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Urinary Cortisol Excretion and Mood Ratings in Aircraft Cabin Crew During a Tour of Duty Involving a Disruption in Circadian Rhythm

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BASSETT, J R AND R SPILLANE *Urinary cortisol excretion and mood ratings in aircraft cabin crew during a tour of duty involving a disruption in circadian rhythm* PHARMACOL BIOCHEM BEHAV 27(3) 413–420, 1987 —A psychophysiological study was carried out on 28 cabin crew, comprising two teams, who were to travel from Sydney to Los Angeles and return, with stopovers in Los Angeles of 58 and 82 hr respectively Every urine sample for a period of nine days, commencing 2 days before the flight, was collected The volume and time the sample was passed were recorded so that urinary cortisol secretion rates could be calculated Mood was also rated on a scale scored 0–9 at the same time the urine sample was collected A control group matched for age, sex ratio, and degree of manual labour involved in their occupation, but not involved with the flights, was included in the study for comparison On the basis of urinary cortisol excretion rates, the crews in Sydney before the flight and in Los Angeles were more highly stressed than the control group The urinary cortisol excretion rates were significantly greater than those of the control group in Sydney before the flight, in Los Angeles, and during the return flight, but not on the flight out The high excretion rates before the flight were attributed to an apprehension factor, whereas the elevated values in Los Angeles and during the flight back were attributed to a disruption in circadian rhythm A factor analysis of mood ratings showed three major factors assessing vitality, distress, and relaxation Analysis of variance of the mood ratings showed significant changes over the tour of duty for 13 of the 14 moods

Cortisol Urinary excretion Circadian rhythm Mood ratings Cabin crew Stress

IN recent years there has been concern about the possible deleterious effects on aircraft cabin crew working long hours on the East-West meridian [11] There appears to be two types of stressors associated with long flights at high altitudes over different time zones First, there are the physical stressors encountered during the flight (such as noise levels, cabin pressure, low oxygen levels, and low humidity) Secondly, there is the problem of adjustment to circadian rhythms and sleep patterns resulting from different time zones The long term effects of high temperatures, low humidity, low oxygen levels, plus a physical workload may have subtle effects on individuals in relation to fatigue [11] Emsting [5] has shown that the lowered PO_2 levels, normally associated with high altitude flights, can lead to a diminution in mental ability and accuracy As a result of time zone shifts there is a tendency for cabin crew to go into sleep debt, loss of sleep tending to increase with the number of night flights on the tour of duty, and in some individuals it may become quite severe [11]

While physical stressors are associated with long high altitude flights, it appears to be the time zone transition itself and not the fatigue or hypoxia of flying that is mainly responsible for impaired performance following flights along the E-W meridian [6] Preston and his colleagues [12] studying the effects of exposure to eight-hour time zone shifts to the east, found a clear decrement of performance of 17 to 32% when averaged over the whole period Similar results were obtained when the shift was to the west [13] When the circadian rhythms of the body are disrupted by E-W/W-E flights the individual may take between five and nine days to re-adjust to the new environment

Cabin crew are subjected to a special combination of stressors As such they represented an ideal group on which to conduct a psychophysiological study of occupational

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TABLE 1

MEAN FREQUENCY OF PEAKS IN URINARY CORTISOL EXCRETION RATE (NUMBER OF PEAKS/24 HR) (MEAN ± S E)

	Sydney (Before Flight)	Los Angeles	Sydney (After Flight)
First Flight		$p<0.05$	
	1.77 ± 0.12	1.67 ± 0.16	1.30 ± 0.16
Second Flight		$p<0.05$	
	1.64 ± 0.12	1.59 ± 0.13	1.13 ± 0.10
Control	*$p<0.05$	†$p<0.05$	
	1.28 ± 0.13		

