Chinese Journal of Physiology 53(1): 19-25, 2010
DOI: 10.4077/CJP.2010.AMH090

Effects of Short-Term Dehydroepiandrosterone Supplementation on Body Composition in Young Athletes

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Abstract

Dehydroepiandrosterone (DHEA) is often promoted as a slimming and weight/fat loss agent and ingestion of DHEA may have hypolipidemic and anti-obesity properties. The main aim of this study was to examine the effects of acute DHEA intake on body composition and serum steroid hormones in young athletes. Twenty young (19 to 22 years) male soccer players were allocated into two randomly assigned trials in double-blind design by ingesting 100-mg daily oral DHEA or as placebo (PLA) for 28 days. Body mass was not affected by 4 weeks of DHEA supplementation ($P > 0.05$). No significant changes in body mass index (BMI), waist-to-hip ratio (WHR) and body fat or total muscle mass for the two groups were detected at the end of the trial ($P > 0.05$). There was no within- or between-group difference in arm fat index (AFI) and corrected mid-upper-arm muscle area (cAMA) ($P > 0.05$). Treatment with DHEA resulted in a significant increase of total testosterone, estradiol and DHEA-S levels in treated subjects versus the placebo group ($P < 0.05$). Results of this study suggest that DHEA supplementation has no beneficial effects on body composition in young competitive athletes.

Key Words: testosterone, body fat, muscle mass, estradiol

Introduction

Dehydroepiandrosterone (DHEA) is a precursor to testosterone produced by the adrenal gland. Although DHEA is considered an anabolic steroid and is banned by many sports governing bodies including the International Olympic Committee, DHEA is a legal substance available from many retail outlets including health food stores and supermarkets. The overall prevalence of DHEA use is not known although several reports have indicated that DHEA is one of the most popular dietary supplements especially amongst adolescent athletes (7).

DHEA is often measured in human sera as DHEA-sulfate (DHEA-S) and serum levels of DHEA-S decline with age (3). It has, therefore, been proposed that supplementation with DHEA may benefit the elderly to a greater degree than younger individuals. Although ingestion of DHEA has been shown to increase blood androstenedione, DHEA and DHEA-S levels, it is unclear whether oral administration of DHEA increases blood testosterone and estradiol levels in men which could of particular interest to athletes (18, 19, 31). While most studies using 50 to 100 mg of DHEA reported no change in testosterone levels in men (15, 26, 28), most have described a change in estradiol levels. Increases in estradiol levels were reported by Bauileu *et al*. (1) after administering 50 mg of DHEA daily, and by Kahn and colleagues (15) after 6 months of daily DHEA administration (90 mg) in men aged 60 years or older. However, no effects were reported in two other studies

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Received: December 18, 2008; Revised: April 13, 2009; Accepted: May 6, 2009.
 ISSN : 0304-4920. http://www.cps.org.tw

using doses of 50 mg DHEA daily for 6 months in age-advanced men (18, 25). Little research to date has examined the effects of oral DHEA on serum hormones in young healthy men (4, 19). In a recent study, Yamada and colleagues (32) reported that serum concentrations of steroid hormones in younger subjects were unaffected by supplementation with DHEA (25 mg) for two weeks.

Fat reduction in young athletes is generally motivated by a desire to optimize performance before and during the season (21) and dietary supplements for weight loss/fat reduction seems to be popular in elite soccer (10). DHEA is often promoted as a slimming and weight/fat loss agent and ingestion of DHEA may have hypolipidemic and anti-obesity properties. Administering 100 mg per day of DHEA to aging men for 1 year was associated with a reduction in fat mass (33). A larger dose of oral DHEA (1,600 mg/d) for 28 days reduced fat mass in five non-obese young subjects (19) with the mean percent body fat decreased by 31%. On the other hand, most investigators claimed no anabolic effects and changes in body composition after supplementation with DHEA (4, 24, 29).

