

## Effects of methandienone on the performance and body composition of men undergoing athletic training

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### Summary

1. In a previous study of the effects of methandienone (Dianabol) on men undergoing athletic training, strength and performance increased, but not significantly more when the subjects were taking the drug than when they were taking placebo. The subjects did, however, gain more weight on the drug, with increases in total body potassium and muscle dimensions. It remained an open question whether the muscles had gained normal tissue or intracellular fluid.

2. In an attempt to distinguish between these possibilities the trial has been repeated, using as subjects seven male weight-lifters in regular training, and including measurements of total body nitrogen. As before, a dose of 100 mg of methandienone/day was given alternately with the placebo in a double-blind crossover experiment. The treatment periods lasted 6 weeks and were separated by an interval of 6 weeks. Body weight, potassium and nitrogen, muscle size, and leg performance and strength increased significantly during training on the drug, but not during the placebo period.

3. The finding of increased body nitrogen suggested that the weight gain was not only intracellular fluid. The increases in body potassium ( $436 \pm \text{SEM } 41 \text{ mmol}$ ) and nitrogen ( $255 \pm 69 \text{ g}$ ) were too large in proportion to the weight gain ( $2.3 \pm 0.4 \text{ kg}$ ) for this to be attributed to gain of normal muscle or other lean tissue, and

imply gain of nitrogen-rich, phosphate-poor substance. Although this action of methandienone might be described as anabolic, the weight gain produced is not normal muscle.

**Key words:** body composition, doping in sports, methandienone.

### Introduction

In a previous paper (Hervey, Hutchinson, Knibbs, Burkinshaw, Jones, Norgan & Levell, 1976) we reviewed the evidence for the reality of an anabolic action of testosterone and the related drugs known as 'anabolic steroids'. We pointed out that the work on animals which originally appeared to show the effect (Kochakian & Murlin, 1935) is open to criticism, and our work on rats (Hervey & Hutchinson, 1973) failed to demonstrate the effect. Studies of the effects of anabolic steroids on performance and body composition in athletes had given inconsistent results.

We described a study in which 11 young men took an anabolic steroid and placebo alternately during two 6-week periods of weight training in a double-blind crossover experiment. Performance and strength increased by similar amounts in both periods; body composition changed when the steroid was taken; body weight, body potassium, muscle widths and limb circumferences increased significantly; body fat did not change. The increase in body potassium (mean  $420 \text{ mmol}$ ) was large in proportion to the body weight gain ( $3.3 \text{ kg}$ ), so that the overall composition of the lean body must have changed. It was left uncertain to what extent the weight gain represented muscle tissue or intracellular fluid.

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This question might have been resolved if we had been able to measure changes in the nitrogen content of the body. Acquisition of 3.3 kg of intact muscle tissue would increase body nitrogen by about 100 g, whereas acquisition of the same mass of intracellular fluid would not change it at all. We have now repeated the study on another group of subjects, measuring total body nitrogen by neutron activation analysis *in vivo*.

The subjects in the previous trial had specialized in various athletic activities other than weight training, and showed large improvements in weight-lifting performance in control and treatment periods. In the present trial the subjects were competitive weight-lifters in continuous training. It was hoped that this would show any effect of the steroid on performance more clearly.

### Subjects and methods

The subjects entering the trial were male weight-lifters who were already training regularly. They volunteered to take part after the aims and procedures of the study had been fully explained to them. The experiment comprised two periods of 6 weeks of treatment separated by a period of 6 weeks without treatment. The subjects continued their regular training throughout. During the first period half of them, chosen at random, took 100 mg of methandienone (Dianabol)/day, orally, on a double-blind basis, and the others took an indistinguishable placebo. In the second period the treatments were interchanged. Tablets were issued weekly. The subjects were examined clinically before the start of the trial, and at weekly intervals thereafter. They were highly motivated toward the experiment, and it was considered unnecessary to monitor swallowing of tablets, or to supervise the training continuously.

The weight training consisted of repetitive leg and arm extension against weights which were progressively increased. Standard techniques known respectively as 'squats' and 'bench press' were used; each subject standardized his own schedule. Performance was assessed as the maximum weight reached in the subject's standard procedure. Grip strength was measured with a Takeii handgrip dynamometer. A dynamometer, designed and made by the Department of Mechanical Engineering, University of Leeds, was modified with a hip harness to measure the combined strength of both legs in a 'dead lift' knee extension. To measure arm strength the dynamometer was fitted with a chain and barbell and a 'double arm upward press' (i.e. shoulder abduction and elbow extension) performed. In each activity the best of three attempts was

recorded, at the beginning and end of each treatment period.