*For both flights vs control
†For first flight vs control

stress The present study was carried out on cabin crew before, during, and after a tour of duty involving the direct flight from Sydney to Los Angeles (L A) and return Urinary cortisol levels were measured together with ratings of perceived mood states Personality and attitudinal data were also collected but are not reported here Cortisol measurements were chosen since there is overwhelming evidence from both human and animal studies that exposure to emotional, sensory and environmental stressors will result in elevated plasma, and finally urinary glucocorticoid levels [8,9] It is generally accepted that the glucocorticoids represent reliable indicators of exposure to stress and that the level of glucocorticoid secretion correlates with the intensity of the stressor [3] While it is not possible to say that a certain level of glucocorticoid secretion is an indicator of the presence of stress that is harmful to the present or future well-being of an individual, there is a strong body of evidence (from both human and animal studies) implicating an association between elevated plasma glucocorticoid levels and the incidence of degenerative disease [2,14]

METHOD

Procedure

Cabin crew (17 males and 11 females) met with researchers three days before flight departures and were informed of the purpose and design of the study The cabin crew comprised two teams of 14 who were to travel from Sydney to L A and return with stopovers in L A of 58 hours and 82 hours respectively Apart from this both flights were identical The outward flights left between 13 00 and 14 00 hr, and the return flights landed between 6 30 and 7 00

Crew were asked to collect every urine sample for a period of nine days and to keep a diary record of times of urination, volume of urine, vial number into which urine sample was placed and a general description of activities since last collection They also rated their moods on a scale scored 0–9 The moods were relaxed, confused, sleepy, efficient, depressed, vigorous, fatigued, tired, irritated, alert, rushed, calm, tense, angry

Sampling commenced two days prior to the flight to L A These two days were 'rest days' in order to establish a 'non-stressed' circadian pattern for each individual Sampling continued throughout the flight, the stopover in L A , the return flight, and for two days after returning to Sydney The volume of urine passed was measured using a conical measuring cylinder, and a sample of urine was placed in a numbered 10 ml vial which was then sealed Urine samples were stored under refrigeration or in ice until collected Samples were collected for analysis before the flight to L A , after both the outward and return flights, and at the end of the sampling period All samples were collected within 48 hr of being passed In the laboratory the samples were stored at −20°C until analysis

Secretion rates were measured on every urine sample collected, rather than the more conventional procedure of sampling only the first morning, midday and last evening sample This procedure was adopted due to the variation in night-day patterns between Sydney and L A There exists a circadian pattern in cortisol secretion, the plasma cortisol peaking at the end of the dark phase [1, 7, 15] This endogenous circadian rhythm takes many days to re-entrain to a phase shift such as a reversal of the night-day pattern Apart from waking and sleeping occurring at different times in the circadian pattern in the two cities, it has been suggested that the underlying circadian rhythm may modify the response to a stressful stimulus For example, ether stress-evoked increments in plasma glucocorticoids vary considerably with the time of day in laboratory rats [4]

Two Ss were excluded from the first flight due to failure to collect sufficient urine samples (less than $^2/_3$ of samples collected) Apart from these two exclusions only 4 1% of total number of samples passed could not be included in the analysis Their non-inclusion was due to either failure to collect the urine sample or failure to provide sufficient data to calculate secretion rate (time of passing sample or urine volume) The average number of urine samples passed per subject over the entire test period was 73

Cortisol Assay

The cortisol assay used was a modification of the competitive binding assay described by Murphy [10]

Cortisol was extracted from urine using dichloromethane and aliquots of the extract were evaporated to dryness in a 47°C waterbath Each evaporated fraction was mixed with a cortisol binding globulin-isotope solution (4% human serum containing sufficient [1,3-H^3] cortisol to saturates available binding sites) The tubes were incubated first at 37°C for 45 min, then at 4°C for 15 min Unbound steroid was removed

using dextran-coated charcoal (625 mg activated charcoal, 62 mg Dextran T70, suspended in 100 ml phosphate buffer pH 7 0) A portion of the supernatant fraction (bound hormone) was then transferred to scintillation fluid and counted in a Packard scintillation counter By subtracting the counts associated with bound hormone from the total counts added, the counts associated with the unbound hormone (Free) were obtained The ratio of Free/Bound was calculated for each sample and standard Standard curves were prepared using solutions of known cortisol concentration and plotting Free/Bound ratio against the amount of cortisol

