# Empty Stomach and Tolerance to Hypoxia and +Gz Forces

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**Abstract**

The importance of taking proper meals before ... has been stressed quite often and a number ... unexplained pilot error accidents and temporary ... incapacitation during flying have been implicated ... relative hypoglycaemia. The practice of ... proper breakfast before the first sortie ... day is not uncommon among aircrew. This ... reports a study on the effect of common ... stress on empty stomach (without breakfast), ... tolerance to hypoxia and 'G'z stress among ... individuals. Tilt table studies (60°) ... hypoxic condition (at 15,000 ft 30 min stay) ... increased inadequacy of orthostatic response ... overnight fasting condition. Studies in a ... centrifuge on 12 healthy subjects, including ... showed a reduction in 'G'z tolerance in all ... under overnight fasting condition. Blood ... estimation did not reveal any significant diffe... during these tests with and without overnight ... Studies after taking non-caloric roughage ... prior to centrifuge runs showed some improve... in 'G'z tolerance in subjects under overnight ... condition. The results have been discussed ... the importance of taking proper preflight meals ... been emphasised.

**Introduction**

Many pilot error accidents, near misses and ... have been implicated with spontaneous ... functional hypoglycaemia. [9, 13, 14] Avoidance of ... a proper meal prior to these flights has been ... related to such occurrences. A heavy meal ... high carbohydrate content may cause a rebound ... hypoglycaemia after few hours [12, 13, 14] and thus may ... to reduced tolerance to stresses like acceleration. Hypoglycaemia, serious enough to cause incapacitation and unconsciousness in flight, is difficult to prove in aviators as it would usually lead to fatal outcome. On the other hand, avoidance of breakfast before a morning sortie in healthy individuals should not cause any undue fall in blood sugar nor is expected to hamper all routine activities mostly of sedentary nature. It is not uncommon to find aircrew going for first sortie in the morning on empty stomach and have their breakfast leisurely later on in the crew room. Whether such practice reduces the pilot efficiency by lowering the individual's tolerance to common stresses like mild hypoxia or acceleration is a very important question. If there is any such reduction, it then compromises the flight safety, and an instruction to avoid flying on empty stomach would avoid such danger.

**Materials and Methods**

The study was conducted in two stages. In the first stage, the effect of mild hypoxia was observed on orthostatic tolerance under fasting and non-fasting conditions. In the second stage, the subjects were exposed to gradually increasing acceleration to determine any alteration in their individual 'G'z tolerance.

In the first phase, the effects of mild hypoxia on orthostatic tolerance were studied on 20 healthy adults (25–35 years).[4] Their response after taking normal breakfast as well as under overnight fasting conditions (12–14 hours) at ground level was noted on different days. Baseline blood pressure (BP) and heart rate (HR) in supine position were recorded at the beginning of the experiment till

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constancy was achieved, followed by tilting to 60° on a Tilt table with continuous monitoring for the next 5 minutes. BP was recorded by indirect method from the brachial artery with the help of suitable transducer on a Polygraph. HR was determined from ECG, recorded continuously on another channel. Each subject was again examined under hypoxic condition in an Altitude Chamber (at 15,000 feet for 30 minutes) after normal breakfast and after overnight fasting condition on two different days. Thus, each subject was studied for 4 days, and each served as his own control. Blood sugar was determined by King's method before and after each run.

In the second phase for acceleration studies, 12 healthy adults (25—35 years) were investigated, of which 6 were trained pilots and were in current full flying category. Subjects reported 2 hours after breakfast on non-fasting days and without breakfast (similar time of the day) on the fasting days. They were exposed to +Gz acceleration in the Human Centrifuge to a series of runs with step-wise increase of 'G'z load by 0.2 g till the PLL value was reached. PLL is the peripheral light loss when a subject fails to notice peripheral lights with eyes focussed at a central point under certain 'g' load. Each subject acted as his own control and was investigated on two different days for fasting and non-fasting condition. Blood sugar was determined by King's method before and after the runs. To compare the effects of empty and partially full stomach 6 subjects were exposed to centrifuge runs for three days. For the first two days, the programme was as mentioned earlier. On the third day, they reported after overnight fasting, were given non-caloric roughage diet of agar and green vegetable one hour prior to the centrifuge runs and PLL values were elicited to determine the 'g' threshold.

**Results**

Of the 20 subjects examined for orthostatic tolerance at ground level under non-fasting condition, 18 showed normal response to immediate tilt and thereafter. 2 subjects initially showed autonomic insufficiency type response but recovered fully within 5 minutes. Under fasting condition, three subjects (including the same two) showed abnormal response which continued for more than 5 minutes in two subjects without recovery. The result is given in Table I.

