

Strength training for female athletes: A position paper: Part I

The increasing use of resistance exercise by women prompted the National Strength and Conditioning Association to form a committee in the fall of 1986 to investigate this matter and to prepare a position paper on it. It was this committee's charge to search for and report on factors that affect strength training for women and that could necessitate different coaching methodologies and approaches than those used for males.

To this end, the committee undertook the preparation of a comprehensive survey and analysis of the scientific literature dealing with strength training for female athletes. In a number of meetings, the committee members pooled their knowledge, their professional experience and their empirical observations relating to women and strength training. The result is this position paper, which is both a research review and a summary of the committee's personal observations and recommendations regarding resistance training and the female athlete. As this position paper makes clear, there are many areas relating to the strength and conditioning of women that researchers have yet to delineate or explore.

It is the committee's hope that this paper will serve not only to inform athletes, coaches and other interested individuals as to what is now known regarding the physiological capabilities of female athletes, but also to identify and propose new directions for scientific research in this field.

An Historical View

Female participation in resistance training is a relatively recent development, beginning in the 1950s with a few female track and field athletes (137). This humble beginning was actually a major step for female athletes and the role of resistance training in their athletic improvement. Previous generations of female athletes were often inhibited from training due to social stigmas and lack of physiological research. A few pioneers, however, paved the way for the eventual acceptance of female athletes and the use of resistance training.

The most popular writer on exercise in the latter half of the nineteenth century was Dr. Diocletian Lewis, who included dumbbell, Indian club and weighted "wand" exercises in his enormously successful book, **The New Gymnastics for Men, Women and Children**, which was published in 1863 (92). Lewis' system was adopted by most of the eastern women's colleges, and he established a school in 1862 to train men and women to teach his system. In the late nineteenth century, Dr. Dudley Allen Sargent of Harvard University continued to popularize resistance training for women. He also invented numerous cable and pulley exercise machines, as well as the earliest known rowing machine. Sargent recommended exercises of this sort for women (54).

Although these physical educators did encourage the use of resistance apparatus, they advocated only

"light" repetitive training for women. However, Dr. George Barker Windship, a Harvard-educated physician who opened a gymnasium for men and women in the middle of the nineteenth century, advocated "heavy" lifting for both genders. Windship introduced at his gymnasium a partial movement he called "The Health Lift" (a "hand and thigh" partial deadlift with the weight suspended below), citing it as the quickest means to strength and vigor. Windship personally reached more than 2,000 pounds in this lift at a body weight of less than 150 pounds. No records have been found of women lifting weights on this apparatus, though advertisements for a parlor version of this machine depicted women using it (54).

In the early twentieth century, resistance training for women was neither popular nor considered socially acceptable. During the 1950s, a few female track and field athletes, primarily throwers, employed resistance training techniques as a regular part of their competitive preparation for strength and power improvement (137). Finally, after the passage of Title IX in 1972, consistent efforts were made to encourage strength training by female athletes.

The growth of resistance training for women further advanced when the first competitive power lifting competition for women was organized in 1977 and the first national weightlifting championships were held in 1981. It is not unreasonable to expect that the disparity between

the performance of trained strength athletes of the genders will diminish. This has happened in many other sports in which women have participated over a number of decades, as the number of women competing in these activities increases and as their desire for strength begins to more closely parallel that of men.

Socio-psychological Aspects of Strength Training in Females

Common barriers many female athletes and coaches must overcome when resistance training are the still-present social norms regarding femininity and participation in sports, particularly strength and power sports. Western cultures have traditionally regarded strength as masculine rather than feminine. There are varying degrees of femininity attached to sports, and those sports requiring aggression and strength have been found to be the least compatible with traditional concepts of femininity (26, 101, 124, 125). Such attitudes may be in flux, but do not change rapidly. A 1986 survey of readers of **Women's Sports and Fitness** magazine reports that although 94 percent of the respondents said that sports participation does not diminish femininity, 58 percent held the contradictory notion that women are often forced to choose between athletics and being feminine (158). Moreover, several researchers have found that these attitudes restrict female athletic performance, and the average female athlete falls far short of her genetic potential when performing (41, 56, 62, 67, 76, 131, 138, 146, 155).

