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16. Abstract Studies related to FIFO aircrew stress and fatigue were carried out at seven FIFO's in the Continental U.S. Forty-one men served as subjects and all crew positions were represented. Each crewmember was studied during flight activities and during office-based activities. Generally, crews were in travel status during flight inspection activities and away from the office for 5 d. Crewmembers completed fatigue checklists before and after each duty on every workday. Urine specimens were collected that represented the night sleep period and the work period; they were analyzed for 17-ketogenic steroids, epinephrine, and norepinephrine, and values were expressed as weight per hundred milligrams of urinary creatinine. Ambulatory electrocardiograms were recorded for determination of heart rate (HR) during work.

The data indicate that office work is distinctly less fatiguing than flight work. This finding is supported by the HR data that indicate a lower workload in the office than in flight. The statement is commonly made by crewmembers that office work is more fatiguing than flight work. It is probable that such statements are based on work preference rather than work level. Some crewmembers at Oklahoma City, Atlanta, Los Angeles, and Battle Creek show severe fatigue associated with flight work.

Rest-to-work differences in stress indicator hormone excretion indicate arousal connected with both flight and office work. FIFO crewmembers appear to experience less chronic stress than do other groups of FAA workers; acute stress associated with on-the-job factors, however, appears to be slightly greater in FIFO crewmembers than in these other groups. In no case, however, does stress appear to be outside that normally connected with work.

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FATIGUE IN FLIGHT INSPECTION FIELD OFFICE (FIFO) FLIGHT CREWS

INTRODUCTION

The Federal Aviation Administration (FAA) performs regular inspection of air navigation facilities to insure that they conform to specified standards. These inspections are mainly made with airborne electronic equipment carried in modified aircraft flown by crews of specialists normally composed of aircraft commanders (AC), copilots (CP), and electronics technicians (T). Inspections of navigational aids generally fall into two categories, terminal and en route.

Inspection aircraft and crews are based at Flight Inspection Field Offices (FIFO's) located in cities around the United States and some foreign countries. Each FIFO is responsible for inspection of terminal air navigational aids, obstructions in the terminal airspace, runway conditions and other factors connected with safe air operations in its assigned geographical area. Airway (en route) inspections over the whole country are carried out by crews based at Oklahoma City and Atlantic City. Terminal inspections (called Basic) are flown mainly in North American Sabreliners (NA-265's) or, less commonly, in Jet Commanders (AC-1121's). Airway inspections (called SAFI) are flown in large aircraft such as the Propjet Convair (CV-580) or Boeing 727.

There are seven FIFO's in the contiguous 48 states located in the following cities: Oklahoma City (OKC), Atlanta (ATL), Atlantic City (ACY), Battle Creek (BTL), Minneapolis/St. Paul (MSP), Los Angeles (LAX), and Seattle (SEA). Crews based at these FIFO's usually are given an inspection schedule that requires 5 d of in-flight work away from the office. These schedules can be, and usually are, changed on short notice because of outages or malfunctions of navigational aids that occur unexpectedly at sites not on the original schedule. The crew is then required to replan its itinerary and rearrange its work schedule on short notice. Work days are normally 8 h in duration; unscheduled inspections commonly lead to overtime work.

BTL FIFO crews usually return to home base each night and do not stay out of the office for extended periods. With the exception of BTL, crews from the other FIFO's characteristically alternate 5 d of flight inspection with 5 d of desk work in the FIFO.

Flight inspection formerly was done in slow, propeller-driven piston airplanes such as the Douglas DC-3. These airplanes required considerable time to fly from one job to the next, affording the crew a certain amount of en route time. With introduction of the executive jet airplane into the flight inspection system, flying time between jobs was reduced and inspection procedures could be carried out more rapidly than before. Work density per workday was thus increased. These factors, plus ever-increasing traffic density at major air terminals, led to allegations by FIFO flight crews of excessive work-connected fatigue and stress. The acting Director of the (then) Flight Standards Service formally requested (FAA Form 9550-1, No. AFS-500-78-2) that biomedical studies be carried out by the Civil Aeromedical Institute (CAMI) to quantitate and identify the causes of work-related stress and fatigue. A preliminary report of most of the data was submitted to the Federal Air Surgeon for transmittal to the Office of Flight Operations in April 1980. The present report contains the previously submitted data plus data on urinary excretion of stress indicator hormones.

METHODS

Studies related to FIFO crew fatigue have been carried out at all seven FIFO's in the Continental U.S. The same biomedical crew collected all the data according to a uniform procedure; i.e., one researcher (J. T. Saldivar) made all the office-based observations while the other researcher (S. M. Wicks, a commercial pilot) collected all the in-flight data. Generally, each FIFO crewmember participated in both phases of the study.

All subjects were male. Table I shows participation by crewmembers at the seven FIFO's. Table II shows flight days and office days of data collection. Table III shows participant days at several FIFO's and indicates that not every subject participated every day of the study. For this reason, data from individuals are not presented; grouped data are shown in subsequent tables.

As an indication of workload, ambulatory electrocardiograms (ECG) were recorded from all subjects throughout every day of their participation. Three adhesive ECG chest electrodes were attached to the subjects each morning. Two active electrodes were placed across the long axis of the heart and an indifferent electrode was placed on the lower right lateral chest wall. The ECG was recorded on a battery-operated portable tape recorder (Avionics Electrocardiocorder) carried in a pouch with a shoulder strap. Tapes were later played back at CAMI for heart rate (HR) determinations.

A fatigue checklist (FCL)(3) was completed by each subject before and after each workday (Fig. 1).

Two urine specimens were collected from each subject every day of his participation. One specimen consisted of urine formed during the sleep period and collected on arising. This specimen is the baseline or reference specimen. The other specimen consisted of all urine voided (pooled) during the workday. Specimens were frozen in an ice chest containing dry ice and were transferred to a freezer when they arrived at CAMI at the end of the data collection period. Urine analysis consisted of determinations of 17-ketogenic steroids (KGS) as an indicator of adrenal cortical activity, epinephrine (E) as an indicator of adrenal medullary activity and norepinephrine (NE) as an indicator of sympathetic nervous system activity. These three metabolic measurements comprise a battery of tests that provide coverage of stress arising from different conditions.

The data presented in this report are derived from measurements of fatigue, HR, and urine biochemistry, together with some nonquantitative subjective observations made by the biomedical crewmembers.

RESULTS

1. Fatigue checklist: The 10 items on the FCL are scored in such a way that the numerical ratings are inversely related to fatigue; i.e., the lower the score the greater the fatigue. Table IV and Figures 2-4 show a comparison of grouped fatigue data for all FIFO's among the three crewmembers as related to different working conditions. Generally, there are no significant differences in fatigue levels among crewmembers when they report for duty regardless of type of work, office or flight, with the exception that technicians are more fatigued than copilots ($p < 0.05$). There are no significant differences among crewmembers' fatigue levels after office work, whereas CP's and T's report significantly greater fatigue after flight than do AC's. Table V shows similar data for each FIFO. OKC and LAX show more postwork significant differences between office and flight days than do the other FIFO's.

Table VI shows mean prework and postwork fatigue levels (office and flight days) for each FIFO with levels of statistical significance of the differences in the means indicated in the charts. SEA shows the greatest prework fatigue on office days, differing significantly from ACY, OKC, ATL, and BTL. The other FIFO's do not differ significantly. On office days postwork fatigue is greatest at ATL with ATL, MSP, and BTL differing significantly from the other FIFO's. Prework fatigue is not significantly different among the FIFO's on flight days. ATL crewmembers report significantly greater mean fatigue levels than do crewmembers at all the other FIFO's after work on flight days. OKC crewmembers only show a significantly greater mean fatigue level than do SEA crewmembers. All crewmembers reported greater fatigue postwork than prework. Table VII shows the difference (increase) in fatigue from the prework to postwork condition. In this chart the larger numbers indicate a greater difference.

Figures 5-10 show daily FCL data graphically at each FIFO, except BTL. Such a graph could not be drawn for BTL because crews did not work the 5-d pattern. Figure 11 shows the same data for all FIFO's combined. These graphs show generally (i) that flight work is more fatiguing than office work and (ii) that there is a day-by-day progressive increase in fatigue associated with flight work, whereas that is not the case with office work. Interestingly, four of the six FIFO's show an "end-spurt" phenomenon--a reduction in reported fatigue the last workday of the week. On the whole (Fig. 11) office work was judged to be less fatiguing than flight work.

2. Heart rate: Mean HR's for each crewmember (all facilities combined) on office and flight days and a comparison of office and flight days are shown in Table VIII and Figure 12. Similar data are shown for each FIFO in Table IX. Mean HR for each facility (all crew positions combined) and the level of significance of the differences between facilities are shown in Table X. ACY and BTL crews show significantly lower HR's than crews from other FIFO's with ACY also being significantly lower than BTL. OKC crews show the highest mean HR (89 beats per minute, flight work). With regard to office work, ACY and BTL crews again show significantly lower HR's than other FIFO crews with ATL crews showing the highest HR. On flight days ACY crews show significantly lower mean HR than crews at all other FIFO's; BTL is significantly lower than OKC, SEA, and MSP.

For all FIFO's combined, AC's and CP's have significantly lower HR's than T's during office work. On flight days AC's show significantly higher HR's than do CP's. AC's and CP's do not differ significantly from T's. AC's and CP's have significantly lower HR's during office work as compared to flight work; there is no significant difference in mean HR for T's during the two work conditions. Mean HR's in flight are higher for all crewmembers (separately and combined) than are HR's during office work; the differences are significant for AC's and CP's.

3. Urine biochemistry: The battery of urinary stress indicator hormones (SIH) showed only one point of statistically significant difference for the resting condition between office and flight duties, that being for elevated NE excretion by T's. AC's and CP's showed significant elevation of KGS excretion during flight work as compared to office work (Table XI).

Regardless of the type of work (office or flight) being done, there was uniformly a significant increase in SIH's from rest to work (Table XII). The exceptions to this generality were shown by CP's doing flight work.

Crewmembers at the different FIFO's did not show significant differences in levels of SIH's except for KGS excretion during office work (Table XIII). SEA, OKC, and ATL crewmembers showed a significantly greater excretion of KGS than did MSP and BTL. ACY crews' excretion of KGS significantly exceeded KGS excretion by BTL crews.

4. Miscellaneous observations: The impression of the biomedical crew was that FIFO crews are composed of highly competent, intelligent, and dedicated men. The impression was further made that the FIFO crews, in spite of good effort, were often frustrated in their attempts to accomplish their assigned workloads. Expressed frustrating factors were lack of coordination with ground personnel, lack of cooperation by ground personnel, aircraft and electronic outages, and lack of managerial understanding of these frustrating factors.

Sixty-eight percent of the crewmembers participating in this study used alcohol as a relaxant at the end of the workday. This was apparently more commonly true after flight work than after office work. Drinking away from bars--e.g., in hotel rooms--was not observed or known to have occurred. All crewmembers who drank were meticulous about observing the "8-hour rule." No crewmember was ever observed to drink to the point of intoxication or to be "hung over" in the morning.

DISCUSSION

"Stress" and "fatigue" are more or less interchangeable terms. Chronic or excessive fatigue can be called "stress"; however, the dividing line between nonexcessive and excessive fatigue is indefinite. Both "stress" and "fatigue" are terms that defy definitions that are not mere tautologies; there are no units of measurement for either condition.

