Some Physiologic Antecedents of Adult Mental Health

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The authors report on 188 healthy college men followed biennially from age 19 years to age 63. A relatively low standing heart rate and long treadmill running time in college predicted mental—but not physical—health during the next 40 years, whereas a relatively low blood pressure predicted future physical—but not mental—health. These relationships remained significant when the effects of physical fitness and body build were partialled out, suggesting that psychological components of physiologic phenomena accounted for their prediction of mental health outcome. The authors speculate that a high resting heart rate reflected social anxiety and prolonged running time reflected perseverance and stoicism.

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Attentive, my hand laid on the woman's wrist, I observed her pulse was irregular, suddenly violently agitated, which points to a troubled mind.

—Galen, cited by Mesulam and Perry (1)

In 1940, at the Harvard Fatigue Laboratory (an exercise physiology laboratory), 130 healthy college men participating in a study of normal young men (2) ran to near exhaustion on a treadmill and were carefully studied at rest. They had previously received a thorough physical examination. Because these men have been prospectively followed to age 63, they provide an opportunity to identify physiologic predictors of the mental and physical health of men over 40 years old.

Interest in heart rate as an index of psychological health dates back to at least the second century A.D., when Galen took a patient's pulse to diagnose emotional distress (1). The present study's original investigators noted that psychologically healthier college men tended to have slower heart rates (3). Since then, contemporary psychophysiologists have studied the significance of heart rate, largely in the laboratory, with a focus on short-term phasic changes induced by such stimuli as snake exposure (4), public speaking (5), and threat of shock (6). Large increases in heart rate are postulated not only to reflect psychological state but also to contribute to the development of cardiovascular disease (7). In a rare nonlaboratory study, Shaffer et al. (8) found that young adults with higher resting heart rates were more likely to develop subsequent mental illness and hypertension. Paffenbarger et al. also linked high resting heart rate in young adults with later hypertension (9) and coronary heart disease (10). However, the relationship of heart rate to mental and physical health is far from established, and the mediating factors remain unclear.

Blood pressure also interested our study's originators. They believed that, like heart rate, it reflected the emotions and might prove useful as a personality index. Since the start of our study, studies have linked high adolescent blood pressure with future hypertension (11), coronary heart disease (12), and stroke (13). Whether emotions, behavior, and personality traits play a role in this relationship has been widely studied (14) but, again, mainly in the laboratory and without conclusive results.

Finally, our study's originators speculated that a long treadmill running time measured willpower and perseverance. Such psychological factors are indeed thought to be among the determinants of aerobic performance (15). However, no study that we know of has assessed the relationship of physical endurance and related psychological factors to subsequent psychological or physical health.

In this paper we examine the relationship of heart rate, blood pressure, and running duration in college to later mental and physical health. We do so from a longitudinal perspective, with a sample and with study conditions that allowed many potentially confounding variables to be controlled.

METHOD

In 1940–1942 a university health service undertook an interdisciplinary study of 204 men from three sophomore classes (2). The health service and college deans had selected men who were without known academic, psychiatric, or physical health problems.

Physiologic studies were conducted in the Harvard

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Fatigue Laboratory (16). After various measurements were made in the basal state, the subjects did two grades of work on a motor-driven treadmill (1). The first consisted of a 15-minute walk at 3.5 mph on an 8.6% grade. After 7 to 10 minutes of rest following the walk, the men did maximal work by running on the treadmill on the same grade at 7.0 mph until exhausted or for a maximum of 5 minutes. Oxygen consumption was measured during both grades of work; maximal oxygen consumption was attained after 2 to 3 minutes of running.

All sophomore subjects received a thorough physical examination performed by the same physician (2). Complete anthropometric assessments were also done, including somatotype and a rating of body build along a masculine-feminine continuum (2). The men were also studied by psychologists and psychiatrists. A family worker interviewed each subject at college and his parents at their home.

For 40 years, the surviving men have been followed prospectively by biennial questionnaires and twice by interviews (at age 30 and at age 47 or ages 55–60). The present data, except where noted, are derived from the questionnaires and have been shown to be reliable.

