized that as a conditioned reflex, the sympathetic control of circulatory responses can deteriorate through lack of use and the reflex can be trained. Training of the anti-g reflexes has been a common and time-honored practice in clinical medicine. Although it is not usually phrased in those terms, any patient placed at prolonged bed rest has deterioration of his anti-g reflexes. While an individual is exposed to transverse g, there is no reason to develop peripheral resistance in the lower portion of the body. After prolonged periods of bed rest, when an individual stands upright, he is subject to faintness and may collapse if permitted to stand upright for any prolonged period of time after a prolonged period of bed rest. The anti-g (sympathetic) reflexes are commonly educated by gradual exposure of the patient to +1 g for short intervals each day, or gradual ambulation. It is common to have the patient sit on the edge of the bed and gradually increase the period of exposure to plus g force over a period of several days before permitting full ambulation without restriction. Thus, the time-honored practice of medicine has clearly demonstrated the role of anti-g reflexes in the prevention of circulatory collapse and the ability of such reflexes to deteriorate and subsequently to be trained again. When viewed in this light, it is also apparent that individual variations do occur and that the anti-g reflex response of any individual varies from time to time. True orthostatic hypotension, as a disorder of the autonomic nervous system, can be favorably influenced by having such individuals sleep in beds with the head of the bed elevated.[5] This is another demonstration of the influence of stimulation of the anti-g reflexes to maintain a high level of reflex activity.

Since circulatory reflex responses are of great importance in an individual's ability to adapt to g forces and in his ability to withstand situations which might result in sudden loss of consciousness, a means of studying individual circulatory reflex action and knowledge that such circulatory reflex action can be trained are of considerable importance.

It is generally appreciated that during space flight individuals will be exposed to periods of increased g load. During such increased g load, sympathetic acceleration of the circulatory system is to be expected. In those circumstances in which the g force is applied in a transverse manner, and such g loads are relatively large in magnitude, compression of the thorax will be expected to decrease return of blood to the heart and the overall influences of such stresses are chiefly sympathetic in nature. Once orbital velocity or a weightless state is reached, g force stimulation of sympathetic reflex action will cease. There are two factors which should influence the change in cardiovascular dynamics at this particular point; one is the termination of the sympathetic stimulation effects of g force, and the other is the momentary increased blood flow to the upper portions of the body. With the termination of the transverse g forces upon the thorax, one would expect a surge of blood into the heart. Since the subject is in the weightless state, the momentary increased volume of blood passing to the carotid sinuses and the central nervous system will stimulate vagal reflexes to induce cardioinhibitory responses and particularly to ablate any sympathetic constriction of the peripheral vascular bed in the lower portion of the body. The latter reflex action provides for normal distribution of the cardiac ouput between the upper and lower portions of the body. A combination of influences, then, is present, the cessation of sympathetic stimulation and the onset of vagal efferent action. This is adequate reason for careful and concentrated study on the behavior of the circulatory system when the reflex control is changed suddenly from one of sympathetic stimulation to one of vagal dominance or vagal inhibition. The purpose of this particular report is an analysis of subjects who have been studied by the tilt table during

+1 g, transverse g and —0.7 g. This report enables analysis of the influences of such factors as physical fitness, heart rate, age and level of sympathetic response upon the degree of vagal inhibition and the type of circulatory responses noted when the balance of autonomic control of the circulatory system is suddenly reversed.

METHODS AND MATERIALS

Tilt table studies were performed in 224 subjects. The procedure consisted of determining the heart rate from continuously recorded electrocardiograms at given intervals during the procedure. The subjects were first placed in the horizontal position and a baseline heart rate was obtained. The subjects were then tilted, feet down, and underwent a series of stresses. These stresses consisted of a 12-minute period of orthostasis followed by maximum breathholding and hyperventilation to the point of symptoms, followed by a second period of maximum breathholding. The heart rate and cardiac rhythm were again determined three minutes after the stress had been discontinued with the subject still feet-down on the tilt table. This interval of the testing is referred to as the post-stress level. Following the period of stress, the subjects were tilted head-down at a 45-degree angle. The heart rate was again determined with the subject in the vertical position immediately prior to the head-down tilt. This point is referred to as the 0 point. The heart rate and cardiac rhythm were then determined for each six-second interval after the onset of the head-down tilt. Two hundred and fifteen of the subjects remained in the head-down tilt position for one minute following which time they were tilted back to the feet-down position. The heart rate and cardiac rhythm were also determined during this period following the head-down tilt. Heart rate was calculated on the basis of the number of beats in each six-second interval. Nine subjects in a specialized training program that had been specially selected on the basis of aviation experience and apparent outstanding medical qualifications were studied in a similar manner with the exception that the head-down tilt was prolonged to a two-minute interval. In all subjects the changes in heart rate were expressed as an increase or decrease in the number of beats in relation to the resting heart rate obtained on the baseline at the beginning of the procedure. The nine individuals in the specialized training group were handled separately inasmuch as the head-down tilt procedure was prolonged. The 215 subjects studied were divided into sub-groups and the changes in heart rate were calculated to express the mean change in heart rate, the extremes or the maximum variations noted, and the standard deviation of the mean. The 215 subjects were studied as a composite group and then divided into groups according to their age, differences in baseline heart rate, and differences in response to exercise tolerance as tested by maximum physical exertion on the treadmill. Of the 215 subjects, 15 individuals were also studied by tilting them to the head-down position immediately after the baseline heart rate was determined. The heart rate was determined in a similar manner during this period. Following the initial head-down tilt the 15 subjects were tilted feet-down and subjected to the same variety of stress tests as listed above, following which they were again tilted head-down to —45 degrees to study the head-down tilt in the post-stress circumstance. A comparison was made between the responses noted in the head-down tilt following the baseline state and the response noted during the head-down tilt after the period of stress.