To the physiologist, fatigue classically means the decrement in physical performance that is a consequence of prolonged effort. Generally, fatigue means exhaustion of energy-yielding metabolic substrates or accumulation of some substance that inhibits cellular interactions. Depletion of acetylcholine at the motor endplate, for example, can account for muscular fatigue, though there may be other causes, also. In short, physical fatigue may be explained physiologically and biochemically. Emotional or mental fatigue is another phenomenon entirely, though there may be somewhat similar sensations accompanying both physical and mental fatigue.

Fatigue is bound up with another concept--workload. Workload may be defined objectively in terms of the imposed load (input) or work accomplishment (output). It may be subjectively defined as the person's perception of loading.

Studies indicate that the piloting task corresponds to light physical work (2) similar to office work or other sedentary activities. This conclusion is based on measurements of energy consumption. Other studies have focused on the pilot performance aspect of imposed load and have relied on the pilot's subjective appraisal of workload (1).

The FCL used in this study is an instrument designed to provide quantitation of the subjective sensation of fatigue. Some generalizations can be derived from these data. It is clear that flight work is perceived as being more fatiguing than office work. This result is at variance with a common statement by crewmembers that office work is more tiring than flight work. The conflict is probably based on confusion of work preference and work intensity. Thus, complaints about office work may be described in terms of fatigue but not be really related to effort. The most commonly identified job element causing dissatisfaction was said to be connected with "management." During office-based activities, of course, contacts with management are more frequent than during flight activities, perhaps leading to negative feelings that were summed up as "fatigue." The FCL, however, forces the individual to examine specific feelings related to fatigue and does not allow confusion with other feelings.

Fatigue must be viewed as a sensation in consciousness that can be engendered by a variety of circumstances. Regardless of its cause, the sensation of fatigue tells of an impending task overload and warns that compensatory measures will be taken to deal with the overload. The most common of these compensations is load shedding; a fatigued individual ranks tasks to be accomplished according to their importance and sheds those of low priority. He may also refuse to accept new inputs (additional tasks) or devote less time to each of the tasks at hand. In short, an encroachment has been made on his reserve capacity for assumption of other tasks.

Work/rest cycles have been established more or less through experience to provide adequate time off from work so that recovery from fatigue is complete between work periods. This time off is ordinarily 2 h for every 1 h worked. The data collected in this study show a difference in regard to accumulation of fatigue between office and flight work. FIFO crews as a group report prework fatigue levels to be virtually unchanged from day to day during office work; however, there is a day-by-day increase in prework fatigue during flight work essentially paralleling reported postwork fatigue. This indicates that there is incomplete recovery during the rest period from fatigue associated with flight days. Carryover fatigue may also result, of course, from off-duty activities. No definite statement can be made in that regard from the observations made during this study. There was adequate attention given by the FIFO crews to getting enough sleep, but quality of sleep was not recorded. A common statement was made by crewmembers that a different bed every night was not conducive to good rest.

The "end spurt" or "end effort" phenomenon is apparent in these data. The expectation of imminent release from duty commonly is reflected in an improvement in performance; in this case it is reflected in a reduction of reported fatigue.

With regard to fatigue at different crew positions, all three show significantly greater fatigue after flight than after office work, whereas there are no significant differences among the crewmembers before work of either type. On office days there are no statistically significant differences among the different crew positions, either prework or postwork. On flight days there are likewise no statistically significant differences between crew positions before work; however, CP's and T's show significantly more postwork fatigue than do AC's. There is no ready explanation for this finding; it does not imply that AC's do less work than other crewmembers. All FIFO's show greater crew fatigue levels after work than before work, and the prework-postwork difference is uniformly greater for flight days than for office days. There are some statistically significant differences among the FIFO's; however, further measurements and observations would be necessary to identify the causes for the differences. It must always be borne in mind that research conducted on volunteer subjects possibly has an inherent bias that is not present in randomly selected subjects.

The FCL used in this study was developed by the U.S. Air Force School of Aerospace Medicine (USAFSAM), at Brooks Air Force Base, Texas, for evaluation of flight crew fatigue. Crew responses have been systematically related to sleep loss, extended duty periods, circadian rhythms, environmental stresses, rest and recovery from stresses (5). In their experience, scores of 11 to 8 represent moderate fatigue and scores below 8, severe fatigue.

For all facilities combined (Table IV), crews are apparently well rested when they report for work with all FCL values being above 12. After work, all crewmembers report moderate fatigue with T's reporting slightly greater fatigue than AC's and CP's.

At the individual FIFO's, OKC, ATL, BTL, and LAX crewmembers showed severe postflight fatigue (Table V), with T's and CP's principally affected. When all crewmembers are grouped at the individual FIFO's, OKC and ATL crews show severe fatigue by the USAFSAM criteria.

It would be profitable to know the causes for differences in fatigue levels at different crew positions and at different FIFO's. Quantitation of workload might be helpful in that regard.

Many studies have been conducted (see references 1 and 4 for bibliographies of pilot workload) in attempts to establish a single valid measure of pilot workload. However, a generally accepted definition of workload is presently not even in existence. Roscoe (4) has devoted a great deal of effort toward validation of HR as the best single measure of a pilot's perception of workload. When consideration is given to the fact that more sophisticated and comprehensive appraisals of workload are likely to interfere with the pilot's ability to fly the airplane, HR probably is the best single measure of workload that is presently available.

The flight task (or, indeed, any other task) involves the reception of data by several sense organs--visual, auditory, kinesthetic, touch, etc. These inputs are integrated in the brain with data in the brain's memory bank (experience). From this integration, present status is appraised and estimates and projections are made. Based on these computations, decisions are made regarding alternatives and an action results (output). The speed with which this processing can occur is largely determined by the level of arousal of higher brain centers. A neural system in the brain stem, the Reticular Activating System, "sets" the level of arousal of these higher centers. As the speed of processing of data is increased, at least to some extent, work capacity is increased. An accompaniment of this increased brain arousal and work capacity is a general body response to mobilize other systems--endocrine, vascular, muscular, etc. These increased responses are largely mediated by the sympathetic nervous system that is responsible for raising blood pressure and increasing HR. Thus, the single simple measure of HR provides important insights into the workload that a pilot perceives.

The data show that ACY and BTL crewmembers have significantly lower mean HR on office days and flight days than do crews at other FIFO's. Whether or not this finding is reflective of objective workloads at those facilities compared with others cannot be determined from the data collected by the biomedical crew.

Urinary excretion of SIH show that FIFO crewmembers did not experience a high level of stress in either work situation compared with other groups of FAA workers. This is most evident with regard to adrenocorticosteroid excretion; FIFO crewmembers' level of excretion of KGS was generally about half that of Air Traffic Control Specialists' (ATCS's) and about the same as experimental subjects in the laboratory. This finding is interpreted to mean that FIFO crews do not experience a high level of chronic stress such as that seen in some ATCS groups (3). On the other hand, FIFO crewmembers show acute stress in their excretion of catecholamines that is comparable to that shown by other worker groups. It has been shown in earlier work in this laboratory that E excretion is related to workload (4); FIFO crewmembers show E excretion that is slightly greater than most other groups of workers. NE excretion is also related to workload but is influenced by physical activity to a greater extent than is KGS or E excretion. NE is also greater in FIFO crewmembers than it is in other groups (Table XIV), indicating that the flight inspection task entails a significant amount of physical work. It cannot be decided from these data, however, what part of the job entails the greatest amount of physical effort. The small difference in excretion of catecholamines between flight and work would lead one to conclude that flight work *per se* is not the principal stressor.

SUMMARY AND CONCLUSIONS

The data indicate that office work is distinctly less fatiguing than flight work. This finding is supported by the HR data that indicate a lower workload in the office than in flight. The statement is commonly made by crewmembers that office work is more fatiguing than flight work. It is probable that such statements are based on work preference rather than work level in that the FCL shows flight work to be more fatiguing than office work. Criteria developed by the U.S. Air Force show that most crewmembers experience moderate fatigue associated with flight work; some crewmembers at OKC, ATL, LAX, and BTL show severe fatigue associated with flight work.

Rest-to-work differences in SIH excretion indicate arousal connected with both flight and office work. FIFO crewmembers appear to experience less chronic stress than do other groups of FAA workers; acute stress associated with on-the-job factors, however, appears to be slightly greater in FIFO crewmembers than in these other groups. In no case, however, does stress appear to be outside that normally connected with work.

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TABLE I. Participation by Crewmembers at the Several FIFO's

FIFO		AC	CP	T
OKLAHOMA CITY	(OKC)	2	2	2
ATLANTA	(ATL)	2	2	2
ATLANTIC CITY	(ACY)	2	2	2
BATTLE CREEK	(BTL)	2	2	2
MINNEAPOLIS	(MSP)	2	2	2
LOS ANGELES	(LAX)	2	2	2
SEATTLE	(SEA)	1	1	3
	TOTAL	13	13	15

TABLE II. Man-Days of Participation Out of Possible 205 Days--Whole Study

OFFICE	FLIGHT
200 (98%)	199 (97%)

TABLE III. Man-Days of Participation by Facility

FACILITY	SUBJECT NO.	OFFICF	FLIGHT
OKC	1	5	5
	2	5	5
	3	4	5
	4	6	9 (4 SAFI flights included)
	5	6	9 (4 SAFI flights included)
	6	3	9 (4 SAFI flights included)
ATL	1	5	5
	2	5	5
	3	5	5
	4	3	5
	5	4	5
	6	5	5
ACY	1	5	5
	2	5	5
	3	5	5
	4	5	5
	5	5	5
	6	5	4
BTL	1	5	5
	2	4	4
	3	5	5
	4	4	4
	5	3	5
	6	4	5
MSP	1	6	4
	2	6	4
	3	5	5
	4	6	4
	5	2	5
	6	1	5
LAX	1	7	3
	2	8	2
	3	3	4
	4	5	5
	5	3	5
	6	7	4
SEA	1	6	4
	2	6	4
	3	3	7
	4	5	5
	5	10	–

TABLE IV. FCL - All Facilities Combined

Condition: Prework

Office Days

	Score			Score	P
AC	13.0	vs.	CP	13.1	NS
AC	13.0	vs.	T	13.5	NS
CP	13.1	vs.	T	13.5	NS

Flight Days

AC	12.8	vs.	CP	13.3	NS
AC	12.8	vs.	T	13.5	NS
CP	13.3	vs.	T	12.4	<0.05

Office Days		vs.	Flight Days	
AC	13.0	vs.	12.8	NS
CP	13.1	vs.	13.3	NS
T	13.5	vs.	12.4	<0.05

Condition: Postwork

Office Days

AC	10.6	vs.	CP	10.5	NS
AC	10.6	vs.	T	10.9	NS
CP	10.5	vs.	T	10.9	NS

Flight Days

AC	9.0	vs.	CP	8.0	<0.05
AC	9.0	vs.	T	7.8	<0.05
CP	8.0	vs.	T	7.8	NS

Office Days		vs.	Flight Days	
AC	10.6	vs.	9.0	<0.01
CP	10.5	vs.	8.0	<0.01
T	10.9	vs.	7.8	<0.01

TABLE V. FCL - Comparison of Crew Positions by FIFO

Condition: Prework

Office Days

Facility		Score			Score	P
OKC	AC	13.5	vs.	CP	15.0	NS
	AC	13.5	vs.	T	12.5	NS
	CP	15.0	vs.	T	12.5	<0.05

