Diet and Urinary Steroids in Black and White North American Men and
Black South African Men

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ABSTRACT

Urinary steroid hormone content was determined in Black and White North American men and in rural Black South African men between 40 and 55 years of age and in Black South African men over 60 years of age when maintained on their customary diets or when transferred to a vegetarian or Western diet, respectively. When eating their customary diets, Black South African men had lower levels of urinary estrogens and androgens than did Black and White North American men.

The total androgen and estrogen content decreased significantly in Black North American men on the vegetarian diet and increased in Black South African men fed a Western diet.

Urinary excretion of estrogens was higher in older than in younger rural Black South African men.

Data indicated that a vegetarian diet modified androgen and estrogen metabolism in North American men and that a Western diet was associated with higher levels of urinary steroid hormones in young Black South African men. Diet-related changes in steroid metabolism in rural Black South African men were age dependent.

The relationship of the increased urinary excretion of steroid hormones in Black South African men, a low-risk group fed a Western diet, and the decreased excretion in Black and White North American men, high-risk groups fed a vegetarian diet, to the development of prostate cancer remains to be clarified.

INTRODUCTION

Higher death rates from prostatic cancer have been reported in Western versus African or Asian societies (24, 30). Thus, Black and White North American men have comparable high death rates while Black South African men have a markedly lower death rate from prostatic cancer. The causative factors of this disease are unclear, but high- and low-risk populations can be separated by geographical location and race.

Epidemiological research (60) and studies of migrants (17, 55) have implicated environmental factors possibly of a dietary nature to be associated with this disease. Such factors may activate small latent lesions which occur at a constant frequency in all geographical areas but which appear to progress to active lesions mainly in Western societies (5, 7). For example, a higher prevalence of the proliferative type of latent carcinoma has been reported in Hawaiian versus native-born Japanese men (2).

Clinically, this disease is endocrine dependent (14) with a lower excretion of 17-ketosteroids and a change in estrogen metabolism occurring in men with prostatic cancer (38, 39).

Despite extensive studies of hormone levels in White men (15, 33), few comparative studies of the hormonal status of men at different risk for this disease have been reported (1) while the effect of diet modification on the hormonal status in healthy men has not been reported.

This investigation reports the hormonal status in healthy Black South African men, a low-risk group, and in Black and White North American men, high-risk groups, for prostatic cancer and the effect of a Western diet on the hormonal status in the Black South African men and a vegetarian diet on the hormonal status in the North American men. Comparison of the effect of a Western diet on urinary steroid hormone levels in young and old Black South African men is reported also.

MATERIALS AND METHODS

Subjects. Nonobese, physically active, rural Black South African men and urban Black and White North American men between 40 and 55 years of age and rural Black South African men between 60 and 73 years of age were selected. All subjects were in generally good health; had no overt endocrine abnormalities or diabetes mellitus; were free from thyroid, renal, and coronary heart disease; and had no history of alcoholism. Black South African men showed no signs of gynecomastia and had normal plasma serum levels of glutamic-oxaloacetic transaminase.

North American men were hospital staff while Black South African men were recruited from rural areas of the Transkei in South Africa.

Diet Modification. Rural Black South African men, young and old, who customarily maintained a vegetarian diet consisting of a few staple plant foods (35, 36) were fed a Western diet for 3 weeks. The diet, which was fed in a cafeteria as 3 meals per day using measured portions, supplied 40% fat with 70% of the protein arising from animal sources. The food was well received. All meals were eaten inasmuch as failure to be present at a meal canceled participation in the program.

North American men who were eating a customary Western diet as determined by two 3-day dietary records were requested to eat a prescribed Western diet for 2 weeks.

This diet, which contained customary foods, was given as detailed daily menus and supplied 40% of the calories from fat with a polyunsaturated:saturated ratio of 0.35 (26). This diet was given to standardize the food of the subjects. North American men were requested then to eat a vegetarian diet for 3 weeks which contained no meat or meat products and which provided approximately 30% of the daily calories from fat. The Western and vegetarian diets were isocaloric supplying 2800 calories per day. Good compliance was obtained from these subjects who were well informed of the purpose of the study.
Informed consent was obtained from North American subjects while the study was thoroughly explained by a physician and an African fieldworker to the South African men before they agreed to join.

