Aeromedical Evaluation of Aircrew with Lower Limb Disabilities

RANDHIR SINGH

Physical fitness of high standard without any disability is required for effective and safe operation of controls in aircraft cockpit. Aeromedical evaluation of aircrew with orthopaedic disabilities poses specific problems during their review and recategorisation medical boards. Assessment of lower limb disability has been discussed with special emphasis on human engineering evaluation and trials in simulated cockpit environment.

****

THE contribution of the pilot in the performance of a close loop system of man machine complex is by means of operating controls efficiently with a well coordinated muscular activity. Physical fitness of high standard without any disability is required for effective and safe operation of controls in the cockpit work space. Aircrew involved in ground vehicular or air accidents sustain injuries resulting in surgical/orthopaedic disabilities. Quite a few cases develop disability in the form of restriction of joint movements, loss of muscle mass, muscle wasting and malunion of fractures with or without shortening of the limb as such.

Once the surgeon feels that clinical recovery is reached with fair degree of radiological healing, the aircrew is subjected to aeromedical evaluation to assess his fitness for flying. He is assessed not only for fitness for safe and efficient flying but also for other activities like ejection from aircraft, survival on ground etc.

Clinical Assessment

Clinical status of the case is reviewed by the surgeon after necessary laboratory and radiological investigations and recommendations are made regarding his fitness or otherwise to resume ground/air duties with or without restrictions. But clinical and radiological assessment cannot indicate accuracy as to how a particular disability will affect the performance of the aircrew under changing leg geometry in the aircraft cockpit environment and during different profiles of flight.

Aircrew Performance in Workspace Environment

In aircraft, the foot operated controls are rudder pedals with or without toe brakes. The rudder pedal assembly has a range of adjustment varying from 8-10 cms depending upon the design. The pedal design also varies from aircraft to aircraft, e.g., foot print type, S shaped, bar type and toe operated brakes. The operation of the rudder pedals in the aircraft is required during taxying, take off, cruising and landing. To reduce the loadings in rudder pedal operation during routine flying (8-10 lbs) the assembly is incorporated with hydraulic systems. During emergency situation, e.g., engine/hydraulic failure in air or crash landings, the force required for operation of rudder pedals may reach a maximum of 300 lbs or so. The aircraft design specification[1] lays

TABLE—I

Design Specifications
Aircraft Control Forces during Rudder Pedal Operation

No.	Specification	Aircraft class	Rudder pedal static force	Forces in Lbs allowable during emergency Minimum	Maximum	Remarks
1.	AVP 970 Chap. 207 Para 2.5.1 (British Military)	Fighter & other aircraft upto 10,000 Lbs	6	—	300	Aircraft between 10,000 (except Fighters) to 50,000 Lbs values can be obtained by linear interpolation.
		All heavy Bombers & other class 50,000 Lbs	10	—	—	
2.	FAR 23.397 (Federal Aviation Regulation, American)	5000 Lbs	8	130	200	Forces for any design can be had from the relation 5000—1, 12,500—1.18 (Linear)
3.	BCAR Chap. 3.6 (British Civil a/c Worthiness requirements)	5000 Lbs	6	100	200	
		2500 Lbs	10	130	300	
4.	Mil—A—8865 A Sec. B 7 (Mil—F—9490D) Sec 3.2.3.2.1	—	—	150	300	
	Mil—F—8785B Para 3.5.2.1 Table—12 (American Military)	Class I, IIC & IV	7	—	—	C—Carrier based
		Class II-L, III	14	—	—	L—Land based

down the admissible and max control force for rudder pedal as shown in Table - I.

A healthy pilot, with properly adjusted seat and rudder pedals, should be able to operate high loadings of controls for short periods till he could trim the controls. The aircrew with disproportionate leg geometry, i.e., leg length too long or too short, knee angles less than 100° and ankle angles more than 20° from natural position (vertical position in a seated man) experience serious handicaps in efficient operation of rudder pedals. Thus lower limb disability in aircraft may seriously compromise flight safety particularly during an emergency in air and crash landings.

Aeromedical Assessment

The statistical data of cases of surgical/orthopaedic disabilities who reported for assessment at Institute of Aviation Medicine during the period Jan 1968 to Oct 1980 showed that 50 cases had lower limb disabilities. Only 8 out of 50 cases also had other disabilities pertaining to upper limb and spine. The breakdown of lower limb disabilities is given in Table II.

TABLE—II

Details of Lower Limb Disabilities

Category of aircrew	Hip Joint	Femur (Fracture)	Knee, Condyles, Patella (Fracture)	Tibia, Fibula (Fracture)	Ankle, Calcaneum/ Talus (Fracture)	Small bones of foot (Fracture)
Flight Cadet	—	2	—	10	—	1
AOP Pilots	—	—	—	—	—	1
IAF Aircrew	—	7	8	13	2	2
IN Aircrew	—	—	1	1	—	—
Civil pilots	—	1	—	—	1	—

All cases included in Table II were considered fit for flying with or without restrictions in period varying from 6 months to 42 months except two flight cadets who were declared unfit for flying duties due to shortening of legs beyond permissible limits. Two cases amputated below knee were considered fit for duties of Navigator. Five cases were recommended fit for flying transport aircraft only.

