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16. Abstract

Physiological and biochemical measurements were made on 22 air traffic controllers at O'Hare tower during five days of the heavy traffic evening shift (1600-2400) and five days of the light traffic morning shift (0000-0800). Pulse rates were higher on the evening shift than on the morning shift. Converging approaching traffic was more excitatory than departing diverging traffic on the evening shift; there was no differential response on the morning shift. Galvanic skin response indicated that adaptation to the morning shift was incomplete in five days. Fibrinogen levels in controllers' blood was not elevated above the expected level for their age group. Controllers had a higher total plasma phospholipid concentration than populations of normal people, schizophrenics and combat pilots. Phosphatidyl glycerol was significantly higher in controllers' plasma than in the normal population but less than in the combat and schizophrenic populations. Findings from urine analyses that are reported separately by Hale, et al., have been summarized in this report. Urine chemistry shows that catecholamine excretion is related to the number of aircraft operations. Corticoid excretion rises late in the morning shift and recovery from morning shift work is incomplete during the off-duty rest period.

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PHYSIOLOGICAL RESPONSES IN AIR TRAFFIC CONTROL PERSONNEL: O'HARE TOWER

I. Introduction.

The air traffic control (ATC) task at high density terminals has been assumed to evoke compensatory physiological responses in the controllers that quantitatively exceed those that are evoked in the general population by less demanding jobs.[27 29] It is reported that there is a higher incidence of stress-related symptoms among ATC personnel than among non-ATC personnel.[7 12-14]

The Civil Aeromedical Institute was assigned the task of carrying out a study that would provide quantitative objective information about physiological responses in working controllers. The purposes of the study were (1) to compare the physiological responses of controllers on different shifts and at different tower positions, (2) to place the air traffic control effort in perspective with tasks carried out by other populations of workers and (3) to compare the physiological responses of controllers at several terminals where there are known to be qualitative differences in the work situations. Thus, the present report and the one by Hale, et al.,[9] are the results of the first of a planned series of studies.

II. Methods.

The study was carried out at the O'Hare Airport tower between July 15 and August 20, 1968. Twenty-two controllers ranging in age from 25 to 37 volunteered to participate in the study; thirteen were journeymen, five were trainees and four were supervisors. Physiological data were collected from each of the controllers during five 8-hour work periods on the 1600–2400 shift (evening, heavy-duty shift) and the 0000–0800 shift (morning, light-duty shift). The practice at O'Hare was for controllers to rotate from one tower position to another approximately every two hours. Thus, none of the shift data relate to one particular job. Not all trainees were checked out on all positions, however.

Urine collections were made from 20 of the subjects and from seven of the biomedical crewmembers throughout the study. The schedule of specimen collection and the results of the urine analyses are summarized in the Discussion Section of this paper and reported in complete form separately.[9 10]

Physiological Measurements

a. *Heart Rate:* The heart rate is perhaps the most widely used physiological measurement in studies of this kind.[16] The quickening of the heart beat is virtually instantaneous when a threatening, alarming or exciting event occurs. Because of its wide use, a measurement of the heart rate is valuable in comparing studies of different populations of people engaged in various activities. The electrocardiogram (ECG) was recorded continuously on miniature magnetic tape recorders throughout every work period from each subject. The ECG was taken from active electrodes placed at each end of the sternum with an indifferent electrode on the right lateral chest wall. This placement minimized interference from muscle potentials. The electrodes were a special silver paste dry type with insulated 36 G silvered copper wires embedded in them. The details of the electrodes and their application to the skin are published separately.[26] The battery operated tape recorders were carried in a case suspended by a shoulder strap. Each nickel-cadmium battery and reel of tape lasted 10 hours; thus, recordings could be made continuously for an entire work period. Capability existed for recording ECG's from four controllers, simultaneously.

The recorders operated at a tape speed of 0.125 inches/sec. Playback was accomplished on a special scanner that operated at a tape speed of 7.5 inches/sec; thus, a 60:1 time advantage was gained on playback. The scanner output was electronically coupled to a digital counter that was set to accumulate the count of R-waves of the ECG for one second when the count was then electronically dumped into a printer which put the accumulated count on a paper strip. Because of the 60:1 time advantage, each second of playback represented one minute of recording. The tape-recorded data were thus reduced to a printed column of one minute heart rates.

Since the heart rate was influenced by physical exertion unrelated to air traffic control, it was necessary to exclude from the data such events as walking up and down stairs, meal breaks, etc. To that end, and for identification of specific air traffic control functions, controller-observers provided commentaries with time identification on small hand-held tape recorders. These logs were transcribed and used to exclude inapplicable heart rate data and to identify specific events.

b. *Galvanic Skin Response:* The galvanic skin response (GSR) is a measure of involuntary nervous system activity. It is considered to be a sensitive indicator of a person's involvement in an activity. It is, for example, commonly used as a lie detector. The skin electrical resistance, particularly of the fingers and palms, decreases when the individual is aroused or excited in any way.

