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POWER SEEKERS ARE DIFFERENT: FURTHER BIOCHEMICAL EVIDENCE

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In an article previously published in this Review I demonstrated that power-seeking, by which I mean the pursuit of social dominance, has a biochemical marker, namely, whole blood serotonin (WBS). Those individuals who are especially hard-charging and competitive have especially high WBS levels. This paper presents the results from an investigation of dynamics in the response of high WBS individuals to actual competition. My expectation—that they would exhibit special physiological activation in the face of challenge—is fully borne out by the evidence. Four hormonal indicators of activation were followed in blood samples taken during a series of social competitions. All four show distinctive patterns for the high WBS group. These results, in addition to providing new evidence on the behavior of the endocrine system in competitive settings, impressively support the view that WBS is a biological property having fundamental significance for behavioral political science.

Those human beings who gain power or dominance over others have long been of keen interest to students of political life. Yet for all of the attention, scientific knowledge about *homo politicus* remains scanty. Little is known about the inner drive of those who devote themselves to the capture and use of power roles in social arrangements.

This report comes from a research program addressing that void. In a paper published earlier (Madsen, 1985) I presented evidence that the pursuit of social dominance has a biochemical marker, namely, whole blood serotonin (WBS).¹ Those individuals who in questionnaire responses showed themselves to be especially hard-charging and competitive—"Type A," in the jargon of medical scientists—were very likely to have high WBS levels. The multiple correlation of defining questionnaire items with WBS reached .70. As noted in

that paper, this discovery echoed similar findings in a species of subhuman primates, where dominance was marked by high WBS levels (see Raleigh and McGuire, 1980; McGuire et al., 1982; McGuire et al., 1983).

It was clear from the outset that questionnaire data were less than ideal for my investigation. An obvious, and indeed crucial, concern was validation: How would high WBS individuals react to actual rather than merely remembered rivalry? That concern is addressed in the analysis reported here. In what follows, high WBS subjects are compared with *normals* in their responses to a series of competitions. The measured responses are physiological (and, it is important to note, involuntary). Four blood-borne hormones, each intimately involved in the body's preparation for action, have been followed in timed blood samples taken while the

competition unfolded. The results show plainly that high WBS subjects are distinctive in their response to this challenge. Actual competition does indeed have a remarkable effect upon these individuals.

Methods

The present research was launched for the purpose of examining the relationship between psychological stress levels and distributions of influence in small social units processing problems of collective importance. Concern with serotonin level and its implications came later. Research design and methodological details are fully described in the earlier report from this project (Madsen, 1985). However, the following points bear repeating: the experimental subjects were 72 young, healthy males; they were processed through the competition in groups of six; the competition itself consisted of a series of logic puzzles that were to be solved collectively; sessions were all given at the same time of day but on separate days; and all sessions were conducted at a university hospital with trained medical staff doing all physiological procedures.

Eleven timed samples of venous blood were collected from each subject. The initial sample was taken when a subject arrived at the hospital, about 90 minutes before the competition began. Starting about 50 minutes later (after a quiet period and a standard dinner), a sample was taken every 20 minutes until 20 minutes after the competition ended.² All samples were subdivided, frozen, and maintained at -80°C until assays of their hormonal content could be undertaken. (The methods used in all assays are available upon request.)

Recall that in keeping with the earlier finding, whole blood serotonin values are used to define power orientation. Thus, the six cases with very high WBS levels (greater than 209 ng/ml, with a mean of 251 ng/ml) were separated out as strongly

competitive, dominance-seeking individuals. They were to be compared primarily with a normals group ($N=55$; WBS from 90–200 ng/ml, with a mean of 144), but also with a low serotonin group ($N=7$; WBS from 40–82 ng/ml, with a mean of 72).

Four endocrine responses were followed, each one intimately related to the complex process through which the human body prepares itself to cope with threat or crisis. A few prefatory remarks about that process and the four hormones being followed are in order.

For human beings, the onset of stress, physical or psychological, brings forth what has aptly been called an endocrine cascade. Moreover, it is a cascade with elaborate feedback mechanisms, which in complex interaction regulate the extent of the endocrine response to that stress (Axelrod and Reisine, 1984). Prominent roles in this process are played by the hormones adrenocorticotropin (ACTH), cortisol, epinephrine, and norepinephrine.