On the same occasions, body composition was assessed by measuring body weight, skinfold thickness (Weiner & Lourie, 1969), body density (Jones & Norgan, 1974) and limb circumferences (Weiner & Lourie, 1969) in the Department of Physiology, University of Leeds. Body fat and fat-free mass were calculated from body density (Durnin & Womersley, 1974). The thicknesses of muscle and subcutaneous fat were measured on soft-tissue radiographs taken in the Department of Radiology, Leeds General Infirmary (Jones, 1970). Total body potassium (Burkinshaw, 1978) was measured in the Department of Medical Physics, University of Leeds, and total body nitrogen (Harvey, Jain, Dykes, James, Chen, Chettle, Ettinger, Fremlin & Thomas, 1973; Vartsky, Prestwich, Thomas, Dabek, Chettle, Fremlin & Stammers, 1979) in the Department of Physics, University of Birmingham. The coefficients of variation of the measurements of density, body potassium and body nitrogen are respectively approximately 0.25% (Jones, P. R. M., unpublished work), 3% (Burkinshaw, 1978) and 4% (Vartsky *et al.*, 1979). The significance of changes and the differences between changes in all measured quantities was tested by Student's *t*-test for paired data.

### Results

Twelve subjects entered the trial, but only seven (aged 25–38 years) completed it satisfactorily. Three were removed because two were found to have taken anabolic steroids shortly before the trial and one during the placebo period; one was withdrawn because concentrations of alanine and aspartate aminotransferase in his blood rose above upper limits of normal; and one because he abandoned the training programme. One subject complained of scrotal pain while taking the steroid but chose to continue the experiment; no other side-effects were observed. Results of soft-tissue radiography are given for six subjects, because one missed an appointment.

Since the trial was crossed over, four of the subjects took methandienone before the placebo. To assess whether they had returned to their original condition by the beginning of the placebo period, the initial measurements for the two periods were compared. At the start of the placebo period their mean body weight, body potassium and some of the performance measurements were above the original starting values, but by amounts which did not reach statistical

TABLE 1. Initial values and changes in body measurements during the two periods of 6 weeks  
Mean values  $\pm$  SEM are shown. Changes were significant at \* the 5% level, \*\* 1% level, \*\*\* 0.1% level.

|                                       | Control period   |                    | Drug period     |                    | Difference between changes |
|---------------------------------------|------------------|--------------------|-----------------|--------------------|----------------------------|
|                                       | Initial value    | Change             | Initial value   | Change             |                            |
| Body weight (kg)                      | 87.9 $\pm$ 1.6   | -1.28 $\pm$ 0.52*  | 87.4 $\pm$ 1.5  | 2.32 $\pm$ 0.45**  | 3.60 $\pm$ 0.72**          |
| Total body potassium (mmol)           | 4932 $\pm$ 162   | -52 $\pm$ 68       | 4791 $\pm$ 119  | 436 $\pm$ 41***    | 488 $\pm$ 68***            |
| Total body nitrogen (g)               | 2101 $\pm$ 75    | 38 $\pm$ 60        | 2028 $\pm$ 50   | 255 $\pm$ 69**     | 217 $\pm$ 86*              |
| Body density (kg m <sup>-3</sup> )    | 1054 $\pm$ 3.0   | 2.4 $\pm$ 1.5      | 1054 $\pm$ 1.9  | 3.2 $\pm$ 1.5      | 0.8 $\pm$ 2.2              |
| Fat (kg)                              | 17.3 $\pm$ 1.3   | -1.24 $\pm$ 1.72   | 17.1 $\pm$ 0.8  | -0.81 $\pm$ 0.65   | 0.43 $\pm$ 0.99            |
| Fat-free mass (kg)                    | 70.6 $\pm$ 1.2   | -0.04 $\pm$ 0.37   | 70.3 $\pm$ 1.4  | 3.13 $\pm$ 0.45*** | 3.17 $\pm$ 0.43***         |
| Sum of four skinfold thicknesses (mm) | 38.6 $\pm$ 2.6   | 2.4 $\pm$ 1.1      | 40.7 $\pm$ 1.0  | -2.0 $\pm$ 1.9     | -4.4 $\pm$ 2.9             |
| Sum of arm + calf muscle widths (mm)  | 183.5 $\pm$ 5.0  | -3.42 $\pm$ 0.95*  | 180.7 $\pm$ 3.2 | 8.16 $\pm$ 1.91**  | 11.58 $\pm$ 2.27**         |
| Sum of arm + calf fat widths (mm)     | 23.7 $\pm$ 2.2   | -0.38 $\pm$ 0.09** | 22.9 $\pm$ 2.0  | 0.40 $\pm$ 0.38    | 0.78 $\pm$ 0.36            |
| Arm circumference (mm)                | 355.1 $\pm$ 6.8  | -2.4 $\pm$ 3.2     | 352.0 $\pm$ 7.8 | 10.7 $\pm$ 3.1*    | 13.1 $\pm$ 4.5*            |
| Thigh circumference (mm)              | 603.4 $\pm$ 10.4 | -5.7 $\pm$ 2.7     | 600.0 $\pm$ 8.1 | 11.1 $\pm$ 2.0**   | 16.8 $\pm$ 4.1**           |
| Calf circumference (mm)               | 383.9 $\pm$ 6.9  | 0.43 $\pm$ 0.78    | 382.4 $\pm$ 7.5 | 5.14 $\pm$ 1.52*   | 4.71 $\pm$ 1.97            |