The conflict between desired image and actuality may be exacerbated for all female athletes, especially those in strength and power sports, when considered in conjunction with prevalent societal expectations about feminine behavior. Athletes who hypertrophy tend to violate the preferred feminine

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body image (42), and female strength and power athletes additionally violate cultural stereotypes for feminine behavior with the performance of their sports. This apparent conflict may lead some female athletes to question their participation in a sport or how hard they should try to succeed.

Development of Belief Systems

Children learn concepts of masculinity and femininity both from observation of models and from direct instruction, and they learn and understand the social expectations for both genders, not just their own. Recent evidence reviewed by Huston (72) suggests that children remember

what they consider appropriate gender-typed behavior better than behavior judged to be atypical, and that they will transform information that is counter to their encoded stereotype in order to fit the expected stereotype. Thus, their belief structure begins to develop in infancy and has a tendency to perpetuate itself by editing and transforming incoming information. In relation to the female athlete using resistance training, the belief structures formed during childhood may be in conflict with her training program because the training program may not match her belief structure of appropriate female behavior.

There is good evidence that from infancy on boys are encouraged to participate in gross motor play and

rough-and-tumble games, whereas girls are discouraged from such activities (55, 108). Beliefs about a desirable body image are formed as early as two to four years of age and emulate the preferences of adults (40). In the United States, chubby, endomorphic physiques are the least popular, and broad-shouldered, mesomorphic physiques are the most popular (40). Thin, ectomorphic builds are more acceptable to girls than boys, however, and girls also appear to be more adamant about their rejection of a fat image (110).

Although attitudes and beliefs about what is acceptable or desirable for a given gender are often resistant to change, they may be changed through long-term, continuous exposure to counterstereotypes (78). For example, researchers have noted that the games of both genders have become more similar since the beginning of the twentieth century because of changing preferences in girls (130). Clearly, changes in beliefs about gender-typed behavior can and do occur, but not always with great rapidity. Although female resistance training might be more accepted now than when it was first introduced, traditional societal beliefs still exist that prevent it from becoming completely accepted. With continued use and increased popularity among coaches and athletes, however, resistance training for female athletes may someday be as common and accepted as it is for male athletes.

Self-perceptions of Female Strength and Power Athletes

To summarize work on the self-perceptions of females who participate in activities such as power lifting, track and field and basketball, we are presented with a picture of women performing in areas traditionally perceived as masculine who nonetheless have self-perceptions that are as good as or better than women in less stigmatized activities or those who do not participate (77, 115, 124). Female bodybuilders, whose sport is in essence the development of a muscular body image, find themselves mi-

nutely examined by an image-conscious, television-influenced society (33), yet they present normal or favorable psychological profiles on traditional psychological instruments (43, 44). Like other female participants in activities that emphasize leanness, however, they may be more vulnerable to eating disorders than athletes whose sports do not emphasize leanness (11).

Several studies have been done on the relationship between strength and resistance training and self-concept in male athletes (29, 47, 139, 140, 141, 142), and recent studies have examined this relationship in females (14, 67, 138). The studies on male athletes have concluded that a positive relationship exists between the athlete's training and his self-concept. The three female studies used untrained subjects and were 16 weeks or less in duration. These studies showed similarly positive results and supported the notion that weight training can result in positive changes in self-concept and self-esteem for women of varying ages and abilities. Because women tend to be underdeveloped in strength and because the skills to develop strength are well within the range of most people, a well-planned weight program can provide a satisfying opportunity for physiological and psychological improvement for many women. Similarly, weight training also deserves consideration among other modalities of therapy to improve the self-esteem of those who suffer from a loss of personal empowerment, such as victims of eating disorders, rape and physical abuse.

