TILT-TABLE TESTING AS A PREDICTOR OF +GZ TOLERANCE

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ABSTRACT

BACKGROUND: G-tolerance assessment is an essential element of both military pilot and pilot candidate evaluation. AIMS: Attempt at prediction of individual relaxed +Gz tolerance on the basis of head-up tilt (HUT) testing. SETTINGS AND DESIGN: In two stages, 20 healthy men at the mean age 21.5 years took part in this study. The first stage, a 45 min, HUT test was performed using the Westminster protocol. During the second stage each underwent a centrifuge evaluation in response to gradual onset rate profiles. METHODS AND MATERIAL: In each subject, heart rate (HR) and blood pressure (BP) before and at 2, 15 and 45 min of the tilt-test were recorded. The gravity-load centrifuge (GOR) studies were carried out [following the standard GOR programme, at 0.1 G/s rate of gravity load increase until the gravity load tolerance limit (loss of peripheral vision) was reached]. STATISTICAL ANALYSIS USED: Relationships between variables were explored using Kendall’s tau-B correlation coefficient. The critical P-level was one-tailed 0.05. RESULTS: In four of 20 subjects (20%), vasovagal syncope occurred during the tilt test. G-level tolerance of this group (of +Gz accelerations) lay in the range from +4 to +8.1 Gz, (+5.72 ± 0.86 Gz average) and was comparable to the group without syncope. Loss of consciousness did not occur in any subjects during the centrifuge test. No statistically significant correlation was observed between HR and BP during tilt test and tolerance to +Gz accelerations. CONCLUSIONS: The result of tilt testing, carried out according to the Westminster protocol, was not useful in predicting individual tolerance to +Gz gravity loads.

KEY WORDS: blood pressure; centrifuge examinations; vasovagal syncope

Examination of cardiovascular responses to a programme of linearly increasing acceleration on a gravity-load centrifuge (GOR) is a routine test in the assessment of head-foot gravity load tolerance. Since this programme uses a low rate of gravity load increase (0.1 G/s), actual efficiency of body compensatory mechanisms can be assessed in this programme. Regulation of changes of heart rate (HR) and blood pressure (BP) during the test depends on many factors, but one main element of adequate circulatory system adaptation to hydrostatic changes depends on normal function of high-pressure baroreceptors of the cardiovascular system. The specificity of flying military aircraft, particularly highly-maneuverable planes, is connected with effects of high +Gz gravity loads on pilot's physiological performance. Pilot candidates must therefore meet not only clinical health criteria but also correctly react to gravity load-induced blood redistribution in the vascular bed.

The +Gz gravity load shifts a significant volume of circulating blood to the lower parts of the body that is thought to provoke relative central hypovolemia. This reduces venous return, cardiac output and stroke volume and decreases arterial pressure. In case of failure of compensatory mechanisms, this sequence leads to critical reduction of cerebral perfusion and loss of consciousness (G-LOC). The response of the circulatory system to increasing gravity load includes increased activation of the sympathetic system followed by humoral activation. As a result of increasing sympathetic activation, peripheral resistance increases, HR accelerates, myocardial contractility increases and constriction of large veins and venous pooling in the viscera occurs. Furthermore, humoral activation (catecholamines, renin-angiotensin-aldosterone system and atrial natriuretic peptide) supports the defence mechanisms activated as a result of unloading of cardiotropic mechanisms (blood redistribution and reflex syncope) even in clinically healthy individuals. It can be claimed, therefore, that one effect of +Gz gravity loading, with respect to the cardiovascular system’s reaction, is an exaggerated case of orthostatic stress.

In clinical practice, head-up tilt (HUT) is the basic diagnostic test applied to otherwise healthy, individuals who present clinically with recurrent consciousness disturbances. Its main purpose is to provoke symptoms of vasovagal syncope in a peripheral model of vasovagal reaction. Thus, to test a GOR programme, HUT could be useful to assess (under monitored conditions) reflex reactions to hydrostatic changes. It seems that the underlying mechanisms may involve similar responses (syncope resulting from orthostatic stress and G-LOC) to both tests. In this respect, HUT has potential to be a first screening test for candidate acceptance.

In view of the fact that the cost of gravity load testing is very high, and determination of tolerance to acceleration is an indispensable condition to qualify a candidate...
for aviation training, new, less expensive methods to carry out this assessment could be beneficial.