TABLE 2. Initial values and changes in performance and strength measurements during the two periods of 6 weeks  
Mean values  $\pm$  SEM are shown. \*, \*\* See Table 1.

|                          | Control period   |                  | Drug period      |                  | Difference between changes |
|--------------------------|------------------|------------------|------------------|------------------|----------------------------|
|                          | Initial value    | Change           | Initial value    | Change           |                            |
| Leg training (kg)        | 137.7 $\pm$ 13.3 | 1.7 $\pm$ 4.8    | 138.3 $\pm$ 12.4 | 15.9 $\pm$ 3.4** | 14.2 $\pm$ 3.4**           |
| Arm training (kg)        | 116.1 $\pm$ 9.0  | 3.6 $\pm$ 2.8    | 111.4 $\pm$ 9.3  | 17.0 $\pm$ 3.5** | 13.4 $\pm$ 5.1*            |
| Left grip strength (kg)  | 55.4 $\pm$ 2.8   | -2.1 $\pm$ 1.8   | 55.4 $\pm$ 3.8   | 1.7 $\pm$ 1.9    | 3.8 $\pm$ 3.1              |
| Right grip strength (kg) | 59.0 $\pm$ 5.8   | -0.9 $\pm$ 1.6   | 58.1 $\pm$ 5.5   | 0.4 $\pm$ 1.3    | 1.3 $\pm$ 1.9              |
| Leg strength (kg)        | 424.4 $\pm$ 41.6 | -16.8 $\pm$ 21.2 | 412.8 $\pm$ 19.4 | 68.4 $\pm$ 15.2  | 85.2 $\pm$ 29.5*           |
| Arm strength (kg)        | 90.0 $\pm$ 5.5   | 4.6 $\pm$ 7.1    | 93.9 $\pm$ 6.4   | 12.7 $\pm$ 6.2   | 8.1 $\pm$ 4.9              |

significance; the only difference which did was a decrease by 6 mm in aggregate skinfold thickness. The data from all subjects have been considered together.

Table 1 shows initial values and changes in body measurements over the training periods. Mean body weight fell over the control period, but increased by 2.3 kg on the steroid. The increase was accompanied by significant increases in total body potassium, total body nitrogen, fat-free mass measured by body density, limb circumferences and muscle widths measured by radiography. Body density, body fat, skinfold thickness and subcutaneous fat thickness measured radiographically did not change significantly. Athletic performance (Table 2) did not

improve significantly over the placebo period, but did over the steroid period. The dynamometer readings showed an increase in the strength of the legs during the period on the drug, but not of the arms or hands.

## Discussion

Our previous study (Hervey *et al.*, 1976) left undecided the exact nature of the lean tissue gained by athletes who took methandienone during training. It may also have been insensitive to the effect of the drug on physical performance, since the subjects showed large changes during both training periods.