The tips of the forefinger and index finger of the left hand were cleaned with alcohol and an adhesive corn pad with a round hole in it was placed over each site. The holes in the corn pads were filled with conductive jelly and cut-to-size GSR electrodes were positioned in the paste at the top of the holes. The electrodes were secured with tape. The electrical resistance between the fingers was measured by a calibrated bridge circuit and recorded directly on a strip chart recorder. Data were collected from 15 controllers.

Four cables were laid around the outer periphery of the tower cab counters and dropped down the stairwell to the first landing where two strip chart recorders were located. The cables' cab terminals were arranged so that when a controller changed work positions his GSR leads could be connected to a nearer cable. In the IFR room at the base of the tower, a strip chart recorder was set up at each departure control position. Cables were run to each of the two approach control and two departure control positions. With this arrangement of cables and recorders, it was possible to record from two controllers in the cab and two controllers in the IFR room, simultaneously.

c. *Other Observations:* Blood pressure of the left brachial artery was taken with an aneroid manometer pre- and post-shift. The subjects were in the sitting position with the cuff at the level of the heart. Systolic pressure was read at the first and diastolic pressure at the last Korotkov sound.

Oral temperature was checked with a clinical thermometer to reveal any fever that might exist. No controllers were found to be febrile during the study.

"Resting" heart rates were taken when the subjects were instrumented by observing and counting for one minute the electrical deflections taken from the recorder and displayed on an oscilloscope. This procedure served primarily to verify the operational integrity of the electrodes, leads and recorder through the amplifier stage. Heart rates thus observed were commonly higher than the on-duty rates reported in *Results* because (1) the controllers were not fully recovered from the physical exertion of walking from the parking lot to the tower and climbing two flights of stairs to the briefing room, (2) anticipatory excitement and concern about biomedical procedures, and (3) the on-duty data were treated during reduction to exclude all periods of physical activity that would contribute to elevated heart rates.

Tape recorders were inspected daily for proper motor and electronic operation. It was not possible to check for proper recorder operation while they were actually in use. One problem involving high-frequency random noise appearing at some point beyond the recorder amplifier was operationally solved by changing the type of tape. The problem resulted in considerable loss of heart rate data before it was corrected.

Blood and Urine

Certain fat-like and protein components of the blood are considered to increase in proportion to the intensity of the environmental, psychic or work stimulus. The pattern and quantity of phospholipids in blood plasma have been used as indicators of stress in combat personnel, mental patients and in people subjected to acceleration in a human centrifuge.[23-25] The appearance of increased amounts of phospholipids in the plasma is thought to reflect a stimulation of energy-yielding reactions in all cells of the body, but particularly in brain cells, whenever an event occurs that is perceived as threatening.

The quantity of fibrinogen in the plasma has been shown to increase in response to noxious stimuli such as electric shocks, the aging process and illness.[11 20 21] Fibrinogen levels have been followed during treatment of patients suffering from a variety of diseases and the degree of remission was correlated with decrements in fibrinogen concentration.[18]

At the end of the work period on the fifth day of each shift, 10 cc of blood was drawn from the antecubital veins of 19 subjects. Only one specimen was obtained from each of three other subjects. The blood was drawn into plastic syringes which were quickly emptied into centrifuge tubes containing dried EDTA, an anticoagulant. The blood was mixed with the anticoagulant by repeated gentle inversion. The blood was centrifuged, the plasma was drawn off with pipettes and emptied into glass test tubes. The stoppered tubes of plasma were immediately placed in refrigerated containers and were sent by air within 12 hours to the Civil Aeromedical Institute in Oklahoma City where the fibrinogen determinations were made.

Fibrinogen was converted to fibrin by reacting 0.2 cc of plasma with thrombin. The fibrin was then solubilized and determined spectrophotometrically by the method of McKenzie, et al.[21]

The remainder of the plasma was frozen and stored until it was taken by courier to the U.S. Naval Air Development Center, Johnsville, Warminster, Pennsylvania, where phospholipid analysis was carried out. Total phospholipid components were determined separately on each controller's plasma by the method of Dawson[5] as used by Polis, et al.[23-25]

Three urine specimens daily during the five-day observation period were collected by 20 of the ATC personnel and by seven of the biomedical crewmembers who served as controls. The three specimens represented three levels of workload. The first part of the evening shift was the heaviest work period of the day while the last part of that shift was fairly light. Conversely, the first part of the morning shift was a light traffic period and the last part was a heavy duty period. Pooled urine specimens were thus collected during the first four hours of each shift (Specimen 1) and during the last four hours of each shift (Specimen 2). For baseline reference, a third specimen was collected at the end of the off-duty sleep period. Obviously, the third specimen was collected at different times of day depending on which shift was worked, the personal preference of the subjects about bedtime and the duration of sleep.

