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The Role of Physical Standards in Jet and Rocket Aircraft Flight

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DID PHYSICAL STANDARDS in military forces begin as a biological selection with "survival of the fittest?" Early commanders probably tried to choose warriors closely resembling in physique the survivors of battle. The successful outcome of warfare has been influenced to some degree by the physical and mental capabilities of the fighting man. Powell[20] describes the attributes of David which allowed him unerringly to direct his missile (stone) from mount (slingshot) to target (Goliath's brow): "He was a healthy young country boy with excellent muscular co-ordination and a steady hand. His visual acuity must have been 20/20 and his height and weight ideal. His mental state appears to have been the best. He was alert and sensitive and had no fear of combat."

Early in World War I there were no formal physical standards for aviators. The man with "nerve" was allowed to fly and those no longer fit for ground duty were assigned to the Air Service. The resulting waste of personnel and money was reduced by the development of selection. Authors in the *Air Service Medical Manual*,[1] however, disdained as "utterly absurd" the concept that a combat pilot must be a "superman." Picking the "birdman" seemed to have so many contradictory requirements that Patten described the ideal fighting pilot as a "tall, short, slim, blonde, brunette, quiet, nervous, languid, alert, reckless and conservative individual."[3] Much of this same contradiction exists today.

Aviation has grown rapidly beyond the time when all the pilot needed was "nerve." The modern, highly complex and expensive aircraft is combined with a missile, or payload, and a pilot, or crew, into a "man-machine system." This system is assigned a particular mission, and thus the man becomes a most important link in the operation of the entire complex. To insure the

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success of a mission, the best possible man must be chosen to function in this select complex. The development of proper selection and aircrew maintenance programs to achieve this end is the goal of the specialist in aviation medicine. It must be remembered that selection is never 100 per cent effective in providing a premium man. Each selection criterion met provides only a certain probability of success.

The aircrew maintenance program requires the development of a new attitude by the physician. He must reject the traditional attitude of deciding everything against a background of "what is good for my patient?" Now, he must assume that this examinee, or patient, may become that vital link in the weapons system complex, and as such must perform effectively. If he cannot, he must be rejected during the selection process or grounded during the maintenance process. An effective man-machine system requires that proper physical standards be teamed with the proper human factors design.

WHY PHYSICAL STANDARDS?

Physical standards are designed for a specific purpose.[2] Regardless of the various specific jobs for which standards exist, such as piloting jet and rocket aircraft, three basic purposes pervade all standards. These are *safety, proficiency,* and *longevity.* Physical standards should provide reasonable assurance that qualified candidates will have no defects which would interfere with their becoming safe, proficient, and successful military pilots of high performance combat aircraft who may be expected to serve for some minimum period without defect or impairment of any type. They should also assure the highest possible yield commensurate with quality desired and manpower requirements.

Selection must be based not only on whether the man would be able to operate an aircraft but also on his ability to do so at peak efficiency under the stresses he will encounter, such as insufficient oxygen, prolonged nervous tension, and G forces. The responsibility of the U. S. Air Medical Service in pilot selection in World War I was stated as "No aviator shall fail in his mission *because of discoverable physical defect.*"[1] This might apply as well today.

Any subject may gain important stature in aviation medicine if it can be shown to be related to the cause of aircraft accidents. In 1955, 56.7 per cent of aircraft accidents, for which the cause is known, were due to pilot error. The human factors which cause the pilot to make errors are physical, physiological, and psychological in nature. Basic deficiencies, such as insufficient size or strength, are seldom causes of error reflecting physical standards. Unrecognized pathology and physiologic tolerances are involved as causes of accidents. Most unsafe pilot actions, however, fall in the area of psychological and behavioral variances. During the year 1956, 14 per cent of all aircraft accidents were listed as "cause undetermined." A high percentage of them are believed to be due to physical or physiologic factors in the pilot's environment. Yet the direct relationship to aircraft accidents of any pathology or physical factor correctible by the use of more stringent physical standards, is rarely clearly demonstrated.[18]

