THE EFFECTS OF THE CHANGES OF THE CIRCADIAN BODY RHYTHM ON THE SPORTSHOOTER*

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Most men live in a world dominated by a single periodicity, the alternation of light and darkness. This alternation adheres closely to a period of 24 hours, and all our life is geared to it. We wake and sleep, work and rest, eat and fast in a pattern which conforms to this alternation of light and darkness. The chief consequence of technological advance, is that now it is possible, by means of modern transport, to travel rapidly through several time zones and upset the physiological pattern which is known as the circadian rhythm of the human body.

I had a unique opportunity to study the effects of long distance travel, and traversing of time zones, had on sportshooters when I travelled with the English shooting team to the British Commonwealth Games in Christchurch, New Zealand. I was able to collect information on the subject, not only from the members of the English team but from those of the Welsh, Scottish and Northern Irish contingent.

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The Physiology of Circadian Rhythms

Many physiological measurements show more or less regular periodicity. Rhythmic variation in blood pressure, in pulse rate, in temperature result from regular alternation of rest and exercise. Rhythmic variations in renal excretion result from the rhythmic habit of meal times and of hormonal activity. Variations in secretions by endocrine organs, such as adrenal cortex and medulla result from rhythmic variation in alertness and drowsiness. Variations in the state of wakefulness cause changes in respiration and a variety of secondary changes ensue, for example, changes in blood CO₂ tension and hence in pH.

Studies of circadian rhythms of the human body showed the existence of such variations in temperature, endocrine secretions (pituitary, adrenals, thyroid, pancreas, testes etc), kidney functions, cardiac output and in respiratory rate. It is outside the scope of this paper to give details of all these physiological rhythms, but a short summary of the major ones is given below:

BODY TEMPERATURE shows a diurnal rise and nocturnal fall. During massive studies upon sleep (Pieron, 1913) it was noted that the variation of body

temperature had an important influence on sleep patterns, and this rhythmic variation of temperature persists even when subjects are recumbent in bed for 24 hours or more. Body temperature depends on the balance between heat production and heat loss, and the circadian variation of heat production and more so of the heat-loss mechanism, is an important factor responsible for the body temperature rhythm; however, recent studies suggest (Adam and Ferres 1954) that as the amplitude of this rhythm is similar in tropical, arctic and in temperate climates; therefore, the rhythm exists either in the temperature regulating mechanism as a whole or at the hypothalamic level.

MICTURITION; It is usual to sleep eight hours or so, uninterrupted by any need to pass urine. That urine flow and, therefore, the functioning of the kidneys show an endogenous rhythm is well established. Further it has been demonstrated that alteration of sleeping habits does not alter the urinary flow rhythm. Urine flow is not, however, in itself a primary physiological variable, but is rather the resultant of other processes, such as the rate of glomerular filtration and of tubular reabsorption and the secretion of the posterior pituitary antidiuretic hormone (ADH), to name a few. It seems from recent research (Wesson 1964) that the true explanation of the changing urine flow lies mainly in the changing rate of excretion of the various urinary solids. Sodium, potassium and chloride account for a large part of the osmolar content of the urine, and are thus likely to exert a major influence upon urine flow. The exact way the various complex physiological processes, mentioned above, which in turn interlock with other body functions, exert their influence on the functioning of the kidney is not yet completely understood.

CIRCULATORY FUNCTIONS also demonstrate circadian periodicity including blood pressure, pulse rate, plasma volume and cardiac output. All circulatory values follow a similar 24 hour rhythm; however, some of them have been found to be independent of the sleep/wakefulness cycle. There are regular circadian changes in skin blood flow with minimum values between 08.00 and 16.00 hours, and maximum values between 20.00 and 04.00 hours. The cyclic pattern of peripheral resistance with peak values in the late afternoon or early evening is out of phase with skin flow. In view of the rhythmic changes noted in peripheral resistance and blood pressure, it is not surprising that a circadian variation occurs in cardiac

output with maxima in stroke and minute volume reported between 12.00 and 16.00 hours and minima between 02.00 and 04.00 hours. The difference is as much as 3 litres between maximum and minimum output per minute. Detailed studies (Kleitman and Ramsaroop 1948) have shown that the heart rate follows a circadian rhythm with lowest values at night. The performance pulse index (the ratio between increase in pulse rate and increase in work output) has been shown to vary with minimum values between 02.00 and 04.00 hours and a peak between 16.00 and 18.00 hours. There are other rhythms too numerous to mention concerned with haemopoiesis.

