

The Use and Effect of Anabolic Androgenic Steroids in Sports

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Abstract Anabolic androgenic steroids (AAS) were initially created for therapeutic purposes, and synthetic derivatives of the male hormone testosterone. Due its great anabolic effects, these drugs are being used on a large scale, for the improvement of sports performance. In this present study, we aim to show the history of it' use, present their mechanisms of action, more particularly its use correlate with improved body composition, muscle mass, aerobic capacity and verify their possible side effects, analyzing their use therapeutic and indiscriminate, through direct scientific research with the sports. Sources were reviewed scientific the following search engines: PUBMED, LILACS and SCIELO. The results showed that in presence of a suitable AAS and diet can contribute to increases in body weight, particularly lean body mass and muscle strength gains achieved by high intensity exercise, these effects can be further potentiated, the use of supraphysiological doses, but in the aspect of aerobic power, there are not scientific evidence to support their improvement. Regarding side effects, the use of AAS, is related to several complications in the liver, cardiovascular system, reproductive system and psychological characteristics, always assigned by the non-therapeutic and abuse of AAS. Thus we conclude that the use of AAS, are directly linked to gains muscle mass, strength, as well several side effects, always assigned to abusive and indiscriminate doses, it is noteworthy that the scientific literature, still has a certain lack of studies, mainly randomized, controlled, with supraphysiological doses in human, so many effects are still unknown.

Keywords Steroids, Sports, Muscle Mass

1. Introduction

The growing cult of the body has characterized the contemporary consumer society thus making the growing importance attached to physical appearance, reflecting itself in the mass media, exposing said models of bodies [1].

In recent years the body has become the target of several techniques to achieve a standard of beauty imposed by the media. However it is necessary to assess to what extent we are risking our health to achieve this standard of beauty, thus contributing to an increasing number of young people who get involved at an earlier age with use of anabolic steroids with muscle development intention quickly [2].

Steroids have become over the years, a method used to increase strength and muscle mass, increasing user performance and its use has always been used on a large scale in sports, thus improving the performance of users athletes, despite their use is improper [3].

The consumption of these drugs is widely consumed in bodybuilding athletes for years, but the widespread use of

these drugs is currently reflecting be in non-athletes and especially in young bodybuilders with purely aesthetic goals [4].

A population study conducted in the United States estimated that about three million is the number of steroid user, and the consumption by high school students has grown by 50% according to the National Institute on Drug Abuse – NIDA [5].

In Brazil, studies show that the consumption of drugs on these population are scarce. Studies such as Sabino (2002); Moreau & Smith (2003); Silva Machado, Figueiredo et al (2007); Araujo, Andreolo and Silva (2002) described the use of these substances and only the last three authors cited, showed high prevalence of use, with 19%, 11% and 9% respectively.

Androgenic anabolic steroids are natural or synthetic compounds similar to the male hormone testosterone, performing changes in their molecular structure in order to delay its absorption into the circulation, minimizing its androgenic actions and maximizing the anabolic [10]. The vast majority of this drug was developed in the 50s, with the intention of causing only androgen masculinizing effect without anabolic effects, being used only with medical prescription [11].

Doping is defined as the use of endogenous or exogenous

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substances in abnormal amounts intended to increase the performance of athletes in competition. Anabolic steroids belong to the class of anabolic agents along with stimulants, narcotics, diuretics, peptide hormones and analogues, composed prohibited substances according to the International Olympic Committee - IOC [12] [13].

Anabolic steroids are widely used by athletes, bodybuilders and physically active in general without being professionals. Studies show that the use of these drugs is due to the increase in muscle mass and strength. But the same studies show deficiencies due some studies did not control important aspects such as protein intake, a food plan for the subjects, variations of stimulus in the exercises, some studies include competitive athletes, as it does not specify the control of the cited variables [14] [15] [2].

The use of steroids associated with sports practice has always been surrounded by doubts about their benefits and actual harm to health, so the benefits are always observed when using associated with resistance training, aerobic and its harmful effects has been associated with cardiovascular dysfunction, dysfunction hormonal, temperament and other effects that have not been specifically identified [16].