By 1964, six men had withdrawn from the study, five had died in World War II combat, and five had died of other causes. This left 188 men for the study of mental health at midlife (17). Since then an additional 19 men have died, further reducing the sample size for later data analyses.

Antecedent Measures

College run duration (N=130). This was the duration of the fatigue laboratory treadmill run; the maximum was 300 seconds.

College physical fitness (N=66). The best objective measure of physical fitness is maximal oxygen consumption during exercise divided by body weight to adjust for differences in muscle mass (ml/kg per minute). Maximal oxygen consumption was measured during the treadmill run.

College standing heart rate (N=188). Heart rate (pulse) was obtained during the physical examination with the subject in a standing position as well as in a sitting and a recumbent position.

College diastolic blood pressure (N=198). Blood pressure was measured during the physical examination with the subject in a recumbent position.

College body build (N=188). With the aid of a standardized chart, subjects' body builds, photographed from the front, side, and rear, were classified on a 4-point scale on which 1=a strong, 2=a moderate, 3=a weak, and 4=a very weak masculine component.

Childhood (ages 0–18 years) environment (N=188). Each man's childhood was rated on a scale of 1 (bleak) to 20 (warm) by two research associates who were blind to all data gathered after the man was 19 years old. The scale is described in detail elsewhere (18) and was based on interviews with the parents and on psychiatric interviews with the sophomore men. (Rater reliability was .71.)

Outcome Measures

Except for estimates of psychological adjustment at age 29, these ratings were made by raters blind to previous ratings.

Psychological adjustment, ages 22–29 (N=111). Using all data from the previous 10 years, the staff reviewed each subject's history and assigned by consensus prognostic ratings for future personality stability. A rating of 1 indicated best stability, and 5 indicated worst stability.

Psychological adjustment, ages 30–47 (N=188). An adult adjustment scale, described in detail elsewhere (17, 19), was derived from earlier empirical work on the global mental health of each subject. The scale's range from 7 (best) to 16 (worst) was derived from the cumulative ratings of seven relatively objectively and longitudinally observed items. Five variables were scored 2 (true) or 1 (untrue): 1) little occupational advancement, 2) limited recreation with others, 3) less than 2 weeks' annual vacation, 4) more than 5 days' annual sick leave, and 5) earned annual income less than $20,000 (1968 dollars). Two variables were scored 3 (definite), 2 (ambiguous), or 1 (untrue): 1) marriage rated by self and wife as unhappy and 2) chronic job dissatisfaction.

Psychological adjustment, ages 48–63 (N=174). This scale was similar to that used for subjects at ages 30–47 except that the income item was replaced by retirement before age 65 (absence=1, partial=2, presence=3). Three items were added: 1) psychiatric visits since age 48 (2 points), 2) tranquilizer use since age 48 (2 points), and 3) a rater's estimate of "global adaptation to aging" (5 points).

Psychiatric visits (N=174). Number of visits to a psychiatrist from age 20 to age 63.

Sick days (N=177). Mean number of days of sick leave per year from age 20 to age 60.

Marital stability (N=181). Overall quality of marriage from age 20 to age 60 was assessed on the basis of questionnaire data gathered from the husband and wife on five occasions. A marriage rated 1 was relatively happy and of at least 25 years' duration; a marriage rated 4 ended in divorce without satisfactory remarriage.

Mood-altering drug use (N=188). Use of sleeping pills, tranquilizers, or amphetamines from age 30 to age 52 was assessed on a scale of 1–5: 1=no drug use and 5=hospitalization or socioeconomic damage due to drug use.