RESPIRATORY circadian rhythms have been observed: The vital capacity falls during the day to a minimum value around midnight and then climbs until the usual time of waking; this rhythm persists in recumbent subjects and is not dependent upon sleep. The diffusing capacity of the lungs also exhibit daily variation. Most of the other respiratory rhythms are closely connected to the sleep/wakefulness rhythm.

PERFORMANCE TESTS were carried out and it became evident that a circadian rhythm exists in relation to applied mental and motor tests. Peak performance in a number of tests appeared around mid-day, with a very similar peak found in measurements of simple reaction time in adults. In other series (Hollingworth, 1914) motor skill has been found to rise in the afternoon when mental skills were falling, suggesting that there is more than one fluctuating influence.

The Changes Forced by Rapid Traversing of Time Zones on the Circadian Body Rhythms

With the advent of the aeroplane as the means of mass transportation it has become possible to travel long distances rapidly, including the traversing of many time zones and hence, produce a time shift in the sleep/wakefulness rhythm causing widespread physiological changes, as the circadian rhythms of the body tend to remain for varying periods in their original time scale. The data of these changes and their effect upon the various body systems, and therefore, on the behaviour pattern of the individuals concerned as the direct result of these changes are far from complete. However, data concerning airline pilots, transatlantic travellers and night shift workers are available thus enabling one to have a basic understanding of the problem.

Experiments during which subjects were kept in conditions of continuous illumination showed adherence to circadian rhythms in body temperature, activity, sleep-wakefulness, and renal function. In a recent experiment (Fröberg and Levi) soldiers were kept awake for three days and practised shooting every three hours.

Their self assessed fatigue increased sharply during the night hours and perceptably diminished during the day although they were screened from any indication of the passage of day and night.

Temperature rhythm was found to take three to four days to adjust to local time after a 5 hour phase shift (Burton 1956). It was also noted that a young child adjusted more rapidly than an adult.

Pulse rate recorded during transatlantic flights (Howitt, Baldwin, Whitside and Whittingham, 1966) have demonstrated a slow rate at times when the subjects should, according to their usual nychthermeral habits, have been asleep.

Renal rhythms have been observed (Gervitzer 1936) in transatlantic travellers. It was found that after 4 days they were still not fully adapted to the new environment. Similar time lapse was observed before adaption to local time in subjects who were experiencing an 11 hour shift in time. That it is the traversing of time zones, and not the duration or distance of flying was involved, was demonstrated (Hanty and Adams 1966) when after similar flights in duration and distance south to north there was no disturbance at all in the rhythm of renal secretion.

It was found (Flink and Doe 1959) that after a 9 hour time shift it took 9 days before potassium and sodium excretion adjusted to the new time, and it took nearly three weeks before the disruption in the sleep/wakefulness pattern gradually diminished.

Recent experiments show that the adrenals were the slowest to adapt to time shift taking over 18 days before they were fully synchronized.

It is, therefore, clear that the long distance air traveller finds himself quite suddenly in a time zone completely out of alignment with his biological processes. Sleep and wakefulness, digestive processes, body temperature and mental activity, may all show quite marked disturbances which, even subjectively, may be noticeable for some days after arrival. It has been found that variations in reaction time appear to be closely related to the body temperature. Circadian rhythms in mental alertness may also be considerably disturbed. The information available on the rapid time-zone transitions on bodily functions is still relatively scanty, but is sufficient to indicate that the physiological and psychological effects of such journeys are considerable and may be rather more long lasting than is at present fully realised.