The intra-assay variability was 3 2% while the inter-assay variability was 6 6% Each urine sample was assayed in duplicate, duplicates being assayed in different assay runs

While the competitive binding assay used is not specific for cortisol alone, the interference by other steroids was insignificant This was partly due to their low cross reactivity (progesterone 20%, aldosterone 3%, testosterone 4%, oestrogens 0 01%) and also because their concentration in the urine was considerably less than that of cortisol In order to prove that the competitive binding assay did give a true estimate of the free cortisol levels in urine, the dichloromethane extracts of urine from 6 individuals (3 from women using the contraceptive pill) were subjected to partition chromatography in order to separate cortisol from the other steroids present Following chromatographic separation the cortisol content was analysed as already described There was no significant difference in the cortisol concentration of the urine samples subjected to chromatographic separation and the same samples analysed without separation

The cortisol concentration in urine did not alter with storage Samples stored at room temperature for up to 7 days showed no significant difference in steroid concentration Samples stored at −20°C were stable for at least 2 months

The cortisol results are expressed as urinary excretion rates rather than urinary concentration of cortisol to overcome variations due to differences in the rate of urine production Secretion rates were calculated by multiplying the urinary cortisol concentration (pmoles ml^{-1}) by the volume of urine passed (ml), and dividing by the time over which the urine was produced (time since the last sample in minutes), and expressed as pmoles cortisol min^{-1}

Analysis of Cortisol Data

Excretion rates were divided into 5 time periods—samples collected before the flight to L A , during the flight, in L A , during and after the flight to Sydney In general the data for each individual showed a circadian pattern with a sharp morning peak occurring between 8 30 and 13 00 hr (in the majority of individuals the circadian peak occurred between 10 00 and 11.00 hr) The elevated excretion rates associated with the circadian peak declined over the next 3 hr and remained at a low level for the rest of the 24 hr period Superimposed upon this circadian pattern there could occur a number of additional peaks in excretion rate associated with emotional, sensory or environmental stress factors For the purpose of this study a peak was arbitrarily defined as an excretion rate in excess of 50 pmoles min^{-1} greater than the rates on either side Such a definition, while including all the major increases in cortisol excretion rate, excluded minor fluctuations in rate occurring throughout the circadian cycle The frequency of peaks was calculated as the number of peaks occurring in the period of time and for comparison was expressed as the number of peaks occurring in 24 hours The mean peak frequencies for the time intervals, Sydney, L A and Sydney, were calculated and compared statistically using an unpaired *t*-test Because of the comparatively small time intervals associated with the flight time (less than 18 hours) and because both the outward and return flights did not include the normal circadian peak, peak frequencies were not calculated for the flights

The mean peak heights (pmoles min^{-1}) were calculated also for each time interval, including the flights, and compared statistically using an unpaired *t*-test There were 6 cases during a flight where no value met the criterion for a peak (50 pmoles min^{-1} greater than values on either side) In these cases there was a progressive increase in excretion rates throughout the flight, peaking in the first urine sample after the flight had ended (in all cases this was less than 30 min after landing, with the previous sample being passed at least 2 hr prior to landing) This peak was included in the flight period rather than the period after the flight since it was felt that it more closely reflected cortisol excretion as a result of the flight and not the short time after landing

For comparison, a control group, consisting of 13 persons, was chosen to match closely the age range and sex ratio of the crews Their occupations were chosen to be as heterogeneous as possible, yet to be similar to those of the crews in the extent of manual labour involved, and involvement with the public The occupations of the control group included university lecturer, high school teacher, business administrator, dental nurse, medical technologist, postgraduate student, bookmaker's assistant and part-time student, university research assistant, research assistant at a large public hospital, laboratory technician, and housewife with a young child The control group was asked to collect every urine sample passed over at least a 48 hr period during the working week, and to note the volume and time of each sample The data obtained were analysed in the same way as that of the crew

