

## Anabolic Steroids

# Androgenic Anabolic Steroids and Arterial Structure and Function in Male Bodybuilders

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- OBJECTIVES** The study examined arterial and cardiac structure and function in bodybuilders using androgenic anabolic steroids (AAS), compared to non-steroid-using bodybuilder controls.
- BACKGROUND** Adverse cardiovascular events have been reported in bodybuilders taking anabolic steroids. The cardiovascular effects of AAS, however, have not been investigated in detail.
- METHODS** We recruited 20 male bodybuilders (aged  $35 \pm 3$  years), 10 actively using AAS and 10 who denied ever using steroids. Serum lipid and hormone levels, carotid intima-media thickness (IMT), arterial reactivity, and left ventricular (LV) dimensions were measured. Vessel diameter was measured by ultrasound at rest, during reactive hyperemia (an endothelium-dependent response, leading to flow-mediated dilation, FMD), and after sublingual nitroglycerin (GTN, an endothelium-independent dilator). Arterial reactivity was also measured in 10 age-matched non-bodybuilding sedentary controls.
- RESULTS** Use of AAS was associated with significant decreases in high density lipoprotein cholesterol, sex hormone binding globulin, testosterone and gonadotrophin levels, and significant increases in LV mass and self-reported physical strength ( $p < 0.05$ ). Carotid IMT ( $0.60 \pm 0.04$  mm vs.  $0.63 \pm 0.07$  mm), arterial FMD ( $4.7 \pm 1.4\%$  vs.  $4.1 \pm 0.7\%$ ) and GTN responses ( $11.0 \pm 1.9\%$  vs.  $14.4 \pm 1.7\%$ ) were similar in both bodybuilding groups ( $p > 0.2$ ). The GTN responses were significantly lower and carotid IMT significantly higher in both bodybuilding groups, however, compared with the non-bodybuilding sedentary controls ( $p = 0.01$ ).
- CONCLUSIONS** Although high-level bodybuilding is associated with impaired vascular reactivity and increased arterial thickening, the use of AAS per se is not associated with significant abnormalities of arterial structure or function. (J Am Coll Cardiol 2001;37:224-30) © 2001 by the American College of Cardiology

The physiologic and pharmacologic effects of androgens on arterial structure and function are poorly characterized. Several lines of evidence implicate a pro-atherogenic effect. Epidemiologic studies demonstrate that cardiovascular disease is more prevalent and severe in adult men than in women at all ages (1). Whether this disparity is due to hormonal, genetic or lifestyle differences remains to be clarified. Some evidence suggests androgens may be directly involved. We have previously observed that androgens may promote monocyte adhesion to endothelial cells (2) and macrophage lipid loading (3). Regarding vascular function, androgens are associated with impaired arterial reactivity in genetic females taking high-dose androgenic steroids (4), and endothelial function is enhanced in androgen-deprived older men (5).

In contrast, certain observations are consistent with an anti-ischemic effect of androgens. Testosterone is an acute coronary vasodilator (6-8). Furthermore, although men

have greater cardiovascular risk than women (9), men with low androgen levels have a higher risk of cardiovascular events (10). The vascular effect of androgens is important in assessing the potential influence of illicit androgenic anabolic steroid (AAS) use on arterial structure and function in healthy young athletes.

The use of AAS is widespread (11,12), and anecdotal reports of premature vascular events in young AAS users have prompted concern (13,14). However, AAS users are difficult to study, because they are secretive about what drugs they use and have rarely participated in voluntary medical research. Furthermore, selection of appropriate bodybuilding but non-AAS-using controls (matched for type and duration of aerobic and anaerobic exercise levels) is challenging. In this study, we investigated arterial and cardiac structure and function in steroid-using and abstinent young male bodybuilders, and we compared arterial structure and function to non-bodybuilding sedentary control subjects.

## METHODS

**Subjects.** Twenty adult male bodybuilders (age 18 to 55 years) and 10 adult male non-bodybuilding subjects (age 27 to 48 years), all in apparent good health, were

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#### Abbreviations and Acronyms

AAS	= androgenic anabolic steroids
BP	= blood pressure
FMD	= flow-mediated dilation
FSH	= follicle-stimulating hormone
GTN	= sublingual nitroglycerin
HDL	= high density lipoprotein
IMT	= intima-media thickness
LH	= luteinizing hormone
LV	= left ventricle/left ventricular
SHBG	= sex hormone binding globulin

studied. Clinical exclusion criteria included chronic medical conditions (ischemic heart disease, diabetes mellitus, kidney, liver or psychiatric disorders) and the use of regular cardioactive medications. All subjects gave written informed consent, and the study was approved by the appropriate institutional ethics review committee.