Most of the available literature has studied the slimming and anabolic effects of DHEA on aged and/or untrained males. Despite the high incidence of usage, the effects of DHEA supplementation on young competitive athletes have received much less research attention. In the present study, we tested the hypothesis that 100-mg daily oral DHEA supplementation for 28 days would reduce body fat and influence sex hormone responses in male athletes. The purpose of this study was to examine the effects of acute DHEA supplementation on body composition and serum steroid hormones in young soccer players.

Materials and Methods

Participants

Twenty young (19 to 22 years) male elite soccer players (1st Serbian League) gave their informed consent and volunteered to participate in the study with the approval of the PA University of Novi Sad Ethical Advisory Commission, and in accordance with the policy of National Anti-doping Agency and Medical Committee of the Serbian Football Association. All participants were fully informed verbally and in writing about the nature and demands of the study as well as the known health risks. They completed a health history questionnaire and were informed that they could withdraw from the study any time even after giving their written consent. All participants were in good health, free from musculoskeletal dysfunctions and metabolic and heart diseases, and had been participating in consistent training (average of six times or 9 h per week) for the past 2 years. Subject were not currently taking a dietary supplement that contains DHEA or other performance-enhancing substance that might alter the endocrine milieu of the subjects.

Experimental Procedures

The athletes were allocated to two randomly assigned trials in double-blind design by ingesting 100 mg daily oral DHEA or as placebo (PLA) for 28 days. Athletes in the placebo group ingested an equal number of identical looking pills that contains rice flour. Both pills were round and white with equal calorie content. According to the standard procedure, before the use of dietary supplement in an athletic environment, evidence of quality assurance and accordance with good manufacturing practice (GMP) were obtained from the relevant institution. After analysis, the Serbian National Institute of Health certified the purity, composition and quality of the DHEA preparation used in the present study along with verification of absence of contaminants that might have other stimulant properties (*e.g.* creatine and related compounds) (No. 3276-B08). Lama Inc. Belgrade, Serbia provided both the supplement and the placebo capsules. Athletes were instructed to take one pill in the morning upon waking and one pill just prior to sleep with pill counts used to determine subject compliance. The groups were matched (DHEA *vs*. PLA) for athletes' age, body mass, height, body fat and maximal oxygen uptake (58.9 ± 3.9 *vs*. 58.3 ± 4.2 ml/kg/min). Baseline testing was performed prior to supplementation, and the athletes were familiar with testing procedures as a part of their regular training process. Before and after the supplementation protocol, each soccer player underwent a series of blood assessment procedures and body composition tests. All athletes were assessed on the same day, and the tests were performed in the same order. In order to assess potential side effects to the supplementation regimen, all participants were instructed to report any adverse effects of supplementation, *e.g.* increased facial hair or perspiration, acne, weight gain, cramping, stomach distress or aggression.

Dietary Control and Training

Three days prior to the baseline testing, athletes met a nutritionist who instructed them to maintain their normal dietary pattern throughout the course of the study and to refrain from using any other supplementation. During the supplementation regimen, all athletes consumed similar standardized diet to ensure adequate macro- and micronutrient intake

(daily energy intake and protein intake were similar between the groups). Compliance was monitored by analyzing 3-d food records pre- and post-supplementation. Diet records were analyzed for composition using a food analysis software package (NutriBase 7, SyberSoft Inc., Phoenix, AZ, USA). Between the baseline and experimental testing, all athletes followed a similar specific training program (12) controlled by a certified conditioning coach. Athletes were strongly instructed to limit exercise to the prescribed training regimen. Exercise logs were also reviewed during and post-supplementation by an exercise physiologist (SMO) to insure compliance with their training program and to ensure that training variations from one group to another did not affect the between-group comparisons.