TABLE 2

MEAN PEAK URINARY CORTISOL EXCRETION RATES (pmoles min^{-1}) ± S E

	Sydney (Before Flight)	Flight Out	Los Angeles	Flight In	Sydney (After Flight)
First Flight	229 ± 17	139 ± 15	255 ± 20	244 ± 57	‡186 ± 12
Second Flight	221 ± 14	136 ± 9	253 ± 15	254 ± 30	‡213 ± 14
Control	178 ± 13	*	*	*	†

Asterisk indicates a significant difference ($p<0$ 05, unpaired *t*-test)

*For both flight group vs control

†For second flight group only vs control

‡For Sydney after the flight vs other periods

RESULTS

Frequency of Peaks

The frequencies in peaks of urinary cortisol excretion rates are shown in Table 1 There was no significant difference in the frequencies observed between the first and sec-

TABLE 3

PERCENTAGE OF PEAK VALUES OCCURRING IN EACH QUARTER OF THE FLIGHT

	First Quarter	Second Quarter	Third Quarter	Fourth Quarter
First Flight				
Out	28 6	35 7	0 0	35 7
	64 3			
In	14 3	7 1	14 3	64 3
			78 6	
Second Flight				
Out	39 9	11 1	16 7	33 3
	50 0			
In	6 3	18 8	12 5	62 5
			75 0	

TABLE 4

PERCENT OF SUBJECTS WITH URINARY CORTISOL EXCRETION RATES >200 pmoles/min

	Sydney (Before Flight)	Los Angeles	Sydney (After Flight)
First Flight	92	92	58
Second Flight	86	79	79
Control	46		

TABLE 5

PERCENT OF SAMPLES SHOWING URINARY CORTISOL EXCRETION RATES >200 pmoles/min (mean ± S E)

	Sydney (Before Flight)	Los Angeles		Sydney (After Flight)
First Flight	17 2 ± 2 6	22 3 ± 4 1	$p<0$ 05	10 1 ± 2 3
Second Flight	19 2 ± 2 7	20 0 ± 2 5	$p<0$ 05	13 2 ± 2 0
Control	*$p<0$ 05 14 4 ± 1 9	*$p<0$ 05		

*For both flights vs control

ond flight groups either in Sydney (before and after the flight) or in L A In both flight groups there was no significant difference in the frequency of peaks between Sydney (before the flight) and L A , but both frequencies were significantly greater than that in Sydney after the flight The control group showed significantly lower frequencies than both the Sydney (before flight) groups and the L A group from the first flight The frequency of peaks in the control group just failed to be significantly different from the L A group from the second flight and was not significantly different from both the Sydney (after flight) groups

Peak Heights

The mean peak values in urinary cortisol excretion rates are shown in Table 2 As with the frequencies there were no significant differences in peak heights between the two flights in any of the periods In both flights there were no significant differences in peak heights in the periods before the flight, in L A , or during the flight back However, while in the first flight both the Sydney (before flight) and L A values were significantly greater than those of the Sydney (after flight), in the second flight only, the L A value was significantly greater than the Sydney (after flight) There was no significant difference between the Sydney before and after values in the second flight

Compared with the control group the peak heights in Sydney (before the flight), in L A , and during the return flight were significantly greater in both the first and second flights On returning to Sydney, in the case of the first flight, the peak heights were not significantly different from the control values However, with the second flight, the Sydney (after flight) values were significantly greater than the control group

In both flights there was no evidence that the flight out was particularly stressful, since the peak heights in both cases were significantly lower than any other time period in the study and were also significantly lower than those of the control group The same could not be said about the return flight where the peak values remained at the elevated levels they were at in L A , and in both cases were significantly greater than the corresponding values in the flight out

