Introduction

Anabolic steroids are synthetic testosterone analogues with androgenic and anabolic properties. These compounds accomplish their anabolic effects by promoting a positive nitrogen balance and supporting constructive metabolism, while decreasing tissue destruction (Scoggins 1980; Snow 1993). Traditionally, anabolic steroids have been used to improve appetite, increase muscle tone and general vigour, improve stamina and brighten hair coat (Scoggins 1980). Therapeutic uses of anabolic steroids have included the treatment of debilitated horses, anaemic horses and horses recovering from surgery; to speed healing and return to work from minor injuries (Snow 1993); and to assist in recovery from malnutrition, parasitism, physical exhaustion, glucocorticoid-produced osteoporosis, fractures and mental fatigue (Beroza 1981). Furthermore, anabolic steroids are used as management supplements to increase muscle size, strength and stamina, improve skeletal development, and promote aggressiveness in equine athletes (Beroza 1981).

Anabolic steroids and performance

Most of the evidence to support the use of anabolic steroids in equine athletes is anecdotal. It is believed that anabolic steroids give athletes an extra edge in intense competition, and that they do so by promoting appetite, appearance and stamina (Dawson and Gersten 1978). One uncontrolled report claimed enhanced appetite and general tonus, accelerated return to training after treatment of various ailments of tendons, muscles, fascia and joints, and subsequent improved performance on the racetrack as a result of methandione administration (Vigre 1963).

Despite this anecdotal evidence, several studies have failed to show any improvement as a result of their administration (Snow et al. 1982ab; Hyypä et al. 1995). While inappropriate training regime (Snow et al. 1982b) and inadequate anabolic steroid dose (Snow et al. 1982a) have been cited as possible reasons for lack of response, in fact, evidence of performance augmentation has never been demonstrated in an experimental setting (Hyypä et al. 1995). Indeed, persuasive evidence, albeit circumstantial, that mitigates against a consistent beneficial effect of steroid administration is the fact that geldings compete successfully (Anon 1982).

Anabolic steroids and nitrogen balance

The primary purported effect of anabolic steroids is the promotion of a positive nitrogen balance. Many studies have analysed nitrogen retention and excretion, as well as total urea and creatinine excretion during and after the administration of anabolic steroids. The results of such studies are inconsistent. While one study observed significantly increased nitrogen retention 12–25 days after anabolic steroid injection when compared with preinjection, nitrogen retention was not further increased by a second injection of anabolic steroid (O’Connor et al. 1973). A significant increase in nitrogen retention in 2 of 4 horses was observed during treatment with nandrolone phenylpropionate, and a significant decrease in nitrogen excretion was found in 3 of 4 horses during administration (Snow et al. 1982a). Nitrogen excretion was lower in anabolic steroid treated animals than in controls, but only in one of 2 trials by one author (Snow et al. 1982b). Control horses had a negative energy balance, while the treatment horses did not, thereby leading to speculation that perhaps anabolic steroids promote a positive nitrogen balance by preventing tissue breakdown associated with training. However, in that regard, there was no difference between the 2 groups with respect to urea and creatinine excretion.

Anabolic steroids and weight

Most studies have found that anabolic steroids either generate weight gain or limit weight loss. Animals twice treated with 1.1 mg/kg bwt boldenone undecyclenate had significantly higher weight gains than control animals (O’Connor et al. 1973). However, this significant difference in weight gain was not observed in animals treated with boldenone
undecyclenate at 0.275 mg/kg bwt. Foals treated with anabolic steroids during their first year of life were significantly heavier than foals that were not treated (Keenan et al. 1987).

Control animals lost weight during a study of the effects of nandrolone phenylpropionate on animals in training (Snow et al. 1982b). However, this weight loss was only seen in the anabolic steroid-treated animals after the anaerobic training phase of the experiment, but not throughout the entire experiment. There were no significant differences between treatment and control groups with respect to change in body measurements. In contrast, in another study, there was no change in bodyweight as a result of treatment with nandrolone phenylpropionate (Snow et al. 1982a).

Anabolic steroids and red blood cells

Red blood cell volume has been shown to have a positive correlation with performance ability. The effect of anabolic steroids on red cell volume has been investigated in various studies. One study noted a 20% increase in red cell volume as a consequence of anabolic steroid administration (Hyyppä et al. 1994). In another study, red cell volume increased significantly in treated horses and remained increased 13 weeks after treatment, while no significant increase was observed in control horses. Interestingly, a positive correlation between red cell volume and $V_{200}$ (a measure of aerobic capacity) as well as between red cell volume and total performance was found in the control group of horses, but not in the anabolic steroid treated group (Hyyppä et al. 1995) and no hypothesis to explain this absence of correlation in individuals treated with steroids was offered.