Future Research and Practical Applications

In keeping with Carron's (17) recommendations for research classifying subjects by gender and sport, more work is needed dealing with the self-perceptions of experienced strength-oriented and resistance-trained female athletes; women who need to train for strength, power or size in order to increase their ability in their chosen sport; and untrained

subjects. More attention needs to be given to the roles sports and social situations play in the female athlete's self-concept of femininity. Research reviewed by Duquin (35) has shown that female athletes may see themselves as less traditionally feminine in sport situations and more traditionally feminine in social situations. Lenney (90) also points out the importance of tailoring research designs to such specific situations and the importance of psychological measuring instruments designed for female subjects.

Physiological Aspects of Strength Training in Females

Absolute and Relative Strength of Females

To fully understand the absolute and relative maximum strength of female athletes, a comparison to their male counterparts must be made. The maximum strength of adult males and females has been studied using a variety of comparative techniques and physiological parameters (3, 21, 66, 88, 89, 154). Comparative examinations of the maximum absolute strength of men and women have consistently found males to be stronger than females (18, 63, 103, 146, 148, 154). In reviewing literature on the topic in 1961, Hettinger concluded that "general muscle strength in women is about two thirds that of men" (65). Fifteen years later, Laubach reviewed nine studies of the comparative strength of men and women and found women's total body strength to be 63.5 percent of men's total body strength, with a range from 35 percent to 86 percent (89). Wells and Plowman concluded in 1983 that the average man is 30 percent to 40 percent stronger than the average woman but that the difference was not consistent for all muscle groups (150). Wilmore cites women as being 43 percent to 63 percent weaker than males in their upper bodies but only 25 percent to 30 percent weaker than males in their lower bodies (152).

When the difference in body di-

mensions and lean body mass between genders is taken into consideration, however, the relative strength differences are less appreciable. In the lower body, using a strength to lean body weight ratio, Wilmore and others (69, 91, 154) have found women to possess approximately equal lower body strength compared to males. Hosler and Morrow, in a 1982 study involving 87 men and 115 women, found that "the impact of gender is rather small when one considers strength differences after allowing for body size and composition" (68). In this study, gender accounted for a difference of only 2 percent in leg strength and 1 percent in arm strength.

As for the maximum absolute strength differences between the genders, there are several explanations. At maturity, males are nearly 13 centimeters taller than females and 14 to 18 kilograms heavier in total weight on the average. Males also possess, on the average, 18 to 22 kilograms more lean body mass and have 3 to 6 kilograms less fat weight, giving them at the age of 21 an average body fat of 15 percent compared to a woman's 23 percent.

The fact that females appear to have the same capacity for strength as males when strength of both is compared per cross-sectional area of muscle (74, 120) reinforces the belief that the greater strength of males is primarily a function of their larger size. Also, the distribution of lean body weight is not the same for both genders. Women have a higher percentage of their lean body mass in their lower bodies. Likewise, the broader shoulder structure of males not only allows them to carry greater muscle mass in their upper body but gives them a biomechanical leverage advantage in tests of upper body strength (68, 126). Of perhaps equal significance to the greater body size of males is their higher androgen level, particularly that of testosterone, which will be discussed in a later section of this paper.

It also is known that although the distribution of muscle fiber types is similar for both genders, males have

larger muscle fibers and, apparently, tend to reach a distribution of more than 90 percent for either "slow twitch" (Type I) or "fast twitch" (Type II) fibers (112, 156). Another physiological difference between men and women is their neuromuscular responses. Karlsson and Jacobs (80) found significant differences between men and women in "force-time" determinations. "Force time" was defined in their study involving 38 males and 22 females as "the time required to develop 70 percent of maximal leg force." It took the female subjects twice as long to develop the same relative force, despite the fact that tests indicated the females possessed greater fast twitch fiber percentages. Karlsson and Jacobs concluded that "sexually mediated differences in neuromotoric control may exist, affecting muscle force production, speed and the 'accepted' relationships between muscle fiber type distribution and exercise performance" (80). Males can sustain much higher stretch levels, but females can utilize a greater portion of the elastic energy stored in countermovement jumping and static jumping (83, 84). Women also have a longer electromechanical delay than men, which may be related to a lower peak force production and a slower rate of force production (8).

