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Association of Waist-Height-Ratio, Waist Circumference, and Body Mass Index with Serum Testosterone Level in Apparently Healthy Men

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Abstract: Previous studies have shown that waist circumference (WC) may be a better predictor of serum testosterone level than body mass index (BMI). The determination of the waist-to-height ratio (WHt ratio) is reported to have certain advantages over other adiposity measures. Our study thus aimed at examining the utility of WHt ratio in addition to WC and BMI in determining their association with testosterone level. The case-control study involved apparently healthy male participants aged between 40 to 60 years. The study participants were divided into normal and abnormal groups according to WC, BMI, WHt ratio with their mean total testosterone level compared. The correlations of total testosterone and adiposity measures along with age adjustments were also determined. Individuals with WC>100cm had a significant low (P=0.003) testosterone level compared to their counterparts with WC<100cm. A significantly lowered (P=0.042) testosterone was observed in the study group with BMI>25kg/m^2 compared to the group with <25kg/m^2. The study group with a WHt ratio of >0.5 had a significantly lower (P=0.012) testosterone than the group with <0.5. An inverse correlation of testosterone was observed with age (r=-0.567), BMI (r=-0.265), WC (r=-0.406), and WHt ratio (r=-0.412) in the apparently healthy Men studied. After adjustment for age, the correlation observed between testosterone and BMI (P=0.010), testosterone and WC (P=0.004), testosterone and WHt ratio (P=0.014) remained significant. After height adjustment, the correlation between testosterone and WHt ratio (P=0.002) also remained significant. In conclusion, the WHt ratio and WC independent of age were the best predictors of the total testosterone level in men.

Keywords: Testosterone, Waist Circumference, Body Mass Index, Waist-to-Height Ratio, Men

1. Introduction

Testosterone is a sex-steroidsynthesized in the testes and has biologic effects on numerous tissues. A physiological decrease in testosterone concentrations has been well documented after the fourth or fifth decade of life and has been postulated to result from a decline in both testicular and hypothalamic-pituitary function [1]. In scenarios in which the patient has a clear pathophysiologic mechanism for the hypogonadism, treatment with testosterone is nearly always recommended to alleviate symptoms of hypogonadism and maintain secondary sexual characteristics [1]. Testosterone deficiency impacts on mood and cognition (decreased sense of well being, lack of motivation, deterioration in work performance, lethargy, low mood, low self-esteem, short-term memory, tendency to fall asleep and frequent headaches), muscle function and body composition (decreased physical energy or endurance, diminished muscle mass and strength), and sexuality (decreased interest or desire for sex, reduced quality of sexual activity, poor erectile function, limited quality of orgasm, and absent or decreased nocturnal erections). Low testosterone has been reported to be an independent predictor of cardiovascular disease, stroke, mortality and Alzheimer's disease [2, 3].

In males, circulating testosterone blood levels have been shown to be influenced by body weight and composition. An inverse correlation between body composition and total testosterone has been described in men of different ages [4, 5]. There has been uncertainty about how best to account for obesity using adiposity measures. Increased abdominal circumference has been described as the best indicator of central obesity, total body fat, and visceral fat, particularly in men who are more than 40 years of age [6]. Data have shown that waist circumference (WC) may be a better predictor of testosterone level than weight and body mass index (BMI) [7]. A 2010 systematic review of published studies concluded that waist-to-height ratio (WHt ratio) may be advantageous over other adiposity measures since it does not require age, sex, and ethnicity in determining the specific cut off values [8]. The present study was motivated based on emerging evidence of the use of WHt ratio in profiling body adiposity [9-11]. The present study aimed at examining the utility of WHt ratio in addition to WC and BMI in determining their association with testosterone level in men.

2. Materials and Methods

2.1. Selection of Participants

Male patients between 40 to 60 years of age attending general health checkup in the outpatient's department of the teaching hospital were randomly selected for the study after obtaining institutional ethical clearance. Patients with diabetes mellitus, smoking habits, history of alcohol abuse (intake of more than 30mL of ethanol per day), conditions requiring any medication and any other possible cause of hypogonadism identified were excluded from the study.

2.2. Study Design

The case-control study involved participants divided into two groups according to WC, BMI, and WHt ratio. Patients with normal WC less than 100 cm and patients with abnormal WC over 100 cm, based on the WHO and American Heart Association criteria for patients at high risk for metabolic disease [12, 13]. According to BMI patients were divided into two groups, as patients with normal BMI less than 25kg/m^2 and overweight patients with a BMI 25-30 kg/m^2, based on the WHO and National Institutes of Health criteria for obesity classification [14]. Patients were divided into normal WHt ratio (less than 0.5) and abnormal WHt ratio (greater than 0.5) based on previously proposed and widely accepted cut-off values [8].

