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Testosterone levels as modifiers of psychometric *g*

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Abstract

In large samples of American armed forces veterans, those below the first percentile and above the 99th percentile in serum testosterone level show significantly and considerably lower *g* factor scores derived from a battery of 19 diverse psychometric variables. Between these extremes of testosterone level, however, there is little relationship between testosterone and psychometric *g*. Factors orthogonal to *g* were also affected only at the extremes of testosterone level. © 2000 Elsevier Science Ltd. All rights reserved.

1. Introduction

Endocrinology is becoming a prominent aspect of the psychobiology of personality and other dimensions of individual differences in human behavior. Studies of behavioral correlates of various hormones have shown that individual differences in testosterone levels (and the testosterone/estrogen balance) are correlated not only with a number of physical variables, but also with a variety of personality factors and socially significant types of behavior, reviewed extensively elsewhere (Dabbs & Morris, 1990; Nyborg, 1994, 1997). More is known about its relation to personality, socialization and educational and occupational attainments than about its strictly cognitive correlates. Christiansen and Knussmann (1987) have reported that in adults higher levels of testosterone are related to higher verbal ability than spatial ability. On the other hand, Geschwind and Behan (1984) have claimed that higher levels of fetal

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testosterone enhance right-brain development, thereby causing relatively higher spatial than verbal ability. These claims are puzzling if one assumes that there is a positive correlation between fetal and adult testosterone levels. However, it is just as likely that the apparent contradiction results from the fact that all cognitive tests are loaded to some extent on a general factor, or *g* (Jensen, 1998) and, although verbal tests typically have higher *g* loadings than spatial tests, the reverse may also be true, depending on the particular tests. Therefore it is necessary to investigate the relationship of testosterone to psychometric *factors*, particularly the *g* factor, rather than merely scores on specific tests or on IQ scales that are an arbitrary unit-weighted composite of subtests that reflect a number of different factors.

The present study, therefore, examines the relationship between testosterone and factor scores for three orthogonal factors, including *g*, derived from a battery of 19 psychometric measures of diverse cognitive abilities.

2. Method

2.1. Subjects

The subject samples are the same as the 3535 white (W) and 502 black (B) US military veterans described in this journal (Nyborg & Jensen, in press).

2.2. Psychometric variables

The tests yielding these 19 experimentally independent psychometric variables and the factor scores derived from a principal components analysis (best described as *g*, visual–spatial memory and motor speed and dexterity) are described by Nyborg and Jensen (in press).

2.3. Testosterone measure

These measurements were obtained in 1985/86, when subjects averaged 38.1 yr of age. Blood specimens were taken in the morning before breakfast, following an overnight fast commencing at 7 p.m. Plasma testosterone concentration was determined (in ng/dl, or ng/100 ml) using a standard double antibody radioimmunoassay system (Leeco Diagnostics, Inc) and monitored with bench and blind repeat quality control procedures. As the Vietnam and non-Vietnam veterans did not differ in testosterone concentration, their data were pooled.

In the present study, the total log-normalized distribution of individual testosterone concentrations was converted to a scale of seven categorical *androtypes* labeled (from lowest to highest) A0 through A6. A0 is the lowest one percent of the total distribution (i.e. 1st percentile and below); A6 is the highest 1% (i.e. 99th percentile and above). The remaining subjects were assigned to five nearly equal-sized categories (A1 through A5). The androtypes, rather than the plasma concentrations of testosterone, were used in the subsequent analyses. The numbers of Ws and Bs of each androtype are shown in Table 1.

Table 1
Number of subjects in each androtype

Group	Androtypes						
	A0	A1	A2	A3	A4	A5	A6
White	34	695	700	695	695	700	37
Black	5	85	101	89	96	116	10

3. Results

In all analyses the data were statistically adjusted for age and test–retest interval by regression or covariance analysis.

3.1. B and W testosterone concentrations

The mean and S.D. (in parentheses) of the basic testosterone measures (in ng/dl) for the B and W samples, respectively, are 701.43 (248.45) and 675.96 (230.48), which, in average within-group S.D. units, amounts to only 0.11 S.D. but is statistically significant ($t = 2.43$, $p < 0.015$).