Flight Days

AC	13.3	vs.	CP	13.7	NS
AC	13.3	vs.	T	11.7	NS
CP	13.7	vs.	T	11.7	NS

	Office Days	vs.	Flight Days	
AC	13.5	vs.	13.3	NS
CP	15.0	vs.	13.7	NS
T	12.5	vs.	11.7	NS

Condition: Postwork

Office Days

AC	11.6	vs.	CP	12.2	NS
CP	11.6	vs.	T	10.4	NS
CP	12.2	vs.	T	10.4	NS

Flight Days

AC	9.8	vs.	CP	6.9	<0.05
AC	9.8	vs.	T	7.0	<0.01
CP	6.9	vs.	T	7.0	NS

	Office Days	vs.	Flight Days	
AC	11.6	vs.	9.8	NS
CP	12.2	vs	6.9	<0.01
T	10.4	vs.	7.0	<0.01

TABLE V. (Continued)

Condition: Prework

Office Days

Facility		Score			Score	P
ATL	AC	13.4	vs.	CP	13.4	NS
	AC	13.4	vs.	T	13.5	NS
	CP	13.4	vs.	T	13.5	NS

Flight Days

AC	11.1	vs.	CP	14.1	<0.01
AC	11.1	vs	T	12.0	NS
CP	14.1	vs.	T	12.0	NS

Office Days		vs.	Flight Days	
AC	13.4	vs.	11.1	<0.05
CP	13.4	vs	14.1	NS
T	13.5	vs.	12.0	NS

Condition: Postwork

Office Days

AC	9.6	vs.	CP	9.0	NS
AC	9.6	vs.	T	9.0	NS
CP	9.0	vs.	T	9.0	NS

Flight Days

AC	6.5	vs.	CP	7.6	NS
AC	6.5	vs.	T	4.3	NS
CP	7.6	vs.	T	4.3	<0.01

Office Days		vs.	Flight Days	
AC	9.6	vs.	6.5	<0.05
CP	9.0	vs.	7.6	NS
T	9.0	vs.	4.3	<0.05

TABLE V. (Continued)

Condition: Prework

Office Days

Facility		Score			Score	P
ACY	AC	14.1	vs.	CP	14.2	NS
	AC	14.1	vs.	T	13.0	NS
	CP	14.2	vs.	T	13.0	NS

Flight Days

AC	13.7	vs.	CP	12.5	<0.05
AC	13.7	vs.	T	12.6	NS
CP	12.5	vs.	T	12.6	NS

	Office Days	vs.	Flight Days	
AC	14.1	vs.	13.7	NS
CP	14.2	vs.	12.5	<0.01
T	13.0	vs.	12.6	NS

Condition: Postwork

Office Days

AC	11.9	vs.	CP	11.4	NS
AC	11.9	vs.	T	11.8	NS
CP	11.4	vs.	T	11.8	NS

Flight Days

AC	9.9	vs.	CP	9.3	NS
AC	9.9	vs.	T	8.5	NS
CP	9.3	vs.	T	8.5	NS

	Office Days	vs.	Flight Days	
AC	11.9	vs.	9.9	<0.05
CP	11.4	vs.	9.3	<0.05
T	11.8	vs.	8.5	NS

TABLE V. (Continued)

Condition: Prework

Office Days

Facility		Score			Score	P
BTL	AC	12.5	vs.	CP	12.7	NS
	AC	12.5	vs.	T	14.3	<0.05
	CP	12.7	vs.	T	14.3	NS

Flight Days

	AC	11.8	vs.	CP	14.1	<0.01
	AC	11.8	vs.	T	13.4	<0.05
	CP	14.1	vs.	T	13.4	NS

	Office Days		vs.	Flight Days	
	AC	12.5	vs.	11.8	NS
	CP	12.7	vs.	14.1	NS
	T	14.3	vs.	13.4	NS

Condition: Postwork

Office Days

	AC	10.5	vs.	CP	9.2	NS
	AC	10.5	vs.	T	9.8	NS
	CP	9.2	vs.	T	9.8	NS

Flight Days

	AC	10.2	vs.	CP	7.4	<0.05
	AC	10.2	vs.	T	6.0	<0.01
	CP	7.4	vs.	T	6.0	NS

	Office Days		vs.	Flight Days	
	AC	10.5	vs.	10.2	NS
	CP	9.2	vs.	7.4	NS
	T	9.8	vs.	6.0	<0.05

TABLE V. (Continued)

Condition: Prework

Office Days

Facility		Score			Score	P
MSP	AC	13.7	vs.	CP	12.3	NS
	AC	13.7	vs.	T	13.2	NS
	CP	12.3	vs.	T	13.2	NS

Flight Days

AC	13.4	vs.	CP	11.6	NS
AC	13.4	vs.	T	12.9	NS
CP	11.6	vs.	T	12.9	NS

Office Days		vs.	Flight Days	
AC	13.7	vs.	13.4	NS
CP	13.4	vs.	12.9	NS
T	11.6	vs.	12.9	NS

Condition: Postwork

Office Days

AC	8.0	vs.	CP	11.0	<0.05
AC	8.0	vs.	T	10.2	NS
CP	11.0	vs.	T	10.2	NS

Flight Days

AC	8.7	vs.	CP	8.4	NS
AC	8.7	vs.	T	10.6	NS
CP	8.4	vs.	T	10.6	NS

Office Days		vs.	Flight Days	
AC	8.0	vs.	8.7	NS
CP	11.0	vs.	8.4	NS
T	10.2	vs.	10.6	NS

TABLE V. (Continued)

Condition: Prework

Office Days

Facility		Score			Score	P
IAX	AC	12.2	vs.	CP	11.1	NS
	AC	12.1	vs.	T	14.9	<0.01
	CP	11.1	vs.	T	14.9	<0.01

Flight Days

AC	13.0	vs.	CP	14.6	NS
AC	13.0	vs.	T	12.3	NS
CP	14.6	vs.	T	12.3	NS

	Office Days	vs.	Flight Days	
AC	12.1	vs.	13.0	NS
CP	11.1	vs.	14.6	<0.05
T	14.9	vs.	12.3	NS

Condition: Postwork

Office Days

AC	10.3	vs.	CP	7.0	NS
AC	10.3	vs.	T	14.5	<0.01
CP	10.1	vs.	T	14.5	<0.01

Flight Days

AC	8.1	vs.	CP	7.0	NS
AC	8.1	vs.	T	9.1	NS
CP	7.0	vs.	T	9.1	NS

	Office Days	vs.	Flight Days	
AC	10.3	vs.	8.1	<0.01
CP	10.1	vs.	7.0	NS
T	14.5	vs.	9.1	<0.01

TABLE V. (Continued)

Condition: Prework

Office Days

Facility		Score			Score	P
SEA	AC	11.3	vs.	CP	11.7	NS
	AC	11.3	vs.	T	13.0	NS
	CP	11.7	vs.	T	13.0	NS

Flight Days

AC	13.8	vs.	CP	12.5	NS
AC	13.8	vs.	T	12.1	NS
CP	12.5	vs.	T	12.1	NS

	Office Days	vs.	Flight Days	
AC	11.3	vs.	13.8	NS
CP	11.7	vs.	12.5	NS
T	13.0	vs.	12.1	NS

Condition: Postwork

Office Days

AC	11.7	vs.	CP	9.7	NS
AC	11.7	vs.	T	10.5	NS
CP	9.7	vs.	T	10.5	NS

Flight Days

AC	11.0	vs.	CP	9.5	NS
AC	11.0	vs.	T	9.0	NS
CP	9.5	vs.	T	9.0	NS

	Office Days	vs.	Flight Days	
AC	11.7	vs.	11.0	NS
CP	9.7	vs.	9.5	NS
T	10.5	vs.	9.0	NS

TABLE VI. FCL - Office Days, Ranked by Facility

Prework:

1. SEA = 12.10
2. LAX = 12.73
3. MSP = 13.04
4. BTL = 13.35
5. ATL = 13.44
6. OKC = 13.70
7. ACY = 13.79

Postwork:

1. ATL = 9.19
2. MSP = 9.84
3. BTL = 9.88
4. SEA = 10.60
5. OKC = 11.41
6. LAX = 11.60
7. ACY = 11.71

Level of significance of differences between facilities, prework.

SEA	LAX	MSP	BTL	ATL	OKC	ACY	
-	NS	NS	*	*	**	**	SEA
	-	NS	NS	NS	NS	NS	LAX
		-	NS	NS	NS	NS	MSP
			-	NS	NS	NS	BTL
				-	NS	NS	ATL
					-	NS	OKC
						-	ACY

Level of significance of differences between facilities, postwork.

ATL	MSP	BTL	SEA	OKC	LAX	ACY	
-	NS	NS	NS	**	**	**	ATL
	-	NS	NS	*	*	**	MSP
		-	NS	*	*	*	BTL
			-	NS	NS	NS	SEA
				-	NS	NS	OKC
					-	NS	LAX
						-	ACY

NS = No statistically significant difference
* = $p < 0.05$
** = $p < 0.01$

TABLE VI. (Continued)

FCL - Flight Days, Ranked by Facility

Prework:

1. ATL = 12.40
2. SEA = 12.50
3. MSP = 12.63
4. OKC = 12.89
5. ACY = 12.93
6. BTL = 13.07
7. LAX = 13.15

Postwork:

1. ATL = 6.13
2. OKC = 7.89
3. BTL = 8.07
4. LAX = 8.20
5. MSP = 9.22
6. ACY = 9.26
7. SEA = 9.50

Level of significance of differences between facilities, prework flight days.

ATL	SEA	MSP	OKC	ACY	BTL	LAX	
-	NS	NS	NS	NS	NS	NS	ATL
	-	NS	NS	NS	NS	NS	SEA
		-	NS	NS	NS	NS	MSP
			-	NS	NS	NS	OKC
				-	NS	NS	ACY
					-	NS	BTL
						-	LAX

Level of significance of differences between facilities, postwork flight days.

ATL	OKC	BTL	LAX	MSP	ACY	SEA	
-	*	*	**	**	**	**	ATL
	-	NS	NS	NS	NS	*	OKC
		-	NS	NS	NS	NS	BTL
			-	NS	NS	NS	LAX
				-	NS	NS	MSP
					-	NS	ACY
						-	SEA

NS = No statistically significant difference
* = $\underline{p}$ >.01<.05
** = $\underline{p}$ >.01

TABLE VII. FCL - Difference in Prework and Postwork Levels, Ranked by Facility

Office Days	Flight Days
1. LAX = 1.12	1. SEA = 3.00
2. SEA = 1.50	2. MSP = 3.55
3. OKC = 2.04	3. ACY = 3.63
4. ACY = 2.07	4. OKC = 4.76
5. MSP = 3.20	5. LAX = 4.85
6. BTL = 3.46	6. BTL = 5.00
7. ATL = 3.77	7. ATL = 6.27

Level of significance of differences between facilities, office days.

LAX	SEA	OKC	ACY	MSP	BTL	ATL	
–	NS	NS	NS	*	*	*	LAX
	–	NS	NS	NS	*	NS	SEA
		–	NS	NS	NS	NS	OKC
			–	NS	NS	NS	ACY
				–	NS	NS	MSP
					–	NS	BTL
						–	ATL

Level of significance of differences between facilities, flight days.

