Waist-to-Hip Ratio Is Positively Associated With Bioavailable Testosterone but Negatively Associated With Sexual Desire in Healthy Premenopausal Women

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Objective: We examined whether high waist-to-hip ratio (WHR) in women is a biomarker for increased testosterone (T) and higher levels of sexual desire. **Methods:** Participants were 99 healthy nonobese premenopausal women. Trait levels of mean bioavailable T were estimated from three saliva samples collected at 8:00 AM, 9:30 AM, and 6:00 PM to 9:00 PM, controlling for phase of the menstrual cycle. Sexual desire was measured with the Sexual Desire Inventory. **Results:** WHR was positively, although moderately, correlated with bioavailable T. WHR, but not T, was negatively correlated with level of sexual desire. **Conclusions:** These results confirm that the positive association between WHR and androgens seen in clinical populations also exists in the general population of healthy adult women. However, the relationship may not be strong enough in healthy women for WHR to serve as a useful biomarker of androgen levels in sexuality studies, especially given its association with other, perhaps negatively valued, morphologic attributes. **Key words:** testosterone, waist-to-hip ratio, sexual desire, central fat deposition, saliva radioimmunoassay.

BMI = body mass index; **T** = testosterone; **WHR** = waist-to-hip ratio; **HPA** = hypothalamic–pituitary–adrenal axis; **CNS** = central nervous system; **SDI** = Sexual Desire Inventory.

INTRODUCTION

Research concerning WHR (the ratio of waist to hip circumference) in women has focused largely on its value as a biomarker for health and attractiveness. Men and women in various Western cultures rate low WHR ratios as more sexually attractive in women (1–3). This preference has ecologic validity because higher ratios (eg, >0.80) are associated with various adverse factors. For example, women with high WHR exhibit decreased fertility (4,5), more menstrual irregularities (6) and cardiovascular disease risk factors (6–8), less physical activity (9), higher levels of anger, anxiety, depression, lower levels of social support (7) and education (9), more stress, a greater stress reactivity (10), and more unemployment problems (9). Some researchers have speculated that hypothalamic–pituitary–adrenal (HPA) hyperactivity may be present in some high WHR women (10), although androgens have been most consistently implicated in high WHR values.

An association between high androgen levels and high WHR has been found in postmenopausal women (11 cf. 12), women with androgen excess (13), obese adolescent girls (14) and women (15,16), female-to-male transsexuals (17), and in women of differing sexual orientations (18). Evidence from female-to-male transsexuals suggests that testosterone treatment increases visceral fat in the abdomen but not hip (19), which would lead to higher WHR. The cellular mechanisms by which androgens cause differential fat deposition and increased WHR are currently not well understood.

Besides exerting effects on peripheral target tissues, circulating androgens affect target neural systems that mediate behavior (20), including, possibly, sexual desire. The etiology of sexual desire is multifaceted, but androgens seem to exert influence (21,22). Women with low androgens experience a loss of sexual desire (23,24). Testosterone administration appears to be effective at alleviating complaints of low sexual desire (25,26) and increases sexual desire in female-to-male transsexuals (27). However, WHR tends to be positively associated with body mass index (BMI), and some data suggest that BMI correlates negatively with sexual desire in women (28). The authors suggested that women with higher BMIs might feel more negative about their bodies, overwhelming any hormonal influences on sexual desire.

Two main hypotheses were tested in the present study. The first was that WHR would be positively correlated with salivary testosterone in a group of healthy young women. The second hypothesis was that WHR would significantly predict individual differences in sexual desire.

METHODS

Subjects

Subjects were 99 female volunteers (mean age, 23.76 years; standard deviation [SD], 5.66; range, 18–42 years) from the University of Western Ontario recruited through newspaper ads and posters on campus. A reimbursement was offered. The notices advised that women of all body types who were healthy, between the ages of 18 and 40 years, not using hormonal contraceptives, and not pregnant or breastfeeding were welcome to participate. It also stated that measures of fat deposition and sexual desire would be collected. Participants may therefore represent a self-selected sample of women comfortable enough to have such measures taken. Not all women who contacted the experimenter agreed to participate, but this was mostly the result of a dislike of the 8:00 AM testing time.