In Australia there are two major competitive bodybuilding associations. Only one features frequent and mandatory drug testing of urine samples to ensure drug-free status as a requirement for eligibility. Bodybuilders actively using AAS and non-AAS-using bodybuilding controls were recruited from these two associations. In every case, self-report was verified by urine drug testing (see below). Anabolic steroid users were enrolled if they were currently using AAS and had been using over a period of at least the previous 24 months. Drug-free bodybuilders denied ever using AAS, hormonal therapy of any kind or other illicit performance-enhancing drugs. Bodybuilding controls were included only when there was both a negative history and negative urine drug screen. Positive urine testing for AAS in two subjects who denied steroid use therefore resulted in their exclusion from further analysis. Finally a group of non-bodybuilding, non-steroid-using controls were recruited from the community and historically had not been on any regular exercise program, nor ever used AAS.

**Study design.** This was a cross-sectional study, with study size determined by power calculations related to the primary end points: a comparison of flow-mediated dilation (FMD) and left ventricular (LV) mass between bodybuilders, who were or were not users of anabolic steroids.

Each of the bodybuilders had one study visit, during which a history was taken, concerning health, regular medications, steroid and other performance-enhancing drug use, exercise patterns (hours of aerobic, anaerobic and total exercise performed per week) and strength capacity. Supine resting blood pressure was measured, fasting blood samples were taken for serum hormone levels, lipids and biochemistry, a urine sample was taken for drug screening, two-dimensional and Doppler echocardiography was performed, and arterial reactivity was assessed using vascular ultrasound. In the non-bodybuilding controls a similar history was taken, blood tests performed, and arterial structure and function studied, as described below.

**BLOOD TESTS.** Serum testosterone and estradiol levels were measured by established immunoassays. Clinical chemistry and lipids were measured by routine autoanalyzer methods.

**URINE ASSAYS.** Urine samples were screened for AAS using gas chromatography/mass spectrometry, incorporating modern high-resolution mass spectrometry methods, as standardized by the International Olympic Committee (15).

**VASCULAR STUDIES.** Arterial reactivity was studied using high-resolution external vascular ultrasound of the right brachial or radial artery, as described by Celermajer et al. (16), using a GE-Vingmed System 5 mainframe and a 10-MHz linear array transducer. Arterial diameter was measured at rest, during reactive hyperemia (leading to FMD, an endothelium-dependent stimulus) and after a 400- $\mu$ g spray of sublingual nitroglycerin (GTN, an endothelium-independent dilator). Reactive hyperemia responses were assessed following temporary (4.5 min) brachial artery occlusion with a sphygmomanometer placed below the target artery (cuff to 250 mm Hg). Comparing arterial diameter measurements during reactive hyperemia to baseline allows calculation of the values for FMD, which is predominantly due to endothelial nitric oxide release (17). Analysis was carried out by two independent observers. Operators and analyzers were blinded to treatment assignment, and analyzers blinded to the stage of the experiment.

Intima-media thickness (IMT) was measured using the same ultrasound machine and transducer, for both the left and right common carotid arteries. The image was focused on the posterior wall, and images of the distal 10 mm of the common carotid artery was recorded from the angle showing the greatest distance between the lumen-intima interface and the media-adventitia interface, as previously described (18). The distance between the characteristic echoes from the lumen-intima and the media-adventitia interfaces was taken as the measure of IMT (19,20). Scans were analyzed with a previously validated computerized edge detection system (21). Two end-diastolic frames were selected, digitized and analyzed for maximum and mean IMT; next, the average reading was calculated from these two frames and from the average of left and right arteries (18).

**CARDIAC STUDIES.** Cardiac echocardiography was performed in the bodybuilders using a GE-Vingmed System 5 mainframe and a 3.5-MHz phased array transducer. Measurements of LV dimensions were obtained from both M-mode and two-dimensional echocardiography. The LV measurements were performed at end-diastole and end-systole according to the recommendations of the American Society of Echocardiography and the Penn Convention (22,23). Only frames with optimal visualization of interventricular septum, posterior wall, and LV internal diameter throughout the entire cardiac cycle were used for measurements. The mean values from  $\geq 3$  measurements for each parameter were computed. The LV mass was calculated using the Devereux formula (24), and LV volumes were