The distribution of peak values during the flights is shown in Table 3 It can be seen that in both the first and second flights the greatest percentage of peaks in the flights out occurred in the first half of the flight, whereas in the return flights, the greatest percentage occurred in the second half (over 60% in the last quarter of the flight)

TABLE 6

FACTOR ANALYSIS LOADINGS, MOOD RATINGS AND CORTISOL LEVELS (N=1860)

Mood	Factor 1	Factor 2	Factor 3	Factor 4	Communalities
Relaxed	0 10	−0 20	*0 84*	0 07	0 75
Confused	−0 26	*0 70*	0 01	0 01	0 56
Sleepy	*−0 70*	*0 38*	0 25	*−0 24*	0 76
Efficient	*0 86*	0 00	0 20	−0 07	0 79
Depressed	−0 04	*0 76*	−0 08	0 05	0 60
Vigorous	*0 78*	0 19	0 11	−0 08	0 67
Fatigued	−0 59	*0 52*	0 02	−0 14	0 64
Tired	*−0 73*	*0 42*	0 06	*−0 21*	0 77
Irritated	−0 09	*0 71*	−0 46	−0 04	0 72
Alert	*0 88*	−0 01	0 08	0 03	0 78
Rushed	0 26	*0 45*	*−0 56*	−0 04	0 58
Calm	0 19	−0 11	*0 87*	0 01	0 80
Tense	0 01	*0 71*	*−0 50*	−0 02	0 75
Angry	0 03	*0 72*	−0 26	0 03	0 59
Cortisol	0 07	0 07	0 09	*0 96*	0 93
Percent of Variance Accounted For	33 4	20 9	10 2	6 7	

TABLE 7

ANOVA
MOOD RATINGS AND CORTISOL LEVELS

Moods	Period 1	2	3	4	5	F	Sig $p<$
Relaxed	6 2	3 9	5 9	4 8	6 4	38 23	0 001
Confused	1 5	2 5	2 4	2 5	2 1	9 76	0 001
Sleepy	3 4	4 7	5 2	4 8	4 5	22 95	0 001
Efficient	5 1	4 1	3 5	3 9	4 0	26 64	0 001
Depressed	1 0	1 1	1 0	0 8	1 1	1 00	n s
Vigorous	4 0	3 4	2 9	3 1	3 2	13 25	0 001
Fatigued	2 3	4 3	4 6	4 8	3 8	50 28	0 001
Tired	3 4	5 6	5 6	6 0	5 0	48 87	0 001
Irritated	1 7	3 6	1 7	2 4	1 8	26 64	0 001
Alert	5 3	4 3	3 7	4 3	4 4	22 52	0 001
Rushed	2 4	3 7	1 8	2 9	1 7	22 78	0 001
Calm	6 0	4 3	5 7	5 2	6 1	19 04	0 001
Tense	2 0	3 7	2 2	2 8	2 0	17 96	0 001
Angry	1 0	1 8	1 0	1 2	1 1	7 91	0 001
Cortisol	128 2	77 9	131 7	108 8	92 0	7 88	0 001

Excretion Rates Greater Than 200 pmoles Min^{-1}

The percentage of crew with urinary cortisol excretion rates greater than 200 pmoles min^{-1} is shown in Table 4 The value of 200 pmoles min^{-1} was chosen since it represented the approximate median of the distribution of peak heights in the control group As with the frequencies of peaks and mean peak heights, the values before the flight and in L A are very similar and well above those of the control group, where only 46% of all control Ss showed excretion values greater than 200 pmoles min^{-1} In the first flight on returning to Sydney the percentage of individuals showing values above 200 pmoles min^{-1} fell back towards the control group In the second flight the percentage remained high on returning to Sydney

The individuals showing excretion rates greater than 200 pmoles min^{-1} were then examined separately to determine the frequency of high values Table 5 shows the percentage of the total urine samples passed by an individual that showed a urinary cortisol excretion rate greater than 200