**Sample Collection.** Twenty-four-hr urine samples were collected during both diet periods, and a 100-mI sample was frozen and sent by airmail to the American Health Foundation in New York.

**Hormone Assay.** The urine was adjusted to pH 5.4. Duplicate 1-ml samples of urine were digested for 24 hr at 37°C in a Dubnoff water bath with 0.2 ml of glucilase (Endo Laboratories, Inc., Garden City, N. Y.) which contained 47.8 units of sulfatase and 1455 units of β-glucuronidase. Preliminary hydrolysis of labeled steroid glucuronides and sulfates indicated a greater than 90% hydrolysis with this procedure while the variation between assays of 24-hr urine collections was approximately 10%.

Urinary DHAS was measured by radioimmunoassay using dextran-coated charcoal with antisera supplied by Pantex, Calif. The sensitivity for DHAS between 50 and 300 ng/ml was 50 ng/ml with an intraassay variation of 8%. Androsterone and ET were determined by radioimmunoassay using specific antisera (Inter Science Institute, Calif.). The sensitivity for androsterone and ET between 50 and 500 pg/ml was 50 pg/ml with intraassay variations of 10 and 12%, respectively. Testosterone was determined by radioimmunoassay as described by Furuya et al. (16).

Estriol was assayed by a double-antibody precipitation method (NMS, Calif.). The sensitivity for estriol between 2 and 30 ng/ml was 2 ng/ml with an intraassay variation of 10%. Estrone and estradiol were assayed after separation on Sephadex LH 20 using cytosol protein binding (43). The sensitivity of the assay was 5 pg/ml with an interassay variation of less than 5%. Recovery of estradiol was 84 to 87% and of estrone was 95%. No change in urinary steroid has been reported to occur when samples are maintained at — 16°C (31).

Statistical differences between urinary hormone levels of men on the 2 diets were compared by Student's paired t-test and between ethnic groups by the t-test.

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3 The abbreviations used are: DHAS, dehydroepiandrosterone sulfate; ET, etiocholanolone.
et, and DHAS tended to decrease to a greater degree in Black versus White men (Chart 1).

With regard to estrogen levels, excretion of estrone and estradiol was increased in South African men (Chart 3). In North American men fed a vegetarian diet, significantly less estradiol and estrone were excreted in Black versus White men.

Thus, in Black South African men fed a Western diet, an increased excretion of both androgens and estrogens occurred (Chart 2), while the opposite trend was evident in Black North American men fed a vegetarian diet.

In older Black South African men, a Western diet decreased the total excretion of estrogens and androgens with diminished estradiol, estrone, estriol, and ET levels (Table 2).

DISCUSSION

Urinary excretion of androgens and estrogens in North American men was significantly greater than in rural Black South African men maintained on their customary diets. Clifford and Bulbrook (9) and Edozien (13) have reported higher levels of urinary 17-oxogenic steroids in Europeans versus Africans while Vestergaard (59) reported a lower androsterone:ET ratio in Jamaican versus American men. Differences in urinary excretion between races are not restricted to men since Bulbrook et al. (8) reported a higher androsterone:ET ratio in Japanese versus British women.

Concerning the comparison of Black South African (Bantu) men with Black North American men, the Bantu following successive migrations from the North settled in the Transkei in South Africa while other groups migrated to the western areas of Africa. Consequently, Black North and South African men arise initially from a common ethnic group. In the rural areas of the Transkei, Bantu eat from weaning a vegetarian diet which is composed mainly of maize and seasonal vegetables and fruits. This diet provides less than 20% fat calories with protein arising predominantly from plant sources (Table 3).

Consequently, feeding a Western diet to Black South African men involved several dietary changes such as increase in fat calories, change of protein source, complex to simple carbohydrates, and decrease in fiber content, all of which may alter hormonal metabolism either directly (40, 45) or indirectly through the enterohepatic circulation (25).