RESULTS AND DISCUSSION

Composite Group.—The most striking observation noted by these procedures was the marked change in heart rate induced by the simple head-down tilt. The heart rate and cardiac rhythm for the 215 subjects studied with a one-minute head-down tilt were analyzed. The mean heart rate for the baseline of the group was 73 beats per minute with standard deviation of ± 14.2. The baseline heart rate per individual subject varied from 35 to 132 beats per minute. During the post-stress period, the mean change in heart rate was 16 beats per minute and at the 0 point immediately prior to head-down tilt the mean heart rate increased 19 beats per minute above the baseline heart rate. The mean heart rate following the head-down tilt decreased to 15 beats per minute less than the mean baseline heart rate, or a change of 34 beats per minute as compared to the mean heart rate just prior to the onset of the head-down tilt. Wide variations in response were noted and not all subjects' heart rates dropped below the level of baseline rate noted prior to the onset of the procedure. However, in almost all instances a discernible decrease in heart rate occurred in respect to the heart rate determined just prior to the onset of the head-down tilt. The mean variations in heart rate with the extremes and standard deviation of the mean for the composite group are plotted in Figure 1. The changes in heart rate for each time interval after the baseline determination are expressed as the change (increase or decrease) in the heart rate as compared to each individual subject's baseline heart rate.

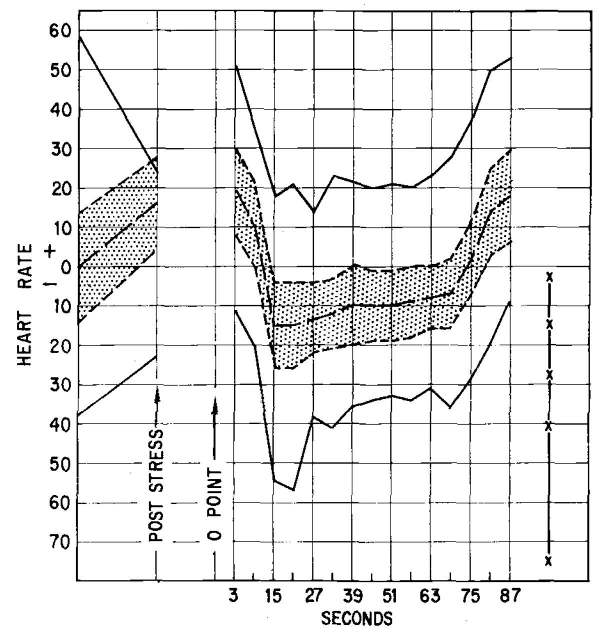

Fig. 1. The mean change in heart rate from the baseline level for 215 subjects is plotted against time. The 0 point is a 6-second period just prior to the head-down tilt. Heart rate is plotted for each 6-second interval thereafter. The increase in heart rate after the 60-second period is following rotation to the feet-down position. The shaded area is the standard deviation of the mean. The upper and lower graphs represent the extremes, high and low values for the group.

The extreme falls in heart rates usually occurred immediately after the head-down tilt was accomplished. Immediately following the period of the precipitous fall in the heart rate a readjustment of the rate occurred at a rate most often below the level of the post-stress heart rate. In all subjects, as soon as the tilt table was reversed to the feet-down position following the head-down tilt, there was an immediate rise in heart rate. The rise in the heart rate was equal to, or in excess of, the post-stress heart rate. When the subjects were suddenly changed from —0.7 g back to +1 g, the sympathetic phase of the cardiovascular response returned at once and at approximately the same levels noted during the post-stress period prior to the onset of negative g.

Factors which are related to the fall in heart rate induced by the head-down tilt include the redistribution of blood to the upper portions of the body which stimulate carotid sinus and central nervous system receptors and induce vagal efferent stimulation with cardioinhibitory responses. In addition to the stimulation of parasympathetic activity, there is a decrease in sympathetic activity. Just prior to the head-down tilt, with the subject feet down, sympathetic reflexes are in a constant state of stimulation, that is, the anti-g reflexes to the peripheral circulation are active. As soon as the subject is tilted head down, the release of sympathetic stimulation decreases sympathetic cardiovascular

TABLE I. AGE DISTRIBUTION OF SUBJECTS

Age	Number of Subjects
21 to 25 years	32
26 to 30 years	57
31 to 35 years	39
36 to 40 years	42
41 to 45 years	41

In the presence of the vagal rebound phenomenon with cardiac slowing, it was very common to note cardiac arrhythmias.