SEA	MSP	ACY	OKC	LAX	BTL	ATL	
–	NS	NS	*	*	*	**	SEA
	–	NS	NS	NS	NS	**	MSP
		–	NS	NS	NS	**	ACY
			–	NS	NS	NS	OKC
				–	NS	NS	LAX
					–	NS	BTL
						–	ATL

NS = No statistically significant difference
* = $p > .01 \le .05$
** = $p < .01$

TABLE VIII. Mean Heart Rate
Comparison by crew position, all facilities combined

Office Work

	Score			Score	P
AC	77	vs.	CP	76	NS
AC	77	vs.	T	82	<.01
CP	76	vs.	T	82	<.01

Flight Days

AC	86	vs.	CP	82	<.05
AC	86	vs.	T	85	NS
CP	82	vs.	T	85	NS

	In Office	vs.	Flight Days	
AC	77		86	<.01
CP	76		82	<.01
T	82		85	NS

TABLE IX. Mean Heart Rate
Comparison by crew position at each FIFO

Office Work

Facility

OKC	AC	85	vs.	CP	74	<.01
	AC	85	vs.	T	85	NS
	CP	72	vs.	T	85	<.01

Flight Days

AC	98	vs.	CP	80	<.01
AC	98	vs.	T	85	NS
CP	80	vs.	T	85	<.01

	In Office	vs.	Flight Days	
AC	85		98	<.01
CP	75		70	NS
T	85		86	NS

TABLE IX. Mean Heart Rate (Continued)
Comparison by crew position at each FIFO

Office Work

Facility		Score			Score	P
ATL	AC	84	vs.	CP	75	<.05
	AC	84	vs.	T	93	<.05
	CP	75	vs.	T	93	<.01

Flight Days

AC	89	vs.	CP	79	<.01
AC	89	vs.	T	91	NS
CP	79	vs.	T	91	<.01

In Office		vs.	Flight Days	
AC	84		89	NS
CP	75		79	NS
T	93		91	NS

Office Work

Facility						
ACY	AC	71	vs.	CP	69	NS
	AC	71	vs.	T	72	NS
	CP	69	vs.	T	72	NS

Flight Days

AC	80	vs.	CP	74	NS
AC	80	vs.	T	73	NS
CP	74	vs.	T	73	NS

In Office		vs.	Flight Days	
AC	71		80	<.05
CP	69		74	NS
T	72		73	NS

TABLE IX. Mean Heart Rate (Continued)
Comparison by crew position at each FIFO

In Office

Facility		Score			Score	P
BTL	AC	73	vs.	CP	82	<.01
	AC	73	vs.	T	72	NS
	CP	82	vs.	T	72	<.01

Flight Days

	AC	80	vs.	CP	88	NS
	AC	80	vs.	T	74	NS
	CP	88	vs.	T	74	<.01

In Office		vs.	Flight Days	
AC	73		80	NS
CP	82		88	NS
T	72		74	NS

In Office

Facility						
MSP	AC	75	vs.	CP	79	NS
	AC	75	vs.	T	83	NS
	CP	79	vs.	T	83	NS

Flight Days

	AC	88	vs.	CP	88	NS
	AC	88	vs.	T	83	NS
	CP	88	vs.	T	89	NS

In Office		vs.	Flight Days	
AC	75		88	<.01
CP	79		88	<.05
T	83		89	NS

TABLE IX. Mean Heart Rate (Continued)
Comparison by crew position at eacn FIFO

In Office

Facility		Score			Score	P
LAX	AC	75	vs.	CP	76	NS
	AC	75	vs.	T	94	<.01
	CP	76	vs.	T	94	<.01

Flight Days

AC	78	vs.	CP	85	<.05
AC	78	vs.	T	90	<.05
CP	85	vs.	T	90	NS

In Office		vs.	Flight Days	P
AC	75		78	NS
CP	76		85	<.05
T	94		90	NS

In Office

Facility						
SEA	AC	79	vs.	CP	81	NS
	AC	79	vs.	T	80	NS
	CP	81	vs.	T	80	NS

Flight Days

AC	89	vs.	CP	87	NS
AC	89	vs.	T	88	NS
CP	87	vs.	T	88	NS

In Office		vs.	Flight Days	P
AC	79		89	<.01
CP	81		87	<.05
T	80		88	<.05

TABLE X. Mean Heart Rate, Ranked by Facility
(beats per min.)

Office Work

By Facility

1. ACY = 71
2. BTL = 75
3. MSP = 80
4. SEA = 80
5. LAX = 81
6. OKC = 82
7. ATL = 84

Significance of Difference Between Facilities.

ACY	BTL	MSP	SEA	LAX	OKC	ATL	
-	**	**	**	**	**	**	ACY
	-	*	**	*	**	**	BTL
		-	NS	NS	NS	NS	MSP
			-	NS	NS	NS	SEA
				-	NS	NS	LAX
					-	NS	OKC
						-	ATL

NS = No statistically significant difference
* = $p > .01 \leq .05$
** = $p \leq .01$

TABLE X. Mean Heart Rate (Continued)
(beats per min.)

Flight Work

By Facility

1. ACY = 76
2. BTL = 82
3. LAX = 84
4. ATL = 86
5. MSP = 88
6. SEA = 88
7. OKC = 89

Level of Difference between facilities.

ACY	BTL	LAX	ATL	MSP	SEA	OKC	
-	*	**	**	**	**	**	ACY
	-	NS	NS	**	*	**	BTL
		-	NS	NS	NS	NS	LAX
			-	NS	NS	NS	ATL
				-	NS	NS	MSP
					-	NS	SEA
						-	OKC

NS = No statistically significant difference
* = $p > .01 \leq .05$
** = $p \leq .01$

TABLE XI. Flight Vs. Office
by Crew Position, Rest, and Work -
Level of Significance of Difference (P)

REST

	KGS	E	NE
AC	NS	NS	NS
CP	NS	NS	NS
T	NS	NS	0.014

WORK

	KGS	E	NE
AC	0.040	NS	NS
CP	0.034	NS	NS
T	NS	NS	NS

TABLE XII. Rest Vs. Work
by Crew Position -
Level of Significance of Difference (P)

Office

	KGS	E	NE
AC	0.006	< 0.001	< 0.001
CP	< 0.001	< 0.001	0.012
T	0.004	< 0.001	0.004

Flight

AC	< 0.001	< 0.001	< 0.001
CP	0.114(NS)	< 0.001	< 0.001
T	0.023	0.042	0.008

TABLE XIII. KGS Mean Values (mg/100mg cr) and Significance of Differences of the Means at the Various FIFO's

Office Work

SEA = 795.1
OKC = 663.1
LAX 625.7
ATL 615.3
ACY 560.7
BTL 353.7
MSP 312.1

SEA	OKC	LAX	ATL	ACY	BTL	MSP	
-	NS	NS	NS	NS	**	*	SEA
	-	NS	NS	NS	**	**	OKC
		-	NS	NS	NS	NS	LAX
			-	NS	**	**	ATL
				-	*	NS	ACY
					-	NS	BTL
						-	MSP

* $p \leq 0.05$
** $p \leq 0.01$

TABLE XIV. Comparison of SIH Excretion by FIFO Crewmembers With Other Groups

	wt/100 mg creatinine					
	KGS (mg)		E µg		NE µg	
	Rest	Work	Rest	Work	Rest	Work
FIFO CREWMEMBERS						
Office	367.13	562.21	0.65	1.72	2.96	5.01
Flight	389.62	567.62	0.86	1.90	3.68	5.10
AIR TRAFFIC CONTROLLERS						
IAH	863.48	1532.90	0.27	1.59	2.44	3.82
OPF	553.00	1005.30	0.50	1.85	2.80	4.91
Academy Instructors	443.72	921.71	0.91	2.32	2.41	3.91
All ATCSs	- - -	954.29	- -	1.14	- -	3.58
EXPERIMENTAL SUBJECTS						
Mental	685.0	636.0	1.23	1.69	3.94	3.67
Physical	685.0	613.0	1.23	1.57	3.94	3.93
AERONAUTICAL CENTER EMPLOYEES (NOT ATCSs)	417.33	777.44	0.52	1.51	1.44	3.80

SUBJECT FATIGUE CHECKLIST

DATE ______________ NAME ______________________________

TIME ______________ TYPE OF AIRCRAFT FLOWN TODAY ______________

INSTRUCTIONS: MAKE 1, AND ONLY 1 ( ) FOR EACH OF THE TEN ITEMS. THINK CAREFULLY ABOUT HOW YOU FEEL RIGHT NOW.

ITEM #	BETTER THAN	SAME AS	WORSE THAN	STATEMENT
1				VERY LIVELY
2				EXTREMELY TIRED
3				QUITE FRESH
4				SLIGHTLY POOPED
5.				EXTREMELY PEPPY
6				SOMEWHAT FRESH
7				PETERED OUT
8				VERY REFRESHED
9				FAIRLY WELL POOPED
10				READY TO DROP

REMARKS:

Figure 1. Subject Fatigue Checklist.