The ATC personnel each collected urine only during the five days of study on each shift. The biomedical crewmembers who alternated five evening shifts and five morning shifts, collected three urine specimens daily for the entire period of the study.

Urine specimens were collected into HCl–charged screwcap plastic bags that were carried in insulated attache cases containing a bottle of frozen coolant. The specimens were adjusted approximately to pH 2 with HCl and 250 ml aliquots were bottled, frozen and shipped to the Applied Physiology Branch of the U.S. Air Force School of Aerospace Medicine, Brooks AFB, Texas, where they were analyzed in duplicate for epinephrine, norepinephrine, 17–OH corticosteroids, sodium, potassium, phosphate, urea and creatinine.

III. Results.

a. *Heart Rate:* Data relating heart rate to work at the various positions for the two shifts are summarized in Table I which shows, for all positions where sufficient data were collected, that the busier evening shift gave rise to significantly higher heart rates than the morning shift.

Heart rates on the different positions within shifts are summarized in Tables II and III. These tables show that on the evening shift, local and approach control were not different, but that each of those gave rise to significantly higher heart rates than did departure control. On the morning shift, it appears that none of the positions differed.

The mean heart rate for humans is reported to be 71 beats per minute with a range of 52–104.[3]

b. *Galvanic Skin Response (GSR):* The means of the maximum and minimum resistances for 15 controllers were graphed for a five-day morning shift and for a five-day evening shift (Fig. 1).

TABLE I. Comparisons Between Morning Shift and Evening Shift.

Number of ATC in Comparison	Activity	AVERAGE HEART RATE Evening Shift	Morning Shift	Significance Level .10, .05, .01, or NS (not significant)**
9	Local Control	101.70	82.51	.01
3	Ground Control	100.43	79.93	*
1	Clearance Delivery	90.50	86.00	*
12	Approach Control	90.77	77.23	.01
12	Departure Control	84.88	74.83	.01

* Data not sufficient to make a statistical test.
** Wilcoxen matched pairs signed rank test.

TABLE II. Comparisons* Between Types of Activity During Evening Shift.

Number of ATC in Comparison	First Activity	Average Heart Rate	Second Activity	Average Heart Rate	Significance Level .10, .05, .01, or NS***
14	Local Control	94.59	Approach Control	89.24	N.S.
14	Local Control	94.37	Departure Control	84.75	.01
17	Approach Control	88.55	Departure Control	84.57	.05
4	Ground Control	99.20	Local Control	105.72	**
2	Ground Control	98.60	Departure Control	95.10	**
3	Ground Control	97.56	Approach Control	94.23	**

* Data not sufficient for comparisons among other activities.
** Data not sufficient to make a statistical test.
*** Wilcoxen matched pairs signed rank test.

TABLE III. Comparisons* Between Types of Activity During Morning Shift.

Number of ATC in Comparison	First Activity	Average Heart Rate	Second Activity	Average Heart Rate	Significance Level .10, .05, .01, or NS***
9	Local Control	81.51	Approach Control	79.51	N.S.
9	Local Control	81.61	Departure Control	77.89	N.S.
11	Approach Control	75.95	Departure Control	74.16	N.S.
6	Ground Control	79.18	Local Control	83.20	N.S.
6	Ground Control	78.47	Departure Control	79.28	N.S.
4	Ground Control	76.30	Approach Control	80.42	**
5	Clearance Delivery	84.02	Local Control	83.98	**
3	Clearance Delivery	83.76	Ground Control	83.90	**
4	Clearance Delivery	83.27	Approach Control	78.82	**
4	Clearance Delivery	85.45	Departure Control	81.22	**

* Data not sufficient for comparisons among other activities.
** Data not sufficient to make a statistical test.
*** Wilcoxen matched pairs signed rank test.

The means of the maximum and minimum resistances were derived from the maximum and minimum resistances recorded each hour for each subject.

Figure 1A (the morning shift) indicates that the opportunity to relax increases through the five-day period. This may be caused by the adaptation to the change in the sleep pattern or to the adjustment to the decreased air traffic activity as compared to traffic of the evening shift. No trend toward adaptation to the evening shift is indicated in Figure 1B. The minimum resistance levels are similar to those shown in Figure 1A, whereas the maximum resistance levels are reduced. The maximum and minimum resistances for both shifts were found to be statistically different at the 1% level of significance.