The composite group was divided into three

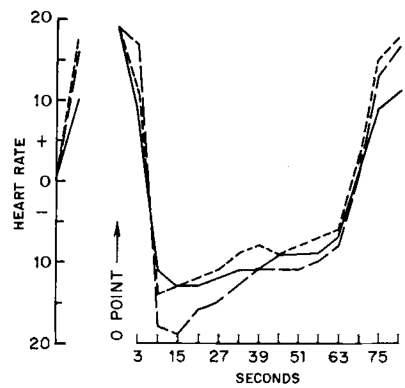

Fig. 2. The mean for the changes in heart rate compared to the baseline rate for three groups are compared. The solid line is the test pilot group. The short dash line are the flying personnel with a variety of medical findings other than history of loss of consciousness. The long dash line graph represents subjects being evaluated for an episode of loss of consciousness.

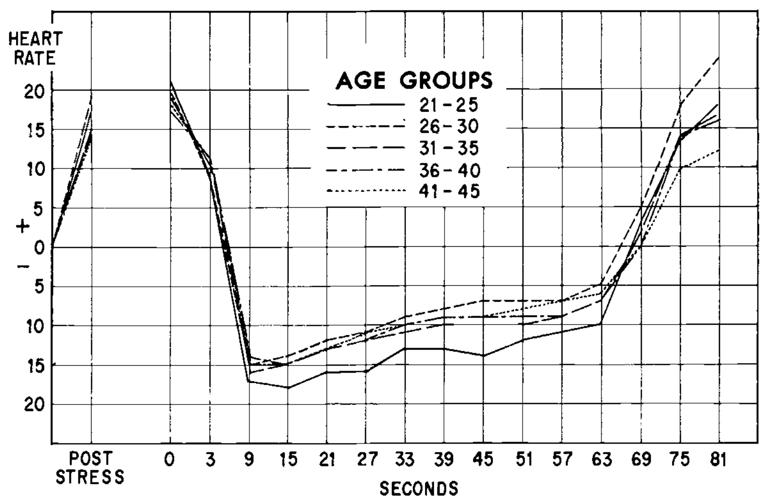

Fig. 3. A comparison of the mean for the changes in heart rate compared to the baseline for subjects in different age groups.

responses and sets the stage for a vagal rebound phenomenon. Thus, an experimental situation is induced in which sympathetic stimulation is terminated and vagal stimulation is augmented.

sub-groups. One group was comprised of 68 individuals who had been referred to the School of Aerospace Medicine for problems of loss of consciousness. Another 19 subjects were test pilots undergoing special examinations. A third group consisted of 128 subjects referred to the Aeromedical Consultation Service for a variety of findings and a number of subjects among laboratory personnel. There was no appreciable difference in the mean change in heart rate between the three different groups. The plot of the mean change in heart rate for each of the three groups was nearly identical (Fig. 2). This suggests that individuals with one episode of syncope would not have any significant difference in response to tilt table procedures from those individuals without such a history and no discrimination between individuals presenting such a history can be expected by this procedure.

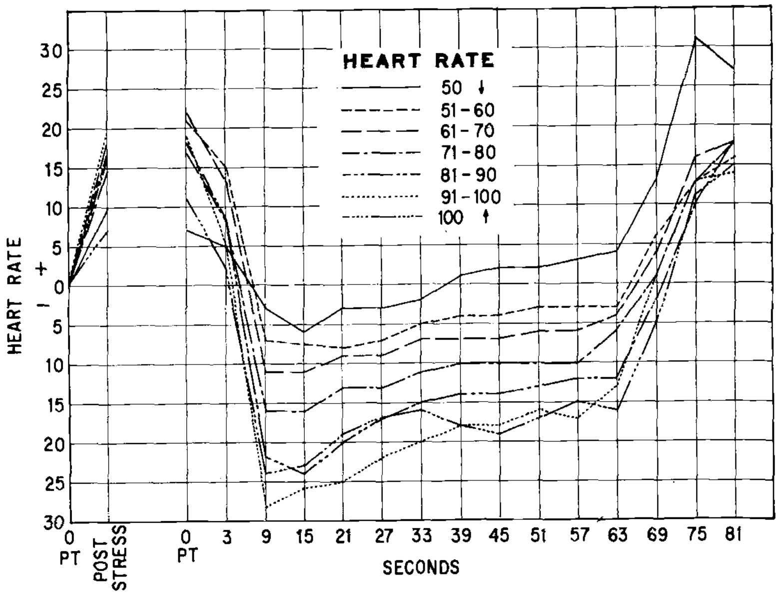

Fig. 4. A comparison of the mean for the changes in heart rate compared to the baseline for subjects with different resting levels for heart rate.