Under the effects of mild hypoxia during non-fasting condition, 6 subjects showed abnormal response immediately on tilt. 2 subjects continued to show inadequacy beyond 5 minutes, whereas 4 subjects recovered. With overnight fasting under hypoxia, 5 continued to show abnormal response beyond 5 minutes. The result is given in Table II. Of these, 2 subjects produced typical vasovagal syncope, with bradycardia, hypotension and collapse. The blood sugar level before and after exposure to hypoxia under fasting and non-fasting conditions did not show any significant differences. From Tables I and II it may be observed that hypoxia has affected the orthostatic tolerance adversely which was further aggravated under fasting condition.

Studies on Human Centrifuge showed a general reduction (0.4 g – 0.6 g) in PLL values under fasting condition in comprison to non-fasting condition. The result is given in Table III. Blood sugar did not show any significant change and was found to be within a range of 2 mgm% to 6 mgm% in individuals on the two days of investigation. BP recorded with indirect method showed a corresponding reduction in relation to PLL values. The reduction in 'G'z tolerance under overnight fasting condition showed some improvement when the subjects were given non-caloric roughage diet one hour prior to the centrifuge runs. The result is given in TABLE IV.

TABLE I

Response to 60° tilt at ground level (n = 20)

| Subject state | Type of response | Immediate | After 5 min. |
|---|---|---|---|
| Non-fasting | Normal | 18 | 20 |
| | Abnormal | 2 | Nil |
| Fasting | Normal | 17 | 15 |
| | Abnormal | 3 | 2 |

TABLE II

Response to 60° tilt under hypoxia (n = 20)

| Subject state | Type of response | Immediate | After 5 min. |
|---|---|---|---|
| Non-fasting | Normal | 14 | 18 |
| | Abnormal | 6 | 2 |
| Fasting | Normal | 15 | 15 |
| | Abnormal | 5 | 5 |

## TABLE III

PLL value and Blood sugar level (BSL) with and without breakfast in Centrifuge Studies (n = 12)

| Subject Sl. No. | With Breakfast PLL value (g) | With Breakfast BSL (mgm %) | Without Breakfast PLL value (g) | Without Breakfast BSL (mgm%) | Change (g) | Subjective Symptoms |
|---|---|---|---|---|---|---|
| 1. | 4.0 | 86 | 3.6 | 82 | –0.4 | Nausea, sweating and tiredness. |
| 2. | 3.6 | 84 | 3.2 | 78 | –0.4 | Marked Nausea |
| 3. | 3.6 | 80 | 3.2 | 76 | –0.4 | Tiredness |
| 4. | 3.4 | 82 | 2.8 | 78 | –0.6 | Nausea & vomiting |
| 5. | 5.6 | 75 | 5.2 | 71 | –0.4 | Nil |
| 6. | 3.6 | 82 | 3.0 | 80 | –0.6 | Nil |
| 7. | 4.0 | 84 | 3.6 | 78 | –0.4 | Nil |
| 8. | 5.6 | 78 | 5.0 | 74 | –0.6 | Nil |
| 9. | 5.2 | 78 | 4.6 | 72 | –0.6 | Nil |
| 10. | 5.4 | 86 | 4.8 | 82 | –0.6 | Nil |
| 11. | 4.8 | 80 | 4.2 | 76 | –0.6 | Nil |
| 12. | 5.2 | 84 | 4.6 | 78 | –0.6 | Nil |
| Mean | 4.5 | | 4.0 | | –0.5 | |
| ±SD | 0.9 | | 0.8 | | | |
| t | | | | | 17.49 (P < 0.001) | |

## TABLE IV

Changes in PLL values with and without breakfast (BF) and also after non-caloric breakfast (n = 6)

| Subject Sl. No. | (a) With Breakfast PLL value (g) | (a) With Breakfast BSL (mgm%) | (b) Without Breakfast PLL value (g) | (b) Without Breakfast BSL (mgm%) | (c) After noncaloric BF PLL value (g) | (c) After noncaloric BF BSL (mgm%) | Improvement from No BF to Non-Caloric BF (g) |
|---|---|---|---|---|---|---|---|
| 1. | 3.6 | 82 | 3.0 | 80 | 3.4 | 78 | 0.4 |
| 2. | 3.4 | 74 | 2.8 | 72 | 3.0 | 72 | 0.2 |
| 3. | 6.8 | 84 | 6.2 | 78 | 6.4 | 76 | 0.2 |
| 4. | 5.6 | 78 | 5.0 | 75 | 5.2 | 76 | 0.2 |
| 5. | 5.4 | 86 | 4.8 | 82 | 5.0 | 80 | 0.2 |
| 6. | 4.0 | 84 | 3.6 | 78 | 4.0 | 80 | 0.4 |
| Mean | 4.8 | | 4.2 | | 4.5 | | |
| ±SD | 1.3 | | 1.3 | | 1.3 | | |
| t | | [between (a) and (b)] | 17.10 (P < 0.001) | [between (b) and (c)] | 6.40 (P < 0.01) | | |

### Discussion

The results show that fasting condition (missing breakfast only) reduces the orthostatic tolerance under mild hypoxia in a few subjects and a reduction in + Gz tolerance in all the subjects. Both the conditions of mild hypoxia and acceleration are met in normal flying and as such it can be easily said that individuals do not maintain their optimal level of flying efficiency if they miss their breakfast.