Body Composition

All anthropometric parameters were determined before and after the supplementation protocol. Height was measured using a stadiometer (Seca 202, Seca Corp., Hanover, MD, USA) to the nearest 0.1 cm while body mass was obtained to the nearest 0.1 kg using a calibrated balance beam scale (Model 3306 ABV, W & T Avery Ltd., Birmingham, West Midlands, UK). The athletes were measured nude, in the same state of hydration and nourishment after voiding. Body mass index (BMI) was calculated as body mass (kg)/height $(m)^2$. Waist and hip circumferences were measured using a Gulick anthropometric tape (M-22C, Creative Health Products, Plymouth, MI, USA) with waist-to-hip ratio (WHR) calculated. Three limb circumferences (calf, forearm, thigh) were identified and measured using anthropometric tape and percentage of muscle mass was estimated according to anthropometric protocol of Martin *et al*. (17) (standard error of estimation (SEE) = 6.1%). Skinfold thicknesses at seven sites was obtained using a caliper (Harpenden Skinfold Caliper, British Indicators Ltd., Burgess Hill, West Sussex, UK). The skinfold sites were triceps, subscapula, mid-axillary, anterior suprailiac, chest, abdomen and thigh. The landmarks were identified and measured according to Wilmore and Behnke (30) with the median of three measurements used to represent skinfold thickness. Percentage of body fat was determined according to equations of Jackson and Pollock (14) (SEE = 8.8%). Arm fat index (AFI) and corrected mid-upper-arm muscle area (cAMA) were calculated according to Gibson (8). The same trained technician performed the pre- and post-tests on each athlete for anthropometric measurements according to International Society for the Advancement of Kinathropometry (ISAK).

Blood Chemistry and Hormone Analyses

Blood samples were obtained after an overnight fast (12 h) between 0700 and 0800 for hormone analyses before and after the supplementation regimen. Hormones were checked at the same time of the day for all participants. Blood was withdrawn without stasis from a catheter inserted into an antecubital vein. Blood sample was centrifuged, and serum was frozen at -80°C until analysis. A commercial laboratory performed all the clinical blood chemistry analyses. Serum concentrations of free and total testosterone, estradiol and DHEA-S were measured by specific radioimmunoassays (RIA) using commercially available kits (Diagnostic Systems Laboratories Inc., Webster, TX, USA). The intra- and inter-assay coefficients of variation for the analysis were 6.1% and 9.7% for testosterone, 10.4% and 12.0% for estradiol and 7.5% and 9.6% for DHEA-S. All samples for each subject was assayed in the same run.

Statistical Analysis

The data were expressed as means ± SD. Statistical significance was assessed using Student's *t* test. Two-way analysis of variance with repeated measures was used to establish if any significant differences existed between subjects' responses over time. Where significant differences were found, the Tukey test was employed to identify the differences. *P* values of less than 0.05 were considered to be statistically significant.

Results

There was no baseline differences in age, height, body mass, maximal oxygen uptake or body fat between groups (Table 1). Body mass was not affected by 4 weeks of DHEA supplementation ($P > 0.05$). No significant changes in BMI, WHR, body fat or total muscle mass for the two groups were detected at the end of the trial. There was no within- or between-group difference in AFI and cAMA. Treatment with DHEA resulted in a significant increase of total testosterone, estradiol and DHEA-S levels in treated athletes versus the placebo group ($P < 0.05$) (Table 2). The increase in total testosterone, estradiol and DHEA-S over time was significant in the DHEA group only ($P < 0.05$). Serum free testosterone values were not significantly changed during DHEA and PLA administration. No athletes reported any vexatious side effects of supplementation.