The majority of the 99 participants were single (n = 63), whereas 20 women were in monogamous relationships and 14 were married or cohabiting (no response from two women). Participants were mostly university students (n = 83). The sample was predominantly heterosexual with only four women scoring 3 or more on the Kinsey items of sexual fantasy and experience (29). The vast majority of women (n = 94) had menstrual cycles between 24 and 34 days in length that varied by 1 to 7 days (n = 90).

A mean testosterone (T) value for each woman was computed from three saliva samples (see subsequently). Four women had T levels greater than three SDs from the mean, likely reflecting trace blood contamination in the saliva. These women were excluded from all statistical analyses involving T. An additional four women were missing one of the three saliva samples and a mean T value could not be computed. One woman with a WHR over three standard deviations from the mean also was eliminated. Therefore, 90 women were included in the T analyses.

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Procedure

Testing took place in the first 7 days of the menstrual cycle, when steroid hormones are relatively stable. Sessions began at 8:00 AM, when T levels are high (30), and lasted approximately 1.5 hours. Saliva samples were collected at the beginning and end of the test session, as well as between 6:00 PM and 9:00 PM when T levels are low (31). The evening sample was collected in the participants' homes. Saliva was chosen for ease of collection and because it is the free or weakly bound steroid that is represented in saliva (32). The times were selected to include the full range of diurnal variation in T.

During the early morning session, measures of mood, cognitive abilities, sexual desire and orientation, health and demographics, and physique were taken. Cognitive data will be the subject of a separate report.

Sexual Desire Inventory

Participants completed the Sexual Desire Inventory (SDI) (33), standardized to an 8-point scale. The SDI was adapted by the addition of one question: "During the last month, *how often* have you had sexual thoughts?" Sexual desire represents the appropriate construct for our study because it is relatively independent of partner availability and because previous research has linked it to circulating hormones. The adapted SDI consisted of 15 questions. Subjects indicated the strength and frequency of sexual desire over the past month on an 8-point scale that ranged from "no desire" to "strong desire." The inventory provided a total SDI score and two subscales: dyadic SDI and solitary SDI.

The SDI has test–retest reliability over 1 month of 0.76 (34). It has been validated as a measure of sexual desire in psychologic studies (33,35,36) and endocrine studies (26).

Control Tests

Subjects completed the Profile of Mood States (POMS) (37), which assesses self-reported mood. There is evidence for an association between negative mood states and high WHR (10). Subjects rated the degree to which 65 emotional adjectives described their characteristic mood state within the past week. Each item is responded to on a 5-point scale ranging from "not at all" to "extremely." The total mood disturbance score was calculated (POMS-TMD).

Finally, a health and background questionnaire was given to collect information concerning demographic, health, or experiential factors that could influence the sexual desire or T findings.

Anthropometric Measures

Height (in centimeters) and weight (in kilograms) (Health-o-Meter, Sunbeam Products Inc., Bridgeview, IL) were measured by a single experimenter to calculate BMI. Waist circumference was measured to the nearest 0.5 cm against the skin at the narrowest point between the chest and hips. Hip circumference was measured to the nearest 0.5 cm against the skin or underwear at the widest point around the hips and buttocks; in a small minority of cases, because of modesty, the hip measurement was done over a towel draped over the hips. In these cases, 2.5 cm was deducted from the measured circumference. (Hip measurements were taken from 20 women both with and without the towel to establish a correction factor. The mean difference between hip-with-towel and hip-without-towel measurements was 2.54 [SD = 1.59].) All four measures were taken twice for greater reliability. The WHR consisted of the mean of the two waist measures divided by the mean of the two hip measures.