For comparison with the controllers' data, values of the GSR for people in a relaxed environment range from 300–800 K ohms.[17]

c. *Blood Pressure:* It has been reported that ATC personnel exhibit a lower incidence of hypertension (systolic over 140 or diastolic over 90) in each age group than do non-ATC personnel; radar operators, however, are reported to have a higher, though statistically insignificant, rate of hypertension than non-ATC personnel.[6] Table IV shows that the mean values pre- and post-shift scarcely differ from each other within shifts or between shifts, nor do the mean values indicate that the controllers are hypertensive as a group. Out of 398 determinations of blood pressure, in only four cases were the above criteria for hypertension met, two systolic pressures of 143 and diastolic pressures of 97 and 100.

For reference, blood pressures of a large population of men in the 25–40 year age bracket are reported to range from 92–155 systolic and 54–101 diastolic.[4]

TABLE IV. Mean Blood Pressures Within Shifts and Between Shifts.

	Pre-Shift	*Post-Shift*
Evening	117± 9/73±10	116± 9/76±9
Morning	115±10/73±10	115±10/72±8

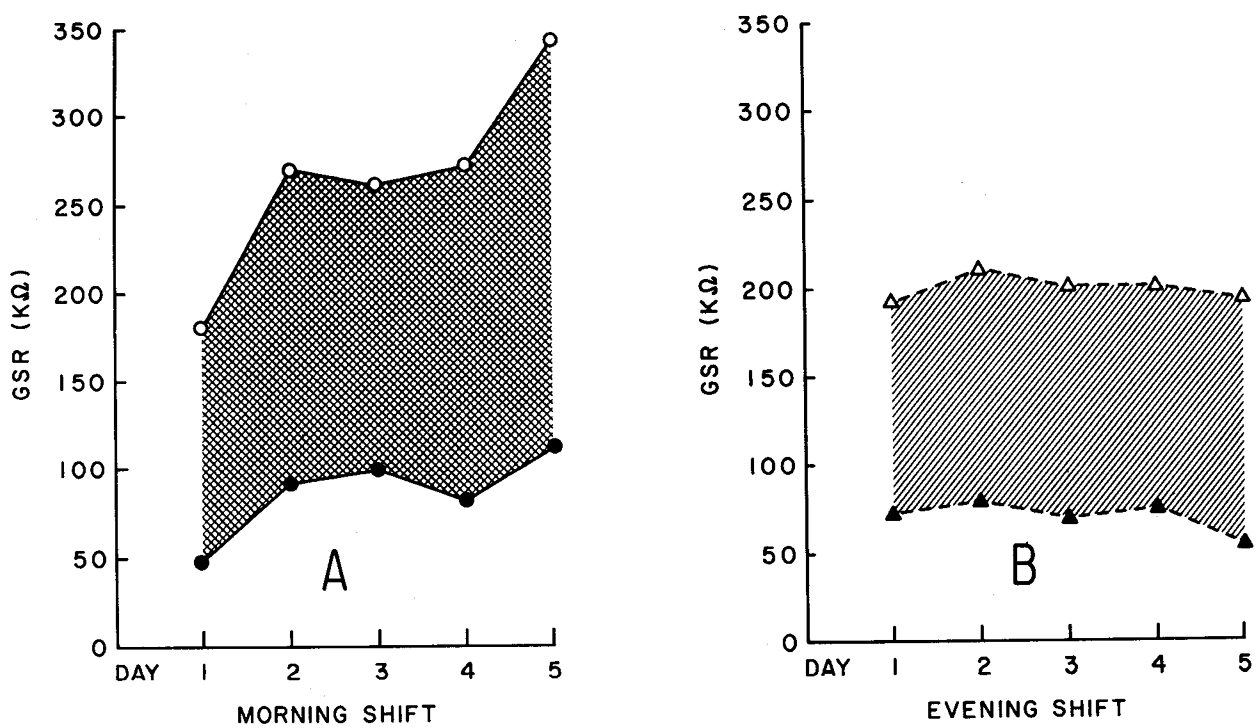

FIGURE 1.—Galvanic skin response on (A) the 5-day morning shift and (B) the 5-day evening shift. The daily values are the means of the maximum and minimum resistances, respectively, for each subject. (A) shows that the upward trend of maximum resistance continues over the 5-day period. Such a trend is not evident for (B).

d. *Blood:*

(1) Fibrinogen: Figure 2 is a plot of fibrinogen vs. age in 23 college students, 330 Aeronautical Center executives and 21 O'Hare ATC personnel. A general trend is apparent, about which the ATC fibrinogen concentrations are graphed. The ATC personnel are apparently positioned along the trend line in proportion to their ages.

The normal value for fibrinogen is reported to be 270 mg/100 ml of plasma.[1]

(2) Phospholipids: Treatment of the data was on a group basis rather than on an individual basis to see whether there was any significant difference between the ATC personnel as a group and a previously studied control group and whether the phospholipid concentrations from the ATC group correlated with any other of the groups (Table V, Fig. 3).

