RELATIONSHIP OF ENDOGENOUS TESTOSTERONE LEVELS TO LEAN BODY MASS IN THE YOUNG AND MIDDLE-AGED PHYSICALLY ACTIVE - SPORTSMEN

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Abstract:

The purpose of this study was to examine the endogenous circulating testosterone levels and lean body mass (LBM) in young to middle-aged physically active - sportsmen to determine, whether there any relationships between these parameters in normal circumstances (i.e., no medical problems or pharmacological manipulations). Healthy, drug-free men (n=127) were recruited for testing (mean±SD, age 25.0±4.8 yr). Morning blood samples were obtained and underwater weighing was performed to determine the body composition (the measures were: LBM, fat weight [FW], body fat percentage [%fat]). Testosterone (T) was analyzed via RIA. Correlation analysis was performed to determine if thee were any significant relationships between the measures. Coefficients between T and LBM (r = 0.266), FW (r = -0.255), and %fat (r = -0.280) were significant ($p<0.005$). These findings show that endogenous testosterone and LBM are significantly related to one another in physically active men; however, the magnitude of the relationship is moderate at best. This suggests that the LBM component of men (which is comprised primarily of muscle mass) is related to circulating testosterone levels; but it is also strongly influenced by other factors.

Key words: *anabolic hormones, muscle mass*

INTRODUCTION

Testosterone is an anabolic-androgenic sex-steroid hormone linked to protein synthesis. Body size and muscular development are often associated with the level of testosterone in an adult male. This notion has developed because of the anabolic properties of this hormone. In reality, the degree of muscle mass development within a person is dependent upon many factors; some physiological, behavioral, and hereditary in nature (Florini, 1987). Nonetheless, there is evidence to support that the circulating testosterone level may be, to some extent, a factor in male muscle mass *in vivo*.

Ongphiphadhanakul et al. (1995) found in sedentary males that lean body mass was significantly correlated with endogenous testosterone levels. In a two compartment model of the human body's composition, the body is divided into the fat component (fat weight) and the lean body mass component (LBM, also referred to as fat free mass). The LBM component is comprised of several individual factors, but the primary one is skeletal muscle mass (Behnke & Wilmore, 1974; Brozek et al., 1963).

Other studies have demonstrated that the administration of exogenous testosterone increases the LBM. Arslanian et al. (1997) reported that 4 months of testosterone treatment to adolescents with delayed puberty resulted in a 7.6 kg increase in LBM. Bhasin et al. (1996) found that testosterone administration in adult men increased LBM, and the administration combined with exercise resulted in an even larger increase in lean body mass. Similarly, Griggs et al. (1989) reported that one month of testosterone administration (combined with a strength-training program) resulted in a 12% increase in lean body mass and a 27% increase in muscle protein synthesis rate.

Collectively, the results of these studies support the concept that circulating testosterone positively affects the LBM and the muscle mass. However, this issue has not be thoroughly researched, and, in particular, not to a large degree in physically active males in the basal state. Therefore, the present study was undertaken to examine the endogenous circulating testosterone levels and LBM in healthy men to determine if there were any relationships between these parameters under normal circumstances (i.e., no medical problems or pharmacological manipulations).

MATERIALS AND METHODS

Subjects

Healthy men (n=127) were recruited for testing in this study. All gave a written consent prior to their participation. Their physical characteristics were as follows (mean ± SD); age 25.0±4.8 yr (range = 18-45), body weight = 77.5±11.0 kg, and height = 177.5±8.9 cm. A questionnaire was completed to determine the physical activity level of the subjects. All the subjects were physically active on a regular basis (3.8±1.2 d/wk; 40±17 min/d) and participated in a variety of recreational and competitive sporting events. Many of the subjects were athletes who participated in various competitions (some of which at a national and international level) in ten different sports (lacrosse, American football, strack-and-field, wrestling, basketball, baseball, football, cycling, swimming). The number of subjects from each sport varied, but was relatively small. Due to the small sample size from each sport, comparisons between the sports groups were not made in order not to violete the statistical principles (Linton & Gallo, 1975). The questionnaire results also indicated that all the subjects were non-smokers, not taking any medications or recreational drugs, and had medical histories free from endocrine abnormalities.

