Psychoneuroendocrinology (2006) 31, 895–899

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SHORT COMMUNICATION

Seasonality, waist-to-hip ratio, and salivary testosterone

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Received 1 December 2005; received in revised form 9 February 2006; accepted 7 March 2006

KEYWORDS
Androgens;
Sex;
Gender;
Seasonality;
Waist-to-hip ratio

Summary Patterns of seasonal variation in testosterone (T) and T-dependent measures are poorly understood in humans and particularly in women, despite their importance in other animals. We examined seasonal fluctuations in salivary T in women and men, and waist-to-hip ratio (WHR) in women. Participants were 220 women and 127 men from central and West Coast North America. Results showed that T was significantly highest in autumn for both women and men, and that WHR in women closely matched the seasonal variation in T, with high values in the fall and summer. This suggests that T does show a reliable fluctuation over the seasons, which may result in meaningful fluctuations in behavioral, cognitive, and somatic variables associated with T.

Understanding seasonal variation in endocrine parameters is important for both methodological and theoretical reasons. Various non-human species show seasonal variations in testosterone (T) production that are associated with fertility, behaviour, cognition, and morphology (for review, see Nelson, 2000). While humans, too, appear to show significant seasonal variation in T, the pattern is far from clear. Higher levels of T have been reported for men in most months and seasons, including May (Valero-Politi and Fuentes-Arderiu, 1998), the autumn months (Dabbs, 1990; Moffat and Hampson, 2000; Svartberg et al., 2003) and late winter (Perry et al., 2000). Few studies have investigated women, but peaks have been reported in the fall (Wisniewski and Nelson, 2000) and July–September (Garde et al., 2000).

In humans, seasonal fluctuations in T-associated variables also have been studied. Wisniewski and Nelson (2000) found seasonal fluctuations in both cerebral lateralization (using an adapted consonant–vowel–consonant identification split visual field task) and T, but reported that the two were not associated. In contrast, Svartberg et al. (2003) measured waist-to-hip ratio (WHR; a ratio of waist to hip circumference) in men, and found that WHR varied with T by season. WHR was highest in the summer when T was the lowest, the expected

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0306-4530/$ - see front matter © 2006 Elsevier Ltd. All rights reserved.
doi:10.1016/j.psyneuen.2006.03.002

direction since T is inversely related to WHR in men (Seidell et al., 1990).

We report here on seasonal fluctuations of T in women and men in an effort to further clarify seasonal changes in T secretion in both sexes. Further, unlike the majority of past research that has assayed serum, we report on salivary testosterone concentrations, which are believed to be directly proportional to the bioavailable fraction of the circulating hormone. In addition, we describe seasonal WHR fluctuations in women, with the expectation that in keeping with previous findings, WHR and T will show a positive correlation (van Anders and Hampson, 2005).

1. Methods

Participants were 127 men (mean age = 28.60 years) and 220 women (mean age = 25.80 years), after exclusion of participants who were using exogenous hormones or other medications that could affect T ($n = 41$). We had 76 heterosexual men, 51 non-heterosexual men, 73 non-heterosexual women, and 146 heterosexual women. Five participants had missing saliva samples. Participants were tested in London, Ont. ($n = 86$; all women), or Vancouver, BC.

Participants completed questionnaires, and provided saliva samples for T assay between 14:00–20:00, and additional samples at 08:00 and 09:30 in London. Two evening samples were returned without time; to avoid losing these samples we arbitrarily assigned them to 18:00. Participants were part of larger studies; for details of recruitment and procedure (including assay and sexual orientation information), see van Anders and Hampson (2005) and van Anders and Watson (in press). The London sample was measured for weight and height to compute body mass index (BMI), WHR, and skinfold thickness at five sites (thigh, abdominal, subscapulae, triceps, iliac crest). Seasonality was based on solstices, and coded as Fall (October–December), Winter (January–March), Spring (April–June), and Summer (July–September).

Salivary flow was stimulated using an inert gum (Trident sugar-free cherry), and samples were collected in polystyrene tubes pretreated with sodium azide and then frozen at −20 °C until assay. The Vancouver samples were assayed in two batches at the Endocrine Core Lab at Yerkes National Primate Research Center in duplicate using a modified kit from Diagnostic Systems Laboratories (Webster, TX). Sensitivity was 2–500 pg/mL per 200 mL dose, and the interassay coefficient of variation was 8.8% at 0.65 ng/mL and 6.9% at 5.06 ng/mL. to the following: Sensitivity was 2–500 pg/mL per 200mL, and the interassay coefficient of variation was 19.16% at 5.03 pg/mL and 15.08% at 170.81 pg/mL. The Ontario samples were assayed in two batches in duplicate at the Endocrine Lab at the University of Western Ontario, each using a single modified coat-a-count kit for total T (Diagnostic Products Corp., Los Angeles, CA). Sensitivity was 2.5 pg/mL and the intraassay coefficients of variation were 4 and 9%.