3.2. General factor (g)

The means of g factor scores (scaled with overall mean = 0, S.D. = 1) for each androtype in the W and B samples are shown in Fig. 1. The main effects of the W–B difference and the mean differences between androtypes in g factor scores are both significant [$F(1, 4042) = 211.51$, $p < 0.000$ and $F(6, 4042) = 2.49$, $p < 0.02$, respectively]. The race × androtype interaction effect is nonsignificant ($F < 1$).

In the present research based on very large samples and in which almost every statistic is significant beyond the 0.05 level of confidence, the measurement of 'effect size' is most important. The proper measure of effect size in the present analyses is the coefficients of nonlinear correlation (η) between all seven androtypes (A0–A6) and g factor scores (based on PC1), separately for the W and B samples. The values of η are shown in Table 2; also shown are the η values when the extreme androtypes (A0 and A6) are excluded, i.e. only for androtypes A1–A5. (Note: η^2 is the proportion of the total variance in the given factor scores accounted for by the variation in androtypes.)

3.3. Factors orthogonal to g

Table 2 also shows the values of η obtained for factor scores based on the remaining significant orthogonal principal components PC2 and PC3 in this test battery. Figs 2 and 3 show the mean factor scores as a function of androtypes for the W and B samples, respectively.

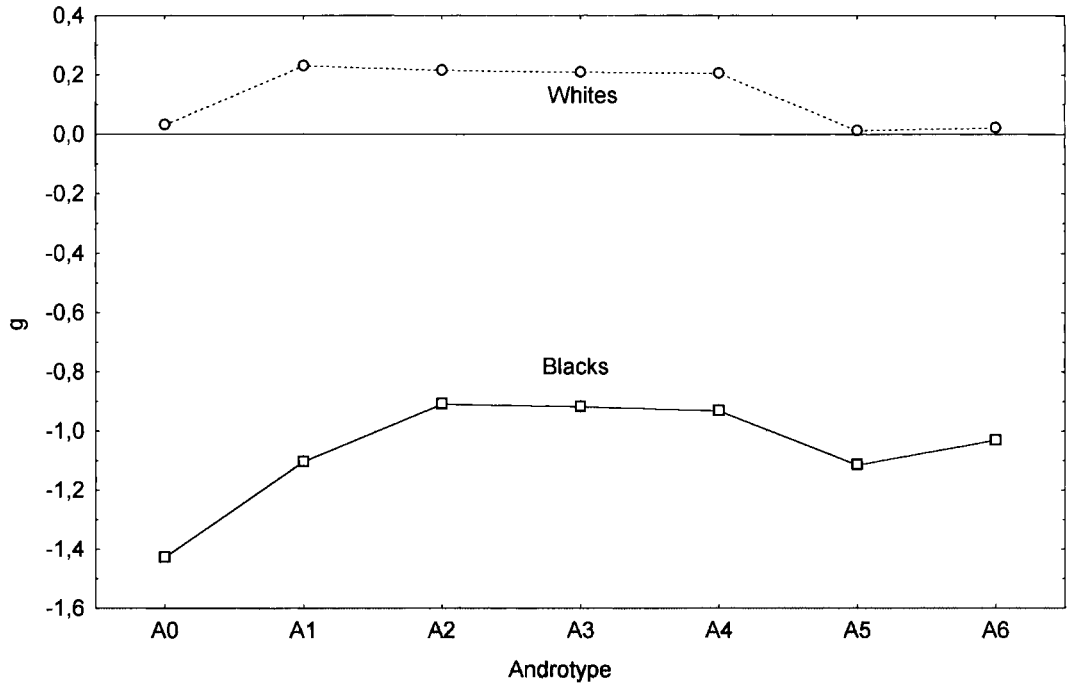

Fig. 1. Mean g factor scores (standardized in total sample to mean = 0, S.D. = 1) as a function of androtypes, from lowest (A0) to highest (A6), for white and black samples.

4. Discussion

The results indicate that the effects of testosterone on mental abilities is undoubtedly real, but is quite limited, accounting overall for between one to two percent of the total variance in ability factors in the present samples. The general effect size of testosterone, as indicated by η, the coefficient of nonlinear correlation is very small. However, this does not negate the fact

Table 2
Nonlinear correlation coefficient (η) between androtypes and factor scores for PC1 (g), PC2 and PC3 in white (W) and black (B) samples for androtypes A0–A6 and A1–A5

