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High incidence of backache problem already established in a field survey in rotary wing aircrew has been studied in detail in Chetak crew. Ergonomic survey of QFI and test pilots vis-a-vis Chetak aircraft crew station geometry has been conducted highlighting the ergonomic deficiencies causing malposture of aircrew in flying environment. A practical solution to the problem is evolved by suggesting ergonomic improvement in aircrew seat design. Air trial of modified crew seat are found satisfactory. A few recommendations are also put forward to minimise the incidence of backache amongst Chetak crew.

Backache in Chetak Crew and Suggested Ergonomic Improvements in Aircraft Seat Design

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HIGH incidence of backache amongst the healthy aircrew of rotary wing aircraft has been established during an earlier field study in IAF[5]. Vibration environment in helicopter is an accepted compromise in aircraft design with main and tail rotars as sources of vibration. However, in addition to the vibrations, faulty ergonomic design of aircrew station geometry, layout and mismatching aircrew equipment are considered other important contributory factors in this problem. In fact a lot of research work is in progress to improve the helicopter cockpit technology in terms of advanced controls/ displays to improve vision inside/outside the cockpit and comfortable crew station geometry[3,6,7]. The chetak aircraft design technology is two to three decades old and hence has a poor ergonomic layout. A detailed ergonomic survey of the chetak cockpit vis-a-vis pilots during flying situations has been conducted. The study has revealed some salient ergonomic deficiencies contributing to the problam of backache. A few comprehensive design modifications in aircrew station geometry have been suggested as practical remedial measures and a few recommendations are made to minimise the incidence of backache.

Ergonomic survey

This survey covered healthy QFI and test pilots with flying experience varying from 500-3000 hrs on the type. The aircrew were free to give unbiased opinion/criticism on flying restraints, aircraft cockpit environment, health standards and aeromedical equipment, high lighting total magnitude of the problem, its actiology and the likely remedial measures. After a detailed briefing and recording of anthropometric measurements, each aircrew was asked to strap in the aircraft seat and adjust himself to his optimal position in relation to controls. A detailed dialogue on various factors leading to backache in relation to cockpit layout[1] and ergonomic measurements, i.e., change in posture, position of upper/lower limbs in relation to controls in different flight profiles was conducted.

Observations

Fig 1 shows the position of aircrew in the seat during flying. All aircrew irrespective of their anthropometric measurements adjusted the seat in forward position mainly to have favourable knee angle so as to support a constant pressure in the right rudder because of tail rotar. All aircrew leaned forward to have a proper vision outside the cockpit and ensure better hand grip to the cyclic by having thigh support to the right elbow. The cyclic is slightly at a higher level particularly to short statured pilots. Due to lack of lumbar support, the spinal curvature is disturbed, i.e., there is flexion at neck and thoracic area and normal lumbar lordosis is neutralised. Hence large portion of the torso is ill supported by seat back. This posture further undergoes change during collective lever operation which is located over floor, on the leftside of the seat. Hence there is torsion (lateral rotation) effect on the already flexed spine. The rudder pedals have no adjustment range except a clip-on adjustment which increases its height by 2.5cms. The aircrew operate the control keeping their heels on the cockpit floor, hence this adjustment is considered inadequate. Majority of aircrew maintain a knee angle around 95° - 125°, which in turn causes slight dorsiflexion at the ankles. These angles are adequate for rudder operation but cause fatigue in prolonged sorties. The main reason for such acute knee angles is the thigh support to the right elbow. Some of the aircrew with long leg length keep the left foot over the left rudder for resting.

(a)

(b)

Fig. 1. *Pilot seated in original crew seat in flying position (a) Seat back (b) Pilot's torso separated from seat back.*

The survey covered 21 h ealthy instructors/test pilots all in Medical Category AIGI except for 3 cases who were in A2G1 due to scoliosis, spinal injury during ejection and prolapsed IV disc L5-SI optd respectively with average age 31.9 yrs (26-38 yrs) and flying experience as given in Table I.

Table I
Flying experience of subjects

A/C Type	Hrs flown	No. of pilots	% age
Alouette III (Chetak)	1154	20	95.2
Cheetah	937	5	23.9
MI 4	868	5	23.9
MI 8	401	5	23.9
TPT	167	3	14.2
Fighters (other A/c)	206	15 (11)	71.4

Incidence of backache was 100%. Most of them experienced backache after a total flying experience of 200 hrs and more. Distribution of backache was (a) Low back 62% Mid back 32.8% and neck 16% with radiation to upper limbs in 15%. Some cases reported the symptoms at more than one place.

Magnitude of pain : Mostly it was mild discomfort to stiffness of back leading to annoyance and irritability of aircrew.

Onset of pain : Usually started after $1\frac{1}{2}$ - 2 hrs after flying, came on andoff during flying without any relation with type of flying. However all cases reported its onset in prolonged sorties. In 67% cases pain persisted after the sortie.