Physical standards usually vary with the laws of supply and demand for manpower. Present-day aircraft and the reduction in the need for large numbers of new pilots require there be no compromise in quality on initial selection. After the pilot is accepted and trained, different standards may function as "selection-in-depth" or continuing selection devices. The standards should serve as a guide, and the training and experience of the pilot should be weighed against the risk and waivers considered. Any relaxation of standards affecting either flying safety or the individual's safety must be avoided. In the final analysis, the standards must be high enough to eliminate the medically unfit and low enough to insure adequate numbers to accomplish the Air Force mission.[20]

PREREQUISITES TO PHYSICAL STANDARDS

The background for development of physical standards includes a detailed job analysis to provide insight in selecting the measuring instruments or tests. These must be validated against appropriate performance measures with reference to each of the purposes the standards are intended to serve. Cutting scores must then be established for each test; these are actually the physical standards. The efficiency of the standards, thus defined, to discriminate successful from unsuccessful pilots must still be ascertained as a consideration separate from the validity of the instruments. The question of the validity of our physical standards has always been a difficult one.

The first problem encountered, prior to determining validity, is the question of the reliability of the measurements. Physical examinations for flying are done by many different physicians with different backgrounds, training and motivation; varying amounts of time and effort are expended on the actual examination. The many factors altering the time spent are not always under the control of the examiner. Many defects are found during the course of thorough history and physical examinations performed by consultants at this school on persons who have had many previous flying-type examinations. More time and effort must be spent on these examinations because in the continual selection process it is becoming increasingly important for the flying surgeon to detect variation of the normal. Unfortunately the average physician's training has been biased toward recognition of pathology.[19]

Frequently someone states we should accept persons with one leg or one eye since it is known that Douglas Bader or Wiley Post flew with those defects. Recognition given to such exceptional individuals may sound like validation of these criteria, but this may often be misleading and much more is needed. To validate physical standards properly, large numbers of applicants should be examined and all entered into training regardless of findings. Naturally, any defect representing an obvious hazard to flight safety would require elimination; this in itself represents a compromise. Follow-up studies should be conducted to check the outcome of the test group as to safety, longevity and proficiency as an officer and pilot over a given period.[24]

The radical type of acceptance study referred to above, would provide normative data allowing the construction of tables useful in predicting the risk in returning an individual with such a condition to flying status. It is doubtful that such a program could ever be initiated, but there are numerous opportunities for follow-up studies under the present system of examination, selection and classification.

There is a great need for additional information on the natural course of certain medical conditions in the flying population. Studies are underway at this school to obtain follow-up data for this purpose on dysbarism, migraine, ulcers and loss of consciousness. These should contribute valuable data for predicting risk of return to flying status.

Frequently a standard must be set without prior validation, since necessary data are not available. This will be the situation in the case of standards for the first space pilots. Probably overly rigid at the outset, they will be modified on the basis of experience.

The value of thorough job analysis, including study of the job environment, is inestimable in such situations, but more needs to be learned of the demands of present aircraft as well. In a recent report Moseley stated: "It is apparent from accident data that we do not have at present adequate objective measurements of the task imposed upon the pilot in high performance aircraft. Nor do we have adequate information regarding the pilot's ability to cope with those tasks."[17] Cockpit and instrument design, in many cases based on data collected in reciprocating engine aircraft, serve to add confusion to the task. Pilots, distracted and overwhelmed by this confusion, are often committed to such destructive accidents that the cause may remain unrecognized for long periods.

The design, and thus the task, have great import for the physical standards necessary to select an operator of the vehicle. An example is limitation of present Air Force pilot trainees to a sitting height of 38 inches. This is necessitated by the limited canopy-head clearance in the T-33, T-34, and T-37 training aircraft. Present-day jet aircraft, where speed is an unforgiving task master, have many design features which act to stress the pilot to his tolerance limits. Through job analysis we can estimate the demands on human performance and tolerance of a particular vehicle or system. From our scientific knowledge of human physiology and psychology we have an understanding of human limitations. It is obvious that every air and space craft must be designed to operate without pushing man to the limit of his tolerances to the many stresses imposed. The present development of space vehicles offers an opportunity at the drawing board stage to demand that the design meet such criteria. Many times a compromise must be made between performance and mission of the aircraft and pilot efficiency and comfort. Heretofore, in such situations there has been no compromise, the pilot has always suffered.