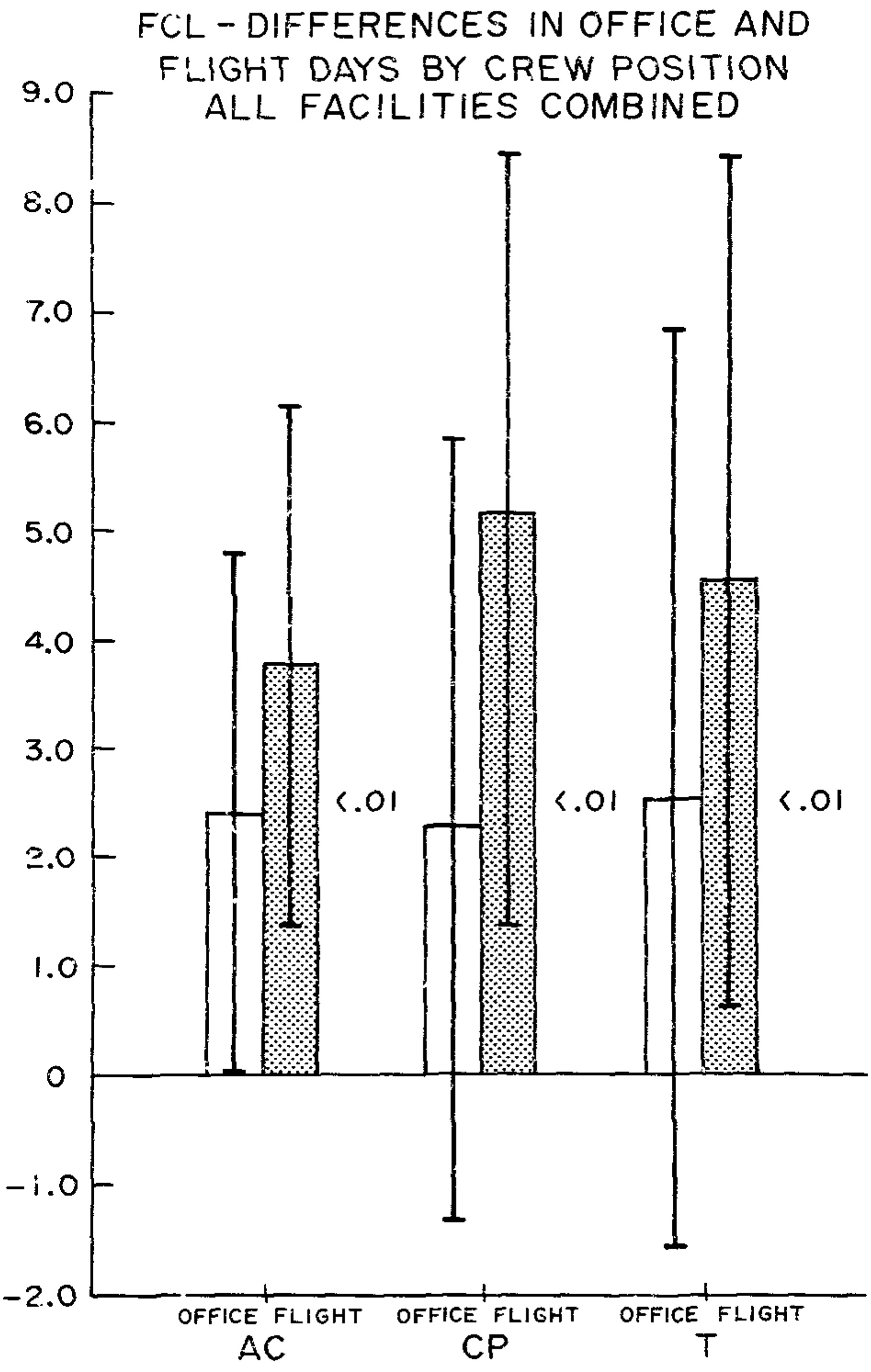

FCL - DIFFERENCES IN OFFICE AND
FLIGHT DAYS BY CREW POSITION
ALL FACILITIES COMBINED
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
-1.0
-2.0
<.01
<.01
<.01
OFFICE FLIGHT
AC
OFFICE FLIGHT
CP
OFFICE FLIGHT
T

Figure 2

FCL - PREWORK VALUES BY CREW POSITION
ALL FACILITIES COMBINED

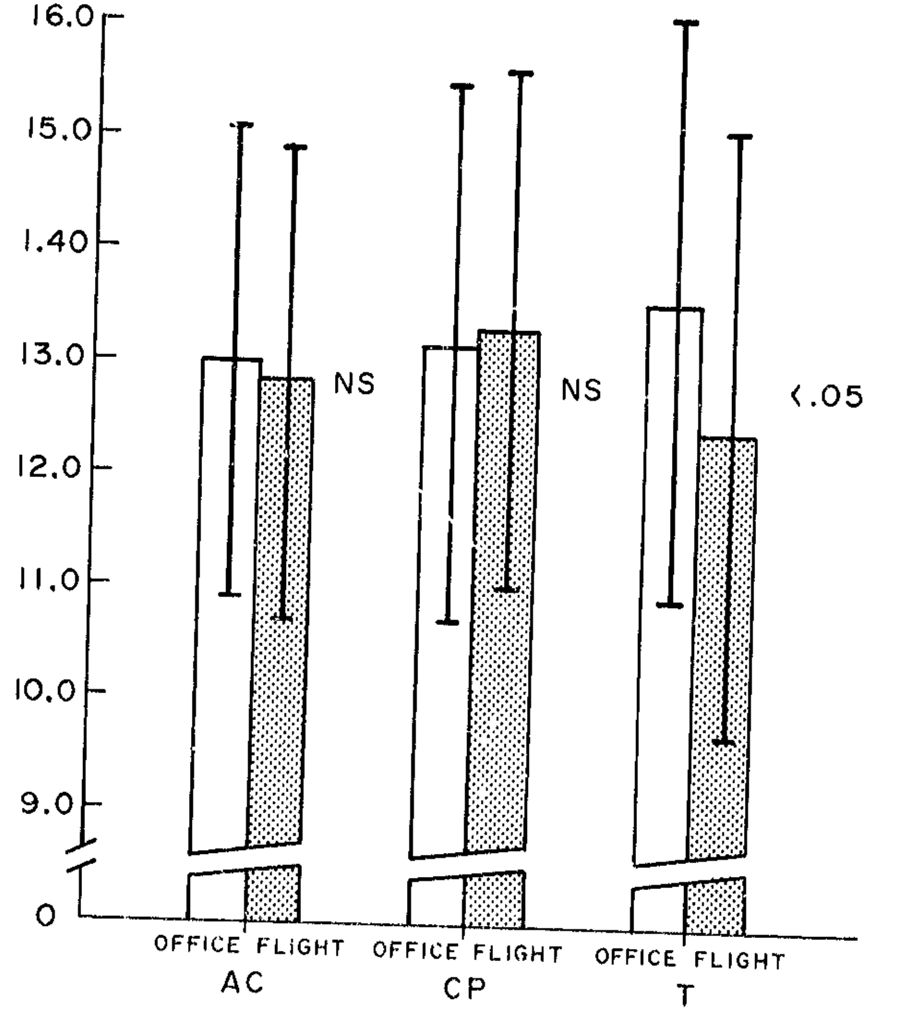


Figure 3

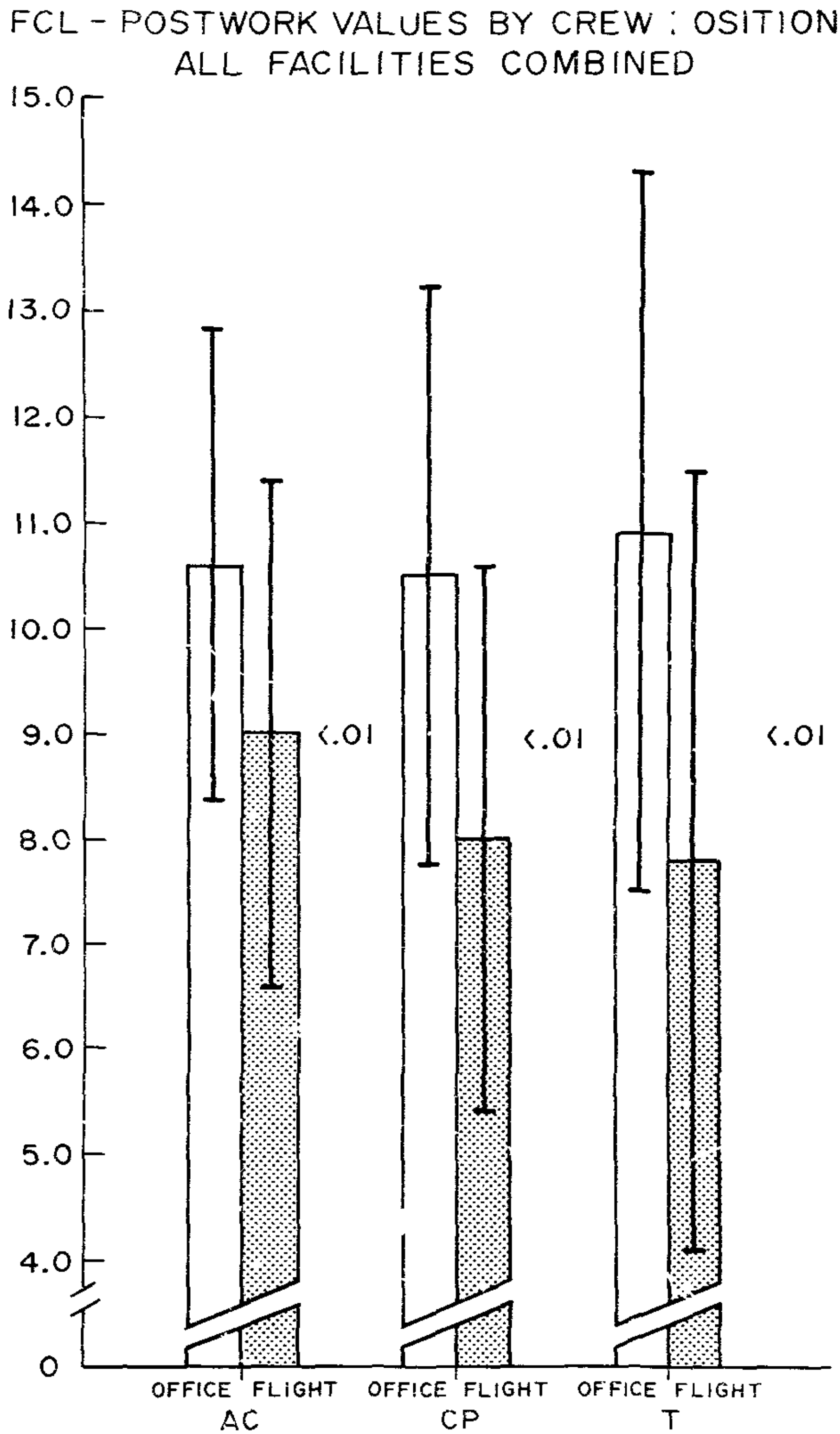

FCL - POSTWORK VALUES BY CREW : OSITION
ALL FACILITIES COMBINED
15.0
14.0
13.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
0
<.01
<.01
<.01
OFFICE
FLIGHT
AC
OFFICE
FLIGHT
CP
OFFICE
FLIGHT
T