Skinfold thicknesses were taken in triplicate to further assess the relation between T and sex-typical fat deposition. Calipers (SlimGuide Calipers; Creative Health Products, Plymouth, MI) were used at five sites on the body's right side. The calipers were accurate to ±0.5 mm. A kinesiologist trained the experimenter. The tricep, subscapula, and thigh were selected to assess peripheral fat deposition, whereas the iliac crest and abdomen represented central fat deposition. The score for each site was the mean of the two closest measurements or of all three with equidistant measures.

Saliva Collection

To optimize the quality of the saliva, subjects were asked not to eat, drink (except plain water), smoke, or brush their teeth for 1 hour before collection. The mouth was rinsed with water and an inert sugar-free gum was provided to stimulate saliva flow. The saliva was collected in a polystyrene culture tube pretreated with sodium azide. After collection, tubes were kept covered at room temperature for 18 to 24 hours to allow separation to occur. The tubes were then stored at −20°C until analysis.

Radioimmunoassays

Specimens were thawed at 4°C and centrifuged at 3000 rpm for 15 minutes. A double ether extraction was then performed. As a result of the large number of specimens, the assay was done in two batches, each using a single Coat-a-Count kit for total testosterone (Diagnostic Products Corp., Los Angeles, CA) modified for use with saliva. Of 10 immunoassay kits evaluated in a recent study, the DPC kit was found to yield the best correlation with a gas chromatography/mass spectrometry measure of T in women (38). All specimens were assayed in duplicate. The sensitivities were 2.5 pg/mL for both assays, and the intraassay coefficients of variation were 4% and 9%. The antiserum used is highly specific to testosterone with negligible crossreactivity with other steroids except dihydrotestosterone (<3.5%). Values used for statistical analysis were the mean testosterone concentrations across the two duplicates.

To ensure the samples showed the expected diurnal pattern of high morning and low evening T (31,39), a repeated-measures analysis of variance was performed. As expected, there was a significant difference among the three samples ($F[2,180] = 93.44$, $p < .001$), and post hoc tests using Fisher's least significant difference (LSD) test showed that all samples differed significantly from each other in the expected direction: 8:00 AM (mean, 22.09 pg/mL; SD, 6.28), 9:30 AM (mean, 17.10 pg/mL; SD, 4.52), 6:00 PM to 9:00 PM (mean, 14.42 pg/mL; SD, 5.01).

RESULTS

Testosterone and Waist-to-Hip Ratio

The first hypothesis was that WHR would be a significant predictor of individual differences in T. WHR values ranged from 0.66 to 0.87. As predicted, WHR was positively correlated with T (Pearson's $r[88] = 0.35$, $p = .001$, Figure 1). The size of the relationship was modest. With age, T declines in women (21) and WHR tends to increase (40) because estrogen shows a more striking reduction than T. As well, high BMI

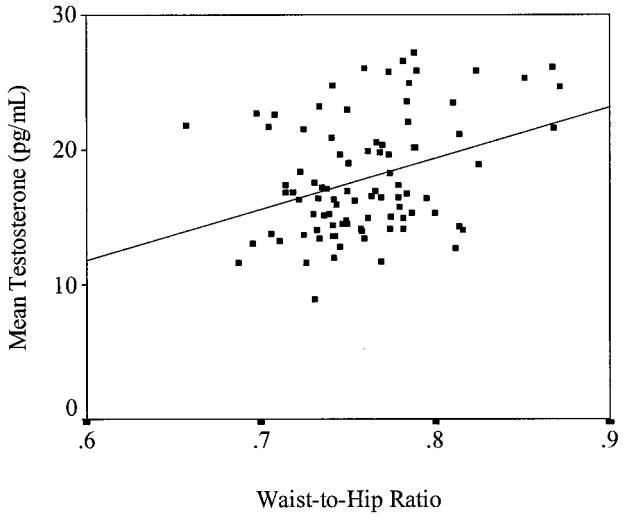

Figure 1. Scatterplot of the relationship between waist-to-hip ratio and mean testosterone (pg/mL).

can be associated with high T (14) and high WHR (41). To determine whether age and BMI were concealing the strength of the correlation between WHR and T, partial correlations were computed controlling for these variables (12). BMIs ranged from 16.1 to 34.4. The partial correlation between WHR and T, controlling for age and BMI, was significant (*partial r* [83] = 0.37, $p = .001$). Thus, WHR was positively correlated with bioavailable T independent of variation in women's body mass.