The tasks and the stress exposure may vary greatly with particular vehicles. It would thus seem logical to have some flexibility of standards and to have some means of classifying the pilots as to their particular physical qualification to pilot various craft. These decisions should be made with reference to each of the major purposes of physical standards—safety, longevity, and proficiency.[23] In aviation today at least two types of flight conditions having distinct stresses may be differentiated: (1) high performance jet and rocket flying, and (2) conventional transport flying. Some system of qualifying individuals for a particular flight condition, such as the service groups in use by the U. S. Navy,[13] should be helpful for complete personnel utilization.

DETERMINATION OF STANDARDS

The environment of the pilot of jet and rocket aircraft imposes a large number of stresses. A partial list of these stresses is as follows:

1. Reduced barometric pressure: Hypoxia and methods to prevent it—pressure breathing and pressure suits, dysbarism.
2. Temperature alterations: heat and cold.
3. Acceleration: positive, negative, transverse and zero G in varying durations and combinations.
4. Disorientation.
5. Psychological: fear and loneliness.
6. Miscellaneous Stresses: Hypoglycemia, fatigue, hyperventilation.

An obvious method of reducing the effects of these stresses is to select pilots and crewmen who have superior tolerances. However, superior tolerances to single stresses may be overcome by the synergistic action of multiple stresses.[19] Thus, in spite of arguments concerning differences in tolerance acquired by the use of personnel protective equipment, our physical standards must be high enough to insure some resistance to the hazards of unexpected events and resultant unprotected states.

Various agencies concerned with physical standards are still coping with the problem of developing reasonable standards for fliers. At this time, physical standards for aircrew are undergoing a critical appraisal by both the Air Force and the Civil Aeronautics Administration. As far as the Air Force appraisal is concerned, most significant is the fact that only a small number of actual major changes have been suggested by reviewers of present standards. Following is a summary of some of the suggested changes of standards and of some of the investigations related to identification of instruments for the initial selection and the maintenance of jet and rocket pilots. In the revised USAF physical standards manual it is contemplated that standards will be arranged by organ systems as in a medical text.

Cardiovascular System.—The need for premium men for premium missions has led to concern with the resistance of the cardiovascular system to stress. Investigation by McQuire[14] has produced a battery of stress tests which shows some promise. These include a double Master's test after a baseline ECG, Harvard step test, and a tilt table study (subject at 65° for 25 minutes following the Harvard step test). This battery needs field validation on flying personnel subjected to the stress of a partial pressure suit before standards can be formulated.

An initial ECG taken at the time of selection is believed to be of value in detecting unrecognized cardiovascular abnormalities. In a study[11] of 5,000 electrocardiograms recorded routinely on candidates for aircrew training in the Royal Canadian Air Force, 0.54 per cent were found to have significant abnormalities requiring rejection. Lamb[9] states that without an electrocardiogram, five of every 1,000 persons accepted for flying duty will have heart disease and further, probably one of every 100 Air Force pilots has undiagnosed clinical heart disease. Baseline ECGs are now required by the Air Force and their retention in an ECG repository at the School of Aviation Medicine, will provide much valuable information. At the repository 1,800 electrocardiograms have been read to date. All of these were recorded in flying personnel less than forty years of age without grossly abnormal conditions. The following abnormalities were noted in the series:

Myocardial infarct	0.4 per cent
Parasystole or other significant ventricular arrhythmia	0.1 per cent
Complete A-V Dissociation	0.1 per cent
Right Bundle Branch Block	0.33 per cent
First Degree A-V Block	0.44 per cent
Wolff-Parkinson-White Syndrome	0.16 per cent

Expanding these figures to the 75,000 flying personnel, we should have 200 persons with myocardial infarct, and 790 flying in the Air Force today with significant pathologic conditions shown by the electrocardiogram. Tentative electrocardiogram standards have been established, and these will be modified in the light of new information from the repository.

The furor concerning the relationship of cholesterol levels and coronary disease has led to the suggestion of the use of lipo-protein determinations in the selection process. Milch[16] states such a move would be premature at the present time, and the various relationships await further validation.