ACTH is released from the anterior lobe of the pituitary gland, located at the base of the brain and triggered by a signal from the hypothalamus. The ACTH travels via the bloodstream to the adrenal glands (situated near the kidneys, one on each side of the body), where it causes in the outer layers of these glands (the adrenal cortex) the formation and release of a group of hormones called glucocorticoids, among them cortisol. Cortisol has a half-life of about 70 minutes. Along with the other corticoids, it exerts an important influence on metabolic processes, blood pressure, brain function, and, in general, on getting the body ready for action. This system is called the pituitary-adrenal cortical system, and its response to stress is neither as quick nor as transitory as it is that of the system to be considered next.

Also important in the human readiness reaction are the hormones epinephrine (E) and norepinephrine (NE), both classified

as catecholamines and both a part of the sympathetic-adrenal medullary system. With the activation of this system by sympathetic nerves, E and, to a lesser degree, NE are secreted from the adrenals' inner portion, an entirely separate gland called the adrenal medulla. (NE is also secreted directly by sympathetic nerves, for which it serves as a transmitted substance.) The system responds to stress almost instantaneously, E and NE both flowing into the bloodstream. The hormones are quickly destroyed as well: the half-life for E is just over 1 minute, and that for NE about 2.5 minutes. With this quick on-off feature, the system is crucial to mobilizing the body for action in acute (as opposed to prolonged) challenge situations.

Although ACTH, cortisol, E, and NE are all involved in the stress response system, they do not all respond to an environmentally posed challenge in the same degree or at the same rate. In fact, there is still considerable uncertainty about the exact behavior of these four hormones in the face of such a challenge. That being the case, my predictions of their behavior in the present study could only be very general.

In the few relevant studies of plasma catecholamines there is evidence that psychological stress of the kind experienced when facing public speaking or mental arithmetic assignments produces a much stronger E than NE response (Dimsdale and Moss, 1980; Leblanc et al., 1979; Ward, Mefford et al., 1983) and does so especially among Type A individuals (Glass et al., 1980; Ward, Parker et al., 1983). The challenge presented by the competition designed for this study was psychological, but also was very different from the stressors used in previous work. Nonetheless, it seemed that I should find similar results if the high WBS individuals were specially activated by social rivalry. Hence, I expected to see marked elevation of E levels, and a more muted elevation of NE levels.

In contrast with the catecholamines,

ACTH and cortisol have been the object of numerous plasma studies in humans. Few of these studies, however, look at the type of competitive challenge posed here, and none look at the WBS connection. However, again there is some important work on vervets to consider. McGuire, Raleigh, and Brammer (in press) have found that in groups from which the dominant male has been removed, cortisol levels were highest for those males which eventually emerged as dominant. Recall that male dominance here is accompanied by elevated WBS levels. This study, which came to my attention after my data already had been analyzed, suggests what I had in fact expected to find in those data: that high WBS individuals would show special elevation of cortisol levels. And since ACTH is a part of the same system, I anticipated similar results for that hormone, though perhaps with an earlier peak.

Measurement of the hormonal responses to environmental stimuli in the study proved to be anything but simple. Both ACTH and cortisol are subject to sizeable daily—i.e., circadian—rhythms, with zeniths coming roughly between 0700 hours and 0900 hours and nadirs roughly between 0100 hours and 0300 hours for normal subjects who adhere to a routine of nocturnal sleep and daytime activity. What I did not know when designing my study was that in the time of day it covered, roughly from 1600 hours to 2100 hours for each session, both hormones normally are falling rather rapidly. Thus, to measure the stress effect on ACTH and cortisol in my subjects, I could not assume a stable baseline, but had to establish the baseline for my comparisons empirically. Fortunately, after another complication discussed below, that baseline could be reasonably estimated from 24-hour data on healthy subjects collected in the Clinical Research Center of the University of Iowa Hospitals and generously made available to me by its director.

There also is some preliminary evidence

of circadian rhythms in the catecholamines (Linsell et al., 1985). However, in the case of NE the evidence suggests only a slight downward trend during the period in which I took samples. And in the case of E, though the downward trend in the latter part of that period is more noticeable, the really striking finding is the presence of very substantial variance around that trend line during the waking hours. Much more work needs to be done to decipher these curious patterns. Lacking any baseline data, I could only proceed with possible circadian effects in mind.