To further clarify androgenic associations with WHR, separate correlations were conducted between T and waist, and T and hip. Neither hip circumference (r [88] = −0.09, $p = .410$) nor waist circumference (r [88] = 0.11, $p = .305$) was correlated with T. This emphasizes that the ratio is important, not absolute body size.

Skinfold thickness, a measure of local fat deposition, was also evaluated (see Table 1 for all sites). Only the central-abdominal sites showed significant correlations between T and skinfold thickness: abdominal site (r [88] = 0.22, $p = .040$) and the iliac crest (r [88] = 0.21, $p = .044$). Therefore, high T was selectively related to increased central fat deposition, supporting the high T–high WHR relationship.

To examine whether the WHR–T correlation translated into a group difference, women were divided into two WHR groups using a median split: low WHR (mean, 0.73; SD, 0.02; $n = 49$) and high WHR (mean, 0.79; SD, 0.03; $n = 49$). An independent samples t test confirmed that the low WHR group had significantly lower mean T (mean, 16.47; SD, 3.64) than the high WHR group (mean, 19.35; SD, 4.52) (t[83] = −3.32, $p = .001$, two-tailed).

Thus, the group results and the correlations indicated that WHR was positively correlated with bioavailable testosterone.

Waist-to-Hip Ratio and Sexual Desire

The second hypothesis was that WHR would be positively correlated with sexual desire. Sexual desire was assessed using the SDI (33). The internal consistencies of the two SDI subscales and the total SDI scale were estimated using Cronbach's alpha and showed excellent reliability with coefficients of: SDI total = 0.90, SDI dyadic = 0.89, and SDI solitary = 0.91. Thus, each scale appeared to be reliably measuring its designated construct. Single and partnered women did not differ significantly in SDI dyadic (r [81] = −1.41, $p = .162$).

TABLE 1. Pearson's Product-Moment Correlations Between Testosterone and Skinfold Thicknesses ($N = 90$)

Skinfold site	Simple correlation	Adjusted for body mass index
Triceps	0.15	0.10
Subscapula	0.10	0.08
Thigh	0.03	-0.03
Abdomen	0.22*	0.20†
Iliac crest	0.21*	0.19†

*$p < .05$.
†$p < .10$.

Women who were using psychoactive medications or who had a psychiatric or neurologic condition ($n = 14$) were excluded from these analyses. This was done to avoid confounds from the dampening effects of various drugs on libido.

Contrary to prediction, neither SDI total (r [82] = −0.16, $p = .160$), SDI solitary (r [82] = −0.14, $p = .212$), nor SDI dyadic (r [82] = −0.08, $p = .455$) was significantly correlated with WHR. Because previous work has suggested that negative affect, BMI (7,9,29), and age (23,42) may covary with WHR and sexual desire, partial correlations were computed. The partial correlation, with age, BMI, and POMS-TMD removed, between WHR and SDI total was significant but negative (*partial r* [76] = −0.23, $p = .047$), and the partial correlation between WHR and SDI solitary approached significance (*partial r* [76] = −0.21, $p = .060$). These results indicate that WHR and sexual desire were not positively correlated and, if anything, were negatively correlated.

The basis for expecting an association between sexual desire and WHR was that sexual desire would be positively correlated with T. However, there were no significant correlations between mean T and the SDI scores (all r's < 0.10; $N = 76$), nor were there any significant partial correlations when the effects of BMI, age, and POMS-TMD were excluded: SDI total (*partial r* [69] = −0.04, $p = .729$), SDI dyadic (*partial r* [69] = −0.10, $p = .410$), SDI solitary (*partial r* [69] = 0.05, $p = .696$). These results indicate that T was not correlated with sexual desire.