Procedures

The subjects reported to our laboratory in the morning (»8:00 AM), 12-hours post-prandial, and rested for »15 minutes in a supine position. Then a blood sample was obtained via veni-puncture from a vein in the dominant arm. The blood sample was collected in an EDTA treated tube, which was immediately placed on ice. The tubes were later centrifuged at 3,000 g x 15 minutes to separate the plasma. The separated plasma was placed into cyro-freeze tubes and stored at –80°C until analysis later. Hormone analysis was done for total testosterone levels, and standard radioimmuno-assay procedures involving a single-phase, solid anti-body coated tube technology (DPC Inc, Los Angels, CA) were used. All the blood samples were analyzed in duplicate determination. Assay coefficient of variations were as follows: between assays = 7.8%, within-assay 5.5%.

Following the blood sampling, the body weight (mass) was determined with a medical grade balance scale (accuracy ±0.10 kg). A large sliding anthropometer was used to determine the subject's height (±0.10 cm). The subjects wore only running shorts during these measurements.

Pulmonary function testing was conducted next to determine the residual volume using the procedure of Sinning and Hackney (1984). This procedure for residual volume determination has been validated in a similar sample population and found to be highly accurate (Sinning & Hackney, 1984).

The subjects then proceeded to be weighed underwater using the procedures of Sinning and Hackney (1984). Briefly, this involved the subjects being weighed completely under the water for 10 trials. The three highest values were averaged together to determine the subject's weight underwater.

From weighing underwater, body density was determined, which was subsequently used with the body composition formula of Brozek et al. (1963) to calculate the percentage of body fat. Lean body mass (LBM) and fat weight (FW) were calculated on the basis of the percentage of body fat (%fat) values.

All of the above procedures were completed in a single testing session. Prior to coming to the testing session, the subjects were asked to refrain from hard physical activity, to eat a normal diet, and abstain from sexual activity for 24 hours before the testing.

Statistics

Mean and standard deviations were calculated for all measured variables. The analysis consisted of bivariate linear regression - correlation procedures being applied to the data. In all cases, testosterone was set as the independent variable, whereas the other outcome variables served as a dependent variable. A probability level of $P < 0.05$ was set as statistically significant.

RESULTS

The mean testosterone concentration of the subjects was 26.34 mmol/L (±SD = 12.57), which was within the clinically acceptable range for males of this age range (Tietz, 1990). Body composition results were: LMB = 67.21 ± 9.16 kg, FW = 9.18 ± 5.48 kg, and % Fat = 11.75 ± 5.66%.

The results of the regression – correlation statistical analysis revealed that significant correlation coefficients existed between testosterone and LBM (see Fig. 1). Several other body composition - physical characteristics were also correlated to testosterone. These results are displayed in Table 1. While significant relationships were found, the degree of variance accounted for by testosterone in each of the variables was relatively small (<9.0%).

al. (1995) they also measured free-testosterone and found the relation to LBM to be of the same magnitude as that of the total testosterone vs. LBM. Their sample was sedentary and of a larger age range, but of a similar size to ours (n=95). Their findings lead us to believe we would not have interpreted our data substantially differently if we had measured free testosterone.

In the human reference male (15% body fat, 70 kg body weight), skeletal muscle mass accounts for »52% of LBM (Behnke & Wilmore, 1974). In physically active men this relationship is typically larger, possibly representing as much as 60% or more (Behnke & Wilmore, 1974). Based upon this relationship, we conclude that the LBM component (and thus the skeletal muscle mass) within physically active men is related to circulating testosterone levels. Nevertheless, it is also recognized that the testosterone-muscle mass relationship is strongly influenced by other factors such as nutritional practices, genetics, and other endogenous hormones (Florini, 1987).

Table: *Correlation coefficients between testosterone and body composition - physical characteristics (n=127).*

	Body Weight	LBM	FW	%Fat	Age
Coefficient (r)	0.046	0.299	-0.246	-0.271	-0.297
Variance (r^2 x 100)	0.21%	8.96%	6.05%	7.33%	8.82%
Probability level	0.397	<0.005	<0.005	<0.002	<0.001

DISCUSSION

The primary finding of this study indicates that endogenous circulating testosterone levels and LBM are significantly related to one another in physically active men. However, the magnitude of the relationship is moderate at best. Our results are in close agreement with those of Ongphiphadhanakul et al. (1995) who studied sedentary men. Since this later study examined a somewhat comparable group of sedentary men, it was felt a “control” group was not necessary for comparative purposes in the present study.