Discussion

This study has provided the first direct analysis of influence of DHEA supplementation on total and regional body composition indicators and serum

Table 1. Demographic and body composition parameters pre- and post-supplementation

	DHEA (n = 10)		PLA (n = 10)	
	pre	*post*	*pre*	*post*
Age (years)	20.2 ± 1.0	–	20.7 ± 1.1	–
Height (cm)	182.4 ± 5.4	–	181.7 ± 7.4	–
Body mass (kg)	71.4 ± 3.2	71.8 ± 2.6	71.3 ± 2.9	71.5 ± 3.2
BMI (kg/m^2)	21.5 ± 1.5	21.6 ± 1.7	21.6 ± 1.8	21.7 ± 2.0
WHR	0.77 ± 0.04	0.78 ± 0.07	0.78 ± 0.06	0.80 ± 0.08
Body fat (%)	8.8 ± 1.6	8.6 ± 0.9	9.1 ± 2.0	9,0 ± 1,0
AFI (%)	19.4 ± 2.3	19.1 ± 2.7	20.1 ± 3.1	19.6 ± 2.8
Total muscle mass (%)	50.5 ± 2.6	51.1 ± 1.8	50.1 ± 3.1	50.9 ± 2.0
cAMA(cm^2)	49.4 ± 7.7	50.7 ± 8.1	50,1 ± 6,8	50.6 ± 8.0

Values are means ± SD. BMI = body mass index; WHR = waist-to-hip ratio; AFI = arm fat index; cAMA = corrected mid-upper-arm muscle area. There were no within- or between-group significant differences.

Table 2. Hormone profile pre- and post-supplementation

	DHEA (n = 10)		PLA (n = 10)	
	pre	*post*	*pre*	*post*
Total testosterone (nM)	18.2 ± 6.8	25.4 ± 8.1[a]	16.9 ± 10.1	17.8 ± 9.2[b]
Free testosterone (pM)	102.9 ± 19.2	107.1 ± 12.6	98.8 ± 15.2	101.4 ± 10.5
Estradiol (pM)	245.5 ± 28.6	312.9 ± 33.1[a]	261.1 ± 21.8	277.7 ± 30.2[b]
DHEA-S (μM)	3.5 ± 2.2	10.4 ± 4.3[a]	4.1 ± 1.8	3.9 ± 2.4[b]

Values are means ± SD. DHEA-S – dehdroepiandrosterone-sulfate; [a] Indicates significant differences pre- versus post at $P < 0.05$; [b] significant difference DHEA versus PLA at $P < 0.05$.

steroid hormones in young elite athletes. While previous studies have showed reduction in body fat induced by DHEA in both obese and non-obese subjects (18, 19), or no changes in body composition in untrained and/or mature men (24, 26-29), the results of the present study suggest no beneficial effect of DHEA supplementation on body composition in young competitive athletes. Treatment with a 100 mg oral daily dose of DHEA for 28 days had no significant effect on body mass, body fat and muscle mass in soccer players, while the levels of androgens and estradiol significantly increased after supplementation in DHEA as compared to placebo.

In the field of sports and exercise nutrition, DHEA is often promoted as a muscle-building and fat-burning agent that could increase muscular strength and exercise performance (16). However, clear evidence supporting the use of DHEA in athletic environment remains less clear. It is well known that age-related decreases in DHEA are associated with increases in obesity and a decline in fat free mass (18) yet the potential usefulness of DHEA as a slimming agent is mostly indicated by previous research in animals, particularly lower mammals (5). In the rat, plasma concentration of DHEA ranges between 14 and 80 nM while in the plasma of humans, DHEA-concentration ranges between 5 and 24 nM and DHEAS-concentration is up to 9 μM (23). The anti-obesity effect of DHEA in animals could be due to several possible mechanisms (5, 6, 16). However, studies that have investigated the effects of oral DHEA supplementation on body composition in humans produced equivocal results, particularly in young men. Nestler *et al*. (19) reported that 28-day supplementation with DHEA (1,600 mg/day) reduced body fat by 31% with no change in body mass in five normal men. Levels of serum total testosterone, free testosterone, sex hormone-binding globulin, estradiol and estrone did not change while serum DHEA-S and androstenedione rose 2.0- to 3.5-fold in DHEA group. Morales *et al*. (18) found that 100 mg of DHEA for 6 months induced decreases in body fat mass (6.1 ± 2.6%) in healthy non-obese men. On the other hand, several investigators showed that body composition was not affected by DHEA treatment in young and adult men, both obese and non-obese (24, 28, 29). Vogiatzi *et al*. (26) suggested that 40 mg DHEA administered sublingually twice daily for 8 weeks has no positive effects on body composition in obese young adults. In s recent DAWN trial (27), no beneficial effects of 50 mg daily oral DHEA supplementation on body composition were found in 110 healthy mature men. In accordance with the above research, the current study failed to show any beneficial effects of oral