Analyses were conducted with the Statistical Package for the Social Sciences (SPSS), version 13.0.1. Post hoc analyses employed the least significant difference (LSD) test, except with month where Scheffé statistics were used to reduce error due to multiple comparisons.

2. Results

2.1. Seasonality and testosterone

We conducted an analysis of covariance (ANCOVA) with T as the dependent variable, season and sex as the independent variables, and time of day of sample collection as a covariate. The results did not differ when sexual orientation was covaried, so these analyses are not reported. There was a significant main effect of sex, $F(1,330) = 334.09$, $p < 0.001$, $\eta^2 = 0.503$, season, $F(3,330) = 31.55$, $p < 0.001$, $\eta^2 = 0.223$, and a significant interaction between sex and season, $F(3,330) = 13.54$, $p < 0.001$, $\eta^2 = 0.110$. For all, T was highest in the fall and lowest in the spring, while the summer and winter did not differ. For men, T was significantly higher in the fall than in the winter, $FS = 7.51$, $p < 0.01$, spring, $FS = 8.27$, $p < 0.01$, or summer, $FS = 8.14$, $p < 0.01$. T was significantly lower in the spring than the summer, $FS = 2.95$, $p < 0.05$, and nearly so than the winter, $FS = 2.67$, $p < 0.10$. T did not differ significantly between the winter and summer, $FS = 0.17$, *ns*. For women, T was significantly higher in the fall than the winter, $FS = 3.12$, $p < 0.05$, and was higher in the fall than in the spring and summer, but not significantly so (Fig. 1). Women showed the same pattern whether from central or West Coast North America.

A similar ANCOVA using month of testing as an independent variable yielded a significant main effect of sex, $F(1,316) = 114.43$, $p < 0.001$, $\eta^2 = 0.266$, month, $F(11,316) = 12.64$, $p < 0.001$, $\eta^2 = 0.305$, and a significant interaction between sex and month, $F(9,316) = 6.64$, $p < 0.001$, $\eta^2 = 0.159$ (Table 1). Here, month of testing actually accounted for more of the variance in T than sex.

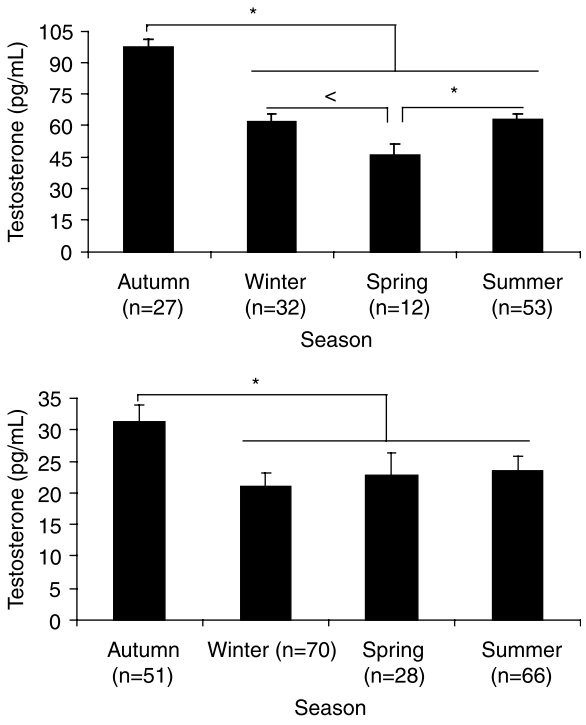

Figure 1 Means and standard errors of testosterone by season for: (a) men and (b) women. '*' Indicates a significant difference at $\alpha < 0.05$, and '<' indicates a trend towards a significant difference at $\alpha < 0.10$.

Some participants ($n = 86$; all women) provided T samples in both the a.m. and p.m. The diurnal rhythm of T (highest in a.m., decreasing over the day) did not differ significantly by season or month. The 08:00 sample showed a trend for seasonal effects on T, $F(3,84) = 2.36$, $p = 0.078$, with autumn significantly higher than the winter, $p = 0.043$, and spring, $p = 0.022$. The 09:30 sample showed significant seasonal effects on T, $F(3,85) = 3.68$, $p = 0.015$, with autumn significantly higher than the winter, $p = 0.006$, spring, $p = 0.007$, and summer, $p = 0.034$.

