Aeromedical and Physiologic Aspects of Fighter Pilot Selection and Performance: Theoretical Considerations

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Abstract

AIRCREWMEN are currently flying high +Gz multistress fighter aircraft which can exceed their +Gz tolerance. A spectrum of events from loss of consciousness to decreased peripheral vision can compromise their performance. All efforts should be made to find methods which enhance +Gz tolerance and thereby maintain air superiority. Certain specific types of physical conditioning may prove beneficial to the fighter pilot. At present there is no evidence that aerobic or endurance training enhances +Gz tolerance, although it may have other beneficial effects, if done in moderation. A complete investigation of the effects of specific types of exercise on +Gz tolerance is needed. Continued investigation into the clinical parameters which affect +Gz tolerance is necessary not only to fully understand the physiologic basis of +Gz tolerance but also to aid the establishment of possible future high +Gz selection criteria. A long-term surveillance program to follow high performance fighter pilots would be ideal to assure aeromedical (occupational) safety.

Introduction

The new high performance fighter aircraft recently introduced into aviation produce a complex multistress environment with severe physiologic and psychologic demands placed on aviators who pilot them. These aircraft are very costly and the aviators represent the most valuable manpower on a per capita basis in today's society (4). For these reasons, it is of critical importance to have stringent selection standards, continual medical surveillance, the utmost in preventive medicine and maximum protection during exposure to this high stress environment. Of particular interest in this regard is protection of pilots during the high +Gz stress of aerial combat. Much emphasis has been placed on physical conditioning to maintain aircrew fitness and additionally to enhance their physical +Gz stress tolerance. Whether or not the currently advocated forms of exercise conditioning are the best for enhancement of +Gz tolerance is questionable. Several theoretical aspects are to be considered before an optimum physical conditioning program can be recommended to fighter aircraft combat crews.

Definition of Aerial Combat Stress

The head-to-foot (+Gz) stress experienced by fighter pilots has been as high as +7g for short periods. Advanced fighter aircraft are capable of sustained periods of +7g in addition to peaks of +9g or higher. In addition, the rate of onset of the +Gz force in the newer aircraft is markedly increased to as high as 10 g/sec. The major hazard during this +Gz stress is the possibility of exceeding one's +Gz tolerance, thereby losing consciousness (and subsequent aircraft control). Results of recent work revealed that loss of consciousness due to +Gz stress on a centrifuge results in an average time of incapacitation of 15 sec with a range of 9 sec to 20 sec (14). Needless to say, an uncontrolled aircraft at 500 knots can travel great distances in this 15 sec period of time. Short of loss of consciousness there can be various degrees of greyout (loss of peripheral vision) through blackout (complete loss of vision), all of which impair visual performance. In the aerial combat arena, vision is all important in target acquisition not only for an offensive posture but also in a defensive posture. Any loss of visual acuity may result in loss of the advantage position. To maintain visual contact with an adversary during aerial combat a large amount of head, neck and body movement is necessary while pulling high +Gz. This results in a tremendous amount of stress on the musculoskeletal

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system of the neck, a stress which is increased with the weight of the helmet worn by the aviator. Not only is neck movement difficult, but movement of the neck and arms is particularly difficult and fatiguing during +Gz stress.

The etiology of loss of consciousness and loss of vision is due to lack of cerebral and retinal perfusion respectively, resulting from the head-to-foot force of +Gz with a corresponding increased pooling of blood in the lower extremities. With knowledge of these physiologic principles, methods to protect the pilot have been developed. In an effort to decrease the left ventricular pressure necessary to pump the blood to the head, tilt-back seat configurations were developed to decrease the effective vertical heart-to-eye distance and therefore the driving pressure necessary to perfuse the head (1). The F-16 aircraft has a 30° tilt-back seat which increases comfort, however it is questionable whether or not it utilizes this principle to enhance +Gz tolerance. Another method used to increase the blood flow to the head is the use of straining maneuvers (M-1 and L-1) which result in increased intrathoracic pressure, and if performed properly can result in substantially increased eye level blood pressure (9). Prolonged maintenance of the straining maneuvers is also very fatiguing. Anti-G suits have long been utilized to enchance +Gz tolerance by preventing venous pooling in the abdomen and lower extremities and thereby increasing venous return (2).

Requisite For Physical Conditioning

The possible use of physical conditioning as an additional means of enhancing +Gz tolerance has been studied previously (5, 6). Aerobic conditioning does not correlate with +Gz tolerance (13) nor has it been shown to enhance Gz tolerance (5, 6, 8, 12). This does not mean that it has no use for fighter pilots, since aerobic or endurance-type exercise (running) is known to promote an overall feeling of well-being and fitness. It may or may not additionally be of value in prevention of cardiovascular disease, although this remains controversial and is not well documented. The point here is, that it has definitely not been shown to enhance +Gz tolerance. There is the possibility that this running or jogging type exercise, which mainly increases lower extremity muscle mass, could lead to a greater amount of venous pooling in the lower extremities with a resultant decreased +Gz tolerance. Previous investigation revealed the effectiveness of the blood pressure control system to be reduced by endurance training (12). This was thought to be advantageous for the integrative control of the circulatory system during exercise but disadvantageous for activity such as +Gz stress. Specifically the heart rate and blood pressure responses induced by baroreceptor stimulation were shown to be reduced in endurance-trained athletes (8). In addition, the sympathetic activation was less as measured by lower norepinephrine blood levels. A specific theoretical contraindication to an excess of endurance aerobic type training for a fighter pilot has been reported (15). In this case and one other similar case (16) seen at the USAF School of Aerospace Medicine (USAFSAM) the possibility of an increase in vagal tone with resultant sino-atrial block (sinus arrest) resulted in a prolonged time of incapacitation (30 sec.) following loss of consciousness during +Gz stress. Recovery in both cases was accompanied by a slow junctional rhythm. Increased vagal tone with its attendant slow heart rate is well known in highly trained athletes. It suppresses all pacemaker and conductive tissues in the heart, in some cases it has been strong enough to provoke long sinus pauses at rest accompanied by cerebral symptoms. The risk of the complications of markedly increased vagal tone was shown to be confined to periods of intensive endurance training and abolished when the training intensity was reduced (11). In addition, highly trained athletes have been shown to have an increased incidence of syncope. Any condition which might predispose a pilot to an increased susceptibility to unconsciousness should be avoided.