Studies showing the effects on the use of indiscriminate steroids should be increasingly disclosed the population to their actual knowledge. Like other substances that affect health such as alcohol and tobacco, the use of steroids has become a concern due to its widespread use by individuals younger and younger, which makes this situation in a public health problem.

The objective of this study is to conduct a literature review, increasing the texts on the subject, and may thus contribute positively to the discussion and analysis of the material referent to the use of anabolic-androgenic steroids and their use in excess by practitioners of various sports as in the scientific community as to the population. It also aims to make a review on the history, benefits and side effects of using anabolic steroids.

2. Methods

This paper presents a systematic review of survey information and clarification on the subject in specialized articles and journals between 1980 and 2013. These documents were consulted in virtual libraries as: "PubMed", "lilacs", "SciELO" and for such consultations were used as key words: "hypertrophy", "testosterone", "steroids", "anabolic steroids", "androgenic anabolic" and "androgenic effects" in Portuguese and their translation into English.

Between January and June 2014, found 977 articles related to the keywords mentioned. These items were selected according to the criteria of exclusion and inclusion, in which were excluded papers that related the use of anabolic-androgenic steroids for treatment, disease control and unrelated to sports practices. At the end, we selected 92 articles with a history of anabolic steroids with the sport, methods and use, sporting performances as strength gains,

hypertrophy, aerobic capacity and side effects, always connected to sports practice.

3. History of Steroids in Sports

Throughout history, the search for better physical performance is very old. There are reports that the Greeks developed hallucinogenic mushrooms, gladiators of Rome used natural stimulators, Indians in South America used coca leaves to stimulate, and there are reports in China that used a plant called "machung" to encourage athletes of the time for their battles [17].

Thus, by the 1930's, researchers announced a breakthrough, it was the synthesis of testosterone and was being created in laboratories. Since then the use of synthetic testosterone was been spread around the world, its use at the time showed the ease of muscle growth [17].

The first synthesis of reports of this drug are 1935 and is used during the second world war, with intent to cause aggression to combatants, also being used in therapeutic treatment in burn and post-surgical patients in the 50s was widely used in causing diseases muscle atrophy and anemia [18].

In 1935 there were accounts of the long and positive effects of androgens on proteic anabolism, being this effect confirmed by Papanicolaou & Falke (1938). The use of this substance by athletes initiated around the 1950's, according to Wade (1972), being complemented by the studies made in athletes [21] [22] [23].

The use of this drug associated with the sport began in 1950 also with reports of abuses by Russian athletes this substance, then for weight lifting athletes in 1954 so widespread its use in sports media and especially in the bodybuilding world with purpose increasing muscle mass and strength [24] [25]. However, its use has shown many adverse effects on the liver, cardiovascular system, reproductive both male and female and psychological behavior [26] [27].

In 1956 American laboratories created the metandrosterone, better known as "Dianabol" is highly used by North American athletes. The use of the substance gained fame in 1960, when the athlete Fred Ortiz showed a muscle and superior to its competitors in a championship bodybuilding [28]. Thus, the use of steroids was widespread in sports, as demonstrated at Mister America 1972, in which 99% of the athletes reported the use of "Dianabol" [29].

In Olympic appearance, due to the spread of steroids in 1960, it was announced that the use of any substance that enhances physical performance of athletes would be declared as doping, which entered into force in 1964, but only in the Olympics 1968 athletes were really tested [30].

Due to the intensification of anti-doping tests, the tests were being made throughout the Olympic period before and after the games in the 2008 Olympics in Beijing, where 10,000 athletes, 4,500 were tested [31].

With this increased control on the antidoping tests,

athletes that were tested positive for the use of steroids, such as Ben Johnson, which in Seoul 1988 had been olympic champion for the 100 m and tested positive for stanozolol [32].

After the Johnson episode, various athletes were caught with positive tests, as it was the case of those with nandrolone in the Sydney 2000 Olympics, being one of those a gold medalist, Lindford Chirstie [33].