The aim of the study was to attempt at prediction of individual relaxed + Gz tolerance on the basis of HUT testing.

**MATERIALS AND METHODS**

The study group included young, clinically healthy (without history of syncope) males (volunteers) aged 20–30 years (mean age 21.5 years), weighing 65–80 kg and of 165–180 cm height who were normotensive, nonsmokers and not on medication. Each gave written consent to participate in the study. An ethics committee of the Polish Air Forces Institute of Aviation Medicine cleared the protocol for execution of the study.

**Study 1: HUT**

The study was carried out in a quiet, partly dark room. The ambient temperature was about 23°C. HUT was performed on an electrically operated tilt-table with a support for the feet, with a possibility of tilt angle change at a rate of 0.75° per second. The subject was protected against falling from the table with special belts. Throughout the whole study, ECG was continuously monitored on a Propaque monitor and by means of a Holter recorder while arterial pressure was determined by noninvasive method (using a finger) based on plethysmographic method (Portapress equipment, TNO-Biomedical Instrumentation, Holland). The tests were performed in the morning between 9 a.m. and 11 a.m. After 15 min of rest in the supine position, each patient underwent passive HUT testing at a 60° angle for 45 min (Westminster protocol). A positive tilt test was defined as a drop in systolic blood pressure (SBP) >60% from baseline values or an absolute value of <80 mm Hg with or without bradycardia (defined as a drop of >30% from baseline value or to <40 bpm), associated with symptoms of imminent syncope (e.g., lightheadedness or dizziness). Syncope was classified (according to Sutton) in three forms: mixed, cardioinhibitory, and vasodepressor. During the test, the subject was obliged to report any symptoms of discomfort. The test was completed (return to horizontal position) after 45 min or after occurrence of syncopeal symptoms. The type of response/reaction to tilt test (physiological reaction, vasovagal syncope, orthostatic tachycardia and dysautonomic reaction) was assessed.

SBP, diastolic blood pressure (DBP), mean arterial pressure (MAP) and HR before and in 2, 15 and 45 min of tilt test were evaluated.

**Study 2: centrifugation**

The GOR studies were carried out on the 10 m radius centrifuge in the Acceleration Tolerance Laboratory, Polish Air Force Institute of Aviation Medicine, following the standard GOR programme, at 0.1 G/s rate of gravity load tolerance limit (loss of peripheral vision) was reached. Additional indications to discontinue the centrifuge test included:
1. Significant abnormality in ECG record.
2. Loss of consciousness (G-LOC).
3. Subject’s demand.

The tests were performed in the morning between 9 a.m. and 11 a.m., after a light breakfast and night of normal sleep. During the test, the subject remained in the seated position in the centrifuge gondola. Constant radio contact was maintained between the subject and the doctor conducting the test. During the test duration, the subject’s behaviour was monitored on a TV-screen at the control desk. During the test, we measured the reaction time to light stimuli – lamps switched according to program and placed symmetrically in the peripheral field of vision at 180°. The subject confirmed the received light stimuli by pressing a button on the lever with their fingers. Throughout the +Gz examination only ECG (HR) was continuously recorded to monitor possible heart rhythm disturbances. BP was not monitored during the +Gz tolerance tests due to difficulty with maintaining signal integrity and the limited value of baroreflex measures in predicting maximal +Gz tolerance.

In four of 20 subjects (20%), vasovagal syncope occurred during the tilt test. In all cases this was a vasodepressive reaction that developed between minutes 15 and 17th (16.2 ± 0.9 min average). In the remaining males, a normal orthostatic reaction occurred. None of the four syncopal subjects had visual symptoms prior to HUT-induced symptoms.

G-level tolerance of this group (of +Gz accelerations) lay in the range from +4 to +8.1 Gz, (+5.72 ± 0.86 Gz average). Loss of consciousness did not occur in any subjects during the centrifuge increase in gravity load. During centrifuge tolerance testing, two individuals with vasovagal syncope demonstrated poor acceleration tolerance (+4 and +5.2 Gz) while two other syncopal subjects tolerated acceleration well and very well (+6.2 and +7.9 Gz). The fact is worth stressing that in as many as five individuals (25%) in whom vasovagal symptoms failed to develop, tolerance to acceleration was very poor (below +5.5 Gz) and, in one, even poorer than subjects with syncope during the tilt test.