The Effects of the Changes Forced by Rapid Traverse of Time Zones on the Performance of Sportshooters

The teams travelling from the British Isles to take part in

the Tenth British Commonwealth Games in New Zealand had to undertake a 28 hour long air-trip, crossing no less than 12 time zones. It is clear from the foregoing that the 12 hour time shift they experienced had a considerable physiological and psychological effect upon their bodily functions, and hence, on their shooting performance.

In my study I examined these effects in 28 shooters from England, Scotland, Wales and Northern Ireland. These included 6 Smallbore Rifle competitors, 6 Rapid Fire shooters, 6 Free Pistol Shooters, 5 Full Bore Rifle marksmen and 5 Clay Pigeon competitors.

The ages of the shooters ranged from 26 to 56 years old.

After a period of rest to recovery from the rigours of the journey they all experienced to a more or lesser degree disturbances in their everyday routine. These included sleep disturbances, irritability, tiredness, forgetfulness, digestive upsets and lack of mental acuity.

All the shooters suffered from some sort of interference with their normal sleep pattern. The two most common, were early wakening and disturbance due to nocturia; others were restless sleep and insomnia.

Almost all the shooters complained of fatigue, especially in the early evening hours, which was described as 'a sensation similar to that of taking a powerful sedative'. There was a general lack of vitality and a sense of lassitude during the daytime hours.

Other physical complaints were:- indigestion, constipation and visual disturbances.

There was a most notable disturbance in behaviour patterns — principally irritability, and to a slightly lesser degree forgetfulness, and inability to act and talk logically. There was also a notable lack of cohesion in normal conversation.

The average length of time required by the shooters to overcome the above listed effects in everyday routine after arrival at Christchurch, was 5/6 days. The individual figures varied from 2 to 10 days. The time required to adjust was noticeably linked to the age factor. All the competitors aged 40 or over required the minimum of 7 days.

A notable exception was one shooter who experienced almost none of the above mentioned effects; significantly, he is on permanent shift work.

When one came to measure shooting performance against the standard achieved before the journey, the effects of the time zone shift were more pronounced and extended in duration.

Fig. 1. Slow-fire shooter's training scores

Fig. 2. Rapid-fire shooter's training scores

The above graphs illustrate the dramatic improvement shown by both slow and rapid-fire shooters in the second week of training after arrival to Christchurch, in relation to the eventual winning score (W). The graph (-----) illustrates training results achieved in England before the journey.

None of the shooters were able to reproduce the form they achieved before the journey under 7 days; the average time being 8/9 days. A considerable number of the samples studied never achieved their previous standard in the time available.

The disturbances of the time zone shift manifested themselves as far as shooting performance was concerned in; inability to concentrate, lack of co-ordination, muscular weakness and tremor, loss of reaction speed, loss of visual acuity, lassitude and early fatigue; in that order.

Inability to concentrate was the single most disturbing factor listed by the majority of shooters in the sample.

These effects were very pronounced in the first seven days of training, the performance graphs of the shooters showing a very uneven pattern, with gradual improvement and stability achieved towards the end of the second week.

Looking at the individual shooting events, the prone rifle shooters were most affected by their inability to concentrate and by variation in their visual acuity. The clay pigeon shooters and the rapid fire competitors suffered from loss of reaction speed and co-ordination.

The free pistol shooters found that muscular tremor and lack of co-ordination resulting in trigger shyness were most disturbing.

Conclusions

From the foregoing it maybe established that rapid traversing of time zones have a considerable and lasting effect on the performance of sportshooters. Unless a sufficient period of acclimatisation is allowed to take place, (minimum of 14 days in my opinion) the competitor may not be able to achieve his full potential.

Further research is indicated, to try to discover training schedules which will accelerate the process of acclimatisation. There is some evidence already available that adopting a sleep/wakefulness pattern corresponding to that of the subject's destination prior to travel (pre-flight synchronisation) maybe of value.

I strongly believe as the evidence of my study shows that training during the first week of arrival should be avoided since the disturbing effects are so great that they may have a profound psychological effect on the sportshooter's performance, even after full acclimatisation. Confidence lost during this period may not be fully recovered, impairing seriously the match performance.

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