In addition, studies of Japanese migrants to Hawaii have implied that environmental factors of a dietary nature alter estrogen metabolism (10) while Hayward et al. (20) have reported changes in androgen metabolism in Japanese women migrating to Hawaii. Furthermore, several studies have shown a direct effect of diet or fasting on hormonal status (23, 27, 42, 57) and physical activity (32, 56), changes in steroid metabolism occurring during diet modification could not be ascribed to these factors.

Men in this study apart from being well nourished and in generally good health did not change their lifestyle, body weight, or physical activity during the study. The increased excretion of androgens and estrogens in Black South African men fed a Western diet and the decreased

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**Table 2**

<table>
<thead>
<tr>
<th>Steroids in North American and South African Men</th>
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</thead>
<tbody>
<tr>
<td>Customary diet (13 subjects) Western diet</td>
</tr>
<tr>
<td>Total estrogens (μg/24 hr)</td>
</tr>
<tr>
<td>Estradiol (μg/24 hr)</td>
</tr>
<tr>
<td>Estrone (μg/24 hr)</td>
</tr>
<tr>
<td>Estriol (μg/24 hr)</td>
</tr>
<tr>
<td>Total androgens (mg/24 hr)</td>
</tr>
<tr>
<td>Androsterone (mg/24 hr)</td>
</tr>
<tr>
<td>ET (mg/24 hr)</td>
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</tbody>
</table>

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<table>
<thead>
<tr>
<th></th>
<th>Customary</th>
<th>Western</th>
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<tbody>
<tr>
<td></td>
<td>Mean ± S.E.</td>
<td>Mean ± S.E.</td>
</tr>
<tr>
<td>---</td>
<td>-------------</td>
<td>-------------</td>
</tr>
<tr>
<td>Total estrogens</td>
<td>14.39 ± 1.44</td>
<td>7.91 ± 1.79</td>
</tr>
<tr>
<td>Estradiol</td>
<td>1.19 ± 0.15</td>
<td>0.76 ± 0.05</td>
</tr>
<tr>
<td>Estrone</td>
<td>4.77 ± 0.80</td>
<td>2.43 ± 0.28</td>
</tr>
<tr>
<td>Estriol</td>
<td>8.42 ± 0.90</td>
<td>4.72 ± 0.67</td>
</tr>
<tr>
<td>Total androgens</td>
<td>2.36 ± 0.37</td>
<td>1.42 ± 1.2</td>
</tr>
<tr>
<td>Androsterone</td>
<td>0.86 ± 0.15</td>
<td>0.60 ± 0.10</td>
</tr>
<tr>
<td>ET</td>
<td>0.90 ± 0.12</td>
<td>0.49 ± 0.05</td>
</tr>
</tbody>
</table>

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* a Mean ± S.E.  
* b p < 0.01  
* c p < 0.05  
* d Androsterone, ET, and DHAS.
estrogen and androgen excretion in North American men especially Black men indicate that diet alters markedly the hormonal status in healthy men. Whether the more evident change in urinary steroids in Black versus White North American men is related to genetic differences and/or dietary factors is unclear.

Studies of clearance rates and interconversion of steroid hormones in men (4, 33, 34) have shown that estradiol is derived from testosterone and that estrone is derived from androstenedione with little conversion of androstenedione to testosterone. Testosterone is synthesized by the testes and adrenals (44, 50) while estradiol may be synthesized by the testes (3, 11) and adrenals (12) also. Consequently, the composition and concentration of urinary steroid hormones represent a number of pathways of steroid metabolism.

In this study, the urinary androsterone:ET ratio in North American men was 1.83 for Black men and 1.73 for White men which is comparable to previously published data (37, 38, 52, 59). However, the androsterone:ET ratio was lower in Black South African men of comparable age (Table 1).

Many factors such as age (61), thyroid activity (53), or coronary heart disease (47) alter the androsterone:ET ratio. However, in healthy men, changes in this ratio reflect changes in dehydroepiandrosterone, androstenedione, and testosterone metabolism (22, 61) which appear to differ between Black South African men and North American men.

In Western men, the majority of the urinary estrogens occurred as conjugates of estrone (51) while in the Black South African men, estradiol was the major urinary estrogen.