Effect on performance : Aircrew agreed that there was qualitative deterioration in flying performance but could not attribute quantitative deterioration leading to any incidence or accident. There was generalised fatigue with stiffness of back, leading to uneasiness in seat which caused general annoyance and irritability/hasty action lowering efficiency. Only one aircrew abandoned sortie because of pain (he happened to be the case of spinal abnormality - prolapsed IV dis optd).

Relief of pain : The aircrew emperically found out that reclining to the seat back, and shift in seat pan, handing over the controls to copilot or switching over autopilot (wherever applicable) relieved the back strain during flying. After the sortie, pain got relieved by rest and sleep. Few cases felt the need of spinal exercise. No subject had to resort to drugs

Ergonomic features of aircrew station geometry as contributing towards backache were reported by 95.2% cases.

(a) Seat design
- i) Seat back angle 70%
- ii) Seat back cushion 95.2%
- iii) Seat pan cushion 33% (mostly short pilots)
- iv) Lack of seat adjustment up/down 40%.

(b) Mainly short pilots felt inadequacy in reach for cyclic for which they had to adjust seat in fully forward position to raise thigh support for the right elbow. 60% cases considered these problems to be mainly due to (a) forward shift in the seat with a slight twist at bottom with right foot on rudder pedal to counter a constant pressure of tail rotar and (b) constant support to right elbow because of too high location of cyclic grip.

(c) Inadequate/faulty aeromedical equipment : Majority of aircrew felt that heavy bonedome with inner helmet add up to backache particularly in neck area. In addition they have to use, O_2 mask only for R/T purposes and this type of combination is cumbersome and leads to annoyance. In high altitude sorties O_2 mask though present is of no use as the aircrew use O_2 hose directly having no suitable O_2 connector.

(d) in high altitude sorties and during winter, lack of heating in the cockpit and localised chilling effect leads to rigidity and muscle spasm causing backache.

(e) Lack of head rest was pointed out by 33% crew as cause of neck strain.

(f) In case of armed version of the aircraft, aircrew had apprehension on protective measures against the ground fire.

Physiological considerations

The paper does not deal with explanations as to the pathology of spinal ailment in chetak crews but rather a practical solution to the problem. However, a brief physiological consideration will not be out of place to high light the need of basic research on vertebral column changes under vibration environment. The strength of the vertebral column as a whole is maintained by the following to sustain constant loads if normal erect posture is maintained.

a) Articular process which locks the spinal column

b) Common anterior/posterior ligament making a sheath and equilibrating spinal movements

c) Inter vertebral ligaments between trasnverse spinous process which restrain movements at articular surface.

d) Para vertebral muscles which act in opposition to the passive movements (they can tolerate a pressure of more than one ton).

The backache of mild rating (back strain, stiffness) is basically fatigue of spinal muscles and ligamentous support causing symptomatology without much immediate residual effect and bony changes. The basic cause is vibration effect on the disturbed spinal posture. 20% of the weight being borne normally by posterior columns (articular process) is also transferred to the anterior end of the vertebral column in malposture. The biomechanical characteristics of inter vetebral discs during vibration forces maintain the spinal shape by absorbing and distributing the force over laminae of annular fibrosus which is wel suited because of elasticity to dissipate energy. It is, quite resistant to forces exerted on horizonal plane but its structure permits moderate lateral inflection (intervertebral angulation) thus a compromise is achieved between spinal stability and flexibility[1]. Anterior periarachidial ligament is more resistant than posterior and pressure on intra articular surfaces in IV disc increase by factor of 1.2 - 2.5 times to 0.7 kg/cm^2 in normal bending. Hence a residual base pressure in nucleus pulposus exists due to turgescence ; elasticity of perivertebral ligament and tone of periarachidial muscles. Physiological stress seems to offer no serious threat to their healthy condition. The extensibility of ligamenta flava and inter spinous ligaments decreases in appreciable fashion until adolescence but subsequently there is no further decrease.

Aetiology of backache

The main factors responsible for backache in healthy aircrew in chetak aircraft assessed during the study are summarised below :

(a) Spinal malposture

(b) Improper R/T, 02 mask and heavy headgear assembly

(c) Lack of specific exercises/rest in between the sortie

(d) Vertebral anomalies

(e) Miscellaneous

(a) *Malposture* : The spinal posture is disturbed, i.e., normal curvatures of spine are affected leading to generalised flexion at cervical/thoracic area and neutralising lumbar curve with slight left lateral rotation of spine. Spinal malposture under vibration environment is considered major factor of backache. The vibrations will remain a major side effect in rotary wing aircraft but these should not exceed the laid limits and transmission of these accelerations to crew through their tie down chain system should not exceed ± .1g at frequencies 22Hz, 0.1mm double amplitude at frequencies between 22 and 86 Hz and 1.5g at frequencies above 86 Hz[6]. Malposture of spine causes more pressure on ventral parts of the vertebral discs and fatigue of post ligament and perivertebral muscles is produced. Pathophysiological changes ie spondylitis, myogelosis may set in after prolonged exposures which need to be investigated.