The athletes with the highest incidence of steroids are in their majority practitioners of activities of strength and speed, being followed by athletes of resistance and collective sports, all of them with the objective of gaining muscle mass, protein synthesis, muscle recuperation and strength [34].

Amongst the sports which presents the greatest numbers of positive tests for doping, cycling is the first place, with 482 cases. Baseball comes in second place with 390 and football in third with 343, finally, athleticism comes with 342 positive tests, however, it is the sport with the highest number of tested athletes [35].

4. Methods and Use of Steroids

The steroid hormones have lipidic origin, being formed from cholesterol and synthesized by organs like gonads, ovaries, adrenal glands, testicles and being classified into three types [36].

First off, there are the androgens, male hormones produced by the testicles, which are fundamental for the male characteristics such: muscle mass, strength and facial hair. Following, we have estrogen, female hormones, produced by ovaries and that are responsible for the female characteristics [37].

Lastly, there is the cortisone hormone, produced by both genders, with the anti-inflammatory effect. They are natural hormones associated to the adrenal cortex, have the function of controlling bodily processes, such as cardiovascular, kidney, skeletal muscle and metabolic functions [37].

Testosterone is responsible for the development of androgenic characteristics as previously said. Its production happens in the Leydig cells, located inside the testicles and in very low numbers inside the ovaries and adrenals. On men, the estimate is that 2,5-11g/day of testosterone is produced, while on women it is around 0,2-0,4 g/day [38]. However, on women, this hormone is converted into female hormone in the fat tissues by enzymatic complex aromatase [39].

The anabolic steroid hormones are derived from the androgen hormones, due to its anabolic properties, being visible in users of these substances, mainly on women. They might be produced in several forms such as sprays, suppositories and skin attachments, however, the most known are the oral and injection forms, even though all the other forms withhold the same anabolic capacities [40].

Testosterone acts by a direct process. At the moment in which its reactions begin when its molecules penetrate the cell, they bind for some hours to an androgen receptor and migrate to the cell nucleus, finding another receptor, binding to determined regions of the DNA and producing RNAm

[51]. After this process, the receptors depart and return to inactivity. These receptors may explain the development of certain muscle groups, as a study has verified that over torso muscles had more receptors than the lower muscles [41].

In this manner, we may explain the possible difference in muscle mass distribution between men and women, being the amount of receptors the justification to this difference, as shown in the studies of [42] [43].

The indirect mechanism of testosterone are also known, however, there is still much speculation as to if its indirect effects are anti-catabolic actions by androgen receptors and the glucocorticoids. Androgens compete with catabolic hormones in this manner, such as cortisol, thus reducing its action, preventing protein degradation caused by this hormone. Furthermore, androgens also might interfere with glucocorticoids production [44].

Another indirect manner is the IGF 1-testosterone axis, in which the androgens stimulate the local production of IGF 1, independently from the production of GH, apart from the inhibition from IGFBP-4, increasing the release of IGF 1 [45]. A hypothesis that had been verified in various studies about the activation of satellite cells, a very important part on hypertrophy, has demonstrated that the injection of testosterone causes proliferation of the satellite cells in little more than a day, occurring the increase in number of mionuclei [46].

The liver, as responsible for fighting off outside bodies, is harmed by the abusive use of steroids, which causes diverse pathologies such as hepatic malfunction being much associated to oral use, different from injections, as they do not pass through the process of alkalization, being considered less harmful. However, these have their disadvantages for showing higher nephrotoxicity, due to its absorption by the blood [16].

A study has shown this use of steroids associated to abusive dosis, up to 100 times more than the therapeutic recommendations by doctors, thus it is possible to affirm that users might use doses of 350 to 700mg of testosterone weekly [47].

Analysing the diverse forms of steroid use, the mentioned author demonstrates that the use of various substances does not make its use more efficient, as, for a bodybuilder, his concern is the retention of nitrogen for muscle growth. As all steroids have this action, there is not plausible motive for the use of many [48].