2.2. Seasonality and anthropometric measures

The subsample of women ($n = 86$) had anthropometric measurements taken, but one woman with a WHR of 0.925 (over 3SD from the mean) was removed from the analyses. We conducted a multivariate ANOVA with the anthropometric measures as the dependent variables, and season as the independent variable, to see if WHR varied by season. There was a significant multivariate effect, $F(21,231) = 1.83$, $p = 0.017$. The only significant univariate effect was for WHR, $F(3,81) = 2.72$, $p = 0.050$, though there were trends towards significance at some skinfold sites: subscapulae, $F(3.81) = 2.36$, $p = 0.077$, abdominal, $F(3.81) = 2.19$, $p = 0.096$, and iliac crest, $F(3.81) = 2.27$, $p = 0.087$. No seasonal effects were evident for BMI, $F(3.81) = 0.96$, $p = 0.414$, triceps skinfolds, $F(3.81) = 0.47$, $p = 0.707$, or thigh skinfolds, $F(3.81) = 0.27$, $p = 0.844$, thus WHR, but not weight, varied by season. This is supported by the trend for seasonal fluctuations in central (e.g. abdominal) but not peripheral (e.g. thigh) fat deposition. WHR was significantly lower in the winter ($M = 0.745$, $SE = 0.007$) than in the fall ($M = 0.771$, $SE = 0.007$), $p = 0.013$, or the summer ($M = 0.770$, $SE = 0.009$), $p = 0.032$. WHR in spring ($M = 0.756$, $SE = 0.009$) did not differ significantly from the other seasons. Entry of evening T level as a covariate in an ANCOVA eliminated the significant seasonal variation in

Table 1 Means and standard errors for testosterone (pg/mL), by month and sex.

Month	Women			Men			
	Mean	(SE)	*n*	Mean	(SE)	*n*	Within-sex ($\alpha < 0.05$)
January	20.61	(4.32)	16	61.76	(6.10)	8	November
February	20.73	(2.99)	33	68.65	(4.10)	18	November
March	20.13	(3.84)	21	47.44	(7.04)	6	October, November
April	19.13	(4.38)	16	54.58	(6.12)	8	October, November
May	26.86	(5.79)	9	35.44	(9.95)	3	
June	29.18	(9.95)	3	19.82	(−)	1	
July	42.43	(8.65)	4	-	(−)	0	
August	20.75	(2.33)	55	62.54	(2.39)	53	October, November
September	33.83	(6.58)	7	-	(−)	0	
October	31.62	(5.53)	10	97.07	(7.04)	6	March, April, August
November	33.46	(2.96)	34	103.97	(3.98)	19	January–April, August
December	22.08	(6.69)	7	45.75	(12.16)	2	

Note. There were no significant differences by month for women. Post hoc tests computed using Scheffé statistics.

WHR, $F(3,82)=1.47$, $p=0.229$, thereby directly implicating T in the seasonal fluctuations in WHR.

3. Discussion

In the present study, T was highest in autumn in women as well as men. This was true for women from central North America (London, Ontario) and the West Coast (Vancouver, BC). In addition, women's WHR was higher in the fall and summer than in other seasons. To our knowledge, this is the first report of seasonal fluctuations in human attractiveness in both sexes, as WHR is associated with attractiveness in both women (Singh, 1993) and men (Singh, 1995).

Our T findings are consistent with previous results in men (Dabbs, 1990; Moffat and Hampson, 2000; Svartberg et al., 2003) and extend results for women (Wisniewski and Nelson, 2000). This is the first report of seasonal variation in T in both women and men with an autumn peak. An autumn peak appears to be the most commonly reported, especially in North American studies, but there is substantial variation. It is unclear why, since the autumn peak has been found in locations that differ in day length, including Tromsø, Norway. Our own study included two locations that differ markedly by season though not day length; London has snowy cold winters and hot humid summers, while Vancouver has cool rainy winters and sunny temperate summers. It is difficult to argue for an effect of either absolute day length or temperature, since women and men showed no difference in T between the winter and summer, when climate differences are most extreme. One possibility is that relative hours of sunshine might be a cue, such that rapid decreases in either somehow initiate increased T production, as suggested by Prendergast (1995). One limitation of our study is the cross section between-subjects nature; future studies could examine seasonality effects using a within-subjects longitudinal design.