A recent report outlines several cases of cardiac arrhythmias induced by such respiratory maneuvers as breath-holding or pressure breathing.[10] The stretch receptors in the visceral pleura or adjacent lung parenchyma are activated and pass impulses via vagal afferents and efferents. As slowing or more marked arrhythmias and unconsciousness may result, it is believed that determination of the threshold for development of such an arrhythmia should be a part of the original examination. Definite standards have not been formulated.

Pulmonary System.—The development of simple pulmonary function tests to provide information on the ventilatory power of the lung, has led to their consideration for use in aircrew selection. The maximum breathing capacity, vital capacity and timed vital capacity are of use in evaluating examinees who have history of pleural or pulmonary disease. This examination may be aided by the use of the low pressure chamber. These procedures are not at present used in routine selection nor considered for such use.

Neuropsychiatry.—In this area also we are faced with deviations from the normal which are not always recognizable. Most flight surgeons believe there is considerable risk in returning to, or accepting for, flying any individual who has had a psychotic break.

In general, psychiatric standards based on diagnosable clinical entities are sound.[15]

The validity of the psychiatrist's prediction of a man's adjustment to military life has been low when it is based on a single interview. The Adaptability Rating for Military Aeronautics (ARMA) was designed to provide a selection psychiatric interview. This technique is "intuitive and subjective" and defies a reliable scoring system. The numerical score should be discarded and examinees either passed or failed. The value of this, as of all physical examination tools, is dependent upon the background, skill and thoroughness of the examiner. The importance of mental standards increases with the increasing complexity and speed of our aircraft. Adequate time for the psychiatric interview is necessary and should become a part of the scheduling procedure. Psychological testing is of proven value in selection.[7]

The large number of cases of migraine seen recently in our aviation medicine consultation service induced one of our residents to review this clinical entity.[26] Frequently the migrainous personality is an outstanding officer, often in whom flying releases tensions. In other cases, the headache itself may be incapacitating, and visual and other neurological symptoms, or severe gastrointestinal reactions, may lead to incapacitation. Several inflight instances of marked reduction in visual acuity with migraine have occurred. Therefore, the person with migraine should be rejected at initial selection, but, in the trained pilot, individual consideration must be given. Persons with ophthalmic migraine or with other associated neurological phenomena should not fly.

Fainting or loss of consciousness, is more frequently a cardiovascular problem but, when found, a thorough neuropsychiatric evaluation of the patient is indicated. The number of persons who actually are victims of cortical seizures remains an interesting enigma. The use of the electroencephalogram (EEG) as a selection device has been suggested, but it awaits further validation and development of specificity.[12] Obtaining an entry or initial selection EEG for purposes of later validation as the RCAF has done[19] has merit.

Weight.—Obesity is of particular concern to the flight surgeon entrusted with the care of jet and rocket pilots. It has been shown to have some relation to coronary artery disease and decompresison sickness. The present U. S. Air Force weight tables are lenient in the maximal values allowed. Many pilots remain grossly overweight until a few weeks before their annual physical when they reduce to within one pound of their maximum allowable weight. They are still overweight. For example, a 28-year-old pilot 6 feet in height has a standard weight of 164 lbs. while his maximum could be 205 lbs., an expansion of 41 lbs. of blubber. The weight standards should allow no more than 10 per cent above the standard weight or in the above case a maximum of 180.4 pounds The best approach to this problem would be the determination of the lean body mass for each individual on initial selection and the requirement that the pilot maintain his weight within a given percentage of this figure, regardless of age. It is hoped that some recent work of Behnke and Siri may have produced a simple method of determining lean body mass.[4] This method utilizes certain anthropometric and x-ray measurements.

Eye.—Inability to pass visual acuity standards has been the most common cause of physical rejection in pilot selection. There has been no true validation of visual standards, but studies which have been done indicate that our present visual standards could not be called standards of flying fitness. In determining standards for the trained pilot, true unfitness should be the criterion for grounding.[21] Nevertheless, the speed and performance characteristics of jet and rocket aircraft require superior visual acuity and will do so until an enclosed cockpit with only television or radar presentation is a reality. Distant visual acuity of 20/15 has been suggested as a requirement for high performance aircraft. Byrnes[8] suggests requiring at least 0.5 diopter of hyperopia in all meridians for initial selection. Myopia up to 3 diopters might be acceptable if and when aircraft control is maintained via radar or television screens. Problems are encountered with corrective lens in high performance aircraft because of the necessity for wearing jet helmets. Contact lenses for use with the pressure suits may be answers to these problems.