Figure 4

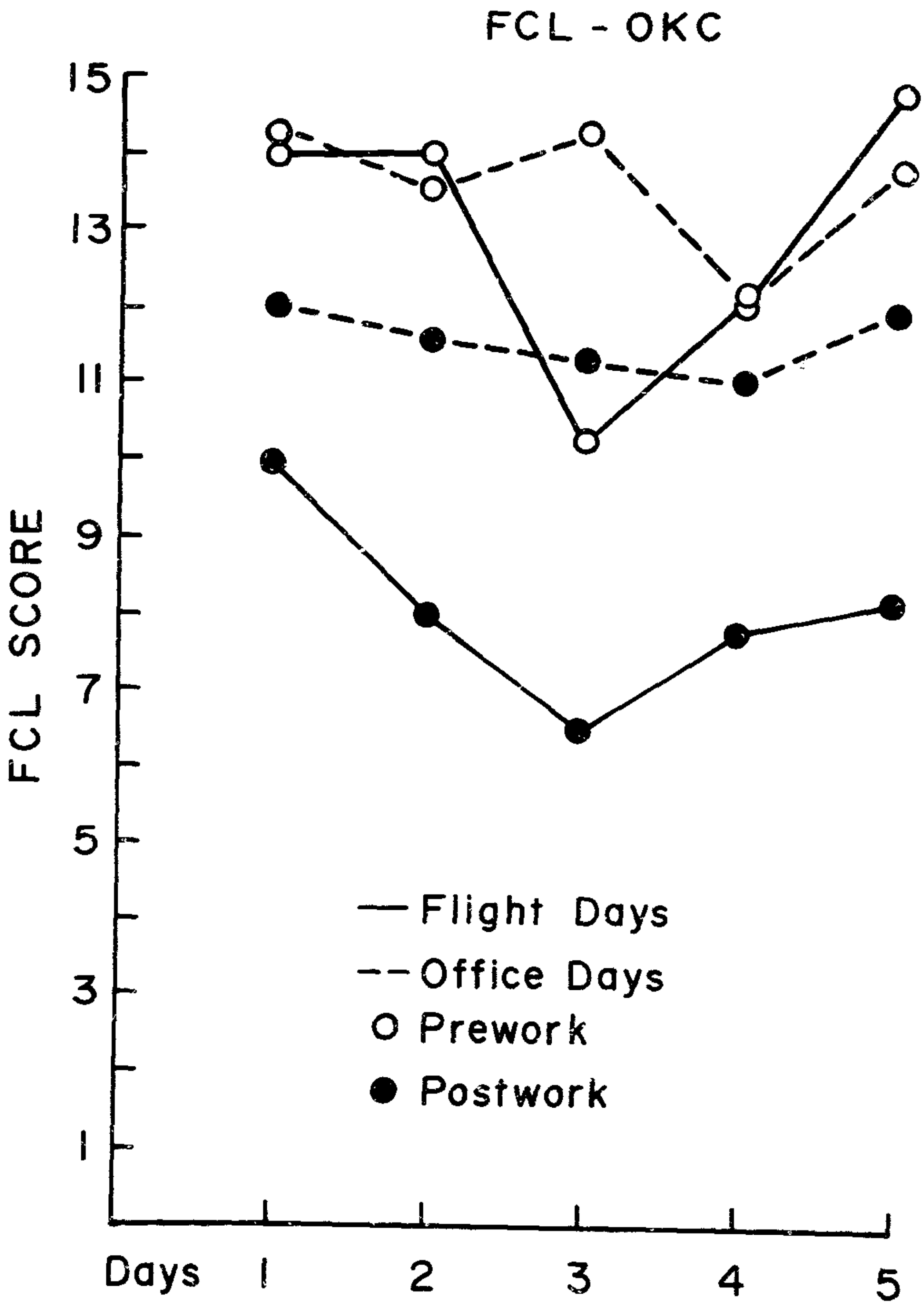

FCL - OKC
FCL SCORE
15
13
11
9
7
5
3
1
Days
1
2
3
4
5
Flight Days
Office Days
Prework
Postwork

Figure 5

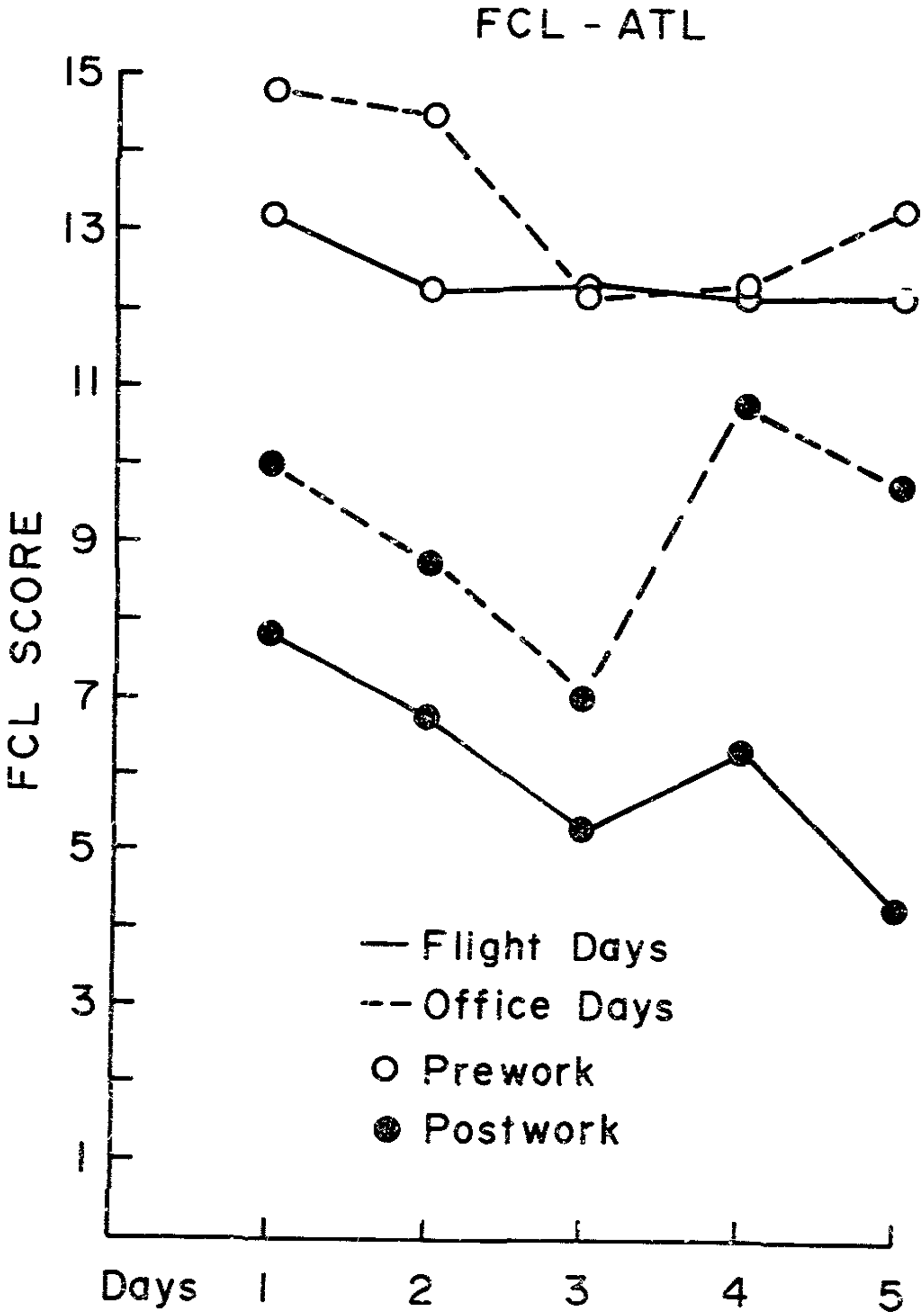

FCL - ATL
FCL SCORE
15
13
11
9
7
5
3
1
Flight Days
Office Days
Prework
Postwork
Days
1
2
3
4
5

Figure 6

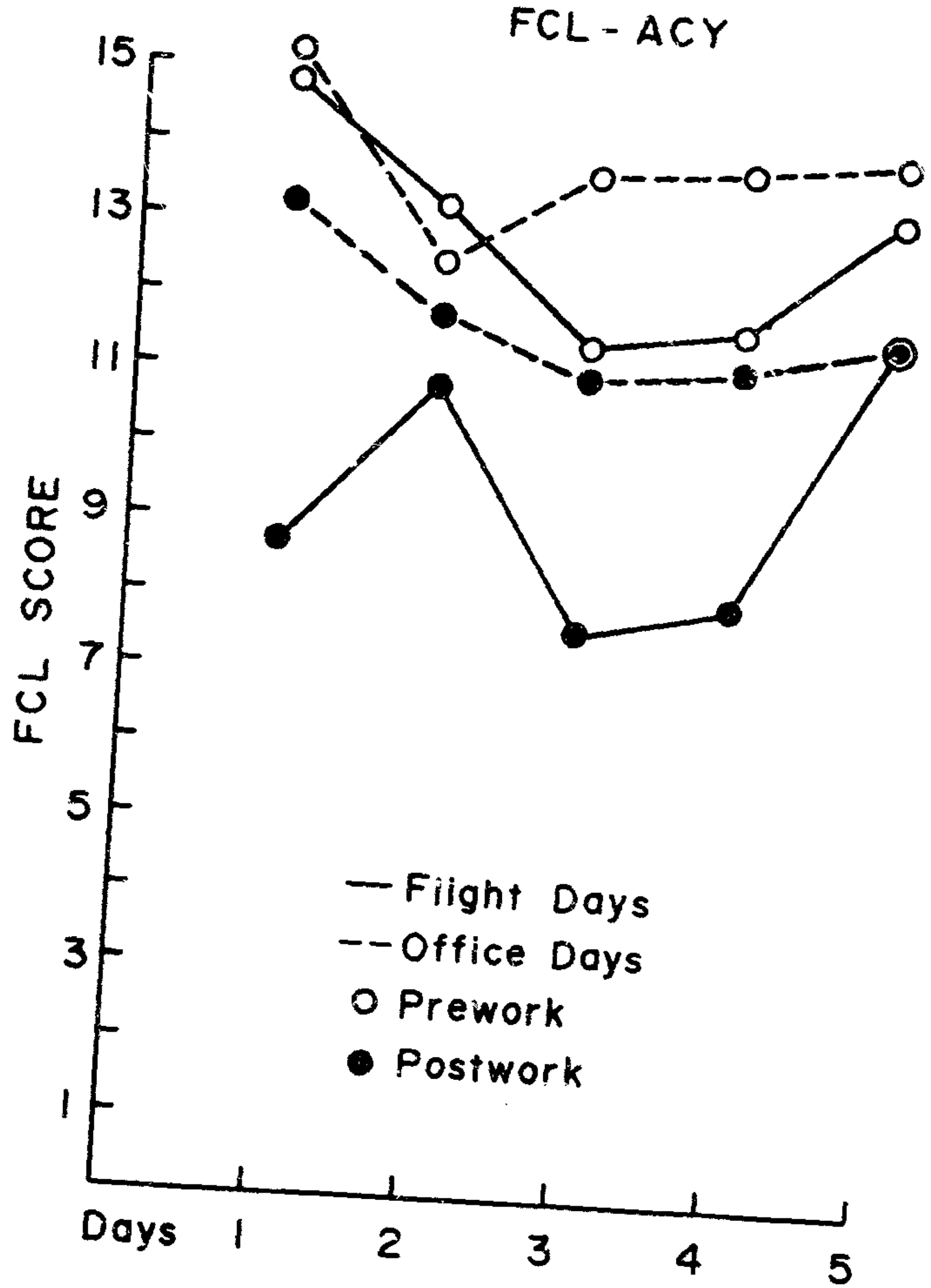

FCL - ACY
15
13
11
9
7
5
3
1
FCL SCORE
— Flight Days
-- Office Days
O Prework
● Postwork
Days
1
2
3
4
5