On the other hand, another study failed to detect an increase in red cell volume or erythropoietin levels (Hyyppä 2001). This was attributed to a shorter duration of treatment with nandrolone laurate in this study than the previous studies. Other studies (O’Connor et al. 1973; Snow et al. 1982b) have also found no significant increase in red cell volume of treated horses over control horses. However, the time of sample collection (post exercise vs. post feeding) may have influenced these results (Hyyppä et al. 1995).

Anabolic steroids and muscle

It has been suggested that anabolic steroid administration could directly affect muscle cells, and that the observed variation in the effects of anabolic steroids could be attributed to the innate disparities between different muscles and the muscles of different individuals (Ryan 1976). Several studies have examined the effect of anabolic steroids on various muscle characteristics. Muscle water content does not appear to be changed by treatment (Nimmo et al. 1982; Snow et al. 1982a) nor does muscle glycogen content (Nimmo et al. 1982; Snow et al. 1982a; Hyyppä et al. 1997; Hyyppä 2001), nor total mean protein concentration (Nimmo et al. 1982; Snow et al. 1982a; Hyyppä et al. 1997). Total mean protein concentration did, however, increase during the follow-up period after treatment (Hyyppä et al. 1997). The number of capillaries per unit fibre area does not appear to be affected by steroid administration (Nimmo et al. 1982), and neither does the mean androgen receptor concentration in muscle cells. A correlation, however, was noted between mean androgen receptor concentration and percentage of Type IIA fibres in the treated group, but not the control group. This thereby suggests the possibility that androgen receptor number in muscle cells could have an influence on conversion of those cells to Type IIA fibres, (Hyyppä et al. 1997) and could elucidate a link between anabolic steroid administration and increased percentage of Type IIA fibre.

Although muscle glycogen content does not appear to be affected by anabolic steroids, one study found that glycogen repletion after exercise is enhanced (Hyyppä 2001). Glycogen repletion rate after exercise trials corresponding with steroid administration was significantly higher when compared with that of glycogen repletion after exercise trials in the same horses without anabolic steroid treatment. In addition, insulin, glucagon and cortisol were significantly higher after exercise when anabolic steroids were administered than in control trials. The hormone balance that exists after exercise in anabolic steroid treated horses could conceivably increase glucose output from the liver, blood insulin concentration and insulin-independent glucose uptake by the muscles, but this has yet to be demonstrated.

The change in muscle composition induced by anabolic steroids with respect to fibre type has been assessed in several studies (Nimmo et al. 1982; Snow et al. 1982a; Hyyppä et al. 1995, 1997). No change in muscle fibre type composition in the semitendinosus muscle was seen in response to anabolic steroid administration, however an increase in the proportion of Type I fibres and concomitant decrease in proportion of Type II fibres was observed in the biceps femoris (Snow et al. 1982a). A significant difference between control and anabolic steroid treated groups with respect to percentage of Type IIB fibres was found in the biceps femoris following anaerobic training (Nimmo et al. 1982). A statistically significant change in fibre composition of the middle gluteal muscle was found in treated horses, but not control horses (Hyyppä et al. 1995). Similar, but insignificant changes were noted in control horses, which persisted beyond cessation of training. This led to speculation that the difference in effects of training on the muscles of anabolic steroid treated animals when compared with controls is related to the time course over which these effects take place, and that adaptations to training may occur more quickly in treated animals than controls. However, conflicting results in the middle gluteal were obtained in another study (Hyyppä et al. 1997) although a moderate, rather than high, intensity training regimen was used during the experiment.