Cardiovascular responses to HUT and +Gz tolerance in the group with normal orthostatic tolerance and the group with syncope are presented in [Tables 1 and 2], respectively.

There were no statistically significant
Therefore, it is interesting that a stimulus of +Gz gravity load, caused no syncope, even in individuals with abnormal orthostatic reaction to HUT. It is commonly known that the gravitational force creates pressure gradients in the circulation. For tilting and centrifugation, local arterial pressure change from gravitational stimulation is calculated as pressure (P) at a distance h from the arterial hydrostatic indifference level, applied along the z (head to foot) body axis according to the following expressions: $P = pg\sin \theta$ – for tilt and $P = ph(\omega/r_\theta)$ – for centrifugation. In accordance with this reasoning the brain level BP during HUT should be higher then during GOR. It has been demonstrated that exposure to hypergravity influences cerebral autoregulation in humans. The particular finding that dynamic autoregulation was impaired in the supine position but restored in the upright position after intraocular pressure at was lowered specifically suggests that exposure to hypergravity results in a leftward shift of the static cerebral autoregulation curve. Although, the mechanism for this proposed shift is unclear, it may involve adaptation to reduced cerebral perfusion pressure during +Gz exposure and/or possibly a vestibular-mediated effect on nervous pathways that modulate cerebrovascular tone. Similar studies have been published attempting to correlate physiological responses to lower body negative pressure (LBNP) with G-tolerance; these failed too. In those studies, differences in calf, thigh and abdominal segment blood volume changes, and carotid-cardiac baroreflex sensitivity confirmed that LBNP effects were not sufficiently similar in nature to the acceleration environment. Lack
of correlation between tilt and gravity load tolerance tests may also be as a result of different hormonal responses to the two stressors. During centrifuge tests, serum adrenaline, noradrenaline, renin, aldosterone and vasopressin concentrations have been shown to increase significantly while atrial natriuretic peptide and cortisol levels decrease.\[5,17\] However, during those centrifuge tests, increases in hormone concentrations were observed throughout the whole test period and for about 2 min after test completion, while in HUT it depended upon the phase of the test. This was confirmed by results of our study. Mean HR was significantly higher during GOR than during HUT. During GOR, HR increased systematically together with Gz accelerations. During HUT, HR increased only in the first 2 min and after 15 min of the test. It has been demonstrated in numerous studies that, during tilting to erect position or HUT, noradrenaline, adrenaline and vasopressin concentrations increased significantly after several minutes of the test, reaching a constant value, which remained unchanged until test completion.\[18–20\] This was true, even if a significant BP decrease and/or HR reduction (fainting) developed in the subject. In addition, the Renin-Angiotensin-Aldosterone (R-A-A) system activation occurred only after about 15–20 min of HUT.\[20\] In our HUT study, syncope developed between minutes 15th and 17th. It was highly probable that it was a disturbance in R-A-A system activation that was responsible for this event, especially since, after 20 min of the test, systolic and diastolic pressures increased in relation to baseline values in as many as 9 and 12 remaining individuals. The fact is worth stressing that the centrifuge test was accompanied by significantly greater emotional stress, responsible for increased adrenal secretion, which may be a condition of good tolerance of gravity loads and may prevent loss of consciousness even in individuals with vasovagal reaction during HUT.

It should however, be mentioned that although tests on the centrifuge were always conducted according to the same programme, tilt test protocols, during which hormonal concentrations were assessed, varied significantly from ours and from each other. Undoubtedly, different tilt angles of the table and divergences concerning test duration affected the type and degree of hormonal response.\[19\] Besides, for reasons not elucidated as yet, tilt test results could be false positive.\[21\]