Specificity of training (10) for a particular task is a well documented principle in sports medicine. Simply stated, this means that if an individual is going to perform a certain task he must exercise train doing that task, i.e. if one is to be a swimmer he must train for this task by doing smimming exercise and further, other exercise training such as running probably will not help improve his swimming capabilities. Applying this principle of specificity to the fighter pilot, running should not improve +Gz tolerance. The isometric muscular tensing used in the M-1 or L-1 straining maneuver is different from running exercise. Weight lifting exercise has been advocated in this respect (mainly upper extremity strengthening) and has been preliminarily shown to improve +Gz tolerance on volunteer centrifuge acceleration panel members (6). Gz tolerance may be enhanced if specific muscle groups are trained and their greater strength utilized under +Gz loads, thus preventing blood pooling in the lower extremities and allowing performance of the M-1 or L-1 more efficiently. Static exercise training with improvement in muscular fitness may be more appropriate for these goals, instead of endurance training which improves cardiovascular fitness (8). For these reasons weight lifting may well serve as a more important exercise to enhance +Gz tolerance. To date, no scientific data exists to indicate that push-ups or any other form of exercise besides weight lifting enhances +Gz tolerance. Added to this upper extremity development a series of neck strengthening exercises would seem appropriate to enhance the muscular support of the neck which must rotate from side to side (checking six o' clock) during high +Gz aerial combat.

Probably most important is the frequent performance of these techniques during actual aerial combat tactics. Most pilots feel they need to have frequent exposures to +Gz to maintain a high level of aerial combat proficiency. Maintenance of flying proficiency is important, therefore, not only for the technical and mechanical aspects of flying but also for maintenance of +Gz tolerance.

An additional unmeasurable factor that influences +Gz tolerance is the psychologic desire to be able to be superior in an aerial combat engagement. The determination to do what has to be done to maintain air superiority is a trait which undoubtedly enchances natural +Gz tolerance. This trait can be promoted by self confidence, motivation and a desire to survive. It would be hoped that the undergraduate pilot training selection and training programs strive to achieve these goals.

Future Directions

Since new fighter aircraft have indeed begun to exceed human tolerance limits, even with the use of protective devices, all methods which can enhance +Gz tolerance must be utilized. If certain types of physical conditioning can indeed enhance +Gz tolerance, then these exercises should be more widely advocated by local flight surgeons to their aircrews. A specific research program designed to evaluate the effects of different types of exercise on +Gz tolerance would be advantageous.

Previous preliminary work on USAF aircrewmen undergoing aeromedical evaluation has revealed that certain clinically measurable parameters are related to +Gz tolerance (13). Associated with a high +Gz tolerance were such parameters as older age, a short heavier stature, higher cholesterol and triglycerides, a higher blood pressure and more experience flying fighter aircraft. Aerobic capacity based on maximal treadmill testing was not associated with increased +Gz tolerance. It would be advantageous to know what parameters are associated with +Gz tolerance if specific selection criteria for high +Gz fighter pilots are to be developed. It is apparent that the above parameters are not necessarily the optimum parameters for pilot selection on the basis of cardiovascular risk factors. There are definite physiologic reasons for the above clinical parameters being associated with increased +Gz tolerance. Whether or not these findings will continue to be associated with increased +Gz tolerance when larger numbers of subjects are investigated will be important to follow. This correlation of +Gz tolerance with clinical parameters is currently facilitated with the maintenance of a centrifuge acceleration repository (13). In addition, those clinical parameters associated with decreased +Gz tolerance are conversely imoortant not only for possible selection criteria but also to more fully understand the physiology of +Gz tolerance.

A final aspect of our aircrewmen moving into a new higher stress environment is the possibility of these individuals being exposed to a potentially hazardous environment. Although previous work in the miniature swine revealed the presence of subendocardial hemorrhage and myofibullar myocyte damage (3), no evidence to date has revealed this type of pathology to exist in humans (7). All of the work to date has been of a short term nature. The real proof of whether or not the high +Gz environment is a benign stress should result from following the high performance fighter aircraft pilot over an active flying lifetime. This is a relatively short lifetime since few pilots remain as an active fighter pilot longer than 10 to 15 years. Initial, periodic, and final clinical parameters should be followed as long as these aircrewmen are routinely exposed to high +Gz stress. These parameters might ideally include newer noninvasive nuclear medicine cardiovascular studies, such as cardiac output and segmental wall motion. Only in this way can aircrewmen be assured that no long-term effects due to high +Gz stress are present. Specific attention to animal model studies (3) regarding high +Gz stress should be carefully followed and the results correlated to the human surveillance program. These studies may lead the way in determining which areas (cardiovascular or otherwise) may be most sensitive to any pathologic effects of +Gz and which areas must therefore be followed more closely.

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