It is realized that the more biologically active form of testosterone is a free component, whereas in this study we measured both the free and the bound component (total testosterone). It is conceivable that the relationship between free testosterone and LBM would have been stronger and accounted for a greater amount of variability. However, in the study by Ongphiphadhanakul et

CONCLUSIONS

Many athletes think there is a direct and strong relationship between testosterone and muscle mass. For this reason, some athletes take extreme actions to enhance their testosterone levels (dietary supplements and/or doping agents). We feel the present data can be used by coaches and sports scientists to convince the athletes that testosterone is only one of the components in their muscle mass development and the use of doping agents such as anabolic steroids is not necessary.

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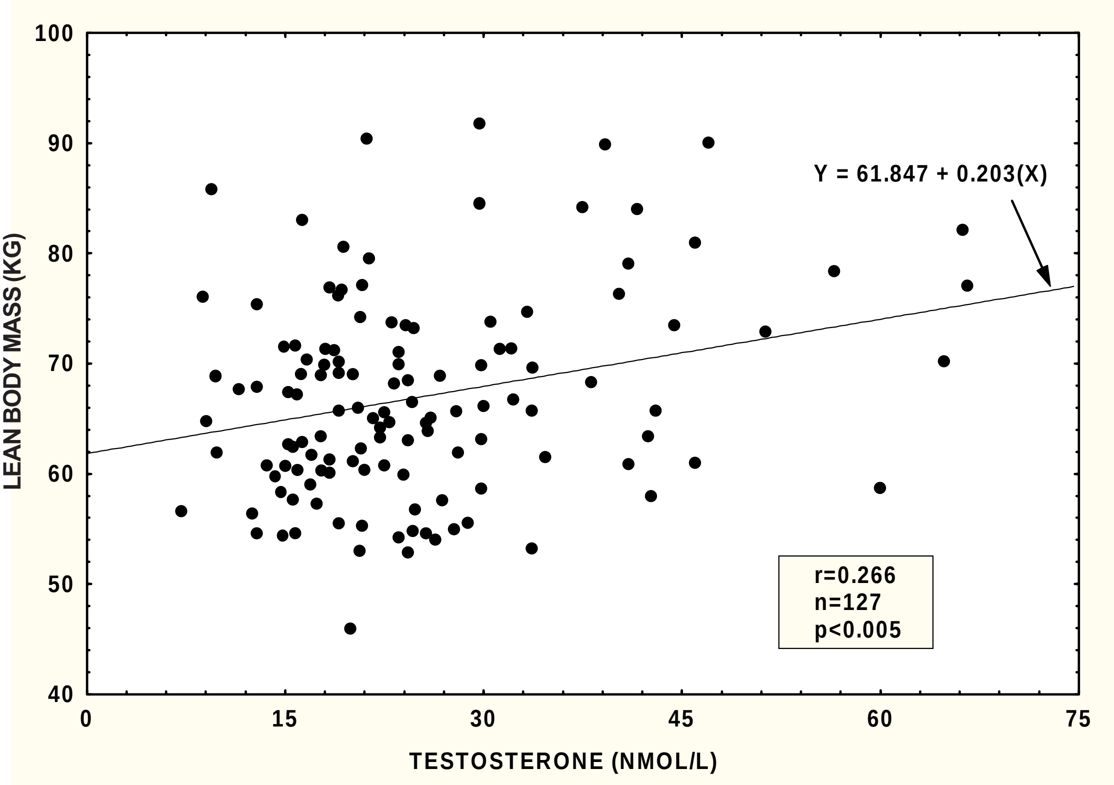
FIGURE LEGEND

Figure 1: *The scatter plot of the bivariate linear regression for the testosterone (T) vs. lean body mass (LBM) analysis.*



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ODNOS BAZALNIH RAZINA ENDOGENOG TESTOSTERONA PREMA NEMASNOJ TJELESNOJ MASI AKTIVNIH SPORTAŠA MLAĐE I SREDNJE DOBI

S A Ž E T A K

UVOD

Testosteron je anabolički androgeni spolni steroidni hormon povezan sa sintezom proteina. Mnogi veličinu tijela i mišićni razvoj povezuju s razinom testosterona u odraslih muškaraca. Takovo se poimanje razvilo zbog anaboličkih svojstava toga hormona. No, u stvarnosti, stupanj razvoja mišićne mase u pojedinca ovisi i o mnogim drugim faktorima; od kojih su neki fiziološke naravi, neki su vezani za ponašanje pojedinca, dok su drugi nasljedne prirode (Florini, 1987). Ipak, postoje dokazi koji podupiru pretpostavku kako opća razina cirkulirajućeg testosterona može biti, u određenoj mjeri, faktor koji doprinosi količini mišićne mase muškaraca *in vivo*.