In the present study, although the subjects were

somewhat older and heavier, the changes of body composition closely confirmed those seen previously. The mean weight gain during steroid treatment, of 2.3 kg, was not significantly different from the increase by 3.3 kg in the previous experiment. The measurements of body density again suggest that the weight gain was in the lean body. The radiographic studies and measurements of limb circumferences show that muscle size increased. Weight-lifting performance and leg strength also increased during treatment but not, as in the previous study, during the period on placebo. The fact that in the four subjects who took methandienone first some of the measurements of performance were still increased at the start of the second phase of the experiment may have diminished the apparent response to training on placebo, and therefore possibly exaggerated the effect of the drug on performance. Nevertheless, the results would again suggest that the drug increased muscle mass, and hence performance and strength.

As in the previous study, however, the substance gained did not appear to have the composition of normal skeletal muscle. We have already reported that the relationship between potassium content and density of the lean body changed (Hervey *et al.*, 1976). A recent review of 11 published reports of analyses of biopsy samples showed that the mean concentration of potassium in normal, fresh, fat-free skeletal muscle is approximately 90 mmol/kg of muscle (Burkinshaw, Hill & Morgan, 1979). If the 2.3 kg of body weight gained during steroid treatment had been normal muscle, the expected increase in body potassium would have been 207 mmol, about half the observed increase of 436 mmol.

The concentration of potassium in intracellular fluid is higher than in whole muscle, but the finding of increased total body nitrogen does not support attribution of the weight gain to intracellular fluid alone. The increase in nitrogen also was large in proportion to the weight gain. Widdowson & Dickerson (1964) reviewed published analyses of biopsy specimens of muscle, which gave a mean concentration of 30.8 g of nitrogen/kg of muscle, and of whole cadavers, which gave a similar mean value of 34 g of nitrogen/kg of fat-free body. If the 2.3 kg weight gain by our subjects during steroid treatment had been normal muscle or lean tissue, it would have been expected to include 70–80 g of nitrogen, about a third of the observed increase of 255 g.

The possibility must be considered that the gain of nitrogen reflected increase in contractile protein (by something of the order of 20%, since there is around 1.2 kg of nitrogen in the muscles of a 70 kg man) without proportionate increase in

cell fluid. The protein would carry charges, which would be electrically balanced by potassium ions. If the amounts of nitrogen and potassium were in the same ratio as in the normal muscle, the water needed to maintain osmolarity implies a greater weight gain than found. More than half the potassium ions in muscle cells, however, are balanced by phosphate ions (Widdowson & Dickerson, 1964). If the substance gained consisted of protein and the potassium associated with this, but less phosphate than would accompany it in normal muscle, our findings might be reconciled.

We can find no published analyses of muscle from athletes. Effects of athletic training, and interactions between these and the effects of the drug, might also contribute to the end-result. The possibility of interactions between training, drug treatment and diet has been raised (O'Shea & Winkler, 1970; Freed, Banks, Longson & Burley, 1975), but there is no theoretical basis or evidence (Hervey *et al.*, 1976). The 'anabolic agents' used in meat production are most often oestrogens, androgens being considered inactive, less active or active only in the presence of oestrogens. It has been reported that an androgenic agent, trenbolone acetate, reduces the rates of both synthesis and breakdown of protein in the muscle of female rats, breakdown being slowed most. The interesting possibility was raised that the compound might act by blocking cytoplasmic receptors for glucocorticoids (Buttery, Vernon & Pearson, 1978). Such a mechanism might well lead to changes in chemical composition, and the flesh of treated meat animals is altered in appearance. No prediction can be made as to the effect on muscular performance; an interaction with glucocorticoid metabolism might be relevant to subjects performing maximum muscular exertions.

Although the present experiment would appear to have contributed a new positive finding in the gain of nitrogen and so strengthened the grounds for belief in an anabolic action of methandienone, the objections remain: in the negative findings from direct carcass analyses in treated rats; in the disproportionate gains of nitrogen, potassium and weight in men; and in the indirect mechanism of action postulated in meat animals. Athletes who take large doses of anabolic steroids undoubtedly gain weight. What they gain is not normal tissue. Whether its acquisition should be called anabolism or not, its value to the athlete must, we believe, remain in doubt.

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