DHEA administration on body mass and body composition in non-obese young athletes. We did not find significant reduction in body fat of young soccer players after DHEA supplementation. Other indicators of body fatness (*i.e.* BMI, WHR, ARI) remained unchanged during the study in both DHEA and placebo group indicating that treatment with DHEA does not result in significant changes to justify its use as an anti-obesity or slimming agent. As in the case of cognition, negative results in healthy volunteers can be attributed either to a true lack of DHEA effect or to body composition too close to ideal at the start of the study to detect changes in the small number of subjects studied.

Although the present study found no beneficial effects in DHEA supplementation on body composition in young competitive athletes, several investigators underlined possible beneficial effects of DHEA supplementation for elderly. Hernandez-Morante *et al*. (9) demonstrated for the first time *in vitro* that DHEA-S stimulates lipolysis in 85 obese patients preferably in subcutaneous fat in women and in visceral fat in men. A study by Ho *et al*. (11) suggested that low DHEA-S is associated with increased waist-to-hip ratio and reduced insulin sensitivity with aging while Hsu *et al*. (13) had reported that body composition and insulin sensitivity could change with aging in early lifetime. Benefits of DHEA supplementation in this regard for early middle-aged people require further clinical investigation.

Several studies reported that serum sex steroid levels in both mature and young men were not significantly affected by DHEA supplementation and with only a minimal amount converted to testosterone and more to estrogen (16, 18, 26). No changes in the levels of testosterone and estradiol were observed for men after supplementation with 50 mg of DHEA for 3, 6 and 12 months (27). In 19 young men (23 ± 1 yr old) participating in a 8-week resistance training, ingestion of 150 mg/day of DHEA did not affect serum testosterone and estrogen concentrations (4). Yet, in the present study, intake of DHEA resulted in significant increases of total testosterone in treated subjects after 28-days of supplementation. Furthermore, serum estradiol levels were significantly elevated indicating that a significant portion of the ingested DHEA had undergone aromatization. The apparent presence of discernible bioconversion of DHEA to active sex hormones among men was unexpected and hard to explain. Although Wolf *et al*. (31) reported a 1.3-fold increase in testosterone levels after supplementation with 50 mg oral DHEA for 2 weeks in 25 men (mean age, 69 yr), no study known to us showed significant increases in serum testosterone and/or estradiol levels after DHEA intake in young trained men. Possible explanations for our positive findings could be due to the small sample size, the dose of DHEA used or to differences in prevailing hormonal milieu and physiological status of the subjects. It seems that both the magnitude of the dose administered and the route of administration affect the extent of change in concentrations of sex hormones. Several studies have confirmed the importance of extra-adrenal and extra-gonadal 3s-hydroxysteroid dehydrogenase activity in the synthesis of androgens and estrogens after DHEA administration (16, 20). Not all subjects respond to DHEA in the same fashion suggesting that additional factors such as diet, type and intensity of exercise influence these responses. It remains to be further investigated whether exercise could result in increased DHEA and DHEA-S concentrations (2) and these elevated levels in athletes could influence response to supplementation. The present study reports an increase of total testosterone and estradiol levels while free testosterone level is normal. These data can be consistent with an increase of sex hormone binding globulin (SHBG) by DHEA administration (20). Total testosterone was increased to keep normal free testosterone or in alternative free testosterone was normal due to an increase activation of 5-alpha reductase. Measuring SHBG LH and FSH in future studies should prove these hypotheses.