Ongphiphadhanakul i suradnici (1999) ustanovili su na uzorku fizički neaktivnih odraslih muškaraca (sedentarni stil života) da je mišićna tjelesna masa značajno povezana s endogenom razinom testosterona. U dvodijelnom modelu konstitucije ljudskog tijela, ono se dijeli na masnu komponentu (udio masnoga tkiva) i na nemasnu tjelesnu masu (LBM – engl. *lean body mass*). I sama sastavnica nemasne tjelesne mase sastoji se od nekoliko faktora, među kojima je nedvojbeno najvažniji onaj koji se odnosi na masu skeletnih mišića (Behnke, Wilmore, 1974; Brozek i sur. 1963).

Neka druga istraživanja pokazala su kako unos testosterona (egzogeni testosteron) povećava nemasnu tjelesnu masu (LBM). Arslanian i suradnici (1997) izvijestili su kako je četveromjesečni tretman testosteronom u adolescenata koji su kasnili u biološkom razvoju (retardanti - zakašnjeli pubertet) rezultirao povećanjem LBM za 7,6 kg. Bhasin i suradnici (1996) su otkrili da primjena testosterona u odraslih muškaraca povećava LBM, a kada se taj unos kombinira s vježbanjem, tada je povećanje količine nemasne tjelesne mase još veće. Griggs i suradnici (1989) dobili su slične rezultate na temelju jednomjesečne primjene testosterona, kombinirane s trenažnim programom za razvoj snage, što je razultiralo 12%-tnim povećanjem nemasne tjelesne mase te 27%-tnim ubrzanjem i povećanjem sinteze mišićnih proteina.

Sveukupno, rezultati navedenih istražinvja potvrđuju tvrdnju kako ukupna razina cirkulirajućeg testosterona pozitivno utječe na nemasnu tjelesnu masu (LBM) i, posebice, na mišićnu masu. Taj problem, međutim, nije do sada bio predmetom iscrpnih znanstvenih istraživanja, a osobito se previše pozornosti nije posvećivalo bazalnom statusu uzorka fizički aktivnih muškaraca. Ovo je istraživanje stoga usmjerenjo na ispitivanje razine cirkulirajućeg endogenog testosterona i nemasne tjelesne mase na uzorku zdravih muškaraca kako bi se utvrdilo postoje li relacije među navedenim parametrima i u uvjetima fizički aktivnog svakodnevnog života.

ISPITANICI I METODE

Uzorak ispitanika činila su 142 zdrava muškarca, koja su dala pismeni pristanak za sudjelovanje u ovom istraživanju. Tjelesne karakteristike uzorka (aritmetička sredina ± standardna devijacija): dob – 25,1±1,4.6 godina (raspon od 18 do 45 godina), tjelesna masa – 77,9±10,8 kg, visina – 176,9±8,8 cm. Ispitanici su odgovorili na jednostavan upitnik o stupnju njihove fizičke aktivnosti. Svaki je ispitanik bio redovito fizički aktivan (3,9±1,3 dana/tjedno; 44±19 min/dan), tj. bio je uključen u neki od mnogobrojnih oblika redovitog tjelesnog vježbanja, od rekreativnog vježbanja do sudjelovanja u natjecateljskim sportskim disciplinama. Mnogi ispitanici bili su sportaši-natjecatelji iz 9 različitih sportova (*lacrosse* – kanadski nacionalni sport, sličan hokeju na travi, ali se igra specijalnim reketima, op. prev., američki nogomet, atletika – trkači, bacači i skakači, hrvanje, košarka, bejzbol, nogomet, biciklizam i plivanje). Svaki sport bio je zastupljen relativno malim, k tome i nejednakim brojem ispitanika. Zato nisu provedene usporedne analize rezultate ispitanika iz pojedinih sportskih disciplina. Naime, mali uzorci ispitanika iz pojedinačnih sportskih disciplina ugrozili bi statistička načela (Linton i Gallo, 1975).

Ispitanici bi se u našemu laboratoriju pojavili približno oko osam sati ujutro, 12 sati nakon posljednjeg obroka. Prvo su se 15 minuta odmarali ležeći na leđima. Nakon toga su im uzeti uzorci krvi iz vene na ruci. Iz krvnih se uzoraka ispitivala

opća razina cirkulirajućeg testosterona standardnim radioimunološkim mjernim postupkom (DPC Inc, Los Angeles, CA).