Figure 7

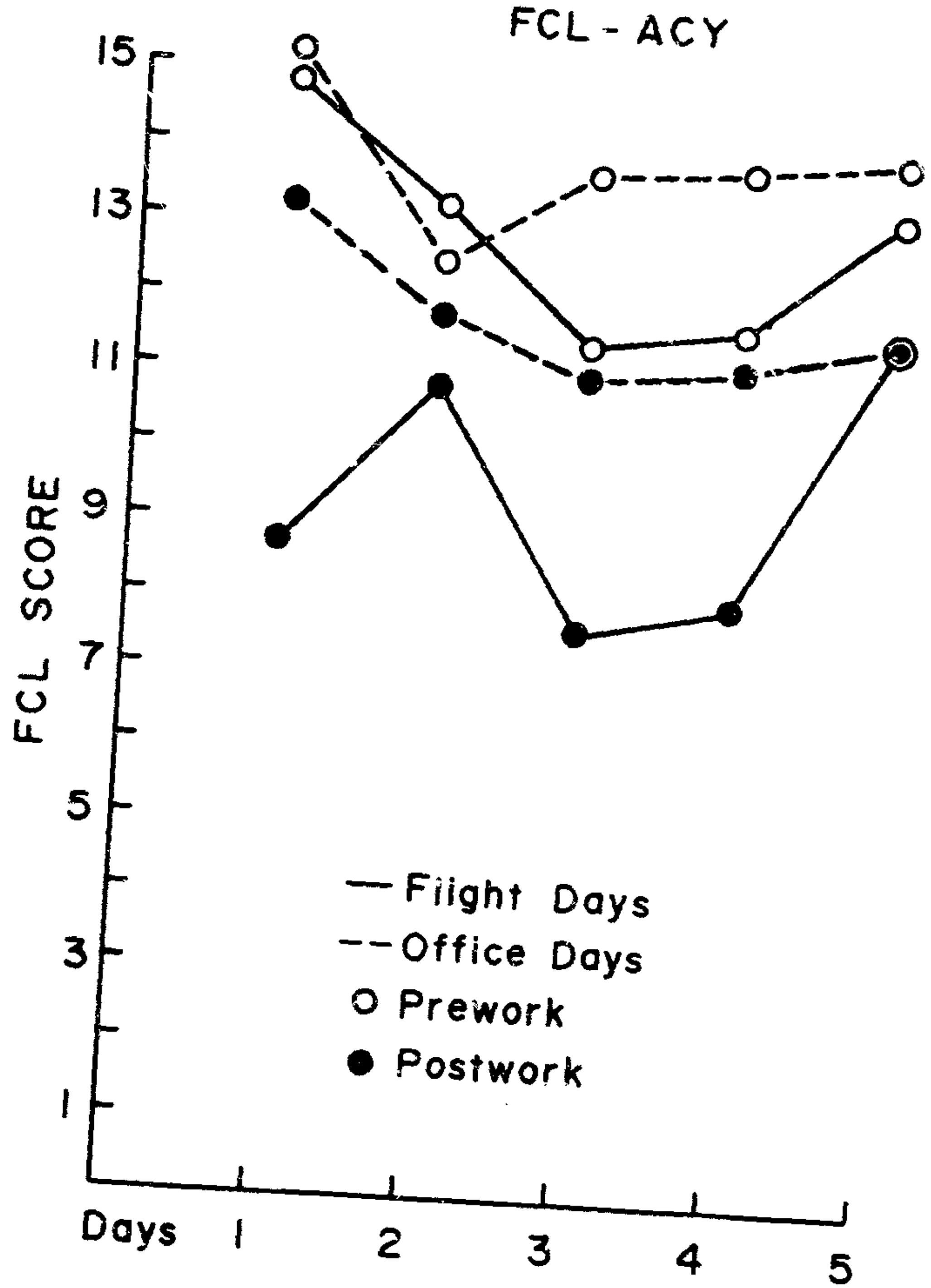

FCL - ACY
15
13
11
9
7
5
3
1
FCL SCORE
Days
1
2
3
4
5
Flight Days
Office Days
Prework
Postwork

Figure 7

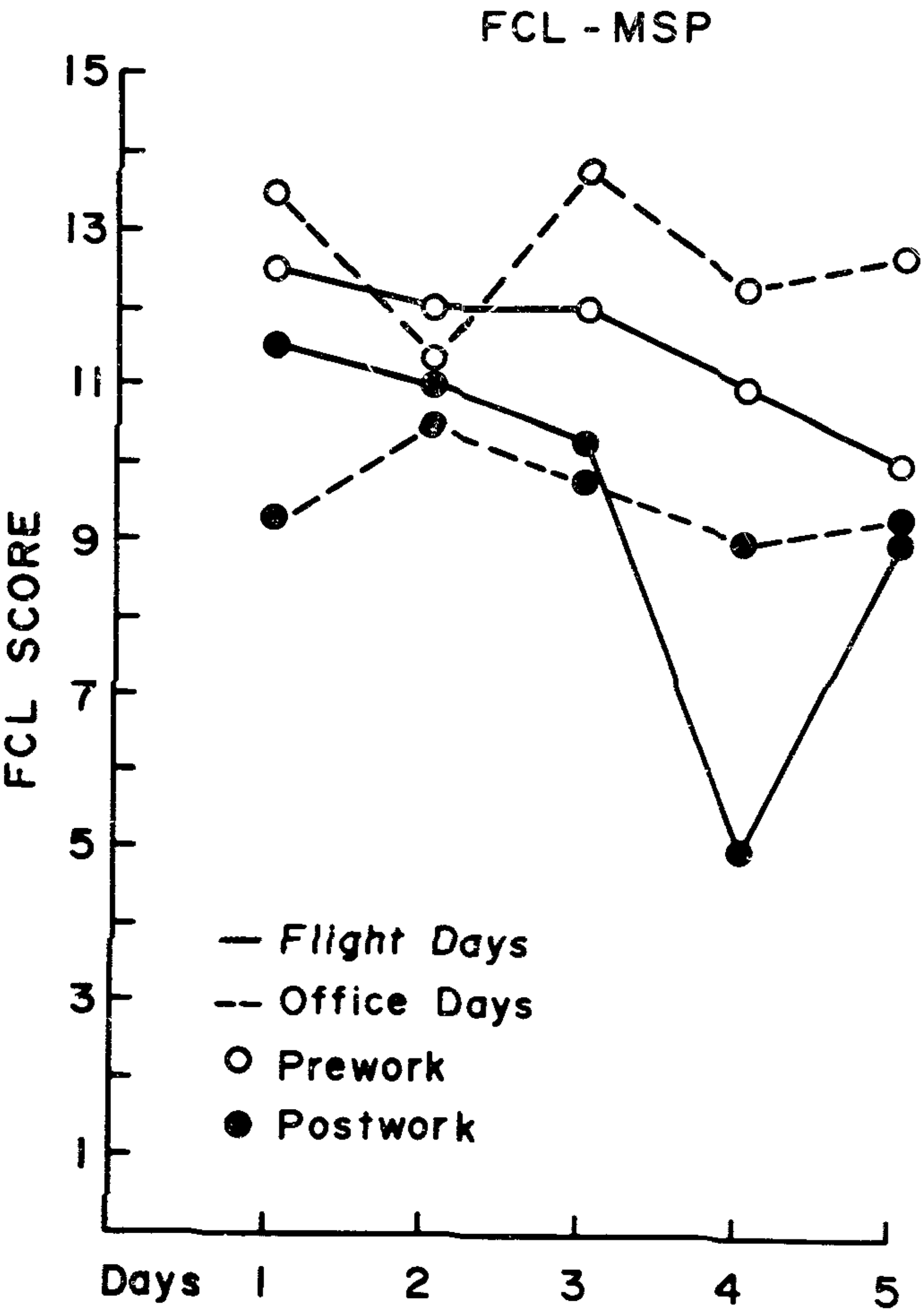

FCL - MSP
FCL SCORE
15
13
11
9
7
5
3
1
— Flight Days
-- Office Days
O Prework
● Postwork
Days 1 2 3 4 5

Figure 8

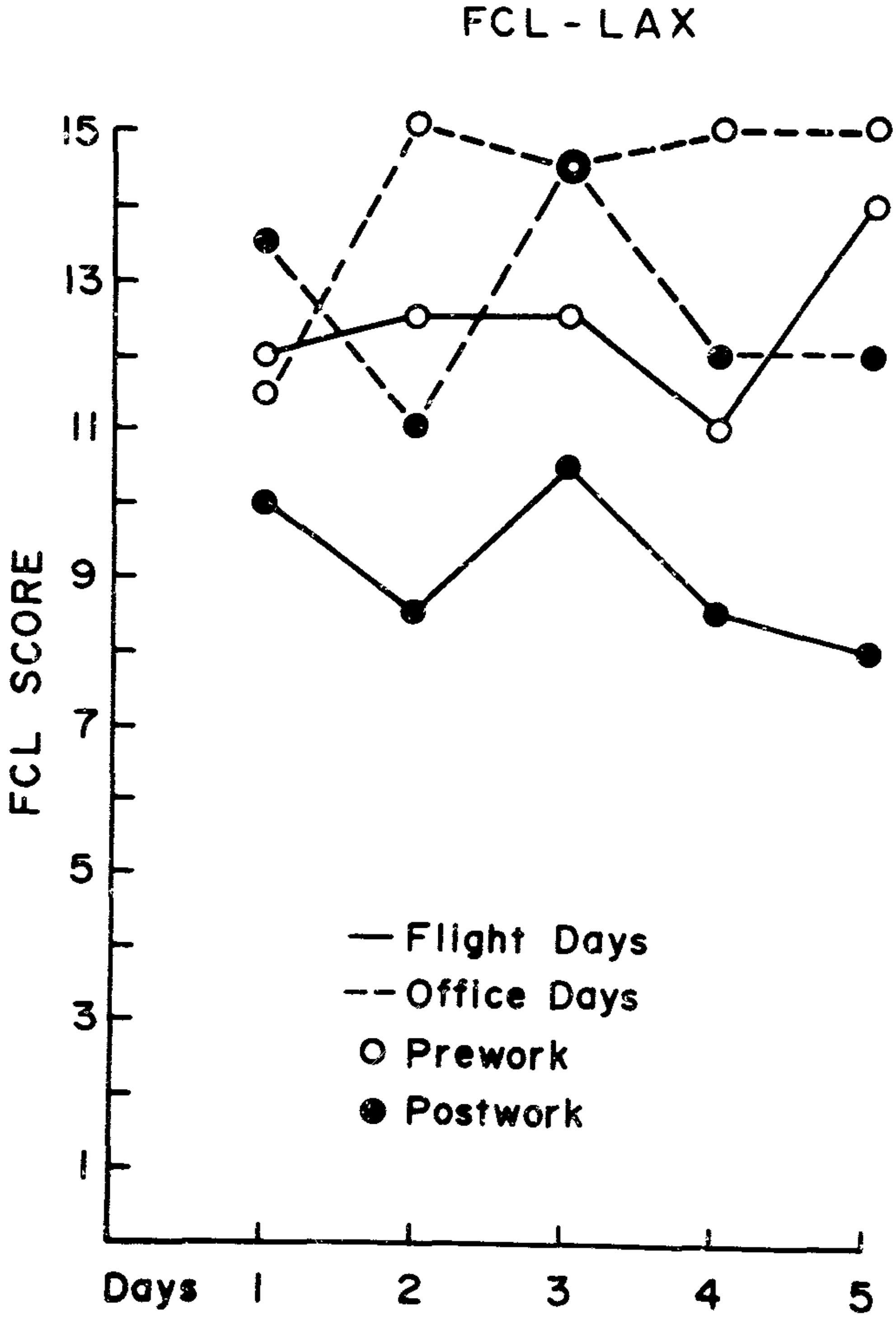

FCL - LAX
FCL SCORE
15
13
11
9
7
5
3
1
Days
1
2
3
4
5
— Flight Days
-- Office Days
O Prework
● Postwork

