FUNCTIONAL ASSESSMENT OF ORTHOPEDIC DISABILITIES IN AIRCREW

By

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Abstract

It has been observed that a strapped pilot can achieve 8 to 9 inches of additional functional reach in the case of upper limbs. This gain is pertinent to the assessment of reduction in static reach caused by anatomical shortening or ankylosis of the elbow. Minor restrictions at shoulder have been found to have more serious effect on function than restrictions at elbow.

In the case of knee joint, it has been found that extension should always be complete, and limitations in flexion can only be accepted when the flexion movement is not less than 110°.

The necessity to test each case of limb disability in aircraft cockpit to assess any deficit pertaining to critical functions in flight is brought out.

Introduction

Skeletal disabilities in experienced pilots require objective assessment in the interest of conservation of trained man power.[1,2] This requires functional correlation between disability and various elements of the task. The criteria for the assessment of fitness for flying are:

(*a*) Ability to operate relevant controls.

(*b*) Freedom from fatigue and cramped behaviour.

(*c*) Effective use of emergency controls and systems.

(*d*) Usefulness as a crew member in ground work, activities in aircraft, passenger and casualty handling.

(*e*) Ability to escape or evacuate an aircraft in emergency.

(*f*) Survival.

Cases of Disabilities of Upper Limb

Functions of upper limb are related to manual control areas. When these disabilities are assessed for flying, the essential nature of motor activities required during various phases of flight has to be kept in mind. For example, it will be of no significance to measure the reach for certain switches or controls with harness tight and locked when such actions are required on the ground or carried out in air with aircraft in steady attitude. In both these cases the 'go forward mechanism' can be used.

Four cases of disability involving limited movement of the elbow and one case of ankylosis of the shoulder were investigated. For measuring the reaches, the lightly clothed

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subject was strapped on a chair with straight back and horizontal seat surface. Lap straps were tightened and shoulders held against a crossbar behind by two loops of straps over the shoulders through the armpit. A semi-circle was drawn on the floor with a radius of 50 inches. The seat was positioned so that the seat reference point (S.R.P.) was vertically above the centre of the semicircle. Radial lines were drawn corresponding to angles of 15° starting with 0° for the midline of the body. A vertical wooden shaft of 1.25 inch diameter and 48 inches hight was fixed on a firm base and it carried a lockable sleeve. The sleeve carried a $\frac{1}{2}''$ diameter tubular aluminium stave, 45″ long and graduated in inches. The shaft of the stand was marked in inches from the floor and the sleeve carrying the stave could be set at any level in reference to the S.R.P. The stave rod was also marked in inches and could be pushed horizontally towards the subject. The end of the stave towards the subject carried $\frac{1}{2}''$ diameter and $1\frac{1}{2}''$ long vertical grip for the thumb and index finger of the subject. After adjusting the sleeve for a particular level in reference to S.R.P. on the shaft of the stand, the stand was placed at a particular radial line of the semicircle. The stave was pushed towards the subject parallel to the radial. The subject gripped the small handle on the end of the stave with thumb and index finger and pushed it away. The final reading on the stave then gave the reach.

During these tests it was found that the thumb-index grip was 2″ less in reach than the reach with extended fingers. Also when the shoulder lock loops were relaxed to simulate aircraft shoulder harness, a gain of 8 to 9 inches was obtained in anterior reach; this gain decreasing to zero as the arm was moved to lateral plane of the shoulders. This gain, due to added movements at the shoulder and trunk, was available at all levels of the body for all lateral angles upto 30° from the midline of the body.

Case 1. An experienced pilot was involved in an aircraft accident that resulted in Supracondylar fracture left ending up with ankylosis of left elbow with range of movement of 90° flexion and 160° extension. Since he was a transport pilot he was taken up in a Dakota aircraft in the left hand seat. He was to handle the control wheel with the left hand and the controls on central pedestal with the right hand. At the start of the test, his reach for forward movement of control column was not in doubt. The problem area appeared to be, when the stick was fully "back". The subject performed well and did a few good landings. It was observed that after 90° of elbow flexion further movement of the stick backwards was obtained by extension at the shoulder. At the beginning he was a bit rough on the control but his performance improved as the sortie progressed.

This officer later went on flying instructor's course and passed out successfully. He is an active instructor now.

Case 2. This pilot ejected from a high performance aircraft in inverted attitude due to an uncontrollable bunt. Injuries to left elbow finally resulted in limitation of extension to 140° and flexion deficit of 10°. His lateral reach of the normal arm was 35.4″ and that of affected arm was 31.9″.

This subject had a basic advantage of having long arm reach. Flexion could be considered complete from all points of view. 40° of limitation in extension reduced the reach by 3 inches.

The front reach at the S.R.P. level was found to be the worst affected movement,

when the shoulders and trunk were kept fixed.

The knuckle reach for his right arm was 15″ and for the affected arm 12″. In a functional situation the added movement of the shoulder coupled with some slumping and forward shift of the trunk, the absolute maximum reach could increase by 5″. The only control required to be performed in this position is the seat pan firing handle in Martin Baker ejection seats requring 15″ of reach and the anti-negative G buckle requiring 13″ of reach. This study strongly suggests, that at this level a minimum grasping reach of 12″ would be an appropriate limiting parameter since additional gains are always available with additional compensatory movements of shoulder and trunk.