Factor Scores	Androtypes			
	A0–A6		A1–A5	
	W	B	W	B
PC1 (g)	0.089, $p < 0.00$	0.125, $p < 0.26$	0.087, $p < 0.00$	0.114, $p < 0.16$
PC2 (spatial memory)	0.045, $p < 0.31$	0.136, $p < 0.16$	0.033, $p < 0.44$	0.084, $p < 0.49$
PC3 (motor speed)	0.067, $p < 0.02$	0.117, $p < 0.34$	0.054, $p < 0.04$	0.083, $p < 0.51$

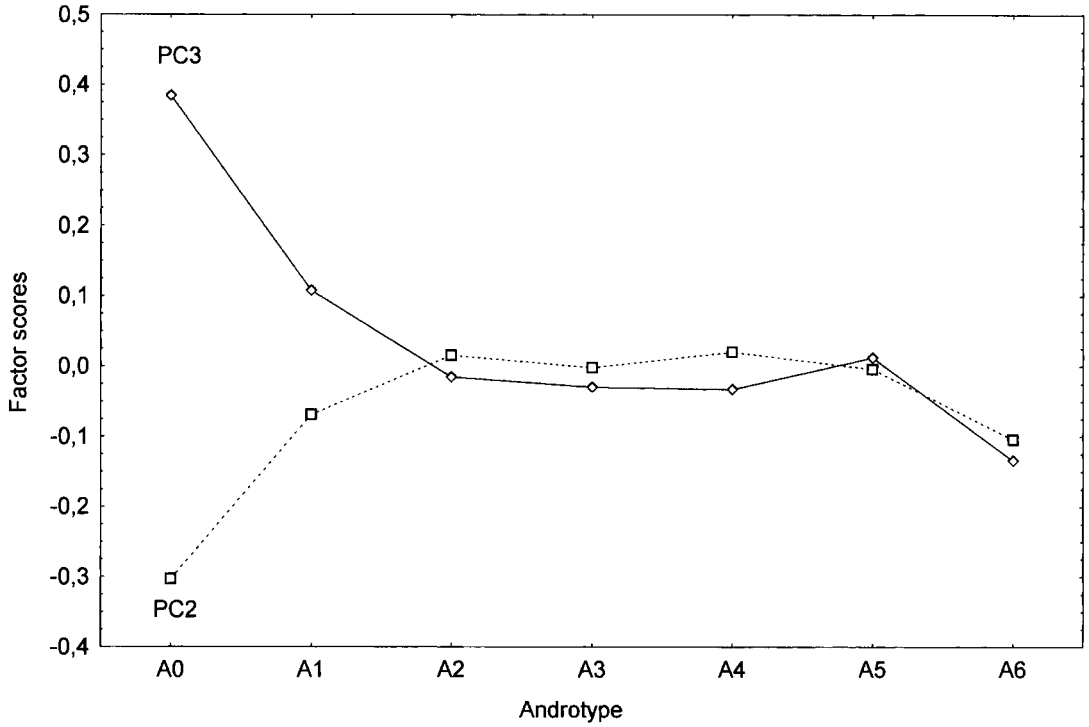

Fig. 2. Mean factor scores of white sample on second and third principal components (PC2 and PC3), standardized in total sample to mean = 0, S.D. = 1.

that groups at the extremes of testosterone level — below the 1st percentile and above the 99th — show rather marked effects.

On the *g* factor, for testosterone levels below the 1st percentile (group A0) the *g* factor scores are lowered 0.143σ in the W sample and 0.429σ in the B sample, relative to the average level of *g* for androtypes between the 1st and 99th percentiles (i.e. androtypes A1–A5). These sigma decrements are roughly equivalent to IQ decrements of 2.1 and 6.4, respectively. At the 99th percentile (A6) the average decrement in *g* factor scores amounts to 0.153σ for Ws and 0.033σ for Bs, corresponding to IQ decrements of 2.3 and 0.2, respectively.

The two significant factors besides *g* are not as clearly defined in the present factor analysis, but they are best characterized as spatial memory (PC2) and motor speed and agility (PC3). In group A0, the PC2 factor scores are lowered by about 0.30 for Ws and about 1.20 for Bs, equivalent on an IQ scale to 5 and 18 points, respectively. For PC3, testosterone has opposite effects for Ws and Bs in group A0, raising W performance by about 0.4σ and lowering B performance by about 0.7σ. These opposite effects in the W and B groups are puzzling and remain unexplained. Considering the relatively small numbers in this extreme group, however, this finding could be a fluke. A high level of testosterone (A6) has small and nondescript effects on PC2 and PC3.