TABLE 8

CORTISOL LEVELS AND MOOD RATINGS
CORRELATION COEFFICIENTS

Mood	Before Flight	Flight Out	Los Angeles	Flight In	After Flight
Relaxed		0 27			
Sleepy	−0 23		−0 19		−0 15
Efficient	0 22				
Vigorous	0 25	0 18			
Fatigued			−0 12		
Tired	−0 26		−0 15		−0 13
Alert	0 21	0 14			
Rushed				0 20	
Calm		0 23			

pmoles min^{-1} Again it can be seen that the percentages do not differ significantly between Sydney (before the flight) and L A in both flights, but in all cases the values were significantly greater than the control group Not only were more individuals excreting greater than 200 pmoles min^{-1}, but they were also doing so more frequently On returning to Sydney the values returned to control level, the effect being greater in the first flight

Mood Ratings

A factor analysis of the mood ratings revealed three major factors (Table 6)

Factor 1 appears to assess *vitality*, Factor 2 *distress* and Factor 3 *relaxation* Factor 4 is clearly a *cortisol* factor with two moods (sleepy and tired) producing small, negative loadings

Analysis of variance of mood ratings shows significant changes over the hour of duty for 13 of the 14 moods—the exception being 'depressed' (Table 7)

The theme here is one of decreased vitality and relaxation, primarily in the second period which paralleled decreases in cortisol excretion Differences between the second and third periods are generally non-significant although cortisol levels increased substantially Similarly changes between the third and fourth periods are minimal except for cortisol levels Compared with Sydney mood ratings before the tour, the final period's ratings show that sleepiness, fatigue, tiredness increased while efficiency, vigour, alertness and feelings of rush decreased

Table 8 presents significant ($p<0$ 01) correlations between cortisol levels and mood ratings throughout the tour by time period It is clear that the pattern of relationships between cortisol excretion and mood ratings alters across time periods In the first period cortisol excretion correlates with "vitality" related moods whereas in the second period cortisol correlates with "relaxation" related moods By the final period the relationship with "vitality" is re-established though less significantly than in the first period

DISCUSSION

On the basis of both frequency of peaks and mean peak heights, the crews in Sydney before the flight and in L A appear to be more highly stressed than the control group This suggestion is supported by the observation that during these periods the crews had a higher proportion of individuals with excretion rates greater than 200 pmoles min^{-1}, and in these individuals the frequency of high values was greater

The elevated values in frequency of peaks, mean peak heights, and proportion and frequency of rates greater than 200 pmoles min^{-1} seen in the crews before the flight to L A , most likely represents apprehension or anxiety in anticipation of the forthcoming flight Very few of the crews on either flight had flown the direct Sydney to L A route before As a result of adverse publicity about the flight, and the fact that a study was being undertaken to investigate the possible stress factors associated with the flight, it is not unreasonable to suggest that there would be a degree of apprehension in individuals before the flight The continuation of such apprehension into the early part of the flight may explain why the greatest proportion of peaks occurred at the beginning of the flights to L A compared to the end of the flights returning to Sydney On the return flights, where the apprehension effect would be less due to a greater familiarity, the distribution of peaks may reflect more closely the build-up of environmental stress factors, such as dehydration and fatigue Another possible contributing factor to the differences in the distribution of peak values between the outward and return flights may be the position of the normal circadian peak While the circadian peak did not occur during the period of either flight, the peak would be closest to the beginning of the outward flight whilst it would be closest to the end of the return flight

While it may also be argued that the high Sydney (before flight) values indicate that both crews were composed of basically stressed individuals, such an argument could not be supported by the findings on returning to Sydney, where crews showed a return to control values