Concerning upper body strength in female athletes, research has indicated they are weaker than their male counterparts. In Laubach's review, the upper body strength of women was found to range from 35 percent to 79 percent of male values, with the average at 55.8 percent (89). When strength was expressed relative to body weight, Bishop found that women's upper body strength averaged 60 percent to 70 percent of men's (9). Even in studies using trained subjects, upper body strength differences are significant, often more than 100 percent more for males than females. In fact, when trained females were compared to untrained males, females exhibited lower upper body strength scores (37).

The percentage of difference between the two genders is consider-

ably lessened when expressed in relation to total lean body mass. Bishop found that women's upper extremity strength was approximately 80 percent to 90 percent that of men's when expressed in this manner (9). Some studies that have examined strength per unit of cross-sectional area of muscle tissue, however, have found no significant difference in strength between men and women (74, 120).

The greater maximum absolute strength of males cannot be totally explained by their larger size; they do not, in other words, exceed women in lean body mass as much as they exceed them in maximum absolute strength. Another contributing factor is that males tend to be stronger because young boys are more likely than girls to engage in vigorous play and perform tasks which require heavy lifting (55, 72, 150).

Body Composition and Its Effects upon Athletic Training

A heightened awareness of the concept of body composition and its implications for performance exists among coaches and athletes. While a substantial body of literature is available on the subject, a great deal of misinformation has been dispersed which can have serious consequences on health and dietary practices. It is important, therefore, that the assessment and limitations of body composition be clearly understood before attempting to alter an athlete's weight and body composition. The next section of this paper will discuss some general considerations of body composition analysis and will present some specific data and considerations for analyzing female athletes.

The need for body composition analysis resulted from the apparent inappropriateness of height/weight tables in assessing health status for athletes. According to the tables, a person would be labeled "overweight" if his/her muscle mass was significantly greater than the average for the general population, even though he/she may have been very lean. Likewise, an individual might be

labeled "average weight" and still be overly fat. The assessment of body composition seemed a better indicator of health status regardless of an individual's weight. Simply defined, body composition is the relative amounts of fat and lean tissue in the body, generally expressed in terms of percent body fat. The lean tissue component consists of fat-free muscle, bone and organs and should comprise the greater portion of total body weight. A number of methods have been devised to determine the ratio of fat to lean body mass (LBM) in the body, among them hydrostatic (underwater) weighing and anthropometric measurement techniques (e.g. skinfold assessment).

Because fat is low-metabolic tissue, it might seem that it is an unnecessary impediment to human movement. A certain amount of fat is required, however, for normal physiologic functioning, and is stored in bone marrow, internal organs and the central nervous system. For men,

Behnke estimates this minimal level of essential fat to be two to five percent of total body weight (7). For women, minimal fat levels have a much greater variation. For example, a male sprint runner should have a relative body fat percent of 3 to 6 percent, and for a female sprinter, the body fat should be 9 to 11 percent. A complete listing of male and female athlete body fat percents relative to their sport is seen in **Table 1**.

In women, essential fat also includes gender-characteristic fat stored around the mammary glands and the pelvic/thigh region. The amount of fat and its distribution in a given individual appears to depend on both genetic and environmental influences. Therefore, a certain amount of variation in body fat percent is expected in athletes who compete in the same sport.

Non-essential fat is termed "storage fat" and represents nutritional reserves that accumulate in adipose tissue (82). It is this non-essential fat

that can be safely reduced through diet and exercise to alter body composition. It should be noted, however, that loss of fat weight is often accompanied by lean tissue and water loss, particularly in short-term rapid weight loss diets. This is especially true if no exercise is included in the reduction program. In addition, repeated cycles of weight loss and regain cause increased food efficiency; the body becomes more efficient at saving calories (15). Therefore, as the number of weight loss/regain cycles increases, greater caloric restriction is required to obtain similar weight losses. Increasing the period of weight loss, decreasing the number of weight loss/regain cycles and increasing exercise will reduce the amount of lean tissue and water lost, as well as minimize changes in food efficiency (15).