To summarize, the results showed support for the first hypothesis. WHR was a visible biomarker of bioavailable T. High WHR was associated with high T. The other hypothesis was not supported. We failed to find evidence that increased WHR is a marker of increased sexual desire.

DISCUSSION

In the present study, T was within the expected range at each sampling time point (26,43,44) and showed the expected diurnal pattern (31,39). Thus, the T levels in our sample showed no aberrations that would limit the generalizability of our conclusions.

As predicted, WHR was significantly and positively correlated with bioavailable T. This correlation presumably represents the actions of long-term trait levels of T that differ reliably across individuals. As well, the skinfold thicknesses representing central but not peripheral measures of fat deposition were significantly and positively correlated with T. Thus, in our data, T was uniquely associated with measures of central fat, and not merely fat deposition at any location.

Other research has shown positive associations between T and WHR in special populations, including women with androgen excess (13), self-identified "butch" lesbians (18), postmenopausal women (11), female-to-male transsexuals (17), and obese women (16,45). To our knowledge, the present study is the first study to illustrate a relationship between bioavailable T and WHR in healthy adult premenopausal women. The size of the correlation ($r = 0.37$) compares favorably with the correlations found in clinical populations,

which range from 0.22 to 0.55. However, the modest size of the correlation between T and WHR probably precludes its use as a biomarker for T in sexuality studies. High WHR does appear to be a useful biomarker for health variables (eg, (4,5,7,8)) and attractiveness (eg, (1)).

Contrary to our prediction, there was no evidence that high WHR is a biomarker for increased sexual desire. Instead, we found a significant negative association. Our failure to find a positive association is understandable because the expected underlying positive relationship between T and sexual desire was not present. Evidence certainly points to a positive association between T and sexual desire in women, but this evidence stems almost entirely from clinical studies (25,26,46). Our large sample size suggests other explanations. It may be that in healthy adult women, the range of T is truncated and too small for associations between sexual desire and T to be found. Another possibility is that only increases in T from some earlier stable baseline are associated with increases in sexual desire; or, the influence of hormones on sexual desire in healthy premenopausal women may be diluted by other factors (eg, (28,47)) because the etiology of sexual desire is multifaceted (22). We found sexual desire to be negatively correlated with WHR. This agrees with some prior evidence (47) and may be the result of factors other than T.

To our knowledge, this is the first study to provide evidence for a positive association between WHR and bioavailable T in healthy premenopausal adult women. It increases our understanding of how WHR is related to physiological and endocrine states, and suggests that increased tissue exposure to unbound androgens may predispose normal-weight women to accumulate fat in a male-typical upper body distribution. A positive association with sexual desire could not be demonstrated.