The ATC personnel had a total phospholipid significantly higher than the control and stressed groups that have been studied, higher even than Navy pilots exposed to combat in Vietnam. Two other phospholipids were significantly different in this population compared to normals; cardiolipin was significantly lower and phosphatidyl glycerol significantly higher than the normal population. The distribution of individual phospholipids in the controller population was not comparable to any of the other stressed groups that have been studied; that is, sleep deprivation, acceleration in a human centrifuge, combat flights, or schizophrenia.[23-25] Within the ATC population there is no statistical difference between the evening and morning shifts.

Events were noted by the observers such as fires in flight, malfunctioning landing gear, loss of power in flight or any other episode that re-

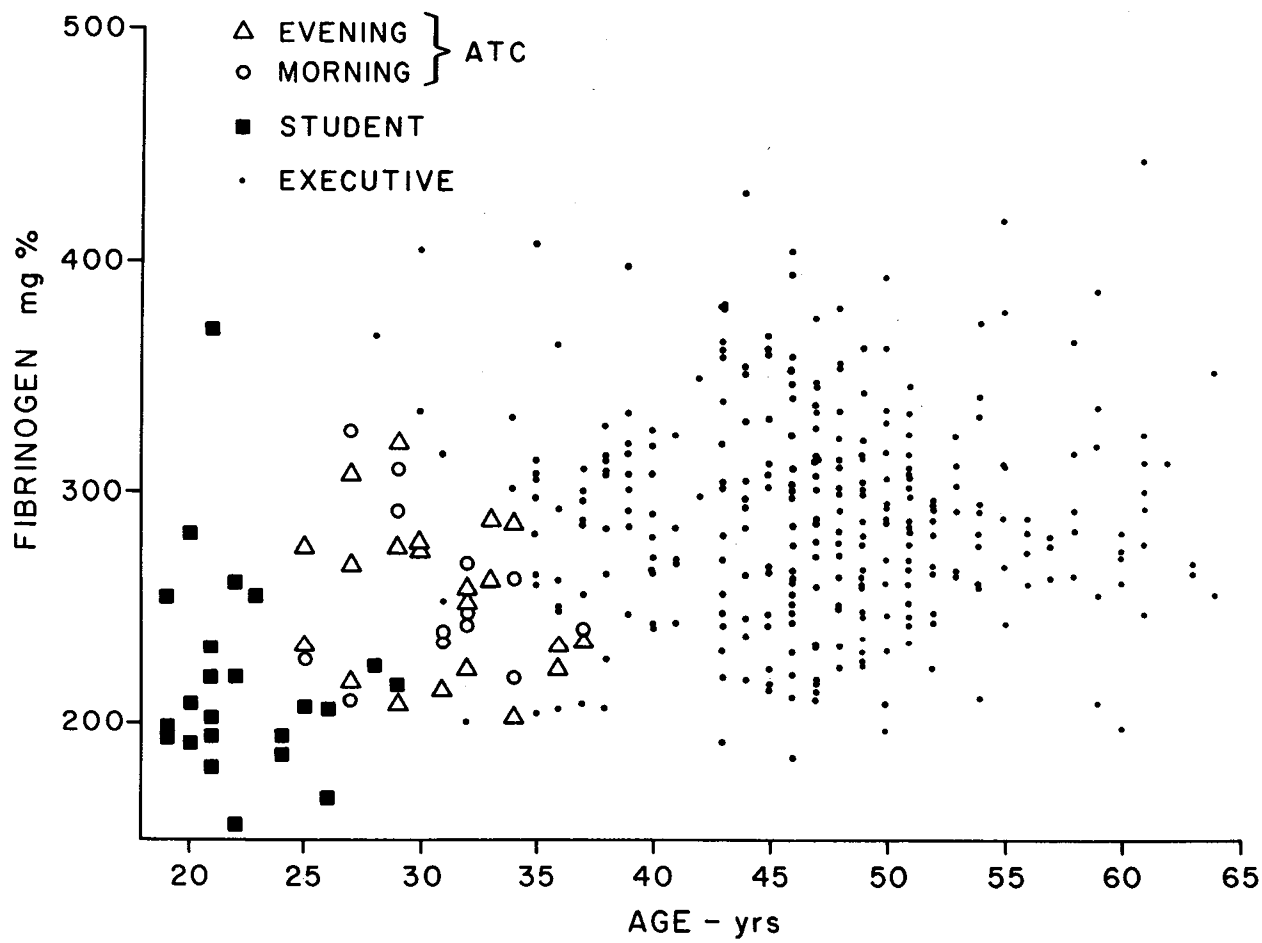

FIGURE 2.—Plot of fibrinogen vs. age for O'Hare controllers, college students and FAA executives. ATC personnel are positioned in the group according to their ages with no apparent differentiation of shifts.

TABLE V. Comparison of Plasma Phospholipids of Air Traffic Controllers and A Normal Population.