**Table 1.** Baseline Characteristics in AAS Users and Bodybuilding Controls

	AAS Users	Bodybuilding Controls
Age (yrs)	37 ± 3.1	34 ± 3.0
BMI	29 ± 1.6	26 ± 0.8
Weight (kg)*	92 ± 5.0	80 ± 2.4
Systolic BP (mm Hg)	127 ± 2.7	119 ± 3.8
Diastolic BP (mm Hg)	74 ± 4.9	71 ± 5.4
Total cholesterol (mmol/liter)	4.9 ± 0.5	4.7 ± 0.3
HDL (mmol/liter)***	0.6 ± 0.1	1.4 ± 0.1
Triglycerides (mmol/liter)	1.2 ± 0.2	1.0 ± 0.2
Testosterone (nmol/liter)*	10.7 ± 5.9	22.7 ± 3.7
Estradiol (pmol/liter)	117 ± 29	142 ± 30
LH (U/liter)**	1.2 ± 0.4	5.6 ± 1.2
FSH (U/liter)***	1.0 ± 0.3	3.7 ± 0.5
SHBG (nmol/liter)**	11 ± 2.7	35 ± 5.4
Total exercise (h/week)	9.8 ± 2.1	8.0 ± 1.2
Anerobic exercise (h/week)	8.8 ± 1.8	6.1 ± 1.0
Bench-press maximum (kg)*	150 ± 16	109 ± 29

AAS = androgenic anabolic steroids; BMI = body mass index; BP = blood pressure; FSH = follicle-stimulating hormone; HDL = high density lipoprotein cholesterol; LH = luteinizing hormone; SHBG = sex hormone binding globulin.  
 \*p < 0.05. \*\*p < 0.01. \*\*\*p < 0.001.

estimated using the prolate ellipsoid method (25). Doppler assessment included the use of color, pulsed wave, and continuous wave Doppler modes.

**Statistical analysis.** Descriptive data are expressed as mean value ± SEM. As the primary research question of this study concerned the arterial effects of AAS use, the two groups of bodybuilders (anabolic steroid users and drug-free controls) were compared by independent sample *t*-tests or Mann-Whitney *U*-tests for nonparametric variables, as appropriate. The prospectively defined primary end points of this study were FMD and LV mass. The *p* values for all the other measured parameters were adjusted by the Hochberg modification of the Bonferroni procedure for multiple comparisons (26). Both FMD and GTN responses as well as IMT values in the three groups (including the sedentary controls) were tested by analysis of variance for trend (SPSS, version 6.0), followed by the Scheffé test for pairwise comparisons where appropriate. Statistical significance was inferred at a two-sided *p* value < 0.05.

## RESULTS

**Baseline characteristics.** Drug-free and AAS-using bodybuilders were well matched for age, smoking history, blood pressure and exercise regimes (hours of aerobic, anaerobic and total exercise per week) (Table 1). There were two smokers in the AAS group (lifetime cigarette history of 8 Pack-years each) and one smoker in the bodybuilding control group (4 Pack-years).

Self-reported strength was significantly higher in the AAS users (best single repetition for bench press, 150 ± 16 vs. 109 ± 29 kg, *p* = 0.04).

The AAS users admitted using multiple agents simultaneously (median, 4; range, 1 to 10) for a mean duration of 6.6 ± 1.4 (2 to 13) years. All users studied admitted taking

**Table 2.** Cardiovascular Results in AAS Users and Bodybuilding Controls

	AAS Users	Bodybuilding Controls
Vessel size (mm)	3.8 ± 0.3	3.4 ± 0.3
FMD (%)	4.7 ± 1.4	4.1 ± 0.7
GTN (%)	11.0 ± 1.9	14.4 ± 1.7
Mean carotid IMT (mm)	0.60 ± 0.04	0.63 ± 0.07
Maximum carotid IMT (mm)	0.83 ± 0.05	0.82 ± 0.1
LV mass (g)*	245 ± 16	199 ± 12
IVS (mm)**	10 ± 0.3	8.7 ± 0.2
PW (mm)*	9.8 ± 0.4	8.7 ± 0.3
FS (%)	41 ± 2.4	41 ± 2.6

AAS = androgenic anabolic steroids; FMD = flow mediated dilatation; FS = fractional shortening; GTN = sublingual nitroglycerin; IMT = intima media thickness; IVS = interventricular septum; LV = left ventricle; PW = posterior wall.  
 \*p < 0.05. \*\*p < 0.01.

intramuscular preparations of AAS; seven users admitted taking intramuscular preparations of testosterone esters and four also used oral AAS preparations. At the time of study these subjects were all currently using AAS, three in cyclical and seven in continuous regimens. One man admitted concomitant use of growth hormone. The most commonly identified agents on urine drug screening were stanozolol (70%) and nandrolone (50%). No subjects were taking other hormonal agents, such as tamoxifen. Two subjects only were taking creatine (one in each group of bodybuilders).