By means of molecular manipulation, it is possible to alter the biochemical structure of testosterone, which creates other derived substances with androgenic anabolic effects and are divided into three classes [40].

The anabolics may be divided in three classes, "A" which have a longer carbon chain, soluble and more used as intramuscular injections. An example of this class is Durateston®. Further, we have steroids of classes "B" and "C", the first has higher difficulty to be degraded. Being ingested orally, it is harmful, an example is Methyltestosterone. "C" class suffers modifications to the A, B and C rings and is used orally, like Mesterolone. Finally,

we have hybrids and mixed “AC” and “BC”, respectively, as examples, Deca-Durabolin®, Durbolin®, Winstrol® and Anavar® [40].

After the use of anabolic steroids, the users maintain a diet and medication regime, which has the objective of suppressing estrogen on the hypothalamic axis, pituitary and testicles. The objective of this is to restore endogenous testosterone production, always preserving muscle mass and strength. This post-cycle therapy, as it is called, has the function of inhibiting side effects [49].

During the post-cycle therapy, medications such as clomiphene citrate (Clomid®), a synthetic estrogen that has anti estrogen effect in men, are used. In the prevention of gynecomastia and normalization of testosterone, other drug is used with the same effect, apart from tamoxifen citrate (Nolvadex®). Such as anastrozole (Arimidex®), a drug developed for the treatment of breast cancer, it is an aromatase inhibitor, used to avoid gynecomastia and the deposit of body fat [49].

5. Body Composition, Muscle Strength and Aerobic Capacity

The acute effects of strength training related to the concentration of testosterone are still controversial. Studies demonstrate a fall in testosterone concentration [50] [51]. However, there are studies which demonstrate the increase [52] [53], as well as studies that did not find any difference in the level of testosterone before and after training [54] [55].

Some training methods are stimulating to increase the testosterone levels, such as tension methods, due to the higher potential given [56] [50]. However, authors defend that any method that uses great intensity produce this increase on concentration, due to the increase of lactate stimulating this production [57].

It was speculated that the increase on training frequency would influence due to higher muscle work. However, results about this are also controversial, studies show that the increase happens both with one or three series [58]. Nevertheless, [53] did not find this difference on the conducted study with two, four or six series for each muscle group.

Thus it is necessary to analyze with caution the acute studies, as the hormonal spike, when fast, might fall right after, we cannot take into consideration the acute changes in testosterone levels. Therefore, neither GH and IGF 1, as these are not associated to the increase of protein synthesis, nor gains in strength and muscle mass obtained through training [59] [60] [61] [62].

Chronically, the changes on testosterone concentration that result from strength training, do not show to be significant for the increase of muscle mass and strength when there is only evidence that the strength training may influence by indirect factors the efficiency of the hormone by changes in receptors and satellite cells [53].

This fact is demonstrated in strength trained athletes that show higher quantities of satellite cells in comparison to

non-trained ones. This shows that a duplication of RNAm after two days of muscle training, the receptors are synthesized by the own nuclei of the muscle fibers, providing a long term hypertrophy [101]. Which may be considered a consequence of the enlargement of the nuclei, thus increasing the efficiency of testosterone. [63][64].

However, as already expected, studies conducted with higher than physiological doses demonstrated surprising gains. For example, one study that compared four groups in which one group did not train and was divided into testosterone and placebo, two other groups that trained and were divided into placebo and testosterone. At the end of 10 weeks, the group that trained and used testosterone had a gain of 6 kg of muscle mass as the placebo had a gain of 2 kg. However, the most surprising was that the groups without training the ones with placebo had, as expected, no gain, however, the group that used testosterone gained 3,2 kg of muscle mass, surpassing the group that trained and used placebo [65].

Another two studies were favourable to the users of steroids in relation the the increase of body composition, due to the water retention by steroids, in general, the use of androgenic steroids contributed significantly to the increase of body composition due to the increase of muscle mass [66].