A common misconception among female athletes is that weight training will cause them to become larger and heavier to their disadvantage. A substantial amount of data demonstrate the inaccuracy of this belief (13, 70, 81, 98, 107, 154, 157). Each of these studies demonstrated a reduction in fat weight, an increase in lean weight, and either no change or only a slight increase in total body weight. All demonstrated significant increases in strength, and in most cases these changes were associated with no change or a decrease in lower body girths and only minimal increases in upper body limb girth (70, 81, 98, 154, 157). Mayhew and Gross suggest that these minimal changes in girth are due to decreases in intramuscular adipose tissue accompanied by muscular hypertrophy (98). Conversely, some female athletes have demonstrated substantial increases in limb circumference (3.5 cm, 1.1 cm and 0.9 cm in shoulder, upper arm and thigh respectively) following a six-month weight training regime (13). This might reflect greater genetic potential for hypertrophy and/or increased training intensity in these women.

Increases in functional muscle mass with subsequent reductions in storage fat would be advantageous for a number of reasons. First, the

Table 1. Relative Body Fat for Athletes in Various Sports

Sport	Relative fat (%)	
	Males	Females
Sprint running	3-6	9-11
Distance running	4-11	6-15
Wrestling	4-8	-
Gymnastics	5-10	8-12
Swimming:		
Sprinting	6-10	8-12
Distance	8-12	10-14
Basketball	8-12	12-16
Baseball/Softball	12-16	14-18
Bicycling	8	15
Orienteering	16	19
Rowing	11-14	9
Tennis	12-16	15-20
Track & Field:		
Hurdles	5-6	16
Jumping	7	17
Discus	16-18	24
Shot Putting	16-20	28
Skiing:		
Alpine	10-15	21
Cross-country	8-10	15-22

*Modified from Wells, C.L. 1985. **Women, Sport and Performance**. Champaign, Illinois: Human Kinetics Publishers. P. 15, Table 1.2. Reprinted by permission.

athlete would be carrying less performance-hindering excess weight. Second, as alluded to above, increased muscle mass is associated with improved performance in strength/power sports; thus, one could expect improved performance. Third, muscle is metabolically active tissue, whereas fat itself has little metabolic activity.

Despite the obvious advantages in altering body composition listed above, such changes can impair performance in some individuals. While a useful tool, body composition alone should not determine an athlete's regimen. Individual fitness levels and performance should also be considered when advising athletes. Furthermore, the perceived pressures to alter body composition, whether internally or externally applied, may lead to pathogenic eating behaviors such as anorexia nervosa and bulimia, which can subsequently impair performance. Anorexia nervosa is characterized by a poor body image, an intense fear of becoming obese, loss of more than 25 percent of the original body weight and refusal to remain at or above a minimal body weight recommended for a certain height and age (27). In comparison, the bulimic may be of normal weight but suffer from recurrent episodes of uncontrolled binge-eating often followed by self-induced vomiting and/or the use of cathartics and/or diuretics in an attempt to avoid weight gain (27). Consequences of such eating disorders include hypoglycemia, severe dehydration and hypokalemia, which are reflected in symptoms like headaches, dizziness, weakness, erratic heartbeat and, in severe cases, paralysis (12, 122). The problem of eating disorders in athletes has gained more attention in recent years (12, 34, 117, 122, 161), and is thought to be at least as prevalent, if not more so, than it is in the general population. Psychotherapy and nutritional counseling are usually required to alleviate symptoms (117, 148), though prevention is the best treatment. Further research in this area is desperately needed, and educational programs involving

recognition, treatment and prevention of eating disorders need to be established for coaches and their athletes.

It is apparent from the literature that body compositional differences exist between men and women, but the implications for athletic performance have yet to be clearly defined. Within the scope of current literature, however, the following conclusions can be drawn. First, body composition assessment is not an absolute science, but does offer estimates within specified ranges which can be used, in conjunction with concern for an athlete's health and performance, to her advantage. Second, weight training has repeatedly demonstrated favorable alterations in body composition in women as it increases lean body weight and decreases fat percent. Third, a growing trend in pathogenic eating behavior has been demonstrated in female athletes concerned about their body composition.