TABLE II. DISTRIBUTION OF SUBJECTS ACCORDING TO HEART RATE

Heart Rate	Number of Subjects
Less than 50 beats per minute	3
51 to 60 beats per minute	31
61 to 70 beats per minute	70
71 to 80 beats per minute	53
81 to 90 beats per minute	39
91 to 100 beats per minute	9
Greater than 100 beats per minute	10
Total	215

Age Groups.—The composite group was divided into five-year age groups to determine if the difference in age of the subjects had any influence upon the responses noted during the procedure. The exact age was known in 211 subjects. The distribution in age groups is given in Table I. By comparison, the youngest age group had a slightly greater decrease in heart rate during the head-down tilt as indicated by

TABLE III.
INFLUENCE OF BASELINE HEART RATE ON CHANGE IN HEART RATE DURING TESTING

Mean Baseline Heart Rate	Mean Heart Rate Change at Onset of Tilt	Lowest Mean Heart Rate Change After Head-Down Tilt
Less than 50	+7	−6
51-60	+21	−8
61-70	+22	−11
71-80	+17	−16
81-90	+18	−24
91-100	+19	−28
100 or over	+11	−24

the lower values expressed as the mean for the group (Fig. 3). The differences in the mean value for change in heart rate for the different age groups, however, were small and for all practical purposes may be considered the same. This would seem to indicate that, in this study of individuals between the ages of 20 and 45, age was not a major factor determining the amount of change in heart rate induced by the procedure.

Heart Rate.—The composite group was divided into seven sub-groups according to the baseline heart rate. The number of subjects in each group is given in Table II. There were only three subjects with heart rates less than 50 beats per minute in the entire group. The changes in heart rate induced by the stress and the head-down tilt procedure appeared to be less marked in those groups with slower heart rates (Table III). This is illustrated by comparing the plots of the mean change in heart rate for each group (Fig. 4).

This study suggests that the baseline heart rate and the heart rate at the peak of sympathetic activity are important factors in the degree of vagal rebound noted. A graph of the mean heart rate changes for different groups established by different baseline heart rates clearly depicts the significance of heart rate on the responses which occur in the head-down tilt. Individuals with relatively slow heart rate, as a group, tended to have a less marked rise in heart rate with the stresses used and the fall in heart rate during the head-down tilt position was not so marked. The peak of sympathetic activity was never very great and neither was the vagal rebound response. In general, the subjects with higher baseline heart rates had higher heart rates at the 0 point, just at the onset of the head-down tilt. The change in heart rate, as compared to the baseline level, was not always as great; for example, those subjects with baseline heart rates between 91 and 100 beats per minute with an average heart rate of 94 had an average increase in their heart rate of 19 beats per minute just prior to the head-down tilt. This is not as much of an increase in heart rate as was noted in those subjects with the baseline heart rate between 61 and

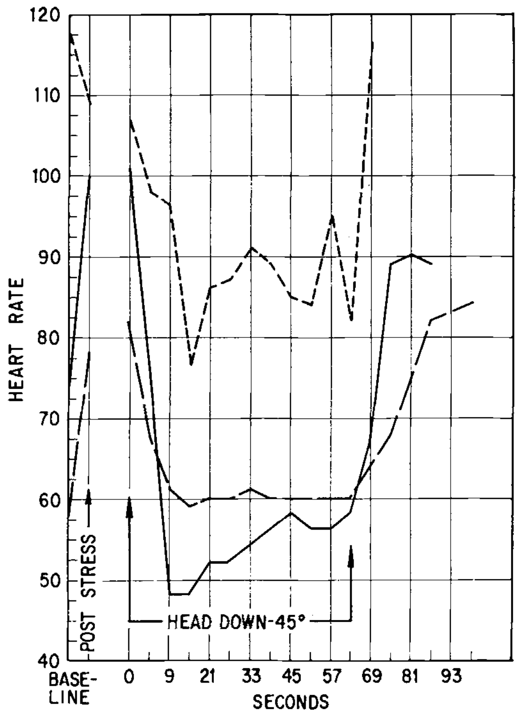

Fig. 5. The short dash line is the graph of a subject with an initial high baseline heart rate. The long dash line is a typical individual with a slow baseline heart rate in which the fall in heart rate from the 0 point was not below the individual's baseline level. The solid line is the change in heart rate of an individual with a resting heart rate of 74 beats per minute with a typical vagal rebound during the head-down tilt.

70. Their heart rates just prior to the head-down tilts had increased 22 beats per minute above the baseline. Even so, the actual heart rate for the latter group, then, at the peak of their sympathetic response is considerably lower than for the group with the faster baseline heart rates. The generalization may be made that those individuals with higher baseline heart rates had a higher level of sympathetic activity induced by the various procedures.

Numerous factors caused considerable variation of the heart rate in individual subjects. Three types of responses are illustrated in Figure

5. Those few subjects with very high baseline heart rates, in excess of 100 beats per minute, occasionally showed a drop in heart rate after the onset of the procedure. One may assume that the initial heart rate was augmented by anxiety and once the stress procedures were over and the anxiety was relieved, the heart rate decreased. This would indicate that in such a subject the influence of anxiety was more marked than the influence of the stress procedures. Individuals who presented this type of response were relatively uncommon.