Our finding that WHR showed seasonal variation that closely matched the seasonal fluctuation in T replicates the finding reported in men (Svartberg et al., 2003), and supports evidence (e.g. van Anders and Hampson, 2005) that circulating T levels are a predictor of WHR. In women, high T is associated with higher WHR, whereas in men it is low T that is associated with higher WHR (Seidell et al., 1990; Khaw and Barrett-Connor, 1992). Previous research has shown that the association between WHR and T is reversed between women and men (Svartberg et al., 2003). Our data, showing opposing seasonal patterns in the two sexes, therefore supports the hypothesis that T contributes to these changes, and indicates that seasonal fluctuations in T may have substantial effects on human morphology. In addition, since evidence supports an association between T and variables like spatial ability (Moffat and Hampson, 1999), mood (van Honk et al., 1999), and sperm production (Uhler et al., 2003), seasonal fluctuations in T may result in meaningful fluctuations in behavioral, cognitive, and somatic variables associated with T.

Acknowledgements

SMvA was supported by scholarships from the Natural Sciences and Engineering Research Council (NSERC), Simon Fraser University, the University of Western Ontario, and UNESCO-NSERC-L'Oreal.

This research was funded by NSERC Discovery Grants to NVW (0194522) and EH.

References

Dabbs Jr., J.M., 1990. Age and seasonal variation in serum testosterone concentrations among men. Chronobiology International 7 (3), 245–249.

Garde, A.H., Hansen, A.M., Skovgaard, L.T., Christensen, J.M., 2000. Seasonal and biological variation of blood concentrations of total cholesterol, dehydroepiandrosterone sulfate, hemoglobin AIC, IGA, prolactin, and free testosterone in healthy women. Clinical Chemistry 46 (4), 551–559.

Khaw, K.T., Barrett-Connor, E., 1992. Lower endogenous androgens predict central adiposity in men. Annals of Epidemiology 2, 675–682.

Moffat, S.D., Hampson, E., 1996. A curvilinear relationship between testosterone and spatial cognition in humans: Possible influence of hand preference. Psychoneuroendocrinology 21, 323–327.

Moffat, S.D., Hampson, E., 2000. Salivary testosterone concentrations in left-handers: an association with cerebral language lateralization? Neuropsychology 14 (1), 71–81.

Nelson, R.J., 2000. An Introduction to Behavioral Endocrinology, second ed. Sinauer, Massachusetts.

Perry III, H.M., Miller, D.K., Patrick, P., Morley, J.E., 2000. Testosterone and leptin in African-American men: relationship to age, strength, function, and season. Metabolism 49, 1085–1091.

Prendergast, B.J., 1995. Internalization of seasonal time. Hormones and Behavior 48 (5), 503–511.

Seidell, J.C., Björntorp, P., Sjöström, L., Kvist, H., Sannerstedt, R., 1990. Visceral fat accumulation in men is positively associated with insulin, glucose, and C-peptide levels, but negatively with testosterone levels. Metabolism 39, 897–901.

Singh, D., 1993. Adaptive significance of female physical attractiveness: role of waist-to-hip ratio. Journal of Personality and Social Psychology 65 (2), 293–307.

Singh, D., 1995. Female judgement of male attractiveness and desirability for relationships: role of waist-to-hip ratio and financial status. Journal of Personality and Social Psychology 69 (6), 1089–1101.

Svartberg, J., Jorde, R., Sundsfjord, J., Bonaa, K.H., Barett-Connor, E., 2003. Seasonal variation of testosterone and waist-to-hip ratio in men: the tromso study. Journal of Clinical Endocrinology and Metabolism 88 (7), 3099–3104.

Uhler, M.L., Zinaman, M.J., Brown, C.C., Clegg, E.D., 2003. Relationship between sperm characteristics and hormonal parameters in normal couples. Fertility and Sterility 3 (Suppl. 3), 1535–1542.

Valero-Politi, J., Fuentes-Arderiu, X., 1998. Annual rhythmic variations of follitropin, lutropin, testosterone and sex-hormone-binding globulin in men. Clinica Chimica Acta 271, 57–71.

van Anders, S.M., Hampson, E., 2005. Waist-to-hip ratio is positively associated with bioavailable testosterone but not sexual desire in healthy premenopausal women. Psychosomatic Medicine 67 (2), 246–250.

van Anders, S.M., Watson, N.V., in press. Relationship status and testosterone in North American men and women of diverse orientations: Cross-sectional and longitudinal data. Psychoneuroendocrinology; doi:10.10161j.psyneuen.2006.01.008

van Honk, J., Tuiten, A., Verbaten, R., van den Hout, M., Koppeschaar, H., Thijssen, J., de Haan, E., 1999. Correlations among salivary testosterone, mood, and selective attention to threat in humans. Hormones and Behavior 36 (1), 17–24.

Wisniewski, A.B., Nelson, R.J., 2000. Seasonal variation in human functional cerebral lateralization and free testosterone concentrations. Brain and Cognition 43 (1–3), 429–438.