Physical health (N=188). Records of complete physical examinations were obtained in 1969, 1974, 1979, and 1984. These were rated by an internist kept blind to other study data. Almost 85% of the examinations included routine laboratory studies, ECG, and chest X-rays. The ratings were 1=excellent health (no

TABLE 1. Correlations[a] Between Adult Health and Childhood Environment and College Heart Rate, Run Duration, and Diastolic Blood Pressure

Adult Health	Childhood Environment[b] (N=188)[c]	College Heart Rate (N=184)[c]	College Run Duration (N=127)[c]	College Diastolic Blood Pressure (N=188)[c]
Psychological health				
Psychological adjustment				
Ages 20–29 years	–.44[d]	.21[e]	–.22[e]	.13[f]
Ages 30–47 years	–.31[d]	.27[d]	–.16[f]	.01
Ages 48–63 years	–.24[e]	.28[d]	–.14	.10
Psychiatric visits, ages 20–60 years	–.23[e]	.14[f]	–.29[e]	.01
Days sick, ages 20–60 years	–.17[f]	.14[f]	–.22[e]	.00
Marital stability, ages 20–60 years	–.13[f]	.10	–.18[f]	–.23[e]
Mood-altering drug use, ages 20–60 years	–.11	.17[f]	–.14	–.03
Physical health				
Age 40 years	–.04	.03	–.08	.12
Age 50 years	–.15[f]	.12	–.15[f]	.16[f]
Age 60 years	–.20[e]	.09	–.11	.16[f]

[a]Spearman rank-order correlation coefficients were used for calculations in which at least one variable had fewer than nine values; Pearson product-moment correlation coefficients were used for all others. Since low values for all health variables indicated health, the positive associations of mental and physical health with warm childhood and long running times are expressed as negative correlations.
[b]High score=warm; low score=bleak.
[c]Number varies by 10% on some correlations due to attrition by death as men grew older.
[d]$p<.001$.
[e]$p<.01$.
[f]$p<.05$.

irreversible pathology), 2=minor chronic problems, 3=irreversible serious illness without disability, 4=irreversible illness with disability, and 5=dead.

RESULTS

Table 1 shows that a relatively low college heart rate and long college running time predicted future mental—but not physical—health, whereas a relatively low college blood pressure predicted future physical—but not mental—health.

College heart rate (mean±SD=82±14 beats/minute, range=54–120 beats/minute) predicted mental health outcome nearly as well as did childhood environment, the study's most robust predictor variable. A high heart rate was associated with poor psychological adjustment from age 22 to age 63 and with several psychological components: psychiatric visits, sick days (a measure in this sample of mental rather than physical illness [3]), and use of tranquilizers, sleeping pills, and amphetamines.

A relatively long college running time (mean=239±67 seconds, range=93–300 seconds) also predicted future mental health. Unlike heart rate, running time did not predict psychological adjustment at midlife or mood-altering drug use, but it did predict stable marital commitment.

College diastolic blood pressure (mean=71±9 mm Hg, range=40–95 mm Hg) had a different correlation pattern: high diastolic pressure predicted deterioration of physical health but did not predict mental health outcome except for—surprisingly—a stable marriage. Run duration, heart rate, and childhood environment significantly intercorrelated with one another, whereas blood pressure correlated with none of these other antecedent variables.

To determine whether the *psychological* component of run duration and heart rate accounted for their predictive power, we computed partial correlations to control the potentially mediating variables of physical fitness and body build for run duration and physical fitness for heart rate. When physical fitness and body build (for the 60 subjects with available data) were controlled for in this way, eight of the 12 significant correlations in table 1 remained significant, including psychological adjustment at all ages with heart rate and at ages 30–47 with college run duration (despite a decrease of statistical power to .38 because of the reduced sample size). This suggests that it was the psychological component of run duration and heart rate that accounted for their prediction of mental health outcome.

DISCUSSION

Our finding that men with a higher standing heart rate at age 19 were not as psychologically "sound" in college ($r=.25$, $N=184$, $p<.001$) or during the next 40 years concurs with the observation of Shaffer et al. (8) in the only other longitudinal study that has assessed the predictive value of heart rate for later mental health. The correlations in table 1 of .11 to .39 should not be viewed as trivial. An exhaustive review of correlations between personality variables observed across 20 years or more (20) revealed that correlations of .3 are as high as are commonly observed.