	μM Phospholipid P/liter				% Distribution		
	Total Phospholipid	Phosphatidyl Ethanolamine	Phosphatidic Acid	Phosphatidyl Glycerol	Phosphatidyl Ethanolamine	Phosphatidic Acid	Phosphatidyl Glycerol
Air Traffic Controllers							
A. Routine Shifts N=25	*3042 ±84	**50.7 ±2.0	*20.7 ±0.7	*45.0 ±2.2	1.68 ±.07	0.69 ±.03	**1.49 ±.07
B. Exceptional Situations N=15	*3272 ±104	*62.4 ±3.6	*20.6 ±1.5	*43.4 ±2.6	1.91 ±.10	0.63 ±.04	1.32 ±.07
Normal Population N=32	2272△ ±84	41.0 ±2.5	14.2 ±.9	24.7 ±2.0	1.83 ±.10	0.65 ±.04	1.12 ±.09

* P (t) $<.001$ when compared to normal population.
** P (t) $<.01$ when compared to normal population.
△ Mean ± S.E.

quired special handling by the controller and where there was an element of hazard. Those shifts on which the emergencies occurred were later identified and the data were extracted.

When the phospholipid analyses for individual controllers in so-called exceptional or emergency conditions were compared to the data obtained in routine conditions, there was no significant difference between the two groups. However, both groups were significantly different from a control population.

For perspective, human plasma is reported to contain between 2225 and 3516 μM of phospholipid phosphorus per liter.[2 15]

IV. Discussion.

The physiological response of air traffic controllers to their work is assumed to arise from their concern for the consequences of their instructions, for the physical work that they do is apparently minimal. The controller's mental image of aircraft positions in the airspace for which he is responsible and his projection of those positions into the immediate future gives rise to central nervous system outflow patterns that are affected by his uncertainties about the accuracy of his projections. The problem associated with any assessment of the controller's physiological state is how to tap that outflow appropriately so that meaningful data are collected.

Central nervous system (CNS) efferents innervate somatic, visceral and endocrine structures. These innervations result in skeletal muscle activity through the somatic nerves; a modification of activity of cardiac muscle or of the smooth muscle of the vasculature, the digestive tract and the genito-urinary system by the autonomic nerves; and glandular secretions resulting from autonomic activity and from the brain itself. In this study, attempts were made to tap these three outflow pathways of the brain by measuring the effector responses of each.

The heart rate is affected by all three CNS effluents. Muscular activity, mediated by somatic motor nervous activity, gives rise to increased cardiac output which involves increasing both rate and stroke volume. Emotional factors may cause direct sympathetic acceleration or vagal (parasympathetic) slowing. Catecholamines from the adrenal medulla and other chromaffin tissue cause acceleration of the heart. Increases in heart rate brought on by muscular exertion unrelated to the control of traffic were removed from the data. Heart rate changes occurring during the periods of traffic control work were undoubtedly due to a combination of emotional and physical factors, the exact proportion being undeterminable but apparently heavily weighted toward emotional factors. The data show that heart rates recorded during the evening shifts are significantly higher than those recorded during the morning shifts. This finding is to be expected since the number of operations during the evening shift sometimes reached 200 per hour, whereas on the morning shift the number of operations was commonly less than 25 per hour. This finding is consistent with Hale's[9] finding that the heavy-duty evening shift is characterized by adrenomedullary stimulation and consequently higher urinary excretion of catecholamines than is the morning shift. The data were not collected in a way that allowed heart rates to be correlated with individual operations; however, it is logical to suppose that each operation constituted an individual stimulus to which there was a response with a temporal decay. When operations were close together, decay did not occur and the elevated heart rate was sustained.

When the heart rate data are examined with respect to tower position, several interesting correlations appear. First, it is apparent that the cab positions engender the highest heart rates. Secondly, approach control gave rise to higher heart rates than did departure control. Thirdly, all positions on the evening shift gave rise to higher heart rates than did the same positions on the morning shift.

When different positions were compared within shifts, it was revealed that local control and approach control were not significantly different