No sedentary controls were taking regular medications of any kind. The age (34 ± 2.4 years), systolic blood pressure (BP) (123 ± 3.8 mm Hg), total cholesterol level (4.3 ± 0.3 mmol/liter), smoking history (one smoker with a 6 Pack-years history) and vessel size (3.7 ± 0.1 mm) were similar in these sedentary controls, compared to both groups of bodybuilding subjects (*p* > 0.2).

**Hormone and lipid levels.** Serum gonadotrophins (luteinizing hormone [LH], follicle-stimulating hormone [FSH]) were significantly decreased in the anabolic steroid-using group (*p* = 0.007, *p* = 0.001, respectively) (Table 1). Serum testosterone and serum sex hormone binding globulin (SHBG) were also significantly decreased in the AAS-using subjects (*p* = 0.02, *p* = 0.002, respectively).

Serum estradiol levels did not significantly differ between the two groups of bodybuilders (*p* > 0.1). Total cholesterol, triglycerides and lipoprotein(a) were similar in both groups and within the normal ranges. Low density lipoprotein levels did not significantly differ between the two groups of bodybuilders; however, high density lipoprotein (HDL) was significantly lower in the anabolic steroid group (0.6 ± 0.1 vs. 1.4 ± 0.1 mmol/liter, *p* < 0.001).

**Arterial studies.** The AAS users had slightly but not significantly larger vessels than did the bodybuilder controls; 3.8 ± 0.3 and 3.4 ± 0.3 mm, respectively (*p* > 0.2) (Table 2). Despite this, FMD responses were similar in both groups of bodybuilders; 4.7 ± 1.4% and 4.1 ± 0.7%, respectively (*p* > 0.2). These responses tended to be lower than FMD in the non-bodybuilding controls, but not significantly so (7.3 ± 0.7%, *p* = 0.10). The GTN re-



sponses were also not significantly different between the bodybuilding groups;  $11.0 \pm 1.9\%$  and  $14.4 \pm 1.7\%$ , respectively ( $p > 0.2$ ); however, they were significantly lower compared to non-bodybuilding controls;  $19.4 \pm 1.4\%$  ( $p = 0.01$ ). Regarding arterial structure, carotid IMT results were similar in both bodybuilding groups ( $0.60 \pm 0.04$  mm in AAS users,  $0.63 \pm 0.07$  mm in bodybuilding controls,  $p > 0.2$ ); however, these values were significantly higher than in the non-bodybuilding controls ( $0.47 \pm 0.07$  mm,  $p = 0.01$ ).

**Cardiac studies.** The LV mass was significantly greater in the AAS-using group compared to the bodybuilding controls ( $245 \pm 16$  and  $199 \pm 12$  g, respectively,  $p = 0.04$ ). The LV volumes were not significantly different in these two groups ( $70 \pm 5$  and  $82 \pm 13$  cm<sup>3</sup>,  $p > 0.2$ ). The LV mass adjusted for LV volume remained significantly greater in the AAS users ( $p = 0.04$ ); LV mass adjusted for body surface area, however, was no longer significantly different ( $117 \pm 7$  vs.  $101 \pm 6$  g/m<sup>2</sup>,  $p = 0.09$ ). After further adjustment for maximum strength capacity, the adjusted LV mass was quite similar between groups ( $p > 0.2$ ). There was no significant difference in LV wall thickness or ultrasound-assessed fractional shortening ( $p > 0.2$ ). Two subjects from the AAS group, but no controls, were noted to have mild aortic incompetence. Resting blood pressure (BP) was similar between groups ( $p > 0.2$ ).

## DISCUSSION

In this study on the cardiovascular effects of AAS use in male bodybuilders, the major findings were a decreased level of HDL cholesterol and a higher unadjusted LV mass in the steroid users, but no evidence of structural or functional abnormalities in the systemic arteries, compared to bodybuilding control subjects.