(b) The aircrew are required to fly with an inner outer helmet for head protection. The equipment in use weighs around 1 kg. The c of g of head in upright seated person is 2cms infront of atlanto occipital joint and hence a tendency for neck flexion. Pilot is already moved forward with no support in cervical area, head flexed forward and has to retroflex neck to see outside the cockpit. Under vibrations, the neck muscles get fatigued unless there is a head rest or other visual aids to the pilot to maintain his vision outside the cockpit.

(c) Lack of specific exercise particularly forneck and trunk muscles lowers the muscle threshold to fatigue.

(d) *Vertebral anomalies* : In this series, only 3 aircrew had history of spinal abnormality. Their cases were reviewed and had positive findings. A long term survey may indicate early onset of spondylytic changes if any.

(e) *Miscellaneous* : Exposure to cold air leads to chilling effect particularly in winter season and sometimes even in warm conditions, after evaporation of sweat. This was reported by some pilots as leading to rigidity and tenderness of the local muscles. There is definite lack of warm air in pedal area of the aircraft.

Remedial measures

As the major factor contributing to backache in Chetak aircraft is the malposture of the crews due to ergonomic design deficiencies of seat and controls, the following modifications are suggested to improve the posture and comfort during flight situations.

Aircrew seat modification

The configuration of seat design has been modified only by changing the cushions rather than any structural change keeping in view the time, cost and weight considerations (Fig 2). The following changes in its configuration are affected :—

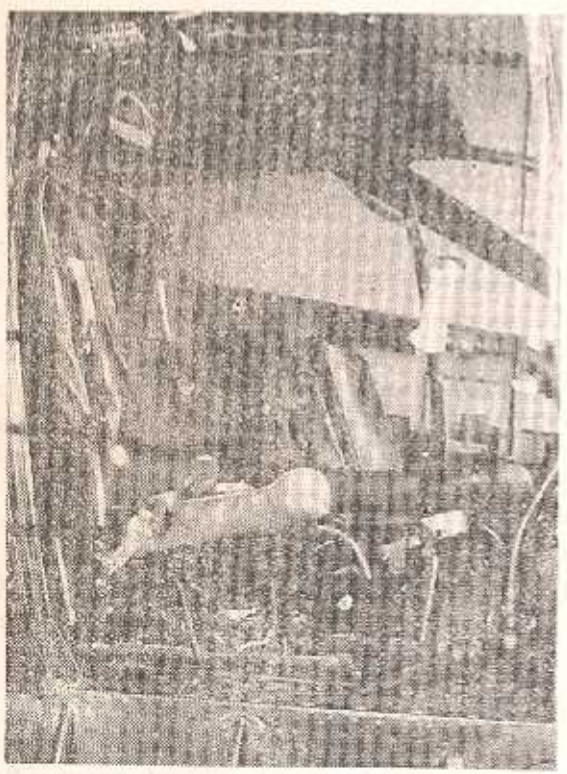

Fig. 2 *Modified crew seat mounted in Chetak Helicopter. (a) Head rest (b) Seat back cushion (c) Lumber pad (d) Seat cushion*

Fig. 3. *Pilot in modified seat in flying position. (a) Seat back (b) Lumbar pad*

(a) Seat back cushion : The seat back cushion has been designed and fabricated so that seat back inclination angle is reduced from 106° to 96° and height of this cushion is increased by approx 15cms ensuring proper apposition of the whole torso of the pilot as shown in Fig 3. The cushion is contoured in the centre to suit the contour of human spine.

(b) Adjustable lumbar pad : An adjustable lumbar pad is also provided over the lower part of seat back cushion The pad can be adjusted up and down with the help of velcro fasteners and retains its position to maintain lumbar curve and hence supports the lower back.

(c) Seatpan cushion : This cushion has been redesigned to reduce the seat pan inclination from horizontal from 16° to 8° for proper contact of the thigh with the cushion. The material used is such that it gets fully compressed with

40 kg weight hence is unlikely to add any amplification of forces during impact/crash landings.

(d) *Provision of head rest* : A small adjustable headrest is provided over the upper edge of seat back cushion which supports the head. The head rest can be adjusted up and down within a range of 10cms. The head rest position is such that in routine flights, aircrew can fly keeping head resting against its contour without affecting his vision inside or outside the cockpit. The head rest width is such that it does not project beyond dimensions of the helmet and hence does not interfere with vision of other crew/passengers in the cockpit.