A study demonstrate a body comparison evaluated by hydrostatic weighing in which one is determined by the significant gain in weight due to muscle mass. [67].

During sports, a factor of high importance is the muscle strength that an athlete may execute. Many factors may contribute for an athlete to develop this strength, like training intensity, diet, psychology. Thus it is difficult to measure all of these factors in one study [27].

In literature, studies are controversial about the gain of muscle strength. However, we might make an analysis, seeing that steroids have a direct effect on the development of muscles, on protein synthesis. We may correlate this increase of muscle mass with the increase of muscle strength [68].

Due to these steroid relations and gain of muscle mass, the advantages about the muscle strength in physical activities are great. Some athletes believe that there is a direct influence on the central nerve system, being related to greater aggressivity, reduce of fatigue and fast muscle recovery [69].

About the advantages to the aerobic capacity, the benefits are related due to the use of steroids are the increase in hemoglobin concentration and blood volume, which is very useful in exercises that demand certain resistance. Thus increasing the circulation of oxygen to muscles during exercise [70].

Athletes that use anabolic steroids for six months of training demonstrated an increase of 9,6% in hematocrite and 9,5 of hematias. However, no considerable changes in hemoglobin. The authors suggested that the increase in hemoglobin could happen with higher doses, which has been a very controversial fact [71]. Others showed that the use compared to placebo has not demonstrated any

differences [72].

6. Side Effects

Steroids are always associated to diverse side effects, such as vascular, reproductive, psychological disorders and epiphyseal ossification. However the greatest repercussions are related to the liver. These effects are researched since a long time and most of the studies related this effect to the wrong use of these drugs [73].

The use during puberty may lead to a deficit of growth, due to the ossification of the bone epiphysis. Therefore, the use of steroids in youngsters must be avoided, except due to medical prescription for some pathologies [13] [74].

There is yet another factor related to the locomotion. The abusive use may increase the risk of tendinosis lesion due to the inhibition to the synthesis of collagen in ligaments and tendons, as it was demonstrated in a study with former football players users of steroids, in which a higher number of articulation, tendinous and ligament lesions were shown [75] [76].

The dermatological effects seem to be one of the most common side effects due to the abusive use. A study reports 63,4% of acne in users. Another one demonstrates a prevalence of 43% of this effect, mainly in former users, probably due to the stimulus to sebaceous glands that increased the production of fat. [77] [78]

Gynecomastia is also one of the side effects most common. In a study made, it was verified that 34% of users reported this problem, being the biggest side effect [79]. The use of anti estrogens is inefficient [80].

After the intake of steroids, the increase of libido is accentuated. However, due to the high concentration of testosterone, our organism inhibits natural production, which may cause impotence as show in this study showed 61% of users with this hormone oscillation [77]. In another study conducted with bodybuilders, the effects most known were 10,7% of sexual impotence and 8,1% of libido loss. Amongst these athletes, many alleged lack of information and high dosage [81].

Related to the effects on genitourinary system, they are oligospermia, azospermia, due to the inhibition of gonadotropin secretion, the aromatization of androgens into estrogens [82]. Another study about the effects on this system demonstrated the results of spermograms in bodybuilders that used steroids for three years, showing a condition of infertility [83].

In another research with bodybuilders that did not use steroids, after the onset of use the athletes showed a testicular reduction and related oligospermia and azospermia [85]. Other effects are the reduction of FSH, progesterone and estrogen and inhibition of ovulation [86].

The use of steroids causes also a masculinization process in women, noticed by the alteration of voice tone, body hair and clitoris hypertrophy. In some men, balding is related [87] [86].

The use of steroids is also related to the decrease in HDL,

being this lipoprotein responsible for removing fat from blood vessels, thus unblocking them. The reduce in HDL promotes atherosclerosis which may cause strokes or coronaropathy [87] [88] [89].

These effects were demonstrated, analysing the lipid profile of users and nonusers, practitioners of resisted training, the users showed reduction of HDL, however, on LDL, neither groups had any change [3].