2.3. Anthropometric Measurements

Height was determined by a stadio meter calibrated to the nearest 0.1 cm and weight was measured on scales calibrated to 0.1 kg to calculate BMI (ratio of body weight in kg to height in m^2) [12]. Waist circumference was measured according to WHO guidelines, at the midpoint distance between the costal margin and iliac crest in the mid-axillary line on the dominantside [12]. Waist-height-ratio was calculated by dividing WC (cm) by height (cm).

2.4. Laboratory Methods

To limit the influence of fluctuations of plasma testosterone levels due to its varied secretion, fasting blood samples for testosterone evaluation were always drawn at the same time of the day, Serum levels of total testosterone were measured using immunoassay kits.

2.5. Statistical Methods

The student's t-test was used to test the significant difference of the anthropometrics, total testosterone level between normal and abnormal adiposity. The WC, WHt ratio and BMI were individually correlated with total testosterone levels using Pearson's correlation analysis. Multiple linear regressions were used to analyze independent variables and to correlate age, WHt ratio, BMI and WC. All statistical tests were deemed significant at a p-value lower than 0.05. The analytical software utilized was the statistical package SPSS version 21, IBM Armonk, New York, United States.

3. Results

The characteristics of the subjects are detailed in Table 1. The mean age, BMI, WC, WHt ratio and testosterone were respectively 47.05 years, 24.62kg/m^2, 90.41cm, 0.53, and 4.70ng/ml. The mean values of anthropometrics and testosterone in different anthropometric groups are displayed in Table 2. Individuals with WC>100cm had a significant low (p=0.003) testosterone level and high (p=0.000) BMI, WHt ratio compared to their counterparts with WC<100cm. A significantly lowered (p=0.042) testosterone and elevated (p=0.000) WC, WHt ratio were observed in the study group with BMI>25kg/m^2 compared to the group with <25kg/m^2. The study group with a WHt ratio of >0.5 had a significantly lower (p=0.012) testosterone and higher (p=0.000) BMI, WC than the group with<0.5. Table 3 shows the correlations of anthropometric measurements and testosterone. An inverse correlation of testosterone was observed with age (r=-0.567), BMI (r=-0.265), WC (r=-0.406), and WHt ratio (r=-0.412) in the apparently healthy men studied. A non-significant (p<0.05) correlation was observed between age and BMI, age and WC. However a significant positive correlation existed between age and WHt ratio (r=0.282), WC and BMI (r=0.880), WC and WHt ratio (r=0.950), BMI and WHt ratio (r=0.845). An adjusted linear regression analysis of testosterone and anthropometrics is presented in Table 4. After adjustment for age, the correlation observed between testosterone and BMI (P=0.010), testosterone and WC (P=0.004), testosterone and WHt ratio (P=0.014) remained significant. After height adjustment, the correlation between testosterone and WHt ratio (p=0.002) also remained significant.

Table 1. *Characteristics of the study cohort (N=60).*

Variables	Mean±SD
Age years	47.05±9.58
Height cm	171.72±6.51
Weight kg	72.70±15.84
WC cm	90.41±10.61
BMI kg/m^2	24.62±5.07
WHt ratio	0.53±0.06
Testosterone ng/ml	4.70±1.19

BMI-body mass index, WHt ratio- waist-height-ratio, WC-waist circumference

Table 2. *Mean total testosterone and anthropometrics in different anthropometric subgroups.*

	WC (<100cm)	(WC>100cm)	t-value	P-value
	N=36	N=24		
Test. ng/ml	5.06±1.02	4.15±1.24	3.066	0.003*
BMI Kg/m^2	21.21±2.11	29.73±3.67	11.410	0.000*
WHt ratio	0.49±0.03	0.59±0.06	8.520	0.000*
WC cm	83.36±3.92	100.98±8.41	10.940	0.000*
Age years	46.31±10.22	48.17±8.61	0.735	0.466

	BMI (<25Kg/m^2)	BMI (>25Kg/m^2)	t-value	P-value
	N=37	N=23		
Test. ng/ml	4.94±1.09	4.30±1.26	2.080	0.042*
BMI Kg/m^2	21.20±2.04	30.12±3.27	13.040	0.000*
WHt ratio	0.49±0.03	0.59±0.06	7.844	0.000*
WC cm	83.78±4.21	101.08±8.93	10.150	0.000*
Age years	46.76±9.95	47.52±9.14	0.299	0.766