Exercise Tolerance.—Of the composite group, 110 subjects had been tested by treadmill studies. Exercise tolerance was gauged by determining the length of time of exercise required to increase the heart rate to a level of 180 beats per minute. Sub-groups, in terms of the length of time required to reach this heart rate, were established. The distribution of individuals in each sub-group is given in Table IV. No appreciable difference in the mean change in heart rate either by stress-testing or the tilting procedure could be detected by dividing the group as to their response to maximum physical exertion. The mean change in heart rate for each group was plotted and the means for each group are, for all practical purposes, identical (Fig. 6). This suggests that the change in heart rate due to tilting procedures is not specifically related to ability to perform maximum physical exertion.

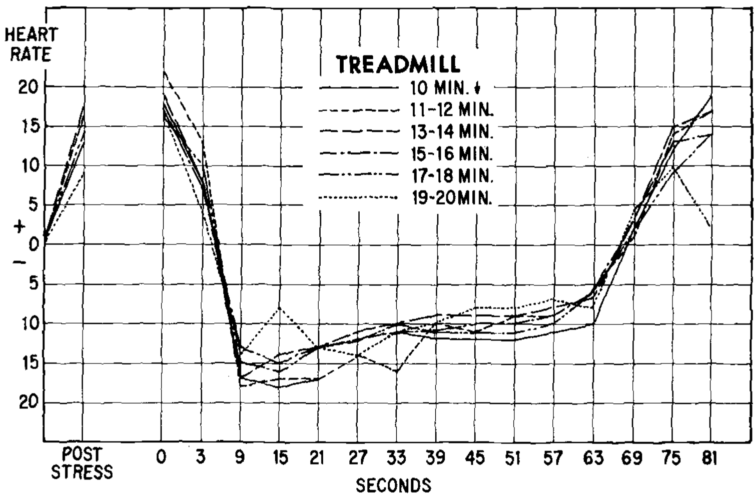

Fig. 6. A comparison of the mean for the changes in heart rate for subjects divided into groups according to their response to treadmill exercise.

TABLE IV. DISTRIBUTION OF SUBJECTS ACCORDING TO EXERCISE TOLERANCE

Duration of Exercise	Number of Subjects
10 minutes or less	10
11 to 12 minutes	25
13 to 14 minutes	30
15 to 16 minutes	26
17 to 18 minutes	16
19 to 20 minutes	3
Total	110

The degree of physical fitness as judged by the response during exertion on a treadmill had no apparent correlation to the changes in heart rate before and after tilt table stresses. One might have expected that those individuals who had better exercise tolerance would have less variation in their heart rates during the tilt table procedures. This was not the case. Increased exercise tolerance is in reality an adjustment to various forms of exercise for a given individual and no direct correlation between exercise tolerance and heart rate was apparent in this group. In other words, good physical tolerance was not always associated with relative vagotonia and conversely, poor physical tolerance was not always associated with increased sympathetic activity. By comparing the treadmill scores in the different groups separated according to their baseline heart rate, this is readily apparent (Table V). As an illustration of the lack of correlation between baseline heart rate and treadmill response, those individuals with a baseline heart rate between 51 and 60 with treadmill studies had performance scores ranging from 10 to 19 minutes and those individuals with baseline heart rates between 81 and 90 beats per minute had scores ranging from 8 to 17 minutes. It would appear, then, that those individuals with increased physical tolerance, who also had slow baseline heart rates were less apt to have marked sympathetic acceleration followed by vagotonic rebound and that, again, the most significant factor was the baseline heart rate rather than the physical tolerance. It is to be expected that the cardiovascular reflex action in relation to plus and negative g is a reflex action to a specific type of stimulus and will not necessarily be influenced by physical tolerance. The level of sympathetic activity in relation to circulatory reflexes is a response not only to physical conditioning, but to the individual's response to anxiety in a given situation, such as an unfamiliar testing procedure, and to a given individual's sympathetic response to g force stimulation. Thus, the circulatory reflex action as indicated by the baseline heart rate is the individual's composite reflex response.

TABLE V. BASELINE HEART RATE AND EXERCISE TOLERANCE

Pulse Rate (Beats Per Minute)	Number of Subjects						Lowest Score	Highest Score
	Less Than 10	11-12	13-14	15-16	17-18	19-20		
Less than 50								
51-60	1	2	10	8	3	2	10 min.	19 min.
61-70	1	5	5	4	3	1	7 min.	19 min.
71-80	4	6	10	7	7	0	8 min.	18 min.
81-90	3	7	5	6	3	0	8 min.	17 min.
91-100	1	4	0	1	0	0	11 min.	15 min.
100 or over		1					12 min.	12 min.
Total	10	25	30	26	16	3		

Before and After Stress.—In the 15 subjects studied when in the head-down tilt position before and after the stress procedures, a significant difference was observed. Each subject served as his own control. When the head-down tilt was performed before stress studies, there was a minimal decrease in heart rate. The same head-down tilt performed at the conclusion of the stress procedures showed a much greater fall in heart rate in the head-down position (Fig. 7). Since, in both circumstances, the change in heart rate was calculated in relation to the baseline heart rate with the onset of the procedures, and during both head-down tilts the subject was placed in identical position, it may be concluded that the difference in the changes in heart rate during the head-down tilt before and after stress