Further complication came from the discovery of a seasonal rhythm in the plasma ACTH and cortisol for my subjects. Returning to the Clinical Research Center's data, which happened to have been collected over the course of nine months, I found and measured the effect of seasonality on this group's cortisols after the effects of age and sex, which also turn out to be influential factors, had been removed. (This finding in 24-hour plasma

cortisol data is new and will be discussed fully elsewhere.) The measured seasonality effect was then used to build a correction into the cortisol data for my subjects.

It was now possible to examine the responses of the entire set of subjects to the challenge imposed by the puzzle competition. The evidence is presented in Figure 1 for cortisol and ACTH, and in Figure 2 for E and NE. In Figure 1, the metric is percent above the healthy patients' baseline values. In Figure 2, the metric is percent above the minimum value in the 10-sample sequence. (The minimum value here may still be well above normal for the individual involved, but it is the only available estimate of such a baseline.) In these figures, and in those which follow, the plotted numbers are median values. Medians are used because the distributions are invariably skewed.

In Figure 1, note first that neither cortisol nor ACTH gets close to baseline levels in the 10-sample sequence. Cortisol does not drop below a 15% elevation;

Figure 1. ACTH and Cortisol Patterns

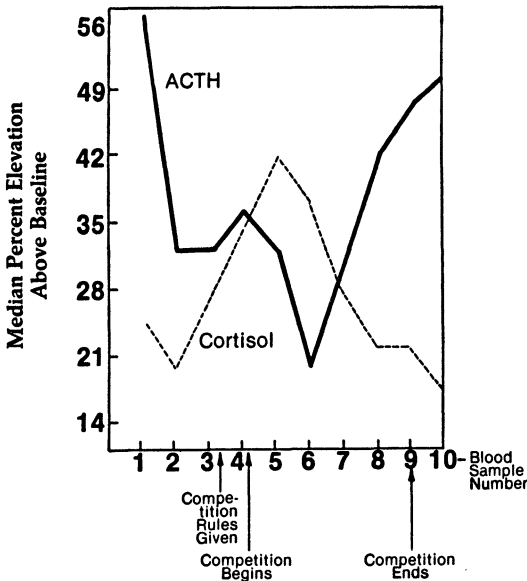
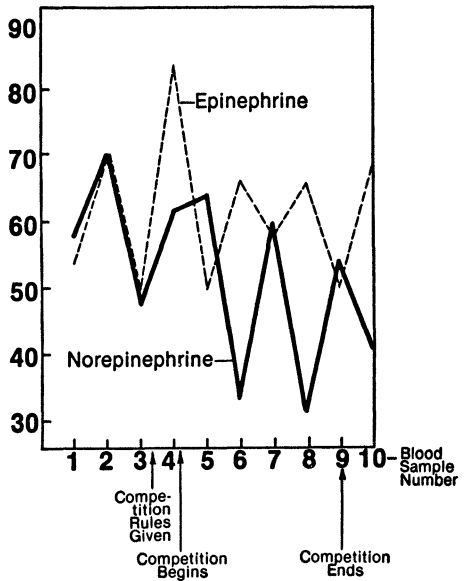


Figure 2. Epinephrine and Norepinephrine Patterns



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ACTH does not drop below a 19% elevation. Even allowing for inexactness in baseline estimation, it is clear that on average these individuals were responding to the competitive context.

The contrast between the two patterns was a surprise. ACTH is highest at the time of venipuncture (when the first sample was taken)—perhaps not surprising given the fear many people have of this procedure. But median cortisol was not close to its highest point then; in fact, it was not far above its low. Cortisol climbed markedly after instructions for the competition were given, and reached its peak after the first two puzzles had been addressed. Thereafter it began a gradual fall. However, just as cortisol was falling, ACTH was climbing, ending the series not very far below the peak value registered with the first measurement. These results, almost mirror images of one another, mean that the point made earlier must be expanded. Not only may hormones in the same stress response

system respond to challenge in different degree and at different rates; they may actually respond in different directions. Obviously, my simple assumption about the ACTH pattern was in need of revision.

In Figure 2 we also find substantial elevation of endocrine values. However, there is much more jerkiness to the trend lines for the catecholamines, which perhaps is to be expected with such short-lived substances. Were lines fitted to these greatly fluctuating data points, that for NE would slope downward (perhaps a circadian decline), whereas that for E would be almost flat. But the differences between these two catecholamine responses are more dramatic than that. On the whole, one is struck by the extent to which the two are completely out of phase.