Although oral DHEA intake enhanced testosterone production for 30%, we did not find changes in total muscle mass or regional muscularity. It seems that effects of DHEA on serum hormones were not mediated by an effect on body composition. Increasing DHEA levels in young trained men may not provide the optimal anabolic environment desired in spite of elevated total testosterone levels due to several possible mechanisms including genetic polymorphism of the androgen receptor or potential hormonal interconversions at the paracrine level (20). Whether the increase of testosterone after intake of prohormones translates into a meaningful change in body composition or rates of muscle protein synthesis is debatable. Studies must be evaluated in terms of the relative potency of various testosterone enhancers with varying effects on different tissues according to receptor-binding properties of the compound and its metabolites (6). The relative potency of DHEA seems to be small with inconsiderable advantageous anabolic properties. Several authors hypothesized that an important part of the musculotrophic effect of DHEA may not be directly mediated through androgen receptors but involve, instead, interference with catabolic effects produced by glucocorticoid hormones binding to their specific receptors (2, 18). With an incomplete understanding of how prohormones exert their effects on skeletal muscle, further studies should analyze nitrogen balance indicators as noninvasive

approximate index of muscle protein status.

A number of dietary supplements have been touted as assisting with short- or medium-term body mass and/or fat loss in young athletes with controversial efficacy of action. Although most athletes do not need to lose weight for health reasons, they may wish to attain a desired body composition in a sport that has an aesthetic ideal. However, athletes should consider several factors before deciding to use a dietary supplement, balancing advantages and disadvantages of usage. Few side effects, *i.e.* acne, fatigue, nasal congestion, headache, emotional changes, insomnia, palpitations, have been reported when oral DHEA supplements are taken in recommended doses (20, 33). Subjects in our study reported no acute side effects, yet caution should be used before recommending DHEA supplements to young athletes since the long-term effects of DHEA on the immature athlete are not known. Moreover, since DHEA products are sold as dietary supplements, there is no control over their contents or the manufacturing practices of the companies that manufacture the supplements. One independent evaluation found that the amount of DHEA in over-the-counter products ranged from 0% to 150% of what the content stated on the label (22). Finally, anabolic agents including pro-hormones are listed as proscribed by the IOC and supplementation with DHEA may lead to a positive drug test. Although we did not assess testosterone-epitestosterone ratio in the present study, competitive athletes should be aware of the potential for DHEA supplementation to alter the testosterone-epitestosterone ratio to exceed the 6:1 limit set by World Anti-Doping Agency in their screening for anabolic hormone doping (3). Since the ergogenic effects of DHEA are not well documented through the present study as well as in previous works in the field, it seems reasonable to limit the use of DHEA in athletic environment to promote doping safety. Sports scientists are responsible for applying this information to athletes practice and to apply pressure to supplement companies to produce only high-quality and well-labeled products.

In conclusion, a daily oral 100 mg dose of DHEA for 28 days resulted in elevations of circulating DHEA and testosterone levels in young athletes but did not induced favorable changes in body composition. Among young competitive soccer players, body composition assessed by BMI, fat and muscle mass and WHR was not affected by DHEA administration. Subjects did not experience any acute side effects of supplementation.

Acknowledgments

Study was partially supported by the Serbian Ministry of Science (Grant No. 145082).