Nakon vađenja krvi, ispitanicima je izmjerena tjelesna masa baždarenom medicinskom vagomi (preciznost mjerenja ±0,10 kg). Velikim kliznim antropometrom izmjerena je visina ispitanika (preciznost mjerenja ±0,10 cm). Tijekom mjerenja ispitanici su bili odjeveni samo u kratke sportske hlačice. Provedeno je funkcionalno dijagnostičko testiranje dišnoga sustava kako bi se odredio rezidualni plućni volumen. Podvodno vaganje korišteno je za utvrđivanje građe tijela (Sinning i Hackney, 1984). Na temelju podvodnog vaganja određena je gustoća tijela koja je uvrštena u formulu Brozeka i suradnika (1963) za izračunavanje postotka tjelesne masnoće (% masti). Nemasna tjelesna masa (LBM) i težina masnog tkiva (FW – *fat weight*) izračunata je na temelju postotnih vrijednosti masnog tkiva.

Podaci su obrađeni bivarijatnom linearnom regresijskom korelacijskom analizom. Vrijednosti testosterona su u svim slučajevima predstavljale nezavisnu varijablu, dok su izračunate varijable korištene kao zavisna varijabla ($p<0.05$).

REZULTATI I RASPRAVA

Srednja vrijednost koncentracije testosterona u ispitanika iznosila je 26,64 nmol/l (±SD = 12,57), što je vrijednost unutar klinički prihvatljivog raspona za muškarce te dobi (Tietz, 1990). Rezultati dobiveni analizom tjelesne konstitucije bili su LBM = 67,21±9,16 kg, FW =9,18±5,48 kg i postotak masnoga tkiva = 11,75±5,66%).

Rezultati regresijske korelacijske analize pokazali su značajnu povezanost između razine testosterona i LBM (slika 1). Neke od ostalih tjelesnih mjera također su pozitivno korelirale s razinom testosterona. Ti su rezultati prikazani u tablici 1. Premda su utvrđene statistički značajne povezanosti između varijabli, dobiven je ralativno nizak stupanj zajedničkog varijabiliteta za udio testosterona u varijanci pojedinih varijabli (< 9.0 %).

Primarni zaključak proistekao iz ovog rada ukazuje na značajnu povezanost ukupne količine cirkulirajućeg endogenog testoserona i nemasne tjelesne mase u fizički aktivnih muškaraca. Međutim, veličina povezanosti je, u najboljem slučaju, umjerena. Dobiveni se rezultati uvelike slažu s nalazima Ongphadhanakula i suradnika (1995) koji su isti problem proučavali na uzorku sedentarnih, neaktivnih muškaraca. Kako je navedeno istraživanje obuhvaćalo, na neki način, komparabilnu grupu fizički neaktivnih, sedentarnih muškaraca, smatrali smo kako u našem istraživanju kontrolna grupa nije nužno potrebna.

Prema modelu prosječnog muškarca (15 % masnog tkiva, 70 kg tjelesne mase), ukupna masa skeletnih mišića iznosi približno 52 % nemasne tjelesne mase (LBM) (Behnke i Wilmore, 1974). U fizički aktivnih muškaraca taj je postotak u pravilu nešto veći, s mogućnošću da dosegne 60% ili čak i više postotaka (Behnke i Wilmore, 1974). Na temelju takvog odnosa zaključili smo da je sastavnica nemasne tjelesne mase (LBM), a onda i mišićna masa u fizički aktivnih muškaraca povezana s razinama cirkulirajućeg testosterona. Ipak, i ovdje se također se pokazalo da na odnos testosterona i mišićne mase znatno utječu i ostali faktori, poput prehrambenih navika, genetskih, naslijeđenih osobina te ostalih endogenih hormona (Florini, 1978).

ZAKLJUČAK

Mnogi sportaši misle kako postoji snažna izravna veza između razine testosterona i mišićne mase. Zbog toga će neki sportaši poduzimati i krajnje, čak i opasne mjere ne bi li povećali razinu testosterona u svome tijelu (dodaci u prehrani i/ili čak i uzimanje nedopuštenih sredstva, preparata ili dopinga). Autori ovog istraživanja vjeruju kako će dobiveni rezultati poslužiti i pomoći trenerima i kineziolozima da uvjere sportaše u to da je razina testosterona samo jedna od sastavnica u procesu razvoja mišićne mase, kao i da je korištenje doping-sredstava, poput, primjerice, anaboličkih steroida, nepotrebno.

Ključne riječi*: anabolički hormoni, testosteron, mišićna masa*