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REFERENCES

1. Singh D. Is thin really beautiful and good? Relationship between waist-to-hip ratio (WHR) and female attractiveness. Pers Individ Dif 1994;16: 123–32.
2. Henss R. Waist-to-hip ratio and attractiveness: replication and extension. Pers Individ Dif 1995;19:479–88.
3. Furnham A, Tan T, McManus C. Waist-to-hip ratio and preferences for body shape: a replication and extension. Pers Individ Dif 1997;22: 539–49.
4. Wass P, Waldenström U, Rössner S, Hellberg D. An android body fat distribution in females impairs the pregnancy rate of in-vitro fertilization–embryo transfer. Hum Reprod 1997;12:2057–60.
5. Zaadstra BM, Seidell JC, Van Noord PAH, te Velde ER, Habbema JDF, Vrieswijk B, Karbaat J. Fat and female fecundity: prospective study of effect of body fat distribution on conception rates. BMJ 1993;306:484–7.
6. Hartz AJ, Rupley DC, Rimm AA. The association of girth measurements with disease in 32,856 women. Am J Epidemiol 1984;119:71–80.
7. Wing RR, Matthews KA, Kuller LH, Meilahn EN, Plantinga P. Waist to hip ratio in middle-aged women: association with behavioral and psychosocial factors and with changes in cardiovascular risk factors. Arterioscler Thromb 1991;11:1250–7.
8. Marti B, Tuomilehto J, Salomaa V, Kartovaara L, Korhonen HJ, Pietinen P. Body fat distribution in the Finnish population: environmental determinants and predictive power for cardiovascular risk factor levels. J Epidemiol Community Health 1991;45:131–7.
9. Rosmond R, Björntorp P. Psychosocial and socio-economic factors in women and their relationship to obesity and regional body fat distribution. Int J Obes Relat Metab Disord 1999;23:138–45.
10. Epel ES, McEwen B, Seeman T, Matthews K, Castellazzo G, Brownell KD, Bell J, Ickovics JR. Stress and body shape: stress-induced cortisol secretion is consistently greater among women with central body fat. Psychosom Med 2000;62:623–32.
11. Kaye SA, Folsom AR, Soler JT, Prineas RJ, Potter JD. Associations of body mass and fat distribution with sex hormone concentrations in postmenopausal women. Int J Epidemiol 1991;20:151–6.
12. Goodman-Gruen D, Barrett-Connor E. Total but not bioavailable testosterone is a predictor of central adiposity in postmenopausal women. Int J Obes Relat Metab Disord 1995;19:293–8.
13. Evans DJ, Barth JH, Burke CW. Body fat topography in women with androgen excess. Int J Obes 1988;12:157–62.
14. Wabitsch M, Hauner H, Heinze E, Böckmann A, Benz R, Mayer H, Teller W. Body fat distribution and steroid hormone concentrations in obese adolescent girls before and after weight reduction. J Clin Endocrinol Metab 1995;80:3469–75.
15. De Pergola G, Zamboni M, Sciaraffia M, Turcato E, Pannacciulli N, Armellini R, Giorgino G, Perrini S, Bosello O, Giorgino R. Body fat accumulation is possibly responsible for lower dehydroepiandrosterone circulating levels in premenopausal obese women. Int J Obes Relat Metab Disord 1996;20:1105–10.
16. Kirschner MA, Samojlik E, Drejka M, Szmal E, Schneider G, Ertel N. Androgen–estrogen metabolism in women with upper body *versus* lower body obesity. J Clin Endocrinol Metab 1990;70:473–9.
17. Bosinski HAG, Schröder I, Peter M, Arndt R, Wille R, Sippell WG. Anthropometrical measurements and androgen levels in males, females, and hormonally untreated female-to-male transsexuals. Arch Sex Behav 1997;26:143–57.
18. Singh D, Vidaurri M, Zambarano RJ, Dabbs JM. Lesbian role identification. Behavioral, morphological, and hormonal correlates. J Pers Soc Psych 1999;76:1035–49.
19. Elbers JMH, Asscheman H, Seidell JC, Megens JAJ, Gooren LJG. Long-term testosterone administration increases visceral fat in female to male transsexuals. J Clin Endocrinol Metab 1997;82:2044–7.
20. Becker JB, Breedlove SM, Crews D, McCarthy MM, eds. Behavioral Endocrinology, 2nd ed. Cambridge, MA: Massachusetts Institute of Technology; 2002.
21. Bachmann GA. The hypoandrogenic woman: pathophysiologic overview. Fertil Steril 2002;77:S72–6.
22. Basson R. Using a different model for female sexual response to address women's problematic low sexual desire. J Sex Marital Ther 2001;27: 395–403.
23. Davis SR. The clinical use of androgens in female sexual disorders. J Sex Marital Ther 1998;24:153–63.
24. Davis S. Testosterone and sexual desire in women. J Sex Educ Ther 2000;25:25–32.
25. Guay AT. Decreased testosterone in regularly menstruating women with decreased libido: a clinical observation. J Sex Marital Ther 2001;27: 513–9.
26. van Anders, SM, Chernick AB, Chernick BA, Hampson E, Fisher WA. Preliminary clinical experience with androgen administration for pre- and post-menopausal women with hypoactive sexual desire. J Sex Marital Ther. In press.
27. Van Goozen SHM, Wiegant VM, Endert E, Helmond FA, Van de Poll NE. Psychoendocrinological assessment of the menstrual cycle: the relationship between hormones, sexuality, and mood. Arch Sex Behav 1997;26:359–82.
28. Kirchengast S, Hartmann B, Gruber D, Huber J. Decreased sexual interest and its relationship to body build in postmenopausal women. Maturitas 1996;23:63–71.
29. Kinsey AC, Pomeroy WB, Martin CE. Sexual Behavior in the Human Male. Philadelphia: WB Saunders; 1948.
30. Khan-Dawood FS, Choe JK, Dawood MY. Salivary and plasma bound and 'free' testosterone in men and women. Am J Obstet Gynecol 1984; 148:441–5.
31. Ankarberg C, Norjavaara E. Diurnal rhythm of testosterone secretion before and throughout puberty in healthy girls: correlation with 17beta-estradiol and dehydroepiandrosterone sulfate. J Clin Endocrinol Metab 1999;84:975–84.