For none of the three factors does it appear that testosterone level accounts for any appreciable degree of the mean W–B differences on these factors. For *g* factor scores, the

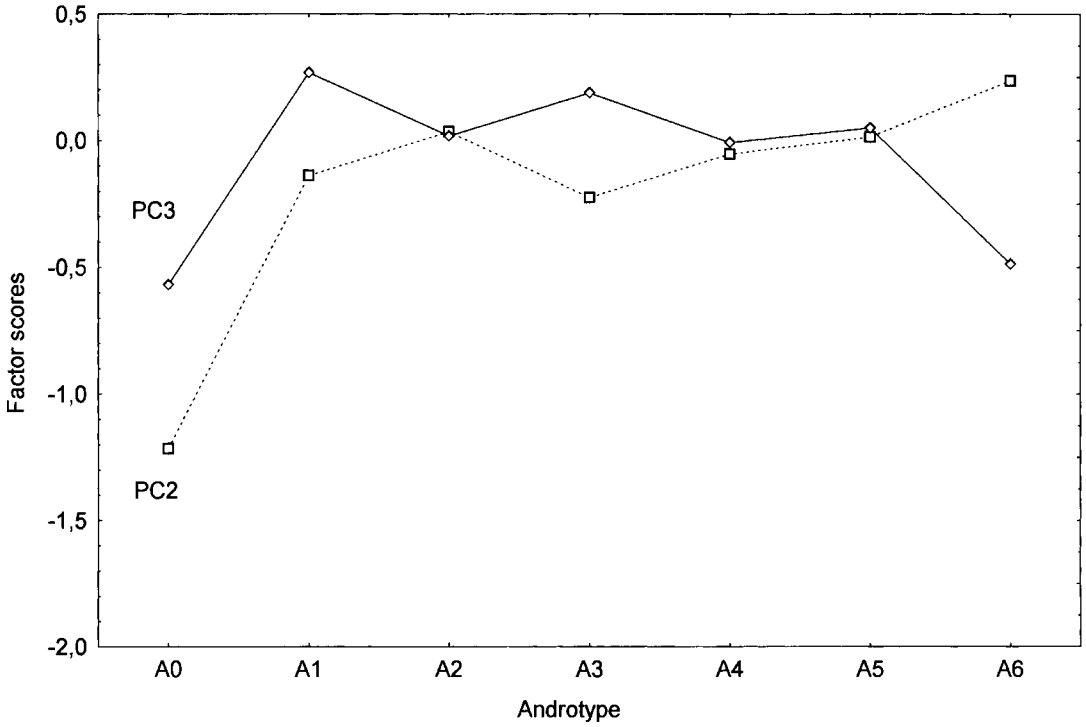

Fig. 3. Mean factor scores of black sample on second and third principal components (PC2 and PC3), standardized in total sample to mean = 0, S.D. = 1.

interaction between testosterone levels (androtypes) and race was nonsignificant. The overall within-groups effects of testosterone are too small to warrant hypothesizing that the mean B–W difference of 0.11σ in testosterone levels, though significant, explains any appreciable part of the large mean W–B difference of 1.17σ in *g* factor scores. Also, very close to 1 percent of both the W (0.96%) and B samples (1.00%) fall into group A0, which has the largest effects on all of the psychometric factors, while 1.04% of the W sample and 1.99% of the B sample fall into group A6, which has a relatively weak effect on the psychometric factors.

The direction of causality is not established, but it seems most unlikely that psychometric factors have any direct effect on testosterone. It is more likely that the observed effects are either a direct cause of extreme testosterone levels or that some third influence, as yet not identified, affects both testosterone levels and test performance.

Finally, we must agree with the statement by Dabbs and Morris (1990) in their study of the effects of testosterone levels on antisocial behavior, that "the effects reported in the present paper are relatively small in size and account for appreciable variance only at the extreme levels of testosterone" (p. 211). Though the observed effects show up as statistically significant in the present immense samples, it is unlikely they could have been detected at a significant level in even moderate sized samples. Such statistical findings, though practically useless for the prediction or explanation of the behavior of individuals, may have explanatory value for epidemiological and demographic differences observed between large subpopulations. The

results are of theoretical interest in showing that individual differences in the blood concentration of testosterone have some modifying effect on mental abilities. It is likely that other hormones also might act as moderators of cognitive variables, manifested as linear or nonlinear effects on psychometric performance.

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