During the past years, the data also show a wide variance between the clinical impression regarding fitness or otherwise of such cases and the aeromedical assessment done by human factor specialist. The methodology followed for aeromedical evaluation for such cases is as follows :—

(a) *Review of clinical assessment :* After routine biochemical/laboratory investigations and routine medical examination including ENT and eye check up, the case is reviewed by the specialist in surgery/orthopaedics for his opinion regarding his clinical status. The detailed pathological examination wherever necessary is also conducted to assess the progress and prognosis of the case. When the surgeon is satisfied with the recovery of the case and he clears the case to resume duties, the case is referred for human engineering assessment.

(b) *Human engineering assessment :* The human engineering assessment of such cases consists of :—

i. Anthropometric measurements of the subject are recorded using Morant-board for total leg length and thigh length to assess any shortening of the leg/thigh (Fig. 1). The joint movements and restriction if any are accurately measured using Goniometers[2]. Cases with apparently marginal disabilities of joints/shortening of leg or loss of muscle mass/ power are subjected to further assessment in the aircraft cockpit.

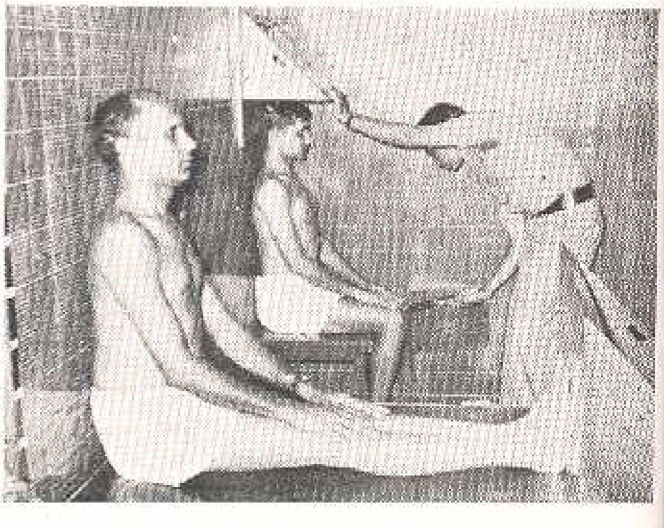

Fig. 1 — Anthropometric Measurements.

ii. Cockpit trial in the aircraft : The cockpit trial in the aircraft is given usually on ground in a side to side twin seater transport/fighter aircraft with the help of a QFI/Test Pilot. The aircrew is asked to operate the rudder pedal control including toe brakes. During the trial the QFI/Test Pilot gives maximum sustained force on contralateral (opposite) rudder pedal while the disabled aircrew is asked to counter this force and the human factor specialist examines his reach and effectiveness in operation of the control. Muscles of the lower limb are examined for any muscle strain in the form of tremors or pain or inadequacy in control operation during sustained action. A qualitative assessment is made jointly by the Test Pilot and the human factor specialist. Air trials are not usually called for in view of lack of authority, nonavailability of aircraft type and current status of the pilot and of course inherent danger of simulating emergency situation. In view of the above factors, quantitative assessment regarding his capability to under take maximum control force as per design specifications is felt necessary. For such a test a rudder pedal assembly has been fitted in the universal cockpit at the Institute of Aviation Medicine (Fig. 2).

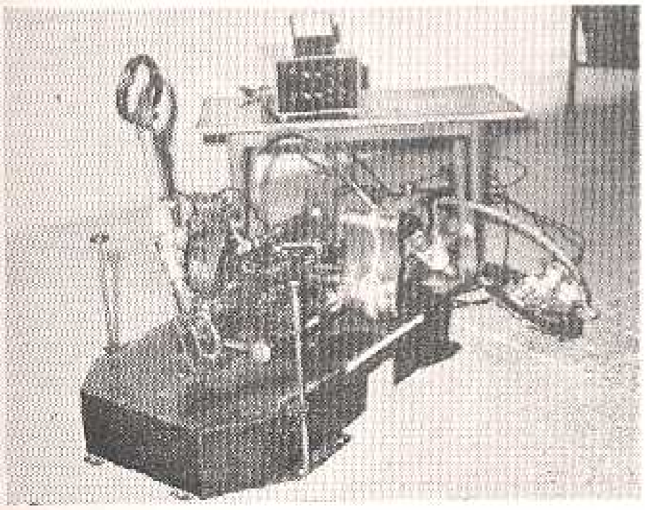

Fig. 2 — Fabricated Rudder Pedal Assembly.

(c) *Trials in the simulated cockpit environment :* A rudder pedal assembly mounted on a metallic base is fabricated having four screw jacks and universal star wheel adjustment for adjusting the assembly in up-down as well as in fore-aft positions by 20 cms and 8 cms respectively. The rudder pedals are having an additional adjustment by which the assembly as a whole slides over the base and can provide an additional fore-aft movement by 22 cms. The rudder pedals along with toe brake facility are mounted with hydraulic feel units and have been instrumented with miniaturised electronic devices for measuring the maximum force applied during operation of the controls. The mockup ejection seat and the rudder pedal assembly could be adjusted as per actual location of the control in a particular aircraft environment. These data have already been collected in the form of an Atlas[1, 6].