**Anabolic steroids and metabolism.** Consistent with the findings of the current study, androgens have previously been demonstrated to lower HDL levels significantly (27). This is primarily due to supraphysiologic hepatic exposure to androgens, whether by oral route or high parenteral doses (28). Such effects on HDL cholesterol are not evident with physiologic doses of testosterone administered transdermally (29) or via implants (30). This potentially pro-atherogenic effect of AAS may be offset by a steroid-related decrease in levels of lipoprotein(a) (31). Nevertheless, studies documenting the extent and severity of atherosclerosis in steroid users are not available. As synthetic AASs are not detected by routine serum testosterone assays, the observed decrease in serum gonadotrophin levels is consistent with net androgen overdosage in the AAS group, together with hypothalamic-pituitary feedback inhibition. This should also result in reduced serum testosterone levels, unless exogenous testosterone is also being taken. The high proportion (70%) using exogenous testosterone among AAS users in this study, however, accounts for the higher than expected mean testosterone level in this group. That is,

while subnormal serum testosterone levels were expected and observed, the findings that mean serum testosterone levels were actually within the normal range is consistent with recent exogenous testosterone administration. Urine testing and lowered serum SHBG levels (32) also serve to confirm the self-reported status of both groups of bodybuilding subjects.

**Effects of exercise on arterial reactivity and structure.** Regular aerobic exercise increases arterial FMD, possibly via enhanced nitric oxide (NO) release, in both animals (33) and in man (34). Intense aerobic exercise, however, has been associated with impaired endothelial function (35). The use of controls carefully matched for type and duration of exercise is therefore an important feature of any study designed to assess the effects of AAS (or any other drugs) in athletes. By contrast, the effects of intense bodybuilding on vascular reactivity are not known.

In this study, endothelium-independent dilation was significantly reduced in both groups of bodybuilders compared to sedentary controls, whereas FMD was not significantly reduced, suggesting a defect in smooth muscle dilator capacity. Possible mechanisms include increased water retention and/or increased vascular muscle mass impairing smooth muscle dilator responses. This may also account for the bodybuilding-related increase in carotid IMT observed in this study. The possibility exists that some or all of the bodybuilding controls have used AAS in the past and that this had not been detected by history or urine drug screening. This appears unlikely, however, as the bodybuilding controls were selected from an official "drug free" athletic society, where continued membership relies on repeated negative urine drug screens. Furthermore, the non-AAS-using bodybuilding controls had significantly lower body mass, muscle strength, serum HDL and SHBG compared to the AAS users, and normal gonadotrophin (LH, FSH) levels, suggesting true anabolic steroid abstinence.

**Anabolic steroids and arterial effects.** Androgenic anabolic steroids are used by a considerable proportion of the community to enhance physique and performance, with more than a million Americans using or having used anabolic steroids (12). From this large population, there have been case reports associating AAS and premature cardiovascular complications including thrombo-embolic disease (myocardial infarction, stroke and pulmonary embolism), cardiomyopathy, ventricular arrhythmias and LV hypertrophy (13,14), but it remains to be clarified if these associations are more than chance observations.

Arterial reactivity is an important functional determinant of vascular health or disease (36), and IMT is a structural marker for the extent of atherosclerosis (21). Changes in these parameters were not seen in association with AAS use in the current study. In an experimental animal model, chronic treatment of rabbits with the anabolic steroid nandrolone has resulted in impairment of endothelium-dependent and endothelium-independent dilation in aortic

rings; however, markedly supraphysiologic doses were used (37).

In previous human studies, androgens have had variable effects on arterial reactivity. High-dose androgen use by genetic females (female-to-male transsexuals) may be associated with impaired vascular reactivity (4), and androgen deprivation (in men having undergone castration for prostate cancer) is associated with enhanced vascular reactivity (5). Acutely administered testosterone, however, results in vasodilatation in both animal and human studies, through an endothelium-independent mechanism (probably via ATP-sensitive potassium channels) (6-8). In postmenopausal women, preliminary data on the use of low-dose testosterone as part of hormone replacement therapy did not reveal any alteration in FMD or GTN responses (38). Finally, a case of improved forearm microvascular function after cessation of AAS use has been reported; however, this occurred in only one of seven such subjects examined (39).

The use of AAS in healthy young men is an unusual situation, however, where high androgen dosage is administered without preceding androgen deficiency. This may be important because of the prevalence of AAS usage and preliminary reports of its potential cardiovascular risk (13,14). The effects of AAS may be dependent on the dose, type of androgen used and outcome measured. In this group of young men, however, no significant arterial abnormalities associated with AAS use were observed, suggesting a lack of the type of deleterious effect observed in genetic females taking high-dose androgens (4).