It is also possible that different mechanisms may be associated with different reactions of the cardiovascular system during orthostasis and Gz acceleration tests. It is commonly known that linear accelerations and gravity are perceived by the otolith organs of the vestibular apparatus.\[22\] It was previously demonstrated\[23\] that bilateral transection of the vestibular nerves in paralyzed, anesthetized cats impaired reflex compensation for orthostatic hypotension produced by HUT. This finding suggested that the vestibular system was involved in BP regulation during postural changes. However, to our knowledge, there have not been many studies showing possible influences of the otolith system on the cardiovascular system in humans during HUT test and head to foot accelerations. It has been demonstrated that the interaction of the baroreflexes and the vestibulosympathetic reflex (VSR) is additive during LBNP and head-down rotation.\[24\] Yates and co-workers have reported that the baroreceptor and vestibular reflex pathways (in cats) remain separate until they synapse on the presynaptic neurons in the rostral ventrolateral medulla.\[24,25\] However, electrical stimulation of the vestibular nucleus has been demonstrated to activate a few neurons in the nucleus tractus solitarii, which is the first central synapse of the baroreflex.\[26\] Although, these two cardiovascular reflexes do not appear to interact centrally to modify sympathetic outflow during an orthostatic challenge, they certainly complement each other. It might be speculated that, during movement or a change in posture, the VSR acts immediately to defend against a possible hypotensive episode before a drop in arterial pressure is sensed by the baroreceptors. Thus the VSR feed-forward property would aid in the stabilization of arterial pressure before the baroreflexes are engaged.\[27\]

In summary, our results indicate that, although, the cardiovascular stimulus for activation of reflex mechanisms compensating gravitational redistribution of blood during centrifuge and tilt tests is similar, circulatory system reactions were different. This difference could be attributable to differences in baroreflex activation, involvement of vestibular inputs, hydrostatic gradient differences, activation timetables of hormones or other, as yet undetermined, physiological determinants of cardiovascular regulation.

### CONCLUSION

The result of tilt testing, carried out according to the Westminster protocol, was not useful in predicting individual tolerance to Gz gravity loads.

### REFERENCES


ABSTRACT

BACKGROUND: Blood pressure (BP) measurement is a routine procedure but errors are frequently committed during BP recording. AIMS AND SETT INGS: The aim of the study was to look at the prevalent practices in the institute regarding BP recording. The study was conducted in the Medicine Department at Government Medical College, Chandigarh, a teaching institute for MBBS students. METHODS: A prospective, observational study was performed amongst the 80 doctors in a tertiary care hospital. All of them were observed by a single observer during the act of BP recording. The observer was well versed with the guidelines issued by British Hypertension Society (BHS) and the deviations from the standard set of guidelines issued by BHS were noted. The errors were defined as deviations from these guidelines. STATISTICAL METHODS: The results were recorded as percentage of doctors committing these errors. RESULTS: In our study, 90% used mercury type sphygmomanometer. Zero error of the apparatus, hand dominance was not noted by any one. Every one used the standard BP cuff for recording BP. 70% of them did not let the patient rest before recording BP. 80% did not remove the clothing from the arm. None of them recorded BP in both arms. In out patient setting, 80% recorded blood pressure in sitting position and 14% in supine position. In all the patients where BP was recorded in sitting position BP apparatus was below the level of heart and 20% did not have their arm supported. 60% did not use palpatory method for noticing systolic BP and 70% did not raise pressure 30–40 mm Hg above the systolic level before checking the BP by auscultation. 80% lowered the BP at a rate of more than 2 mm/s and 60% rounded off the BP to nearest 5–10 mm Hg. 70% recorded BP only once and 90% of the rest re-inflated the cuff without completely deflating and allowing rest before a second reading was obtained. CONCLUSION: The practice of recording BP in our hospital varies from the standard guidelines issued by the BHS.

Key words: blood pressure measurement-accuracy; blood pressure measurement-optimum technique; hypertension; observer errors.

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The blood pressure (BP) measurement is one of the commonly performed procedures by the doctors. Raised blood pressure (hypertension) is a common condition that does not have specific clinical manifestations until target organ damage develops. The most common indication of hypertension is the inaccurate measurement of blood pressure by the doctors. The blood pressure measurement is one of the routine procedures but frequently committed errors are seen in the hospital. The present study was designed to find out the prevalent practices in the institute regarding blood pressure measurement. The study was conducted in a tertiary care hospital. The observations were performed in the in-patient and out-patient setting. The observation was performed by a single observer. The results were recorded as percentage of doctors committing these errors. The statistical analysis was performed using descriptive statistics. The results were found to be significantly different from the standard guidelines. The errors committed were due to lack of training and awareness in the doctors. The results were discussed with the doctors and the importance of accurate blood pressure measurement was emphasized.