The subject is asked to harness in the mockup seat and adjust the pedals as per his anthropometric parameters. He is instrumented for recording IEMG (Integrated electromyography) of thigh muscles. The leads are connected to an EMG integrator and output is fed to a four channel Grass polygraph. The electronic load cells are connected to four channel amplifier and 12 volts excitation battery and the amplified output is fed directly to the polygraph (Fig. 3).

Fig. 3 — A Subject in the Simulated Cockpit.

The subject is asked to operate the control using maximum force. The biomechanical parameters, i.e., maximum force applied vis a-vis IEMG are recorded simultaneously and compared with that of healthy side. Thus the loads operated during the application of control under varying leg geometry could be recorded, (Fig. 4). Hence an objective scientific device has been set up to supplement the clinical and qualitative assessment already being conducted.

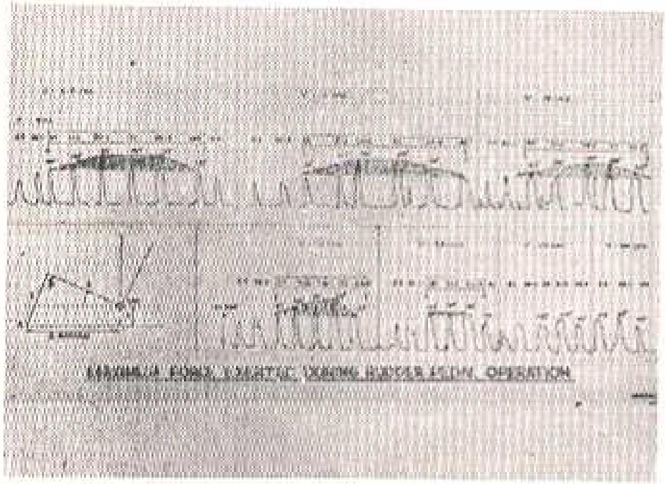

Fig. 4 — Integrated Electro myogram

Discussion

Aircrew evaluation on clinical basis alone is considered inadequate to assess his fitness or otherwise for flying duties. Cockpit trials in aircraft and simulating emergency in air is neither practicable nor safe. Hence a thorough clinical examination with an accurate measurement of anthropometric parameters and joint movement in relation to work space is the only answer for a complete evaluation. A ground based simulated cockpit environment with a facility to record all biomechanics for maxima likely in the aircraft emergency as per design specification is considered a realistic supplement in the aeromedical assessment of aircrew with lower limb disabilities.

A pilot study consisting of small number of healthy subjects with anthropometric parameters falling in 5th to 95th percentile group of IAF aircre has been conducted. The trials have proved ve useful for such assessments. An additional importa information has been obtained during the trial whic helps the designer to set a range of adjustment f foot operated controls keeping the maximum force operable with foot operated controls, varying sea adjustment and leg geometry particularly at knee joi and ankle joint. This important information regardin IAF aircrew is considered very useful durin assessment of anthropometric limitations of a cockp for IAF aircrew.

Recommendations

A few suggestions/recommendations are pu forward to improve the present method of aeromedica evaluation :—

(a) For an accurate measurements of joint move ments and other body features, there is need t develop orthopaedic special calipers and goniometers

(b) All cases of surgical disability involving upper/lower limbs, howsoever marginal, should b given a cockpit trial before assessing their fitness o otherwise for effective operation of all cockpit control under harness fit conditions.

(c) All doubtful cases with disabilities for lowe limbs should be given a trial in the universal cockpi (simulated cockpit environment) to assess the capability to operate loads required in emergency situations.

(d) The specific data obtained from the trials on healthy aircrew on this device along with rudde pedal Nomogram[7] is recommended for assessment o anthropometric limitations of aircraft cockpit for IAF aircrew.

References

1. Aircraft Design specifications — Military specifications — Mil/A 8865 A Sect B, BCAR Specification AVP 970 Chapter 36, Chapter 207 and FAR 23397.
2. Garg Hemraj. Design of Goniometers, IAM, 1988.
3. Mukherjee, BK. Radiological standards of axial angles of major joints and extremities. Medical Journal Armed Forces India Vol XXXV (2) : 97, 1979.
4. Randhir Singh. Three dimensional atlas of aircraft cockpit controls and locations Fighter aircraft. AFMRC 826/78 Report, 1977.
5. Randhir Singh. Study of dynamic anthropometry in relation to cockpit layout. AFMRC 827/76 Report, 1980.
6. Sodhi, SS. Three dimensional atlas of cockpit controls AN-12 and AVRO HS-748 aircraft. A field study project report, 1978.
7. Verma, SP and Verghese, CA. Nomogram for aircraft rudder pedal design. Journal of Aeromedical Society of India Vol II (1) 15 Oct 1968.