About the cardiovascular effects, some authors point out the left ventricle hypertrophy due to the abusive use of steroids, an important factor for the risk of sudden death [90] [91]. However, [84] conducted a research in which an echocardiogram was carried out on bodybuilders users of anabolics, and no cardiovascular changes were detected.

Nevertheless, studies conducted with bodybuilders, in which the arterial structure and its functionality was verified in these athletes, no difference was demonstrated in comparison to non users. Although the authors themselves cite several limitations to this study [92].

Another factor of extreme importance was verified on the study of [93], in which the effects of steroids associated with intense strength training were compared. In this study, it was verified the morphology and proprioception of the patellar tendon. The authors demonstrated chronic changes with the use of steroids, mainly collagen remodeling significant proprioception loss. These aspects render the tendon more propense to lesion, however this is one of few studies to verify this change. It is important to note that another hormone used in sports, even though not anabolic, GH, also shows the same changes to soft tissues. Therefore, the combination of both could be very harmful for tendons and ligaments [4] [94].

The hepatic effects are, doubtlessly, the most prevalent and severe on users, such as hepatotoxicity and hepatomegaly. A study with 85 user subjects concluded that 12,6% showed hepatomegalia and 13,7 hepatic steatosis [95].

In ultrasonographic analysis on bodybuilders it was shown 64% of hepatomegaly, being 36% due to hepatic steatosis [84]. Data that was corroborated by an author which reported cases of hepatocellular adenoma in steroid using bodybuilders [96].

Peliosis hepatis is also very common amongst people that abuse steroids. In these cases, blood cysts are formed within the liver. These hepatic risks are associated mainly to oral steroids, due to 17 alkylated, for their toxicity being too high and resistant [80]

Amongst the side effects of steroids, there is change of mood, increase of self-esteem, motivation and reduction of insomnia. However, authors also associate the use of high doses of steroids to effects like mood and aggressivity disorders [97].

One study demonstrated the effect of doses of testosterone higher than physiological. In this study, the users were submitted to a questionnaire for the evaluation of their temper and their families and couples were also interviewed. None of the interviewed pointed to the increase of

aggressiveness by the users, however, the authors did not discharge behaviour changes in higher doses than the ones by the study [66].

Finally, one of the biggest studies on this subject, demonstrated that 31% of the elite swedish athletes used androgen anabolic steroids in competitions [21] and, recently, publicized two articles [92] [93] showing the mental health aspects in an analysis of 30 years and the increase on death rate and suicide of ex elite swedish athletes. One of them showed high rates of melancholia, depression and anxiety, the other one showed high rates of death due to vascular diseases, malign diseases and suicides. The data were compared with the swedish population studies, corroborate the study of Parssinen *et al.* (2000) in which athletes that used androgen anabolic steroids had a higher rate of mortality 4,6 higher than the normal population. It is important to note that these study designs are scarce and with some methodological errors, which the authors themselves admit, due to the lack of control in these 10, 20 and 30 years and external factors.

7. Conclusions

The effect of anabolic androgen steroids on the human body is an evolution process of diverse phases, depending on the way it is utilized, this determining a final result, becoming impossible to foresee this final result. The side effects are diverse, may be caused by the therapeutic use or not, being aggravated by the abusive use of these substances, seeing that many of the effects are not yet known by literature due to the lack of information for the refusal of participating on researches by the users. Since a big part of the users make use of doses higher than physiologic, with little or no information about these drugs, being very common the associated use to other drugs such as insulin, GH, stimulants and others making it harder to measure the cause and effects, with it, studies conducted with athletes are also scarce, being found on literature a great number of studies for the therapeutic use. Thus, the intent of the article was to show a little about the history of steroids and their methods and most common use, demonstrating their beneficial effects mainly on muscle mass and strength gain, however alerting to the great deleterious effects to the human body. As its use is ever growing with time, due to the cult of the human body being ever greater, it is becoming a case of public health. Finally, we hope that more research is ade about this theme, mainly randomized studies using doses higher than physiological in humans, to better enlighten this so common practice.

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