The estrone:androsterone ratio, 2.0 × 10^-3 for White North American men, was comparable to that reported by Marmorston et al. (39), but it was higher in Black South African men (Table 1). Thus, comparison of the contents of urinary estrogens estrone, estradiol, and estril to androgens DHAS, androsterone, ET, and testosterone indicated proportionally greater excretion of androgens in White North American versus Black South African men.

The increase in urinary steroids in Black South African men on the Western diet indicated that unknown components in a Western diet are able to increase the urinary levels of estrogens and androgens in young men.

Lack of change in urinary DHAS levels suggested that diet modification in Black South African men as well as in North American men appeared to have little effect on adrenal activity. Metcalf and Cowles (41) have reported about 52.8% reduction in urinary androsterone and ET in men given dexamethasone indicating that approximately 50% of urinary androsterone and ET must arise from testicular androgens. Consequently, in North American men fed a vegetarian diet or Black South African men fed a Western diet, respectively, evidence would suggest that dietary factors are modifying primarily testicular activity.

In Western men, plasma testosterone decreases after the fifth decade (29) while plasma estradiol and estrone increase (46). Urinary excretion of estrogens (51) and androgens decreases with a decrease in the androsterone:ET ratio (53, 61).

The exact nature of these age-related changes is unclear. Changes in steroid hormone conjugation (58), decreased sulfatase activity (48), and/or levels of sex-binding globulins could in part explain different plasma steroid hormone levels.

Comparison of 40- to 55-year-old Black South African men with those over 60 years old (mean age, 66 ± 2 years) showed an increase in urinary estrogen excretion with age, 10.68 ± 1.10 to 14.39 ± 1.44 μg/24 hr, while no significant change occurred in the total androgen excretion.

Interestingly, in the older group of men, a Western diet decreased the total estrogen and androgen excretion (Table 2) with a significant decrease occurring in estradiol, estrone, estriol, and ET.

These changes which are opposite to those found in younger Black South African men indicate that the effect of environmental factors on plasma hormones varies depending on age.

It should be noted that Bersohn and Oelofse (6), who reported differences in estrogen metabolism in Black South African (Bantu) men previously, have commented, "European subjects when habituated to the 'Bantu type diet' show an estrogen pattern very similar to that of the Bantu."

Since prostatic cancer occurs predominantly in men after 60 years of age at a time when hormonal activity is in a state of flux, differences in organ site synthesis, testes, and adrenals or peripheral conversion could activate latent prostatic lesions.

Despite the markedly higher incidence of prostatic cancer in White than Black South African men, the incidence of latent lesions is comparable (5).

Although few changes in the overall excretion of androgens and estrogens in prostatic-cancer patients have been reported, Marmorston et al. (38, 39) have reported a decrease in androsterone and an increase in estradiol excretion in patients. Hellman et al. (21) reported a lower androsterone:ET ratio in patients together with a lower plasma testosterone level which increased with clinical improvement. However, no definitive change appears to be evident in plasma steroid levels in patients with prostatic cancer (18, 19). The higher rate of excretion of estrogens in older versus younger Black South African men together with the decreased rate of excretion of estrogens in older Black men fed a Western diet implies a difference in estrogen profile which could explain the lower incidence of not only prostatic cancer but also coronary heart disease in this group of men.

Further studies of rate of production and clearance in healthy men and men with prostatic cancer are necessary to determine the relationship of these hormonal changes to the development of prostatic cancer.

REFERENCES

2. Akazaki, K., and Stemerman, G. N. Comparative study of latent carcinoma

<table>
<thead>
<tr>
<th>Table 3</th>
<th>Diet composition and death rate from prostatic cancer in North American and South African men</th>
</tr>
</thead>
<tbody>
<tr>
<td>Death rate / 100,000 men</td>
<td>% of daily calories</td>
</tr>
<tr>
<td>White North American</td>
<td>13.8</td>
</tr>
<tr>
<td>Black North American</td>
<td>18.4</td>
</tr>
<tr>
<td>White South African</td>
<td>18.6</td>
</tr>
<tr>
<td>Black South African</td>
<td>4.6</td>
</tr>
</tbody>
</table>

a Numbers in parentheses, ratio of animal to plant protein in diet.

b Incidence rate (28); death rate unavailable.
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