PHYSIOLOGY OF STRESS

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Hans Selye was one of the first who explained the physiology of stress with his theory of 'General Adaptation Syndrome' (19). This theory denotes an all inclusive three stage mode of adaptation to stressful situation:

a. *Stage of alarm,* an initial phase of shock followed by a stage of counter shock during which the individual's defence mechanisms become active.

b. *Stage of resistance,* a stage of maximum adaptation which will help to preserve the homeostasis; but if the stress continues unabated the adaptation may fail and the individual may pass into the third stage.

c. *Stage of exhaustion,* a phase where the adaptation collapses as the compensatory mechanisms fail.

Since Selye first postulated this process of environmental stress and the resulting physical strain, much research has been done in the field of the physiology of stress.

Stress, Workload, Fatigue

Stress is an emotive word which conveys different meanings to different people. It makes considerable difference whether one is a physiologist, a biochemist, a clinician or an engineer. To some, stress is outside the body - something acting on the organism from without - perhaps better denoted as stressor. To others, it is the resulting effect of the stressor on the organism, i.e., strain, to borrow an engineering term. Stress, therefore, is a term which eludes simple definition. But if we accept the definition formulated at the 1971 Stockholm WHO Symposium on Society, Stress and Disease, "stress is the nonspecific response of the organism to any demand made upon it" (20,21).

In physiological terms, stress represents a threat if not a breakdown in homeostasis which can impair health if not removed (7). Three types of stresses are possible - environmental stress, acute reactive stress and domestic stress. It is very important to note that stress is an intrinsic factor in many occupations (5). A very pertinent question in aviation, which is a very complex man-machine interaction, is how hard does the aircrew work? If this is only physical work, then a variety of accurate techniques of study could be proposed (6). However, there is a significant element of non-physical workload in flying. This involves the neuroendocrinological system of the body. The workload, both physical and non-physical, acts as the stressor and induces stress in the pilot. Beyond certain limits this workload may produce fatigue which will adversely affect the task performance of the aircrew. Workload may be defined as the basic demand of the machine and mission and fatigue as the weariness that is produced by prolonged workload in the absence of sufficient rest schedule.

Sources of Stress in Military Aviation

Pilots operate in a three-dimensional dynamic environment often under the pressure of limited time. While the majority has accepted this fact, there is no doubt that any pilot who is inclined to worry has ample chance to do so (9). Therefore, aviation can be considered as the source of a wide range of stressors (9,13). Physiological and environmental stressors include the physical work involved, heat, cold, noise, vibration, hypoxia and acceleration. Sleplessness and inadequate recovery from fatigue are other major factors. Psychological stress factors include information overload, continuous vigilance and anxiety due to any reason. Beehr et al (1) have indicated that organisational stressors stemming from role ambiguity and conflict can result in stress related illness. Counterphobic activities if present in an aircrew (14) or 'testitis' (excessive anxiety about flying checks) (15) can be principal sources of stress.

Nonspecific Stress Response

Covering all types of aircraft, existing literature (3) considers heat, noise and vibration to be the most frequent stressors whereas cold, acceleration, work overload, fatigue and boredom occur less as frequent, while hypoxia, fear and isolation have been reported to occur only occasionally. Some of the stressors are known to produce specific stress responses and in order to ensure flight safety and aircrew health, primary attention is focussed in alleviating the individually identified and defined stress factors. However, while dealing with the subject of stress and performance, it is the nonspecific stress responses of the body that demands particular attention.

Stressor affects human performance by influencing some common intermediate variable. This intermediate variable may be the 'arousal'. Thus, it may be proper to assume that whatever be the stressor, the non-specific reaction can be similar. This arousal reaction is accompanied by endocrinal, cardiovascular and muscular reactions to prepare the individual for fight or flight reaction.

An activation of ascending reticular formation, limbic system and hypothalamus produces stimulation of large portions of sympathetic nervous system simultaneously (sympathetic mass discharge). This in turn increases the alertness and motor capability of the individual till an optimal level is reached beyond which there occurs a decrement in performance efficiency. These effects are mediated by the catecholamines. Some of the important physiological manifestations are as follows :

a. increased heart rate and arterial pressure,

b. selective increase of blood flow to active tissues such as muscles and heart,

c. increase in cellular metabolism,

d. increase in blood glucose level,

e. increased glycolysis in muscles,

f. increased muscle strength,

g. increased rate of blood coagulation, and

h. increased neural activity.

Measurements of the respective physiological parameters appraise the degree of sympathetic mass discharge and have been used in assessing the workload and the stress response of the individual.

Physiological Measures of Inflight Stress

Inflight heart rate measurements and postflight changes in urinary catecholamines and its metabolites have been found to be valid and feasible measures for field studies and have been appropriately used as measures of inflight workload and stress.

Roman and Lamb (17) measured heart rates in flight and observed that it correlated well with the pilot's estimate of the difficulties in handling their aircraft during any phase of flight. Roscoe (18) observed that heart rate responses, when used as comparative measures, give good indications of the workload generated by particular handling qualities of the aircraft.

Catecholamine responses to flying stress have its potentialities in appreciating individual's participation in workload and also his emotional arousal and thereby in interpreting his stress coping behaviour (11).

The original description of epinephrine as a stress hormone was forwarded by Cannon (2). Paolucci and Blundo (16) showed that post-flight changes in the excretion rate of vanillyl mandelic acid (VMA), a metabolite of catecholamines, can be used in evaluating the psychic load inflight; an excessive increase in VMA excretion may point out to over arousal due to anxiety stress.

In a recent study, Krahenbuhl et al (10) observed that VMA excretion rate increases significantly between low order and medium order flight emergencies but shows a fall during high order emergencies. They also observed that VMA excretion rate was significantly higher in student pilots than in the instructors during medium order flight emergencies indicating a higher stress response in the student pilots.

Ellison (4) suggested that the nor-epinephrine/serotonin ratio provides the most useful index of excitement. In flight emergency situations, as studied by Krahenbuhl et al (10), four indices of urinary excretion of biogenic amines/metabolites, viz., epinephrine, the sum of epinephrine and norepinephrine, the ratio of dopamine/nor-epinephrine and the ratio of norepinephrine/serotonin were found to show marked and measurable changes as compared to basal values. Blood analysis may not be readily acceptable in field studies but indications are there that the use of post-flight changes in blood sulphydryl group may help in evaluating the degree of stress and work load in flying (8).

Studies in identifying physiological indices of flying stress are not yet conclusive. The search for the most appropriate index of the stress response identifying the individual differences in stress coping behaviour or that showing the best interaction with the degree of stress is on. At the Institute of Aviation Medicine, IAF, studies are at hand in identifying the differential stress response in terms of postflight changes in epinephrine and norepinephrine excretion rate in different groups of pilots and in flying cadets during their course of training.

Conclusion

The existence of a high degree of psycho-physiological stress in flying is apparent from the endocrine stress response of the trainee pilots. With training, pilots learn to do away with the exaggerated emotional arousal and increasingly divert their participation to workload. An appropriate physiological data based prediction of the failure of this mechanism during flight emergencies or under excessive life stress would go a long way in ensuring flight safety.

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