Case 3. An experienced pilot, who after an accident had been left with ankylosis of left elbow fixing the forearm at 90° to the line of the humerus was assessed. A small movement of ±5° was, however, available. The lateral reach with extended fingers for the normal right arm was 31″ at the level of the shoulder. The officer was to be assessed for high performance fighter flying. Tests in a jet fighter aircraft cockpit were conducted simulating strapping in, ground checks, vital actions before take off, checks in flight, checks after landing and operation of overhead blind firing handle.

With the harness locked, it was found that with an increase in forward reach of 8 to 9 inches which was available with effort he could reach all the switches, knobs, and levers in front meant to be used by left hand. The switches and controls on left side console in any case did not pose a problem. Operation of the throttle was done with left hand, completely prone and elbow pointing downward. The tip of the elbow was clear of all the fittings on the left console behind the throttle.

The subject could operate the throttle fully and even reach for another toggle switch 2″ left of fully open throttle on the left console by using additional movement of shoulder and trunk inspite of the shoulder harness being in tight and locked position. Measurements showed that the throttle moved between 54° to 62° angles to the body at a level of around 8″ above the S.R.P. The left arm knuckle reach requirement was 22″ for throttle "closed" and 25″ for the throttle "fully open".

Actual measured knuckle reaches of left arm in this subject were 20″ at 54° and 18″ at 62° left of midline of body. He gained control of the throttle because of additional compensatory movement of shoulder and trunk. Reach and operation for another emergency control push button located on the upper left of the main instrument panel was tested. Horizontal distance of this button from a vertical projection off the S.R.P. was 28″. The experimentally measured anterior thumb-finger reach at a level of 20″ above the S.R.P. in this case was 18″. Extended finger reach for push button operation makes it 20″. Taking actual reach as 0.5″ less (Morgan *et al.*) for push button operation and 8 to 9 inches of effort was added, it was found that this button could be operated with reasonable margin of safety. In this connection it may be borne in mind that the shoulder harness straps in Martin Baker seats and in many other seats cannot be over tightened. Over tightening causes downward pressure on the shoulders tending to press down the pilot. Pilots are therefore advised to tighten the harness enough to establish contact with the shoulder.

The case considered above had some limitations. Fighter cockpits are necessarily small and all controls are close by. However, this subject had to put in all the reserve to achieve the measurements of reach. Except for the throttle, the hand is used for positional setting of other controls and switches. Further, +5 degrees movement available at the elbow contributed to mitigate the effects of 90° ankylosis

With this degree of ankylosis the officer was unable to fly from left hand seat of a transport aircraft since the left hand had to handle the control wheel. If further extension or flexion was not possible, all the movements of the control wheel had to be translated by movements at the shoulder and trunk. Rapid and accurate adjustments would therefore not be possible in flight.

From the foregoing, the following conclusions can be drawn:

(*a*) If ankylosis of elbow exists, any limitation in supination/pronations of the wrist will have adverse effects on operations of controls in flying.

(*b*) Ankylosis of shoulder when present with ankylosis of elbow is a serious limitation. Such cases may not be considered for aircraft operation.

(*c*) When ankylosis is restricted to one limb only, such cases may be investigated. Cases with ankylosis of both elbows should not be considered for flying as far as possible. This will cause increased load on the operator to an extent that satisfactory compensation is not possible. Special cases may be considered on their merits.

(*d*) Ankylosis with fixation of elbow in full extension is unacceptable since with this type of disability the arm behaves like a straight rod.

(*e*) Fixed ankylosis, within the range of 100°–90° is worth investigating. Cases of fixed ankylosis pose critical problems in assessing short pilots.

(*f*) Shoulder level 'thumb-index grasp' with static reaches of less than 21" at 60° and 24" at 30° should be viewed with suspicion. These values can be used as standard checks before further investigation.

Case 4. Anklysosis of shoulder joint: An officer whose left humerus was fixed in glenoid cavity at 30° of internal rotation as a result of an accident involving posterior dislocation of the shoulder was investigated. No other joints were involved. All shoulder movements were scapular. Straight ahead, the arm could be raised above the head upto a point where the shoulder made an anterior angle of 30° to the forehead. Although this officer was fit to operate all controls in front, down, side and above upto 30° in front of the head, he was unable to grasp the overhead firing handle of the ejection seat as the humerus could not be externally rotated to direct the flexed forearm posteriorly over the head. He could be considered fit for all fighter aircraft where overhead handle is not provided and seat is fired with right arm rest grip mechanism.

Lower-Limb

The disabilities examined after accidents have been mainly those that involved limitation of movement at the knee joint. Besides, affecting the reach for rudder pedals, limitation of flexion at knee joint effects the ankle angle. As one pedal is operated, the

other pedal advances towards the pilot. Unless proper degree of flexion is available the ankle has to be dorsiflexed to take up the rearward movement of the pedal. The maximum possible dorsiflexion at the ankle is 70° and would permit the pedal to advance by 2.5" at the most. In case where knee joint cannot be flexed beyond 90°, that leg will become an obstruction to the rearward atravel of the pedal unless it was either shifted above or to the outer side of the pedal. If the knee is limited in range of extension, then, not only the leg reach suffers, but also the ability to apply force. In cases where ankle is not involved and muscle power is not affected, we found that minimum flexion at knee joint of 110° was essential. Extension capability of less than 160° seriously affects the reach especially for short pilots. Besides this reduces the ability to apply sufficient force on the rudder pedals during asymmetric flight of a multi-engine aircraft.

Acknowledgement

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