References

1. Baulieu, E.E., Thomas, G., Legrain, S., Lahlou, N., Roger, M., Debuire, B., Faucounau, V., Girard, L., Hervy, M.P., Latour, F., Leaud, M.C., Mokrane, A., Pitti-Ferrandi, H., Trivalle, C., de Lacharriere, O., Nouveau, S., Rakoto-Arison, B., Souberbielle, J.C., Raison, J., Le Bouc, Y., Raynaud, A., Girerd, X. and Forette, F. Dehydroepiandrosterone (DHEA), DHEA sulfate, and aging: contribution of the DHEAge Study to a sociobiomedical issue. *Proc. Natl. Acad. Sci. USA*. 97: 4279-4284, 2000.
2. Bernton, E., Hoover, D., Fein, H., Galloway, R. and Popp, K. Adaptation to chronic stress in military trainees: adrenal androgens, testosterone, glucocorticoids, IGF-1 and immune function. *Ann. N. Y. Acad. Sci.* 774: 217-231, 1995.
3. Bowers, L.D. Oral dehydroepiandrosterone supplementation can increase the testosterone/epitestosterone ratio. *Clin. Chem.* 45: 295-297, 1999.
4. Brown, G.A., Vukovich, M.D., Sharp, R.L., Reifenrath, T.A, Parsons, K.A. and King, D.S. Effect of oral DHEA on serum testosterone and adaptations to resistance training in young men. *J. Appl. Physiol*. 87: 2274-2283, 1999.
5. Cleary, M.P. The antiobesity effect of dehydroepiandrosterone in rats. *Proc. Soc. Exp. Biol. Med*. 196: 8-16, 1991.
6. Ebeling, P. and Koivisto, V.A. Physiological importance of dehydroepiandrosterone. *Lancet* 343: 1479-1481, 1994.
7. Eichner, E.R. Ergogenic aids: what athletes are using - and why. *Phys. Sportsmed*. 25: 70-79, 1997.
8. Gibson, R.S. Nutritional Assessment: A Laboratory Manual. Oxford: OUP, 1993.
9. Hernández-Morante, J.J., Pérez-de-Heredia, F., Luján, J.A., Zamora, S. and Garaulet, M. Role of DHEA-S on body fat distribution: gender- and depot-specific stimulation of adipose tissue lipolysis. *Steroids* 73: 209-215, 2008.
10. Hespel, P., Maughan, R.J. and Greenhaff, P.L. Dietary supplements for football. *J. Sports Sci*. 24: 749-761, 2006.
11. Ho, C.T., Su, C.L., Chen, M.T., Liou, Y.F., Lee, S.D., Chien, K.Y. and Kuo, C.H. Aging effects on glycemic control and inflammation for politicians in Taiwan. *Chinese J. Physiol*. 51: 402-407, 2008.
12. Hoff, J. and Helgerud, J. Endurance and strength training for soccer players: physiological considerations. *Sports Med*. 34: 165-180, 2004.
13. Hsu, T.H., Liu, Y.F., Lee, S.D., Chen, S.M., Lee, J.P., Fang, C.L., Liu, T.C. and Kuo, C.H. Suppression of age-dependent increase in insulinemia in early middle-aged females with exercise habit. *Chinese J. Physiol*. 51: 263-268, 2008.
14. Jackson, A.S and Pollock, M.L. Generalized equations for predicting body density of men. *Br. J. Nutr*. 40: 497-504, 1978.
15. Kahn, A.J., Halloran, B., Wolkowitz, O. and Brizendine, L. Dehydroepiandrosterone supplementation and bone turnover in middle-aged to elderly men. *J. Clin. Endocrinol. Metab*. 87: 1544-1549, 2002.
16. Kroboth, P.D., Salek, F.S., Pittenger, A.L., Fabian, T.J. and Frye, R.F. DHEA and DHEA-S: a review. *J. Clin. Pharmacol*. 39: 327-348, 1999.
17. Martin, A.D., Spenst, L.T., Drinkwater, D.T. and Clarys, J.P. Anthropometric estimation of muscle mass in man. *Med. Sci. Sports Exerc*. 22: 729-733, 1990.
18. Morales, A.J., Haubrich, R.H., Hwang, J.Y., Asakura, H. and Yen, S.S. The effect of six months treatment with a 100 mg daily dose of dehydroepiandrosterone (DHEA) on circulating sex steroids, body composition and muscle strength in age-advanced men and women. *Clin. Endocrinol*. 49: 421-432, 1998.
19. Nestler, J.E., Barlascini, C.O., Clore, J.N. and Blackard, W.G. Dehydroepiandrosterone reduces serum low density lipoprotein levels and body fat but does not alter insulin sensitivity in normal men. *J. Clin. Endocrinol. Metabol*. 66: 57-61, 1988.