On the basis of the parameters measured the direct flight from Sydney to L A itself does not appear to involve an excessive physiological or psychological cost On the other hand, the period of time spent in L A does appear to be associated with enhanced stress factors It is possible that stress factors associated with the flight may have contributed to an enhanced stress experienced on first arriving in L A However, such contributions must only have been small, since after the return flight to Sydney all values rapidly returned to control values, even though the return flights appear to have been more stressful than the outward flights (based on cortisol values) The most acceptable explanation for the enhanced stress experienced in L A is the disruption

in the circadian rhythm resulting from the change in night-day cycle An individual does not immediately begin to adjust to the alteration in night-day cycle, and as a result there is a conflict between his/her biological clock and sensory information from the environment The long established circadian rhythms in physiological functions find themselves out of phase with the existing environment Such an asynchrony in the cycles associated with major bodily function is extremely stressful, and requires an adaptation time in the order of several cycle durations This is the essence of the 'physiological cycle shift syndrome' or 'jet-lag ' Such a disruption in circadian rhythm as experienced in L A would be carried over into the return flight, and would explain the greater stress experienced on the return flight when compared to the outward flight

In the first flight, on returning to Sydney, all parameters measured rapidly returned to levels that were not significantly different from those of the control group However, this was not the case with the second flight On returning to Sydney, the mean peak heights remained significantly elevated above the control value, although they were less than in L A A similar trend is seen in the proportion of individuals showing peak values in excess of 200 pmoles^{-1}, and the percentage of samples that were greater than 200 pmoles min^{-1} In order to explain this difference between the first and second flights it must be remembered that individuals do not immediately adjust biological rhythms to bring them into synchrony with their environment, and that it may take several cycles before this will begin to occur If, in the first flight, the individual had not made any appreciable adjustment in circadian rhythm during the stay in L A (58 hr), then on returning to Sydney the circadian rhythm would not be in variance with the environment As a result of this stress factor no longer existing, the parameters measured would almost immediately begin to return to normal values However, if in the second flight where the stopover is longer (82 hours), the individual had began to change his/her circadian rhythm (adapt to the L A environment), then on returning to Sydney the circadian rhythms would again be in conflict with the new environment This continued stress factor would explain the delayed recovery seen in the second flight on returning to Sydney

Relationships between cortisol excretion and mood ratings show the influence of circadian rhythm Insofar as cortisol levels peak early in the day and decrease throughout the normal working day it is not surprising to find that as the day progresses people become more tired, sleepy and less alert, vigorous and efficient Thus, the correlations between cortisol levels and these moods are attributable, at least in part, to circadian rhythm When the normal circadian pattern is disrupted, such as when flying and working with time-zone shift, we might expect to find the relationship between moods and cortisol excretion alters We would not expect this to occur in the period before the flight and the results confirm this However, as the tour of duty progresses and the effects of circadian disruption become greater the pattern of correlations alters This can be seen clearly in the L A period and the return flight to Sydney The period after the return flight shows a partial return to the initial pattern However, while the cortisol excretion rates and mood ratings both show the influence of circadian rhythm, the correlation between urinary cortisol and any mood is not high A major problem with attempting to correlate mood with urinary cortisol levels is the 2 to 4 hr lag-time between plasma levels of cortisol and the urinary levels of the hormone An enhanced urinary cortisol excretion rate is a delayed measure of an increased adrenocortical output that has occurred several hours previously, and as such may not correlate well with the mood rating at the time the urine sample was passed Attempts to correlate urinary cortisol levels with the mood rating associated with the previous sample did not show any better correlation, no doubt for similar reasons The factors involved in the increased adrenocortical output may have occurred after the previous mood rating was taken Despite this difficulty, however, these results point to a relationship between cortisol and a circadian mood pattern which is disrupted during and after stopover in L A

In summary, the data suggest that crews experienced feelings of distress on the flight out of Sydney which may be due to novelty and adjustment effects The stopover period and flight home are characterised by fatigue and perceived lack of vitality As the effects of circadian dysrhythmia accumulate perceived vitality and vigour decrease The major finding, therefore, is the psychophysiological cost associated with the tour of duty which appears to be largely a result of circadian dysrhythmia manifested in changes in cortisol excretion levels and mood states

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