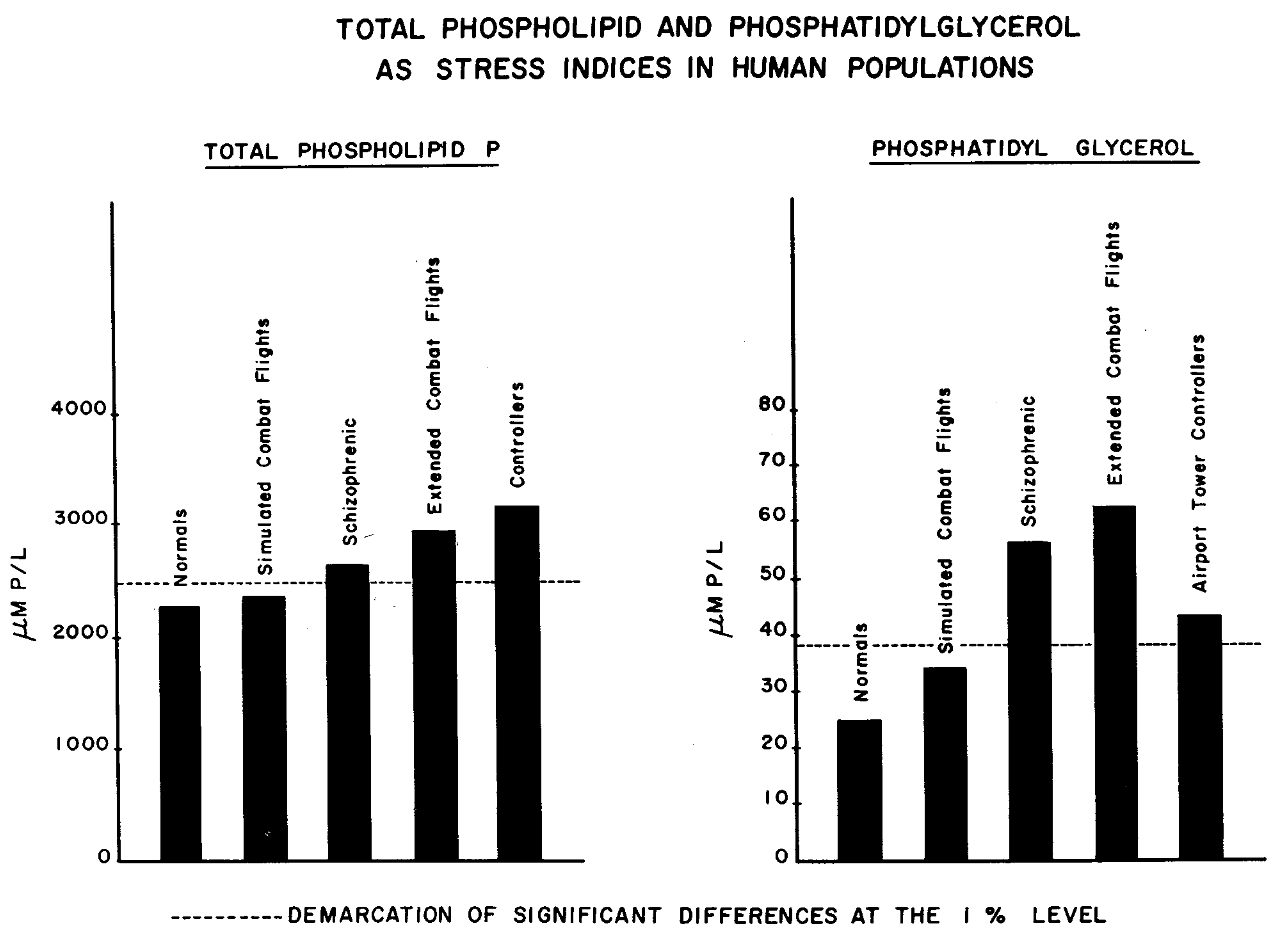

FIGURE 3.—Graph of total phospholipid phosphorus and phosphatidyl glycerol for five groups of subjects. Controllers show a higher titer of all phospholipids than any of the other groups but their phosphatidyl glycerol level (a more specific and less variable index than total phospholipid) exceeds only those of the normal population and simulated combat flight group.

on the evening shift with regard to controllers' heart rates. However, each of those positions gave rise to significantly higher heart rates than did departure control. On the morning shift, there was no statistically significant difference between any of the positions.

The heart rate data can be summarized as follows: (1) The evening shift elicited a greater response than did the morning shift, (2) cab positions were more stimulating than radar positions, (3) approaching traffic evoked a greater response than did departing traffic.

The skin electrical resistance (GSR) is taken to represent the level of central nervous system arousal.[8] It is fairly nonspecific in that any event that is attention getting, arousing, exciting or emotional will cause a drop in skin resistance. In an earlier study on pilots operating an aircraft simulator, the skin resistance consistently took an abrupt drop a second or so before the subject reached to his pocket for a cigarette. The skin resistance is related to the activity of sweat glands. The sweat glands of the hands are activated by sympathetic nerve discharge which, in turn, is related to the activity of the reticular formation in the brain stem. The reticular activating system is the lower brain center that is responsible for arousal of the higher brain centers.[19 22]

The GSR data show that the level of arousal, derived from the minimum resistances, is about the same on the two shifts. However, the maximum resistances indicate that there is less sustained stimulation associated with the morning shift than with the evening shift. Also, the data show that the maximum resistances continued to increase over the five day shift, indicating that adaptation was occurring, but not reaching completion. There was no indication of adaptation to the evening shift.