20. Nestler, J.E., Clore, J.N. and Blackard, W.G. Metabolism and actions of dehydroepiandrosterone in humans. *J. Steroid Biochem. Mol. Biol*. 40: 599-605, 1991.
21. Ostojic, S.M. Yohimbine: the effects on body composition and exercise performance in soccer players. *Res. Sports Med*. 14: 289-299, 2007.
22. Parasrampuria, J., Schwartz, K. and Petesch, R. Quality control of dehydroepiandrosterone dietary supplement products. *J. Am. Med. Assoc*. 280: 1565, 1998.
23. Svec, F. and Porter, J.R. The actions of exogenous dehydroepiandrosterone in experimenatl animals and humans. *Proc. Soc. Exp. Biol. Med*. 218: 174-191, 1998.
24. Usiskin, K.S., Butterworth, S., Clore, J.N., Arad, Y., Ginsberg, H.N., Blackard, W.G. and Nestler, J.E. Lack of effect of dehydroepiandrosterone in obese men. *Int. J. Obes*. 14: 457-463, 1990.
25. Villareal, D.T., Holloszy, J.O. and Kohrt, W.M. Effects of DHEA replacement on bone mineral density and body composition in elderly women and men. *Clin. Endocrinol*. 53: 561-568, 2000.
26. Vogiatzi, M.G., Boeck, M.A., Vlachopapadopoulou, E., el-Rashid, R. and New, M.I. Dehydroepiandrosterone in morbidly obese adolescents: effects on weight, body composition, lipids, and insulin resistance. *Metabolism* 45: 1011-1015, 1996.
27. Von Muhlen, D., Laughlin, G.A., Kritz-Silverstain, D., Bergstrom, J. and Bettencourt, R. Effect of dehydroepiandrosterone supplementation on bone mineral density, bone markers, and body composition in older adults: the DAWN trial. *Osteoporos. Int*. 19: 699-707, 2008.
28. Wallace, M.B., Lim, J., Cutler, A. and Bucci, L. Effects of dehydroepiandrosterone *vs*. androstenedione supplementation in men. *Med. Sci. Sports Exerc*. 31: 1788-1792, 1999.
29. Welle, S., Jozefowicz, R. and Statt, M. Failure of dehydroepiandrosterone to influence energy and protein metabolism in humans. *J. Clin. Endocrinol. Metab*. 71: 1259-1264, 1990.
30. Wilmore, J.H. and Behnke, A.R. An anthropometric estimation of body density and lean body weight in young men. *J. Appl. Physiol*. 27: 25-31, 1969.
31. Wolf, O.T., Neumann, O., Hellhammer, D.H., Geiben, A.C., Strasburger, C.J., Dressendorfer, R.A., Pirke, K.M. and Kirschbaum, C. Effects of a two-week physiological dehydroepiandrosterone substitution on cognitive performance and well-being in healthy elderly women and men. *J. Clin. Endocrinol. Metabol*. 82: 2363-2367, 1997.
32. Yamada, Y., Sekihara, H., Omura, M., Yanase, T., Takayanagi, R., Mune, T., Yasuda, K., Ishizuka, T., Ueshiba, H., Miyachi, Y., Iwasaki, T., Nakajima, A. and Nawata, H. Changes in serum sex hormone profiles after short-term low-dose administration of dehydroepiandrosterone (DHEA) to young and elderly persons. *Endocrine J*. 54: 153-162, 2007.
33. Yen, S.S., Morales, A.J. and Khorram, O. Replacement of DHEA in aging men and women. Potential remedial effects. *Ann. N. Y. Acad. Sci*. 774: 128-142, 1995.