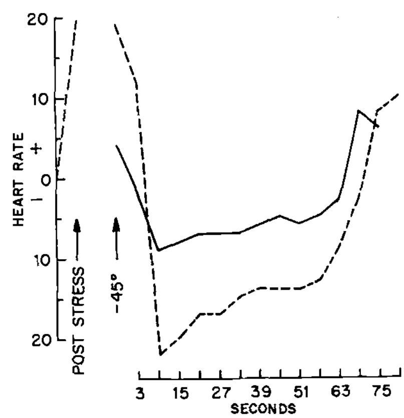

Fig. 7. A comparison of the mean for changes in heart rate during the head-down tilt without preceding stress (solid line) and during the head-down tilt after stress (dashed line).

is initiated by the stress procedures. The change in heart rate in the head-down tilt after stress cannot be attributed to the influence of the 45-degree head-down position alone.

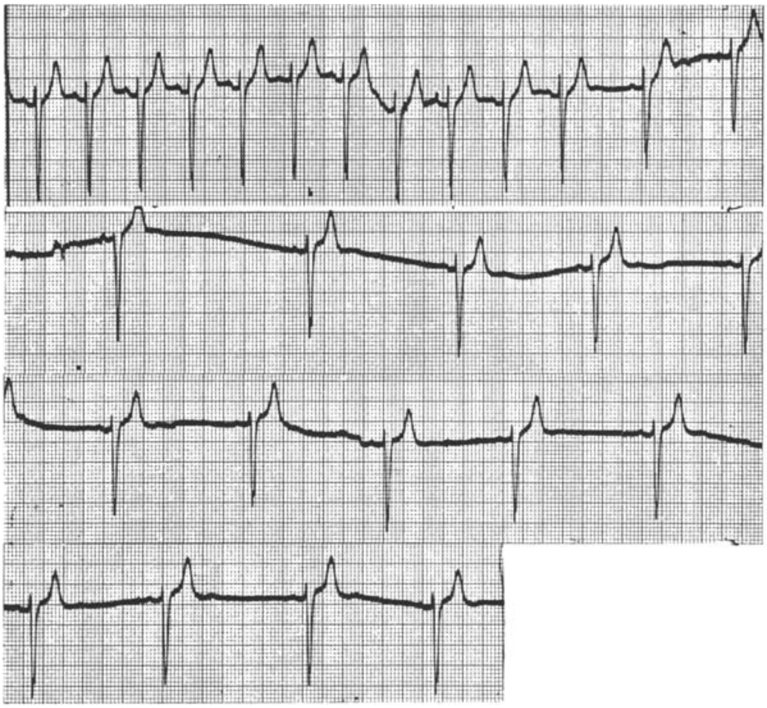

Fig. 8. Sinus tachycardia, rate 115 beats per minute just prior to tilting head-down (first part of top strip) changing to sinus bradycardia with a rate less than 45 beats per minute after tilting.

During the +1 g force stimulation and the stress period, the peak of sympathetic activity was achieved. This peak of sympathetic activity was considerably above the sympathetic level noted during the exposure to simple transverse g. During the head-down tilt, the vagotonic rebound was significantly more marked. The influence of the head-down tilt alone should have been the same before and after stress, thus, it may be concluded that the level of sympathetic activity induced by the +1 g force and the stress had considerable influence on the degree of vagotonic rebound noted during the head-down tilt.

Cardiac Arrhythmias.—Sinus bradycardia was commonly noted in the 215 subjects during the head-down tilt (Fig. 8). In 25 subjects, the pacemaker was displaced to an atrial focus inducing atrial rhythm. In the presence of the bradycardia, ectopic prematurities were noted. In 69 subjects, atrial prematurities occurred (Fig. 9). In 27 subjects, ventricular prematurities were present. Four subjects had short bursts of atrial tachycardia (Fig. 10). Sinus arrest and escape beats of ventricular origin were less commonly noted (Fig. 11). Varying degrees of A-V block also occurred.

The common occurrence of atrial prematurities may be due to distention of the atria during the head-down tilt. Frequent ventricular ectopic impulses were particularly apt to occur if occasional prematurities had been noted on previous electrocardiograms. An example of ventricular bigeminy induced during the head-down tilt in an individual with occasional ventricular premature contractions is noted in Figure 12. Ectopic pacemakers become more apparent in the presence of bradycardia reactions in which the primary pacemaker of the heart is suppressed.