The present depth perception examinations actually test binocular parallax and this has been shown to have no relation to ability to land a fixed wing aircraft. Motion parallax is related to this ability. The only value of binocular parallax testing is the verification of the visual acuity and of the fact two eyes are used simultaneously. A portable motion parallax tester is in use at Lackland Air Force Base, Texas, for validation studies, but the high cost of the machine makes it impractical for use at smaller installations.

Color vision requirements could be engineered out of the flying environment, but the test must be kept until this is done.

NEWER CONCEPTS OF STANDARDS

In the study of problem cases at this school, every effort is made to simulate significant stresses and conditions of the patient's flying environment. I submit that more of our tests should be directly related to the stresses encountered, or likely to be encountered, in piloting high performance aircraft. Thus, tolerance to hypoxia (determination of the time of useful consciousness), dysbarism, pressure breathing, cold, heat, and wear of the partial pressure suit should be determined. Recent evidence points to severe difficulty produced by a summation of two or more concomitant stresses.[6] Unusual susceptibility to any one of the stresses might speed the development of the summation reaction.

A test for prediction of G tolerance has been proposed by Shirley[25] based on the work of Bondurant.[5] The increase in systolic blood pressure occurring after a Valsalva maneuver is such a predictor.

Numerous attempts have been made to select those individuals most susceptible to decompression sickness.[22] In general this has not been a fruitful approach due to the operation of numerous factors altering momentary susceptibility.

SPACE PILOT SELECTION

An analysis of the task of the space pilot is largely speculative at this time but must be accomplished prior to the determination of physical standards for such pilots. In a recent paper Sells and Berry[23] predicted, that in the early experimental developmental missions, the crewman will be subjected to many compromises and will have some responsible duties involving control of the ship, monitoring flight and cabin environment instruments and making observations. Re-entry glide and landing probably will be under his direct control. The nature of the compromise made in the space vehicle will determine many of the standards. Unless mission capability and reliability is sacrificed, an effort must be made to select the highest qualified men.

A superior cardiovascular system, as determined by such tests as those listed above, is mandatory for pressure suit wear. Thorough psychiatric, neurological, and psychological studies are necessary. The psychiatric interviews should take at least two hours daily for five days. Baseline EEG work up is a necessary prelude to any inflight study. Weight should meet the criteria stated previously and, as a further antidysbarism factor, the age should be less than thirty-five. Visual standards may be relaxed below those presently used for initial selection due to the type instrument display and information devices. The wearing of pressure suits dictates minimal decrease in visual acuity however, or wear of contact lenses. Indoctrination of future space pilots in all the possible stresses will serve further as a selection device because failure under any of them should cause the man to be rejected. Stresses to be evaluated should include zero G state produced by parabolic flight, heat, accelerations (transverse and mixed), confinement and isolation. Balloon flights may serve as test beds for these latter stresses. A detailed analysis of the human qualifications for space flight has been published elsewhere.[23]

CONCLUSION

It is important continually to review and revise the physical standards in the light of new knowledge, validity or the appearance of new tasks and equipment. In any case the role of physical standards in high performance aircraft, or space craft, is to insure that the candidate will not fail at his task *"due to discoverable physical defect."*

SUMMARY

Complex modern weapons systems demand that the flight surgeon develop proper aircrew selection and maintenance programs to insure the greatest probability of successful human function. Physical standards attempt to provide personnel who will fly with increased safety, proficiency and longevity. Standards should offer some assurance of acceptable performance under the stresses of flying. Prior to establishing definite standards a good job analysis is needed to determine proper instruments or tests required. These must then be validated. Suggested tests for jet and rocket pilots, which involve the cardiovascular, pul-

monary, and neuropsychiatric systems, and weight, vision, and mixed stresses in the flying environment, have been discussed. Consideration was given to special requirements for space operations.

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