Normal brain function can be interfered with either by reduced blood flow or diminished metabolic content subsequent to exposure to acceleration, hypoxia and hypoglycaemia. When more than one of these stresses are acting a summation of their physiological effects may lead to a reduction in tolerance. Episodic unconsciousness in aircrew during flight has been linked with probable hypoglycaemia by many workers. Some have tried to relate incidence of functional hypoglycaemia following high carbohydrate breakfast. Powel[12] in his studies could not get any case with marked reduction in blood sugar levels with associated symptoms and he suggested that other factors like hyperventilation and anxiety can play a part in an episode in the air. Hyperventilation, as such, can reduce cerebral blood flow by constriction of pail vessels. Conn and Seltzar[3] have laid down stringent criteria for the diagnosis of functional hypoglycaemia and they demanded that the attacks must occur 2 to 4 hours after meals, that the blood sugar tolerance curve must show a normal fasting level, that there is a normal absorptive rise and a secondary profound rapid hypoglycaemia. The true blood sugar must fall below 40 mgm% for a diagnosis. However, none of the cases investigated by Powel[12] did show any such characteristics. Taylor[14] examined 193 aircrew before and after flight but failed to reveal any case of relative hypoglycaemia and unusual symptoms. Robbin et al[13] reported a larger study. They also failed to show any correlation between blood sugar changes and dietary histories. In our present study, the changes in blood sugar were not found to be significant after an overnight fasting condition.

Hypoxia, as such, may lead to reduced orthostatic response. Nair and co-workers[11] exposed 20 subjects to 13,500 feet and found that ten percent of the subjects showed a vaso-vagal response on tilt table. They explained the findings to be due to autonomic system mal-adjustment and a reduced response to peripheral arteriolar constriction mechanism under hypoxia. Hartzell and co-worker[5] have shown a significant reduction in mean arterial pressure (MAP) under fasting condition in hypoxic environment. They explained that hypoxia would lead to vasodilatation in the lower limb and pooling of more blood. With fasting, the RQ is reduced, pulmonary oxygen tension falls, thereby enhancing the effects of exposure to hypoxia and a disturbance in homeostatic mechanism mediated by chemoreceptors and baroreceptors.

Besides the disturbance in homeostatic mechanism under the combined effects of hypoxia and fasting, a reduction in tolerance to 'G'z after missing breakfast is interesting. It is a common knowledge that a feeling of faintness or emptiness in stomach is associated with hunger. Miles[9] observed lowering of syncopal threshold in sea divers who are more prone to collapse when fasting. He explained that this lowering of syncopal threshold was due to hypoglycaemia and a reduction in readily available metabolic content in brain.

That the BP could not be maintained at normal level on exposure to 'G'z stress on empty stomach which was otherwise well tolerated after taking breakfast, is shown by reduced PLI values under fasting condition. That the reduction is due primarily to lowered blood glucose at the cortical level leading to autonomic disturbance and insufficient peripheral vascular response cannot be proved as there was no significant reduction in blood sugar under the experimental condition. On the other hand, when the stomach is partially full with non-caloric roughage diet, 'G'z tolerance was found to have improved to some extent. Study of pressure waves[2] in the gastric antrum with the help of a swallowed balloon and pressure transducer showed some interesting finding. This is shown in Figure 1. As soon as the stomach was empty, a type of regular rhythmic contraction started with periods of relaxation in between. As the fast continued, the periods of contraction became more frequent with the period getting reduced. This was associated with a conscious sensation of a vague feeling of emptiness. These contractions could be associated with certain systemic effects with changes in the heart rate, nervous reflex, salivation and a vague feeling of weakness. In some subjects it was even associated with sensation of nausea. Even otherwise, attacks of vasovagal syncope have been found to be precipitated by empty stomach. Thus empty stomach by itself may lead to a reduction in peripheral vasomotor tone and a reduced response to peripheral arteriolar constriction mechanism when a subject is exposed to acceleration. This has been found in every subject when exposed to +Gz in the centrifuge. The blood pressure at heart level and at eye level fell appreciably on exposure to