Factors influencing heart rate in healthy people are age, sex, sleep, body position, muscular activity, physical fitness, and emotional arousal (21). The first five factors were held constant by virtue of our study design and homogeneous sample. When the sixth factor, physical fitness, was controlled for, most correlations of heart rate with outcome variables remained significant. Thus, in this study, emotional arousal—the remaining factor—may account for the association of heart rate with mental health outcome.

Although heart rate can increase in response to many different stimuli and emotional states (22), we speculate that in the setting of a physical examination, which required close interaction and physical contact with another person, emotional arousal reflected social anxiety. Socially anxious adults have a larger increase in heart rate during social interactions than those who are not socially anxious (23), and socially inhibited children have a higher resting heart rate than socially uninhibited children (24).

Astrand and Rodahl (15) described five factors that influence the ability to perform sustained physical work such as treadmill running: 1) nature of the work (e.g., intensity and technique), 2) environment (e.g., altitude and ambient temperature), 3) somatic factors (e.g., sex and body build), 4) physical fitness, and 5) psychological factors (motivation and attitude). In our study, sex, nature of the work, and environment were held constant by the study design and laboratory conditions. Partialling out physical fitness and body build had little effect on the correlation of running time with the mental health outcome variables. Thus, again, psychological factors—the only remaining variable—seems the most logical explanatory variable. Indeed, Astrand and Rodahl stated that "physical performance is to a significant extent a function of psychological factors, notably motivation, attitude to work, and the will to mobilize one's resources for the accomplishment of the task in question" (p. 451). For patients with chronic bronchitis, positive attitudes were more important than pulmonary function tests in predicting aerobic exercise tolerance (15). However, we do not conclude that physical fitness is irrelevant to physical and mental health. Rather, we conclude that in this sample, selected without reference to athletic ability or physical fitness, psychological factors were the important factor.

Astrand and Rodahl's "motivation," "attitude," and "will" require more precise definition. We speculate that such terms may reflect suppression, the ego mechanism of defense most powerfully correlated with multiple facets of mental health in previous studies of these men (25) and inner-city men (19, 25). In these studies, suppression was defined as the conscious or semiconscious decision to postpone paying attention to a conscious impulse or conflict, minimizing but not denying discomfort and anxiety, looking for silver linings, and employing a stiff upper lip—in short, being stoical and persevering (26). The study of adult development by Terman and Oden (27) also suggested that suppression in adolescence was important to mental health and vocational success at age 50. We suspect but cannot prove that perseverance, stoicism, and suppression reflect facets of a common trait. In our study, the use of suppression from age 20 to age 47 (assessed on a 4-point scale) correlated at .22 ($N=127$, $p<.01$) with duration of the treadmill run. It also correlated at $-.25$ ($N=183$, $p<.001$) with college heart rate. Although some studies have linked suppression of anger and hostility with higher blood pressure, others have not (14, 28); we found that suppression did not correlate with diastolic blood pressure ($r=.06$, $N=187$).

Because so many disparate influences and discontinuities exist in the life span, it is notable that two physiologic variables—heart rate and running duration—studied in late adolescence should have predicted future mental health nearly as well as did childhood environment, the most robust predictor. As Baldwin (29) has written, "Longitudinal studies seem to have gambled on the existence of clear developmental trends that would shine through the welter of influences of uncontrolled events." It is gratifying to find that such trends do exist.