It is plain that these two figures show mysterious differences in the behaviors of the separate elements of the stress response system, but it is equally plain that all four trend lines show significant acti-

Figure 3. Cortisol Patterns for WBS Groups

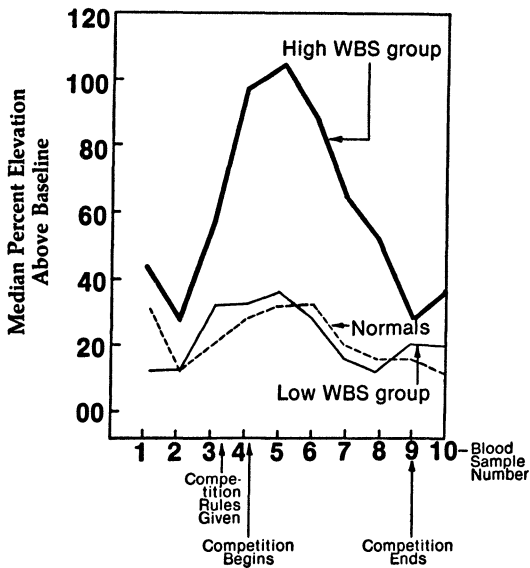
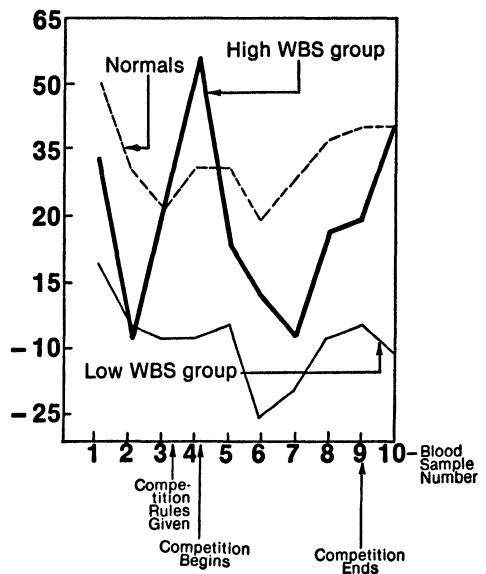


Figure 4. ACTH Patterns for WBS Groups



vation of the adrenal mechanisms. These subjects, on average, appear readied for a challenging situation. But were some more ready than others? It is to that question we now turn.

Findings

Hormonal responses for all three of the WBS groups are presented in each of the figures which follow. Figure 3 presents the cortisol series, Figure 4 the ACTH series. Figures 5 and 6 present two views of the E series, and Figures 7 and 8 two views of the NE series. Again, what is sought in these figures is evidence of a special activation for the high WBS group.

Figure 3 presents a clear and dramatic finding. The average cortisol values for the high-WBS group soar with the onset of competition. The peak, coming in the first sample taken after the competition had begun, shows just over a 100% increase. Neither the normals nor the low-WBS group show any such effect, although both show small elevations in the early stages of the competition and then a decline.

Figure 4, presenting the ACTH series, is puzzling. The high WBS subjects do not look here at all like they did in the cortisol series. In most instances their values, though above baseline, are not as high as those for the normals. What is distinctive for this group is the extraordinary variance in the series. The great peak, coming right after the nature and rules of the competition have been spelled out, is intriguing, as is the sharp drop for the main part of the competition. But while it is true that this variance is unique, the high-WBS series does have two things in common with the other series: all show at least a brief downward dip in the middle of the contest, after puzzle 4 or puzzle 6, and then all climb upward from that dip.

Figures 5 through 8, which give the catecholamine responses, must be interpreted with caution. In the E series miss-

ing data reduce the number of cases to between two and four.³ Less consequentially, the number of cases in the NE series is reduced to five. Obviously, estimates become more problematical with smaller numbers of observations.

Figure 5 presents the E series. In the clutter of trend lines, that for the high-WBS group is notable in several respects. It actually begins at a level of zero elevation, much lower than any other, then climbs to the highest of any group for measures 2 and 3. Just before the beginning of the competition there is a great spike, followed by a jerky but typically high trend line to the end of the series. Unfortunately, the spike at measure 4 is based upon only two cases. To mute the effect of this estimate and to provide a sense of the overall E pattern, I have presented a second view of the series. A robust nonlinear data smoother (running medians) developed by Velleman (1980) yields a trend line based upon averaging adjacent values with a particular measurement point. Hence, in this case it downplays a value like that in the spike just prior to the onset of the competition. The results are presented in Figure 6, where the distinctiveness of the high WBS group is again found to be dramatic.