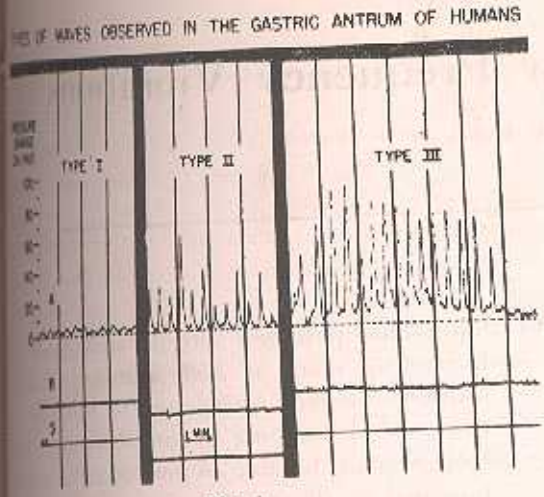


Fig. 1

Types of mobility recorded from normal human gastric antrum. Type I shows normal contraction of low tone causing pressure change of approximately 5 cm of water. Type II are longer contractions each lasting for 20 sec with pressure changes ranging from 10 to 50 cm of water (at times 100 cm of water). Type III contractions are of higher amplitude and are superimposed on a raised basal pressure. After an overnight fast the contractions in a normal person usually consist of 25 percent of Type I, 15 percent of Type II and 1 percent of Type III. (From Code et al. 1952).

over level of +Gz. Besides, a full stomach can offer some resistance to the descent of diaphragm under +Gz load whereas under fasting condition an empty stomach cannot offer such resistance and a more downward excursion of the diaphgram under Gz load may lead to pooling of more blood in the dependent parts and reduced venous return to the heart.

Studies with hypoxia and 'G'z stress in association with fasting condition suggest a reduced peripheral vascular tone under change of posture and acceleration when the blood is pooled to the dependent parts. Normally this should lead to the stimulation with neurocirculatory adjustment mediated by the autonomic nervous system[6]. However, this response has been found to be inadequate in healthy subjects under fasting condition or a deconditioning in the peripheral arteriolar constriction mechanism. [5, 11]

## Conclusion

Missing a meal (avoiding breakfast) leads to reduced orthostatic tolerance under mild hypoxia in some subjects and also a reduction in + Gz tolerance in healthy subjects. Though the reduction is not marked, it may affect the efficiency of a pilot so far as his tolerance to common flying stresses, like hypoxia and acceleration are concerned. Aircrew should, therefore, be instructed not to fly on empty stomach. Taking proper breakfast before the first sortie of the day should be ensured. Changes in blood sugar level were not found significant and thus hypoglycaemia may be ruled out in a healthy subject missing his breakfast. Other mechanisms are related to insufficient cardiovascular response under tilt associated with hypoxia and also during exposure to acceleration.

## References :


1. BRENT HP, CAREY TM, POWELL TJ, SCOTT JW, TAYLOR WGR and FRANK WR — Synergism between effects of hyperventilation hypoglycaemia and positive acceleration. J. Aviation Medicine : 31, 101, 1960.
2. CODE CF, HIGHTOWER NC, MORLOCK J : Mobility of the alimentary canal in man. Amer. J. Med 75 : 13, 1952.
3. CONN JH and SELTZAR HS : Spontaneous hypoglycaemia. Amer. J. of Medicine 19 : 460, 1955.
4. DIKSHIT MB and CHATTERJEE PC : Changes of orthostatic tolerance during short duration mild hypoxia. J. Aviation Medicine 20 : 9, 1976.
5. HARTZELL WG and NEWBERRY PO : Effects of fasting on tolerance to moderate hypoxia. J. Aerospace Med. 43 : 321, 1972.
6. HOWARD P : The physiology of positive acceleration in the Textbook of Aviation Physiology. Ed. JA Gillis — Blackie & Sons, 1965.
7. KIRCHHEIM HR : Systemic arterial baroreceptor reflexes Physiol. Review. 56 : 100, 1976.
8. LAMB LE : Hypoxia — An anti deconditioning factor in manned space flight. J. Aerospace Med. 35 : 97, 1965.
9. LAWTON WH : Physiological investigation in the flight safety programme, US Armed Forces Med. Journal 8 : 937, 1957.
10. MILES S : Unconsciousness in underwater swimmers. Medical Research Council. Royal Naval Personnel Res. Comm. Rep. RNP 57/901 in FPRC 1044.
11. NAIR CS, GOPINATH PR, PRAKASH C and TALWAR OP : Effect of prolonged stay at high altitude on orthostatic tolerance in man. Ind. Journal of Med. Research 61 : 11, 1973.
12. POWEL TJ, CAREY TM, BRENT HP and TAYLOR WJR : Episodes of Unconsciousness in pilots during flight. J. Aviation Medicine. 28 : 374, 1957.
13. ROBBIN JH, KRATOCHVIL CN, ELLIS JP and HOWEL TR : Studies of Hypoglycaemia in flight. J. Aviation Medicine 30 : 268, 1959.
14. TAYLOR ER : Incidence of hypoglycaemia in flight. J. Aviation Medicine. 31 : 462, 1960.