REFERENCES

1. Mesulam M, Perry J: The diagnosis of love-sickness: experimental psychophysiology without the polygraph. Psychophysiology 1972; 9:546–551
2. Heath CW: What People Are: A Study of Normal Young Men. Cambridge, Harvard University Press, 1945
3. Hooton E: Young Man, You Are Normal. New York, GP Putnam's Sons, 1945
4. Lang PJ, Levin DN, Miller, GA, et al: Fear behavior, fear imagery, and the psychophysiology of emotion: the problem of affective response integration. J Abnorm Psychol 1983; 92: 276–306
5. Knight ML, Borden RJ: Autonomic and affective reactions of high and low socially-anxious individuals awaiting public performances. Psychophysiology 1979; 16:209–213
6. Hodges WF, Spielberger CD: The effects of threat of shock on heart rate for subjects who differ in manifest anxiety and fear of shock. Psychophysiology 1966; 2:287–294
7. Lovallo WR, Picomb GA, Wilson MF: Heart rate reactivity and Type A behavior as modifiers of physiological response to active and passive coping. Psychophysiology 1986; 23:105–112
8. Shaffer JW, Duszynski KR, Thomas CB: A multivariate analysis of circulatory data and their relationship to later disease. J Chronic Dis 1983; 36:869–877
9. Paffenbarger RS, Thorne MC, Wing AL: Chronic disease in former college students, VIII: characteristics in youth predisposing to hypertension in later years. Am J Epidemiol 1968; 88:25–32
10. Gillum RF, Paffenbarger RS: Chronic disease in former college students, XVII: sociocultural mobility as a precursor of coronary heart disease and hypertension. Am J Epidemiol 1978; 108:289–298
11. Oberman A, Lane NE, Harlan WR, et al: Trends in systolic blood pressure in a 1000 aviator cohort over a 24 year period. Circulation 1967; 36:812–822
12. Thorne MC, Wing AL, Paffenbarger RS: Chronic disease in former college students, VII: early precursors of nonfatal coronary heart disease. Am J Epidemiol 1968; 87:520–529
13. Kannel WB, Wolf PA, Verter J, et al: Epidemiologic assessment of the role of blood pressure in stroke: the Framingham Study. JAMA 1970; 214:301–310
14. Waal-Manning HJ, Knight RJ, Spears GF, et al: The relationship between blood pressure and personality in a large unselected adult sample. J Psychosom Res 1986; 30:316–368

15. Astrand P, Rodahl K: Textbook of Work Physiology: Physiological Bases of Exercise. New York, McGraw-Hill, 1977
16. Horvath SM, Horvath EC: Harvard Fatigue Laboratory: Its History and Contributions. Englewood Cliffs, NJ, Prentice-Hall, 1973
17. Vaillant GE: Natural history of male psychological health, VII: effects of mental health on physical health. N Eng J Med 1979; 67:1249–1254
18. Vaillant GE: Natural history of male psychological health, II: some antecedents of healthy adult adjustment. Arch Gen Psychiatry 1974; 31:15–22
19. Vaillant GE: Adaptation to Life. Boston, Little, Brown, 1977
20. Kohlberg L, LaCrosse J, Ricks D: The predictability of adult mental health from childhood behavior, in Manual of Child Psychopathology. Edited by Wohlman BB. New York, McGraw-Hill, 1972
21. Berne RM, Levy MN (eds): Physiology. St Louis, CV Mosby, 1983
22. Schwartz GS, Weinberger DA, Singer JA: Cardiovascular differentiation of happiness, anger, and fear following imagery and exercise. Psychosom Med 1981; 43:343–364
23. Beidel DC, Turner SM, Dancu CV: Physiological, cognitive, and behavioral aspects of social anxiety. Behav Res Ther 1985; 23: 109–117
24. Kagan J, Reznick JS, Clarke C, et al: Effect of attitudes and beliefs on exercise tolerance in chronic bronchitis. Br Med J 1983; 286:171–173
25. Vaillant GE, Drake RE: Maturity of ego defenses in relation to personality disorders. Arch Gen Psychiatry 1985; 54:597–601
26. Vaillant GE: Theoretical hierarchy of adaptive ego mechanisms. Arch Gen Psychiatry 1971; 24:107–118
27. Terman LM, Oden MH: The Gifted Group at Mid-Life. Stanford, Calif., Stanford University Press, 1959
28. Julius M, Harburg E, Cottington E, et al: Anger-coping types, blood pressure, and all-cause mortality: a follow-up in Tecumseh, Michigan (1971–1983). Am J Epidemiol 1986: 124:220–223
29. Baldwin AL: The study of child behavior and development, in Handbook of Research Methods in Child Development. Edited by Mussen PH. New York, John Wiley & Sons, 1960

Change of Address for American Board of Psychiatry and Neurology

As of June 15, 1987, the address and telephone number of the American Board of Psychiatry and Neurology were changed to the following:

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