32. Quissell DO. Steroid hormone analysis in human saliva. Ann N Y Acad Sci 1993;694:143–5.
33. Spector IP, Carey MP, Steinberg L. The Sexual Desire Inventory: development, factor structure, and evidence of reliability. J Sex Marital Ther 1996;22:175–90.
34. Carey MP. Test–retest reliability of the Sexual Desire Inventory. Unpublished raw data; 1995.
35. Spector IP, Fremeth SM. Sexual behaviors and attitudes of geriatric residents in long-term care facilities. J Sex Mar Ther 1996;22:235–46.
36. King BE, Allgeier ER. The Sexual Desire Inventory as a measure of sexual motivation in college students. Psych Rep 2000;86:347–50.
37. McNair DM, Lorr M, Droppleman LF. Profile of Mood States. San Diego: EdITS; 1971.
38. Taieb JT, Mathian B, Millot F, Patricot MC, Mathieu E, Queyrel N, Lacroix I, Somma-Delpero C, Boudou P. Testosterone measured by 10 immunoassays and by isotope-dilution gas chromatography-mass spectrometry in sera from 116 men, women, and children. Clin Chem 2003; 49:1381–95.
39. Aedo AR, Landgren BM, Diczfalusy E. Studies on ovarian and adrenal steroids at different phases of the menstrual cycle: II. A comparative assessment of the circadian variation in steroid and lutropin levels during the follicular, periovulatory, and luteal phases. Contraception 1981;23:407–24.
40. Lahmann PH, Lissner L, Gullberg B, Berglund G. Sociodemographic factors associated with long term weight gain, current body fatness and central adiposity in Swedish women. Int J Obes Relat Metab Disord 2000;24:685–94.
41. Pasquali R, Casimirri F, Labate AMM, Tortelli O, Pascal G, Anconetani B, Gatto MRA, Flamia R, Capelli M, Barbara L, and the VMH Collaborative Group. Body weight, fat distribution and the menopausal status in women. Int J Obes Relat Metab Disord 1994;18:614–21.
42. Davis SR, Tran J. Testosterone influences libido and well being in women. Trends Endocrinol Metab 2001;12:33–7.
43. Moffat SD, Hampson E. A curvilinear relationship between testosterone and spatial cognition in humans: Possible influence of hand preference. Psychoneuroendocrinology 1996;21:323–37.
44. Moffat SD, Hampson E. Salivary testosterone concentrations in left-handers: an association with cerebral language lateralization? Neuropsychology 2000;14:71–81.
45. Evans DJ, Hoffmann RG, Kalkhoff RK, Kissebah AH. Relationship of androgenic activity to body fat topography, fat cell morphology, and metabolic aberrations in premenopausal women. J Clin Endocrinol Metab 1983;57:304–10.
46. Van Goozen SHM, Cohen-Kettenis PT, Gooren LJG, Frijda NH, Van De Poll NE. Gender differences in behaviour: activation effects of cross-sex hormones. Psychoneuroendocrinology 1995;20:343–63.
47. Kaplan HS, Owett T. The female androgen deficiency syndrome. J Sex Marital Ther 1993;19:3–24.