Figure 9

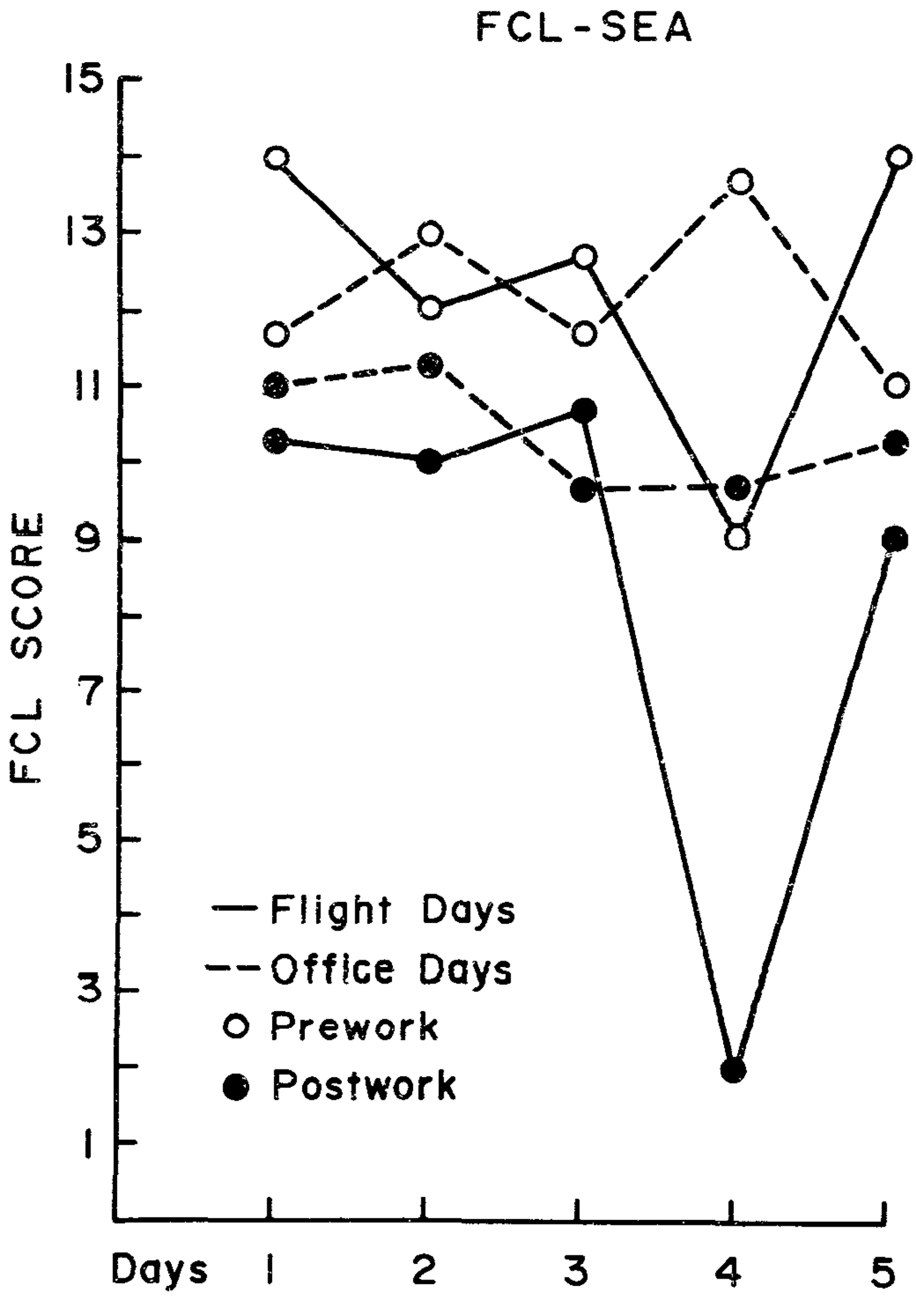
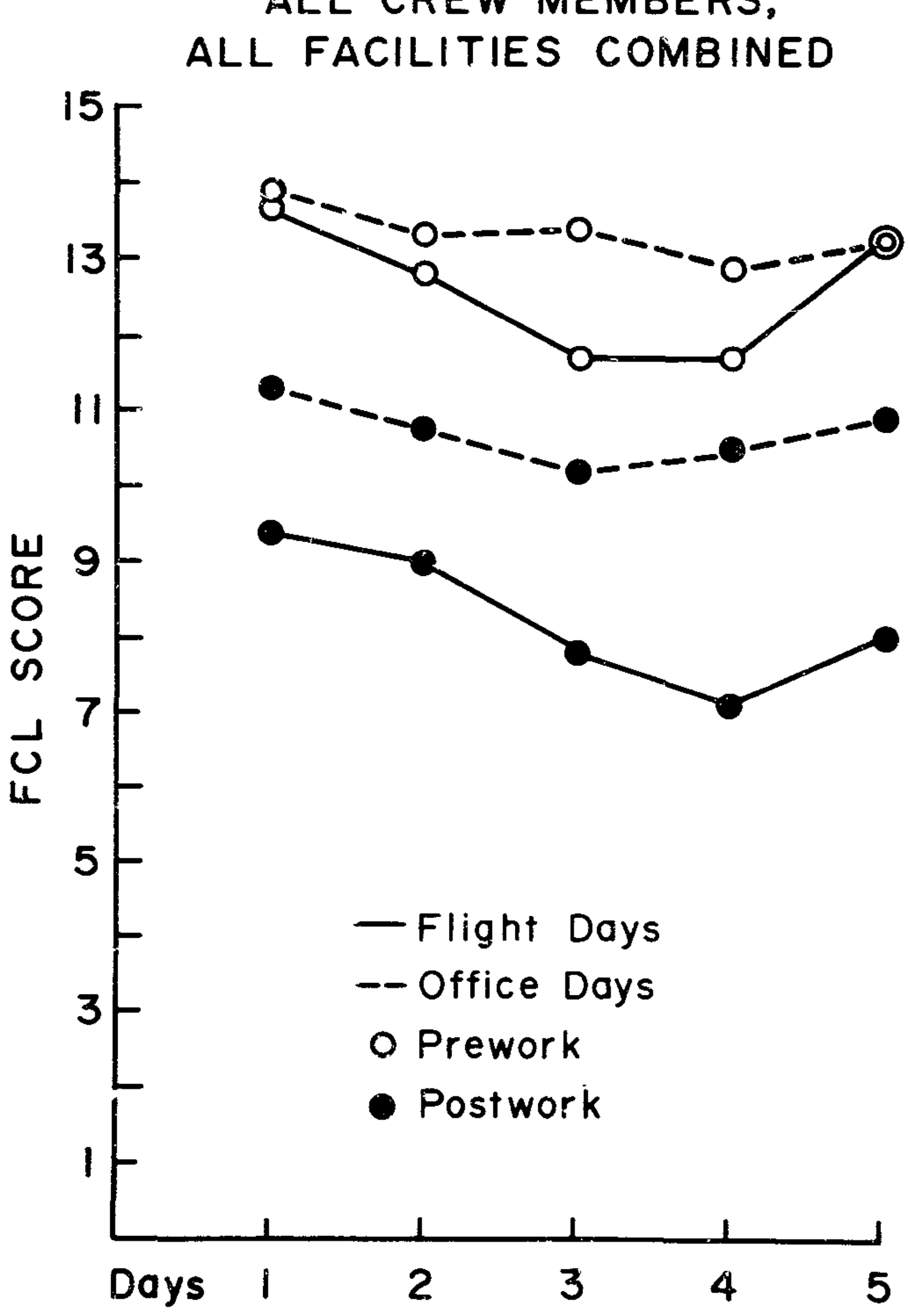

FCL-SEA
FCL SCORE
15
13
11
9
7
5
3
1
Days
1
2
3
4
5
— Flight Days
-- Office Days
○ Prework
● Postwork

Figure 10



ALL CREW MEMBERS,
ALL FACILITIES COMBINED
FCL SCORE
15
13
11
9
7
5
3
1
Days
1
2
3
4
5
Flight Days
Office Days
Prework
Postwork

Figure 11

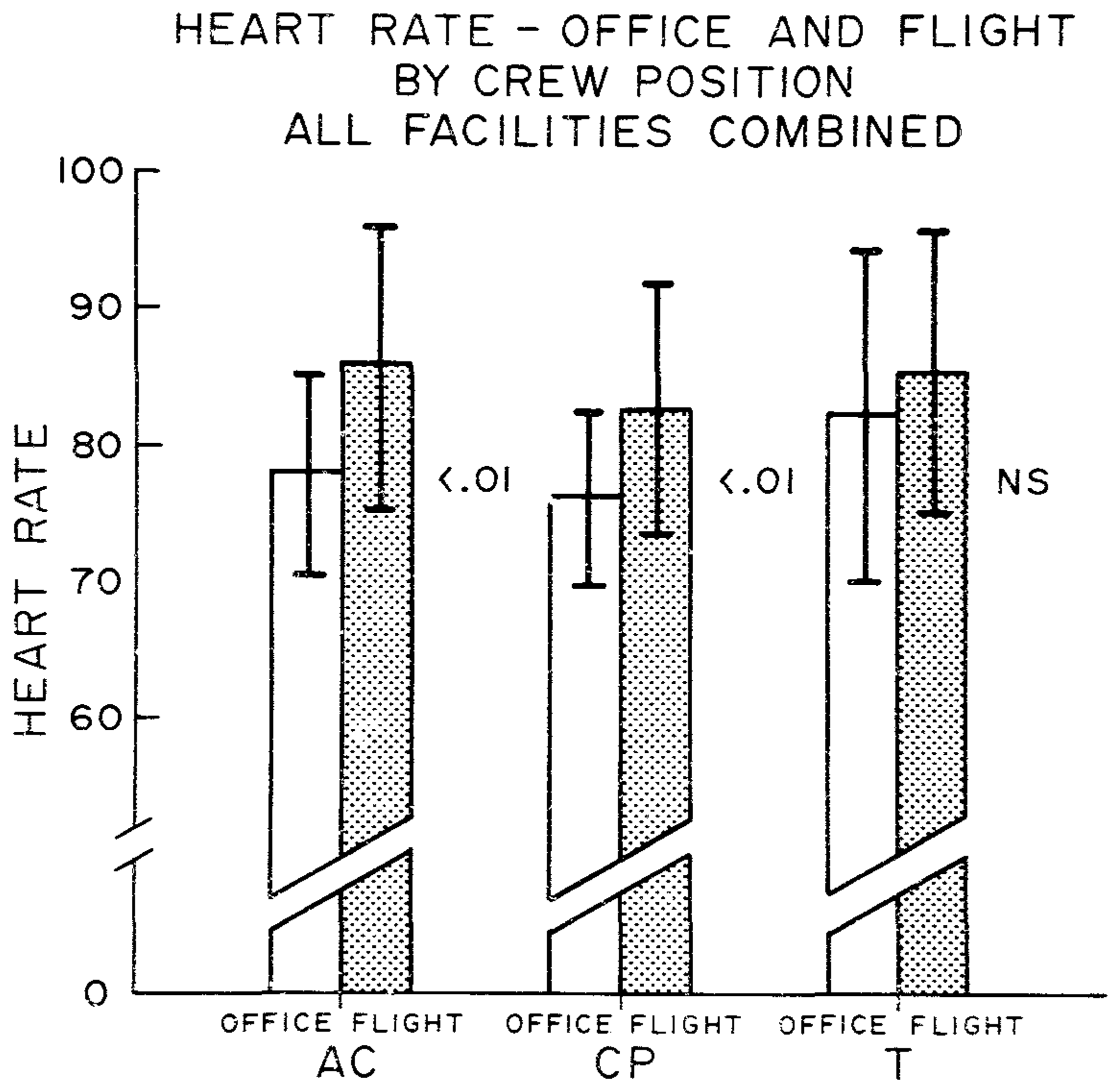

HEART RATE - OFFICE AND FLIGHT
BY CREW POSITION
ALL FACILITIES COMBINED
100
90
80
70
60
0
HEART RATE
<.01
<.01
NS
OFFICE
FLIGHT
AC
OFFICE
FLIGHT
CP
OFFICE
FLIGHT
T

Figure 12