Although the level of circulating fibrinogen is known to increase following exposure to a variety of noxious stimuli, no studies of the effects of workload have been made. It is generally believed that elevation of the fibrinogen level is a function of both degree and duration of the stimulus. Thus, the finding that fibrinogen values of the O'Hare personnel are consistent with those of other personnel of comparable age may reflect the observation that the chronic stimulus of ATC work is below the threshold of response of the fibrinogen system.

Also, it must be remembered that most of the data found in medical literature on the subject are derived from samples taken in the morning by hospital laboratories. Therefore, the data presented in this study are subject to the additional qualification that they may represent a circadian ebb in fibrinogen level; however such circadian studies have not been made.

When the controllers' plasma phospholipids were compared with those of a control population, however, important differences appeared. Total plasma phospholipid and plasma phosphatidyl glycerol were significantly elevated in the controllers. The total phospholipid concentration has been associated with sustained action of injected catecholamines in animals[28] and may, in these controllers, be associated with their elevated urinary catecholamine excretion.[9]

The complete data derived from biochemical studies of the urine of ATC personnel and control subjects will be published separately in the open literature[9 10] and the reader is urged to consult those papers for the complete results and interpretations. However, a summary of those findings is offered here so that the essentials of the whole study can be available in one document.

There were many points of statistically significant differences in excretion of metabolic products between equivalent periods of the evening shift and the morning shift, generally in the direction of a decrease in excretion of those products on the morning shift for the first four hour period and an increase in the last four hour period. This finding is a reflection of the fact that the first four hour period of the evening shift is an extremely busy period while the first four hours of the morning shift is a relatively quiet time while the last four hours of the morning shift is a rather busy time at O'Hare when freighters are bringing goods into Chicago for the day's business. The rise in 17–OH corticosteroid excretion by the controllers during the last four hours of the morning shift is noteworthy in that it indicates that the workload at the end of that shift is acutely stressful. The interpretation might be placed upon this finding that at the end of the mid-shift the controller is called upon to make an intense effort to meet the demands of his job.

After the evening shift, the controllers apparently accomplish complete recovery during the sleep period, for the excretion of 17–OH corticosteroids shows a highly significant decrease; the catecholamines also decrease significantly. After the morning shift, however, the 17–OH corticosteroids decrease only slightly and insignificantly during the rest period indicating that there are residual stress effects that would be expected to be carried over into the next work period.

Urea is one end product of protein breakdown. ATC work at O'Hare is characterized by a relatively high urea output, indicating a rather high rate of protein catabolism.

ATC work at O'Hare was characterized by a general elevation of the end products of metabolism. When the controllers at O'Hare were compared with other groups, upon which the same urinary variables were measured, the comparison showed that O'Hare Tower work was more stressful than long or difficult flying operations, prolonged decompression in an altitude chamber or a 10-hour period in a flight simulator by inexperienced subjects.

The control subjects responded to their work with elevated excretion of metabolic end products, also. These biomedical crewmembers were, obviously, not controlling traffic but were alternating evening and morning shifts every five days. As the schedule worked out, each crew got 24 hours off duty after every ten days of work. When one crew was off for 24 hours, the other crew worked a "quick turnaround" schedule (morning and evening shift on the same calendar day). This work schedule was unfamiliar to these people and their response to the first five days of the morning shift was the most marked of the entire study. Relatively high values for epinephrine and 17–OH corticosteroids were obtained, also, in the morning specimens after evening work, indicating that the entire task was somewhat stressful. Adaptation to the morning shift work was evident in that there was a lessening of the physiologic disturbance with each return to the morning shift; however, full adaptation was not attained over the six-week period of the study. When the control subjects' values for excretion products were graphically compared with those of the ATC personnel, it was evident that the controls' responses were, on the whole, quantitatively less than those of the ATC personnel.

All measurements indicate that the controllers are generally in a state of sympathetic excitation, particularly on the evening shift. This state is probably accounted for by the controllers' intense concern for the separation of aircraft. This concern is most evident on approach and local control for it is on these positions that the controllers must deal with converging traffic.

This study was carried out in the summer when good weather (VFR) conditions prevailed most of the time. It is to be expected that prolonged bad weather (IFR) conditions, common to the Great Lakes area in winter, would engender quantitatively greater responses than are reported here.

This report deals only with the first of the three objectives listed in the introduction, i.e., a comparison of physiological responses of controllers on different shifts and at different tower positions.

For perspective, the ranges of the various measurements for other populations of subjects have been included. These are commonly accepted values and indicate that the data of the ATC personnel fall generally within these ranges. This comparison serves to emphasize that these ATC subjects were normal individuals and that significant evaluation of their response to ATC work can only be made by comparing them quantitatively with themselves in different work situations.

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