It should be emphasized, despite the variations in cardiac rhythms, bradycardias and arrhythmias noted in a large number of subjects, that none of the subjects exhibited discomfort or evidence of circulatory collapse during the head-down tilt procedure. In every instance, despite the occasional occurrence of rather dramatic cardiac arrhythmias, the procedure appeared to be wholly innocuous. The cardioinhibitory responses noted would have been siginficant in an individual feet-down at +1 g. In the head-down position, a large percentage of the cardiac output is distributed to the head. In the feet-down position, a greater percentage of the cardiac output is distributed to the lower portions of the body and marked cardioinhibitory re-

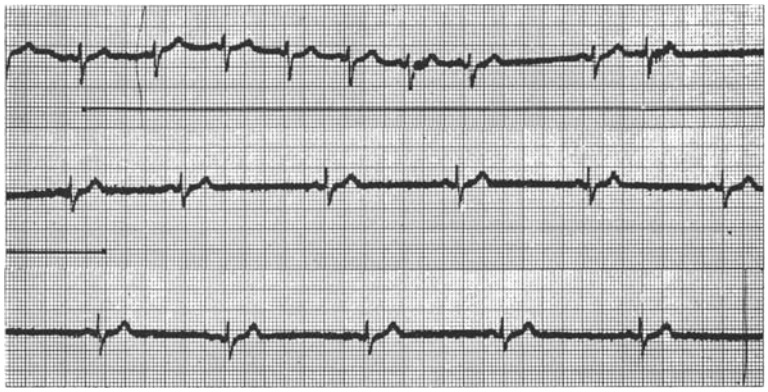

Fig. 9. Sinus rhythm rate approximately 100 beats per minute changing to sinus bradycardia rate approximately 45 beats per minute with one atrial premature contraction with head-down tilting.

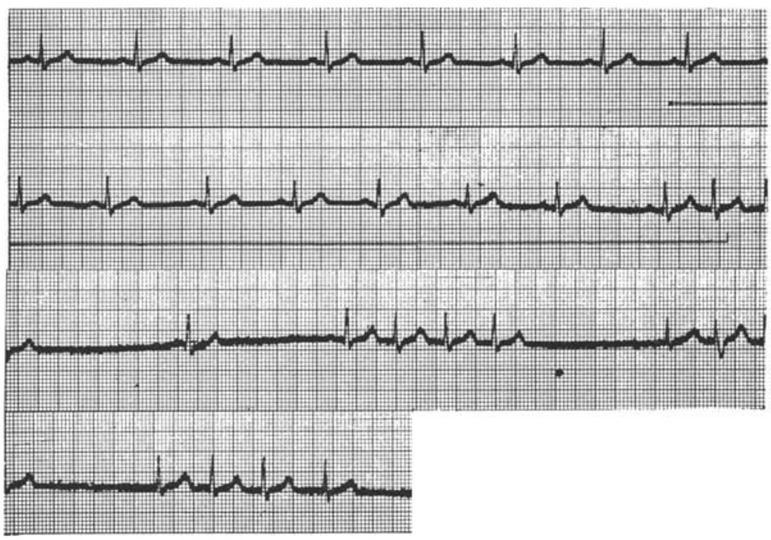

Fig. 10. Normal sinus rhythm rate approximately 65 beats per minute changing to basic sinus bradycardia rate 35 beats per minute. A short burst of atrial tachycardia is seen in the middle of the third strip and at the end of the fourth strip.

sponses in the latter circumstance may contribute to inadequate blood supply to the brain, resulting in loss of consciousness. The differences in the response noted emphasizes that the importance is not so much the amount of cardiac output, but its distribution. This observation serves to point up the importance of considering the circulatory behavior as a whole rather than emphasizing only one manifestation such as a change in heart rate or a decrease in blood pressure. It is obvious that in the head-down position considerable fall in cardiac output can be tolerated and still maintain adequate circulation to the brain.

Fig. 11. Sinus tachycardia rate approximately 115 beats per minute changing to transitory sinus arrest with ventricular escape with the head-down tilt.

Two-Minute Head-Down Tilt.—The nine subjects studied with the two-minute head-down tilt did not differ appreciably from the composite group of 215 subjects (Fig. 13). Individual variations were noted, but the general characteristics noted were an increase in heart rate in the post-stress period and a precipitous fall of heart rate immediately after the head-down tilt. The mean value for the change in heart rate did not return to the baseline throughout the two-minute period. As noted in the composite group, as soon as the subject was tilted again to the upright position following the head-down tilt, the cardiac rate immediately increased to levels above the baseline determination.

CONCLUSIONS

After careful analysis of all the data from this study, it would seem apparent that the most important factor controlling the degree of vagotonic rebound which might be induced during small periods of negative g is the level of sympathetic activity achieved earlier. Sympathetic activity is obviously influenced by the normal +1 g force to which an individual is exposed in the upright position. Sympathetic tone is responsible for maintaining proper circulatory dynamics. Sympathetic control over the circulation is a rather large variable and is influenced by anxiety, environmental circumstances, metabolic activity and a host of other factors. When the majority of the stimuli inducing sympathetic control of the circulatory system are removed, for example, removal of the sympathetic stimulation of g force activity and removal of exercise or stress procedures which increase sympathetic activity, a normal vagotonic rebound period occurs. When this is combined by even minor vagal stimulating mechanisms, such as the head-down tilt, the change in heart rate is striking. It has been amply demonstrated before that individuals exposed to increased g load will undergo a sympathetic phase and after termination of the increased g load, a vagotonic rebound period occurs.[3] The use of the tilt table which provides a means of exposing individuals from +1 g to transverse g and —0.7 g, provides a useful means in the laboratory for studying the circulatory reflex action. The influence of familiarization of a subject to his environment, the influence of physical training and the degree of changes in circulatory responses can easily be studied in the laboratory by such a tool.