Muscle Fiber Composition

A primary consideration in the expression of human power and strength lies in the characteristics of the muscle(s) producing the associated movement. Thus, it would seem advantageous for an athlete involved in power events (those that require large force generation in a short period of time) to possess a relatively larger number of type II fibers, particularly in those muscles used in his/her event. A number of investigations have supported this idea (22, 49, 50, 57, 113, 134), although great variations in fiber types within specific muscles can occur between individuals of the same sport. Although relationships appear to exist between fiber composition and performance, further investigations are required before establishing fiber composition as a predictor of various athletic success (52).

The most consistent finding in muscle following resistance training is increased cross-sectional area. Because cross-sectional area appears to be a major determinant of muscle strength (74, 97, 120), one might an-

ticipate this adaptation with training. Interestingly, this alteration has been demonstrated to occur primarily within the fast contracting fiber population; heavy resistance training has resulted in significantly increased FT:ST fiber ratios of cross-sectional area (23, 30, 61, 132, 133). These studies also demonstrated corresponding increases in strength and power, although the changes in these parameters varied between individuals, possibly due to the different training regimes and recruitment patterns used. Thus, resistance training has been consistently shown to increase muscle cross-sectional area, primarily due to hypertrophy of FT fibers.

Most of the fiber type literature to date deals with male subjects; relatively few have been performed with women. A number of studies comparing fiber composition between male and female athletes of similar sports, however, have demonstrated few gender differences. Muscle fiber type distribution has been found to be similar in track athletes (22), physical education students (120) and untrained individuals (118), regardless of gender. In those studies that have shown differences in fiber distribution between male and female athletes of similar sports, the activities varied significantly. Oarswomen with fewer ST fibers than their male counterparts rowed considerably shorter distances (19). Likewise, women springboard and platform divers with fewer FT fibers than male divers performed dives of considerably lower degrees of difficulty (49). In general, differences in fiber composition are more marked between athletes of different training backgrounds than between genders (31).

Fiber number is difficult to assess in humans but can be estimated through indirect techniques. Schantz (120) estimated fiber number in the triceps brachii of men and women by dividing muscle cross-sectional area with mean fiber area, with no significant differences apparent. Conversely, Sale (118) estimated the number of muscle fibers in the triceps brachii to be significantly lower in untrained women than untrained men or body-

builders using similar methods. It is therefore difficult to draw conclusions regarding gender differences in fiber number; further investigation is needed.

Fiber cross-sectional area does appear to be significantly smaller in females than in males of similar activity levels, as does FT/ST cross-sectional area (22, 112, 118, 120). When compared to untrained women, however, female athletes have significantly larger cross-sectional areas of individual fibers (112). It is speculated that the gender differences in fiber cross-sectional areas may be the result of different androgen levels, as will be discussed in a later section.

It is interesting to note that muscle cross-sectional area is proportional to maximal voluntary force development, regardless of gender (74, 120), although this may vary between muscle groups as well as testing velocities. In fact, a recent study found higher voluntary peak tension per arm flexor cross-sectional area ratios in untrained women than untrained men and bodybuilders at velocities greater than 30 degrees (118). The women also had greater work to cross-sectional area ratios than both male groups in this study, possibly due to gender differences in optimal joint angle for voluntary torque. It is apparent that further work needs to be done in the area of fiber type alterations in women consequent to resistance training. For now, the following conclusions may be drawn from the literature to date:

1. Muscle hypertrophy, which can be correlated with increases in strength in both men and women, appears to be the result of increases in fiber cross-sectional area. Although hyperplasia may play a role in this process, evidence to date has been of an indirect nature and requires further substantiation.

2. Heavy resistance training can produce greater muscle cross-sectional area, primarily due to increases in fast twitch fiber cross-sectional area. These changes are positively correlated with changes in strength and

power.