Figure 7 presents the NE patterns. The high WBS group is special, but in a wholly unanticipated way. The initial NE value for the group is the highest of the entire series and the highest to be found anywhere in the figure, a full 129% above the minimum baseline. The series stays high through the first four measurements, again showing a spike, though much smaller, at sample 4. But then the trend line plunges to much lower values through most of the puzzle solving, before once again climbing to high levels at the end. The smoothed version of the data for all three groups is given in Figure 8. Obviously, much is lost in Figure 8, but what remains is a very interesting and distinctive pattern for the high WBS group.

Indeed, the general shape of their response curve is the opposite of that for the others, with the high start, the low middle, and the high finish. What these patterns might mean must be left to endocrinologists to explain. I can only underscore the point that the high WBS group is again found to be very different indeed.

Discussion

This study is only a beginning. Nonetheless, the findings presented here are much more than suggestive. The simple and intriguing fact is that the high serotonin individuals are indeed a special lot. A behavior pattern which had been tied to WBS only through questionnaire data has now been given striking physiological representation. The dynamics of the best understood of the plasma hormones here presented, cortisol and epinephrine, reflect for the high WBS group precisely the kind of internal response that one would expect from aggressive competitors in the context of rivalry. The patterns for ACTH and NE, while fascinating and equally distinctive, are much more mysterious.

There are some complementary studies in humans (Lewis and Sherman, 1984; Ward, Mefford et al., 1983; Ward, Parker et al., 1983) and in subhuman primates (McGuire, Raleigh, and Brammer, in press). Most intriguing is a new line of research by McGuire and his colleagues (personal communication) testing whether pharmacological enhancement of central nervous system serotonergic function raises the probability of becoming dominant. These tests have been run on groups of male vervet monkeys. After the experimenter has removed the dominant male from the group, a randomly chosen male is treated with fluoxetine, a drug which increases serotonergic function. In each of the three tests run, the treated male became dominant! (An early report

from the larger project of which this is a part is Raleigh et al., in press.)

With respect to the investigation at hand many fascinating and important questions arise. Findings inevitably lead to questions. But the crucial point here is that there indeed are strong findings. All indications are that whole blood serotonin is a biological property of fundamental significance for behavioral political science.

Notes

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1. Serotonin, also known as 5-hydroxytryptamine (or 5-HT), is a hormone with neuroregulatory functions and is found in the central nervous system, in the blood, and in several other body locations. Blood serotonin is relatively stable, and not subject to significant seasonal or daily rhythms, or to short-term perturbations as a function of situation (for example, diet changes or social encounters). How serotonin works its effects, and exactly what those effects are, are matters of limited understanding at this point. Direct tests of its role in the dynamics of human behavior, few in number, are ambiguous in their findings. For extensive and revealing work on animal models, however, see McGuire et al. (1982, in press), McGuire et al. (1983), Raleigh and McGuire (1980), Raleigh et al. (1981), Raleigh, Brammer, and McGuire (1983), Raleigh, Brammer et al. (1983), and Raleigh et al. (in press).

2. The blood samples were taken in the following contexts: sample 1 (1600 hours) when the subject arrived at the hospital and had the catheter placed in his arm; sample 2 (1730 hours) after a quiet period and a standard dinner, followed by the move, along with five other subjects, to the experimental room; sample 3 (1750 hours) after 20 minutes of (seated) social conversation; sample 4 (1820 hours) after the rules for the competition had been given and a short paper-and-pencil questionnaire completed; sample 5 (1840 hours) after puzzles one and two had been finished by the group; sample 6 (1900 hours) after

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puzzles three and four; sample 7 (1920 hours) after puzzles five and six; sample 8 (1940 hours) after puzzles seven and eight; sample 9 (2000 hours) after puzzles nine and ten; samples 10 and 11 (2020 hours) after a second questionnaire, some general discussion, and payment for participation. Sample 11 was used for the WBS assay.

3. The number of high WBS cases for each estimate in the epinephrine series is, in order: 3, 4, 4, 2, 3, 3, 3, 3, 3, and 3.

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