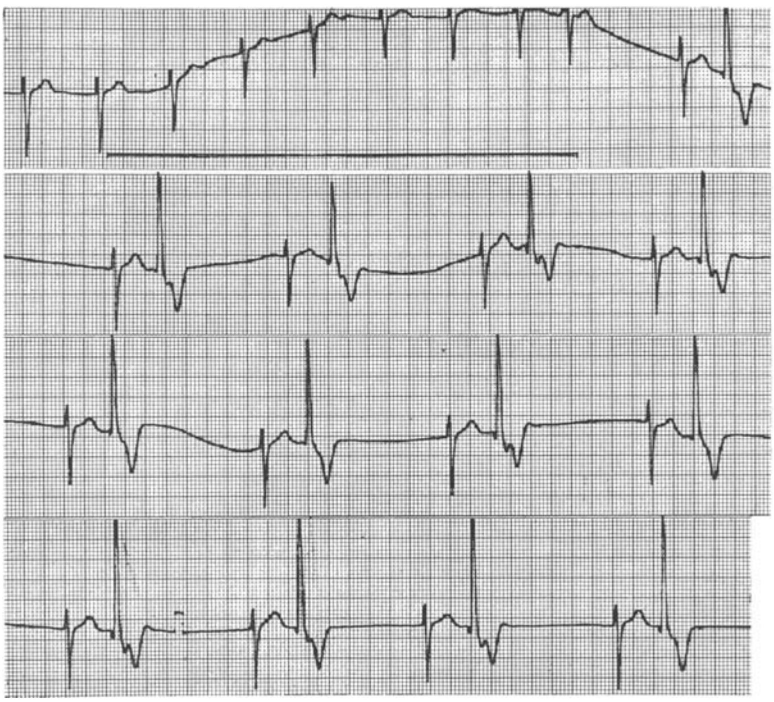

Fig. 12. Normal sinus rhythm rate 80 to 90 beats per minute changing to a basic sinus rate of 70 beats per minute with ventricular prematurities occurring in bigeminal fashion.

SUMMARY

1. A study of 224 subjects with feet down (+1 g), horizontal (tranverse g), and 45-degree head-down tilt (—0.7 g) in the laboratory on a standard tilt table was carried out.

2. Marked changes in heart rate were noted by using this simple laboratory tool. The changes in heart rate were frequently associated with striking cardiac arrhythmias. Despite arrhythmias of the magnitude of sinus arrest with idioventricular rhythm, no examples of significant circulatory disturbance were encountered during a one-minute period of head-down tilting.

3. The subjects studied ranged from 20 to 45 years of age. Age did not appear to be a significant factor influencing the changes in heart rate or rhythm.

4. Analysis was carried out in reference to the influence of physical fitness as judged by relatively standard treadmill exercise tests, and it was apparent that physical fitness or exercise tolerance was not a significant factor in influencing the level of sympathetic acceleration or vagotonic rebound indicated by changes in pulse rate for this group.

5. As a group, there were no significant differences between individuals who had had previous history of loss of consciousness, individuals who presented for a variety of complaints to the Consultation Service other than loss of consciousness, and individuals undergoing special testing from the Test Pilot School.

6. The most significant factor influencing the degree of cardioinhibitory response noted in the head-down tilt was the level of sympathetic activity in an individual as indicated by his baseline heart rate and his post-stress sympathetic acceleration level..

7. The tilt table provides a convenient tool for studying an individual's circulatory reflex response in reference to adaptation to stresses imposed during +1 g and to responses incurred following termination of stresses and exposure to —0.7 g.

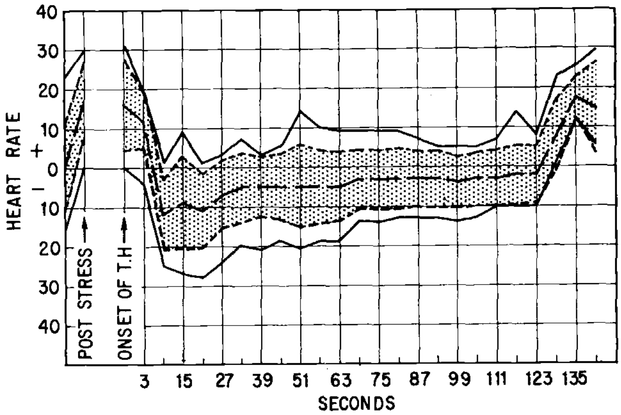

Fig. 13. The mean, standard deviation of the mean (shaded area) and extremes (upper and lower lines) of changes in heart rate noted in nine subjects with a 2-minute head-down tilt.

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