Up/Down seat adjustment mechanism

A criss cross mechanism has been introduced in the same seat which affect 15 cms up/down adjustment while fore-aft adjustment of the seat is also retained. This range will accommodate 100 percentile of IAF aircrew maintaining the vision outside/inside the cockpit for all pilots to the same reference point. The adjustment is easy. Pilot after strapping himself in the seat can adjust his seat up and down by operating the lever provided on left side of the seat pan. For upward adjustment he is to operate the lever and lift himself in the seat. The air jacks of the mechanism will automatically lift the seat to desired position. Similar proven mechanism is available in HPT-32 aircraft. Hence crashworthiness of the mechanism is not in doubt. It also raises the thigh level for good elbow support to the right elbow and hence improves cyclic grip. The general features of modified seat compared to original seat is given in table II.

Trials

The modified seat has been subjected to air trials covering 45 hrs of flying by different test pilots. The comfort rating correlating the different features of the modified Vs original seat is tabulated in table III.

Table II

Comparison of modified and original crew seat parameters Alouette III (Chetak) Aircraft

Item	Crew seat			Pilots seated posture values		
	Original	Modified				
		I	II		Min	Max
Length of seat (cms)	75	75	+100			
Width of seat („)	35	38	38	Sitting Ht	81.5	96.5
Seat backrest angle (degree)	106	96	96	Leg length	99	125
Height of seat reference point (cms)	22.5	23.5	48			
Width of backrest (cms)	35	18	22	Thigh length		66
				Knee angle	100°	140°—150°
Thickness of lumbar support (cms)	Nil	1.5—2 adjustable	1.5—2 adjustable			
Height of lumbar support (cms)	N/A	18	18	Trunk thigh		
Length of backrest (cms)	52	70	70	angle	107°	90°
Length of top of headrest (cms)	N/A	90	94	Elbow angle	90°	
Headrest rack angle (degrees)	N/A	96	94			
Head headrest clerance (cms)	N/A	Nil	Nil			
Height of headrest (cms)	N/A	20	24			
Width of headrest (cms)	N/A	18	22			

Table III

Comparison of comfort rating with different features of Chetak seat

Seat feature	Comments	Modified seat			Original seat		
		Seated	Post exposure	Total	Seated	Post exposure	Total
Seat pan	Too hard	OK	Comfortable	Sat	—	OK	
	Too soft						
	Increase thigh support						
	Too narrow			Sat			
	Wrong shape						Needs hollowing
Back rest	Lumbar support			Sat			Unsat
	Produces backache						Unsat
	Supports shoulder level			Sat			"
Head rest	Too high	Adjustable	OK	Sat			Unsat
	Too low						
	Needs one						Yes
General	Comfortable	—	—	Sat			
	Uncomfortable	—	—	—			Unsat
	Rest less			—			

Sat—Satisfactory Unsat—Unsatisfactory

Conclusion and Recommendations

The study reveals that incidence of backache is high amongst chetak crews for which the aetiology is also apparent. Suitable modifications of the aircrew station geometry are suggested to improve the seated posture of aircrew during flying and provide him more comfort. Radiological assessment has not been done; hence correlation of backache on pathological basis is not done. A practical approach to the problem is put forward with following recommendations :

(a) Modifications in seat configuration should be implemented and introduced in the aircraft at the earliest.

(b) Provision of a light weight integrated helmet with double visor having a provision of boom mike and/or proper O_2 mask connector facility be made. Light weight helmets available weighing approx. 500 - 600 gms may be procured or could be made indigenously if the technical know is available. For armed version a bullet proof helmet is recommended. This along with head rest will reduce the fatigue of neck muscles to quite an extent.

(c) To avoid chilling effect, relocation of hot air feed pipes may be needed particularly for winter season. Adequate winter clothing like a winter flying jacket may be introduced for helicopter pilots.

(d) Aircrew room may be provided with well cushioned hard board in addition to easy chairs for resting between the sorties.

(e) Suspension/bar exercises and spinal exercises are recommended to tone up the neck and back

muscles. For regular exercises, well equipped Gymrooms near the living out accommodation will go a long way to keep the aircrew healthy.

(f) Cycle grip may be provided with adjustment up/down or additional 'L' shaped lever for adequate reach and grip for all pilots.

(g) Rudder pedal may need modification in the form of foot support so that pilot can rest his feet in the receptacle or the control should be trimmed to reduce the constant physical pressure on the right foot.

(h) Routine x-ray of spine prior to enrollment may be re-instituted for comparison later on say after 1000 hrs flying. A long term survey of helicopter aircrew may be needed to assess ill effects of vibration on spine if any, i e., bony changes. myogelosis, tenderness of dorsal processes and paraesthesia etc.

(j) The design constraints as governed by military standards and specification regarding aircrew station geometry and vision inside the cockpit should not be compromised in the aircraft design.

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