Muscle enzyme activity has been employed as a means of investigating the consequences of anabolic steroid administration, but has failed to show effects of anabolic steroid administration. No changes in the activity of aspartate aminotransferase, alanine aminotransferase, citrate synthase, lactate dehydrogenase, aldolase or 3-hydroxyacyl-CoA dehydrogenase were seen as a result of anabolic steroid
treatment in one study (Snow et al. 1982a), nor were changes in lactate dehydrogenase, phosphofructokinase or β-glucuronidase activity seen in another. While an increase in citrate synthase and 3-hydroxyacyl-CoA dehydrogenase activity was identified in treated animals following anaerobic training, and an increase in cytochrome oxidase activity was observed in both treated and control groups (Nimmo et al. 1982), these hormones have been known to fluctuate in response to type and intensity of exercise, and this variation could simply be a reflection of that fact. The activities of citrate synthase and 3-hydroxyacyl CoA dehydrogenase were significantly elevated after treatment with anabolic steroids in one study (Hyppä 2001); however, in another study by the same author, no such increase was seen (Hyppä et al. 1997). In the latter study, lactate dehydrogenase activity appeared to decrease in both treated and control groups. Such variation in study results makes it impossible to draw any concrete conclusions as to the effect of anabolic steroids on muscle enzyme activity.

**Other physiological parameters**

Other measures of physiological status, including blood creatinine levels, total protein, sodium, potassium, chloride, magnesium, calcium, phosphorus, alkaline phosphatase, aspartate aminotransferase, creatine kinase, white blood cell count, urine specific gravity and urine pH, have shown no significant effect from anabolic steroid treatment (Snow et al. 1982b). Although it never exceeded the normal reference range, a significant increase in γ-glutamyl transferase activity was noted in one study (Snow et al. 1982a), but not in another (Snow et al. 1982b). A significant increase in plasma urea, phosphate and cholesterol following treatment was shown in one study (Snow et al. 1982a), but, again, not in another (Snow et al. 1982b). It should be noted that elevated plasma urea levels could indicate that nitrogen retention resulting from anabolic steroids could be due to higher blood nitrogen levels in treated animals rather than an anabolic effect (Snow et al. 1982a); that is, the nitrogen retained by steroid treated animals is circulating and not incorporated into muscle tissue, as has been traditionally assumed.

No change in serum cortisol or growth hormone levels resulted from anabolic steroid treatment in one study, (Hyppä et al. 1997) however a subsequent study observed a significant decrease in cortisol levels for 30 min following exercise in anabolic steroid treated horses (Hyppä 2001). Plasma triglyceride levels were increased during exercise in control animals, but not in those given anabolic steroids, thereby suggesting that prompt glycogen repletion in muscles after exercise in treated animals is not due to increased fat availability in the blood (Hyppä 2001).

Finally, anabolic steroids were not found to have an effect on peak heart rate (Hyppä 2001), V200 (Hyppä et al. 1995), or VLa (a measure of anaerobic capacity) (Hyppä et al. 1994, 2001). Peak blood lactate concentration was similar in treated and control horses (Hyppä 2001). Curiously, a correlation between blood lactate and performance time was detected in control, but not treated horses (Hyppä et al. 1997).

**Anabolic steroids and behaviour**

Finally, it has also been hypothesised that theoretical improved performance that occurs as a result of anabolic steroid therapy could be due to changes in behaviour. Several studies have observed increased stallion-like behaviour in treated individuals, although the degree to which each individual was affected varied (Nimmo et al. 1982; Snow et al. 1982a,b; Hyypä et al. 1995). Only one study has reported no undesirable side effects in horses treated with anabolic steroids (O’Connor et al. 1973). These virilising effects lasted as long as 6 weeks after cessation of anabolic steroid administration, which is longer than metabolites of the steroids were found in urine (Snow et al. 1982b). It has been suggested that the androgenic effects of anabolic steroids enhance the horse’s motivation and ability to train, thereby indirectly increasing muscle performance (Freed et al. 1975); however, enhanced motivation was not observed in treated horses that were trained with a pace horse (Hyppä et al. 1995).

**Conclusion**

The physiological and psychological consequences of anabolic steroid use in horses is highly inconsistent, and appears to depend on a number of factors, including the steroid used, as well as the individual animal. There is a high degree of variability and irregularity in the response of the numerous physiological parameters to anabolic steroid treatment and subsequent exercise. It is possible that the parameters that correlate with improved athletic performance are not affected sufficiently to produce detectable performance enhancement. It is also possible that a satisfactory experimental model for the investigation of anabolic steroid effects has yet to be designed. Nevertheless, despite much anecdotal support of the benefit of anabolic steroid use in equine athletes, there is little scientific evidence with which to corroborate it, and there is little evidence that anabolic steroid treatment offers an advantage in equine athletic performance.

**References**


If you have a submission for a future Clinical Question to be included in EVE, please contact David Ramey at ponydoc@pacbell.net