	WHt ratio (<0.5)	WHt ratio (>0.5)	t-value	P-value
	N=25	N=35		
Test. ng/ml	5.14±0.89	4.37±1.29	2.581	0.012*
BMI Kg/m^2	21.27±2.12	27.01±5.22	5.187	0.000*
WHt ratio	0.47±0.02	0.57±0.06	8.260	0.000*
WC cm	81.94±3.58	96.46±9.78	7.081	0.000*
Age years	43.84±9.92	49.34±8.75	2.270	0.027*

*significant, Test.-testosterone, BMI-body mass index, WHt ratio- waist-height-ratio, WC-waist circumference

Table 3. *Correlations of anthropometric measurements and testosterone.*

	Test.	Age	WC	BMI
Age	-0.567**			
WC	-0.406**	0.196		
BMI	-0.265*	-0.017	0.880**	
WHt ratio	-0.412**	0.282*	0.950**	0.845**

**Correlation is significant at the 0.01 level (2-tailed), *Correlation is significant at the 0.05 level (2-tailed).
Test.-testosterone, BMI-body mass index, WHt ratio- waist-height-ratio, WC-waist circumference

Table 4. *Adjusted linear regression analysis of testosterone and anthropometric measurements.*

Testosterone	WC	BMI	WHt ratio
Age adjustment	P=0.004*	P=0.010*	P=0.014*
Height adjustment	-	-	P=0.002*

*significant, BMI-body mass index, WHt ratio- waist-height-ratio, WC-waist circumference

4. Discussion

Low testosterone level is a risk factor for metabolic syndrome, type 2 diabetes, cardiovascular disease and all causes of mortality in men [15]. The objective of the present study was to correlate the WC, WHt ratio, and BMI with the levels of total testosterone.

This study observed an association of total testosterone with WC, WHt ratio, and BMI in the participants. Total testosterone (TT) level decreased as WC, WHt ratio, and BMI increased. Pearson correlation showed an inverse correlation of TT with WC, WHt ratio, and BMI. A stronger correlation of TT with WHt ratio than WC and BMI was observed in the present study.

The finding of this present study is similar to that of other studies. Data from the Massachusetts Male Aging Study

(MMAS) [16] and the European Male Aging Study (EMAS) [17] performed in large groups of middle-aged and elderly men have shown that BMI and WC are independently associated with decreased values of total testosterone. Jaworski *et al*., in addition to observing an inverse association of testosterone with BMI and WC, further reported a higher strength of association between abdominal circumference and TT, when compared to the association between BMI and TT [18]. The only study in the literature that determined the relationship of WHt ratio with testosterone showed that the WHt ratio was more strongly correlated with TT than either WC or BMI [19].

The present study observed an inverse correlation between age and testosterone, but an absent correlation of age with adiposity measures. Men's testosterone synthesis has been shown to decrease with increasing age, whereas central obesity tends to increase [20-22]. The absent correlation of age with adiposity indices implies that testosterone and adiposity impact each other based on the findings of this present study.

The association of testosterone with adiposity measures can be explained by the pathophysiological mechanisms of low testosterone in obese men. The mechanism is believed to be mediated by insulin resistance, estrogen, adipokines, and cytokines at the hypothalamus-pituitary axis, leading to a hypogonadotropichypogonadal state. Compensatory hyperinsulinemia accompanying the insulin resistant state in visceral obesity inhibits hepatic sex hormone binding globulin (SHBG) secretion which impacts negatively on bioavailable testosterone [23-24]. Ahn and colleagues found that hyperinsulinemia may directly exert a suppressive effect on testicular Leydig cell steroidogenesis [25]. In the mesenchymal cells and preadipocytes of adiposetissue of male subjects, androgens can be converted to estrogens by increased aromatase activity as a result of increased adiposetissue mass resulting in a reduction of gonadal testosterone production [26]. Elevated adipokines and cytokines are produced by visceral adipose tissues which exert both paracrine and endocrine functions [27]. Several of these adipokines have been involved in the development of insulin resistance and has been shown to increase oxidative stress in the testes [28].

5. Conclusion

The results of this present study show that all the adiposity measures determined predict the total testosterone level independent of age. The results further suggest that, of the anthropometric measures compared in this study, WHt ratio and WC are the best predictors of total testosterone level in men.

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