In our study, AAS use was associated with low HDL levels, a potential risk factor for vascular dysfunction and disease. In previous reports, low HDL levels have been associated with impaired endothelial function in hypercholesterolemic adults (40) and in healthy young men (41). Our current data suggest that pharmacologically induced low HDL levels in AAS users may not per se lead to vascular dysfunction.

Study numbers were limited in the current report owing to the secretive nature of AAS use in the community and consequent reluctance to participate in medical research. For this reason, few if any previous studies have addressed the vascular effects of AAS use. Nevertheless, this study had reasonable power to exclude important deleterious effects of AAS on the systemic arteries. Our study had >80% power to exclude a decrease of 4% in FMD in AAS users compared with bodybuilding controls (less than the impairment observed, for example, in young adult passive smokers) (42) and a similar power to detect a difference of 0.2 mm in mean carotid IMT between the bodybuilding groups (at the  $p < 0.05$  level). It is possible that studies of larger numbers of subjects might reveal a significant reduction of FMD in all bodybuilders (AAS using or not) compared with sedentary controls, in addition to the GTN impairment. This would still suggest, however, predominantly a defect in smooth muscle rather than in endothelial function.

**Anabolic steroids and the heart.** There are several case reports associating AAS use with LV hypertrophy, increased LV mass, cardiomyopathy and sudden death (13,14). In studies comparing steroid-using weightlifters and controls, after adjusting for body surface area and exercise capacity, there has been no significant association noted between steroid use and LV mass or wall thickness (43,44). Statistically significant elevation of resting systolic BP levels in men taking AAS have previously been demonstrated to become nonsignificant once adjusted for body weight or biceps size, implying that this may be an artifact of the larger arm circumference in these subjects (45). The BP readings in the bodybuilding groups in the current study were not significantly different and therefore seem unlikely to account for the significant increase in LV mass seen in AAS users. Regarding our observations of mild aortic incompetence in two of the AAS users, there have been previous small reports of aortic valve pathology associated with steroid use (46); however, no large series investigating this issue have been reported to date.

**Androgens and cardiovascular disease.** Androgens may act by receptor-dependent and receptor-independent mechanisms. Androgen receptors are present in the cardiovascular system, including human vascular endothelium, smooth muscle cells, macrophages and cardiac myocytes (3,47-49). Gender differences exist in androgen receptor number and distribution, and certain vascular effects of androgens are gender specific (2,3). There is an important gender difference in atherosclerosis, with men having a higher risk of clinical events at all ages (9), but whether estrogen exposure explains the gender disparity remains unproven (50). Androgens may be pro-atherogenic, promoting cell adhesion and macrophage lipid loading (2,3). Animal data, however, are inconsistent regarding the effects of androgens on atherogenesis and thrombosis (51-53). These data imply complex interactions among androgens, lipids, and the vessel wall, and further pathophysiologic studies in humans will be required to clarify this area.

**Study limitations.** As outlined above, AAS users represent a difficult group to study, both in terms of recruiting steroid users and appropriately matched controls, as the type and duration of exercise per se may importantly influence vascular reactivity (54). Thus, although our study involves few subjects, it is (to our knowledge) the first report of its kind. Subject numbers are similar to those reported by us previously in other unusual but interesting groups, such as female-to-male transsexuals and androgen-deprived older men (4,5). The AAS users had been self-administering multiple agents, and histories regarding those dosage were incomplete; therefore, the effects of particular steroids could not be evaluated. Finally, although the bodybuilder groups were closely matched for age, total cholesterol, BP and smoking, it is possible that unmeasured differences may have been present among the subjects.

Endothelial dysfunction is an early and important event in atherogenesis (55). Measurement of arterial endothelial

function has recently become established as an important method for the detection of early arterial abnormalities in humans (16). Arterial FMD measurements reflect predominantly NO release (17) and correlate significantly with coronary endothelial function (56) and coronary atherosclerosis (57). As NO is a key mediator of arterial health, our current findings may be reassuring regarding the vascular effects of steroid use in otherwise healthy young men. Nevertheless, other markers of arterial health (for example, inflammatory cytokines) have not been assessed in this study.

Although AAS may therefore not be associated with early signs of arterial dysfunction or thickening, other systems may be affected. Nonvascular health risks of AAS might include sterility, gynecomastia, acne, balding, psychological changes, and risks of liver abnormalities (58).

**Conclusions.** High-level bodybuilding is associated with impaired vascular reactivity and increased carotid IMT, but the use of anabolic steroids per se is not associated with significant arterial thickening or endothelial dysfunction in otherwise healthy young men.

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