3. Women involved in athletic activities appear to have similar fiber type distribution to their male counterparts, although their fibers appear to be smaller in cross-sectional area.

4. It might be speculated that women will respond to resistance training similarly to men, though to a lesser extent due to lower androgen levels; this requires further substantiation.

Hypertrophy in Females

One aspect of weight training for females that has fostered several investigations is the question of whether muscular hypertrophy occurs in women as a result of training. Most of these studies have sought a physiological explanation for the observed gender differences in muscle size. Because strength is a major contributing factor in athletic performance, and because strength is closely related to the size of a muscle (97), the extent to which females hypertrophy as a consequence of weight training becomes an important consideration.

A popular theory is that the lower androgen levels of females are responsible for the fact that less muscle hypertrophy occurs in females than in males when both genders engage in weight training (13, 98, 106, 154). Weiss and colleagues (147) state that the role of androgens, as well as testosterone alone, in exercise-induced skeletal muscle hypertrophy is unclear and has yet to be defined.

Numerous investigators have accumulated evidence to support the fact that testosterone is not solely responsible for gains in strength (36, 64, 85, 147, 151). As Fahey and colleagues noted in their 1976 study, "Higher testosterone levels alone do not appear to insure superior strength and musculature . . . Because testosterone is involved in only a part of the process of protein synthesis, other factors may be of equal or greater importance in explaining muscular differences" [between the genders] (36). Wall et al, however, state that increases in muscle mass as a result of

strength training may, at least in part, be mediated by chronic changes in androgenic hormonal milieu (145). Also, Strauss, Liggett and Lanese interviewed 10 weight trained female athletes—women who had competed at the national level in strength sports—concerning their anabolic steroid use, and found that all 10 subjects believed that muscle size and strength increased in association with anabolic steroid use (129). These investigators noted that these were the effects the subjects sought, and they represent the participants' perceptions, rather than objective measurement. [The NSCA position paper, **Anabolic Drug Use by Athletes**, should be consulted for further information on the effect of anabolic steroids on athletes.]

Several investigators (13, 98, 106, 154) have examined the effects of weight training on females and have found that strength gains occur with little or no muscular hypertrophy. Within these investigations, three important factors have been overlooked: (1) pretraining status of the subjects; (2) duration of the training program; and (3) specificity of training. In a review of the factors influencing muscular strength during short term and prolonged training, Hakkinen (59) noted in 1985 that increases in maximal strength differ greatly with the level of pretraining strength. Not surprisingly, he found that increases in the strength of subjects with high pretraining strength were more limited than strength increases in those subjects with low pretraining strength and especially in those subjects who were untrained. Furthermore, the great strength increases during the first two to four weeks of training in untrained subjects is primarily due to neuromuscular adaptations of the newly trained muscles. Major hypertrophic adaptation, Hakkinen concluded, resulted after "prolonged" training: i.e. of several months duration (59).

Given this definition, Brown and Wilmore (13) were the only investigators to apply a training stimulus for a prolonged period (in this case, six months). In regard to pretraining

status, however, three of their five subjects had prior weight training experience, yet none had participated in any weight training for at least three months before the study began. O'Shea and Wegner's subjects had all undergone 10 weeks of weight training in a beginning weight training course prior to the study. These researchers did not state whether this participation immediately preceded the experiment. Assuming that it had, the total duration of the training program was only 17 weeks (106). Neither Mayhew and Gross (98) nor Wilmore (154) make mention of the pre-training status of their subjects. Furthermore, the length of the training programs in these particular studies were nine and 10 weeks, respectively.

Some possible explanations for the lack of hypertrophy in these weight-trained females are that the weight training program was not employed long enough to produce hypertrophic adaptations and that the subjects were untrained at the outset. Another possible explanation for the lack of hypertrophy in these females is that hypertrophy was not the objective of any of the weight training programs employed.

The research to date concerning strength training and females indicates that the functional quality of muscle is the same in males and females in regard to contractile properties and the ability to develop muscular strength (13, 22, 58, 106, 154). It is likely that an appropriate stimulus applied for a prolonged period of time will produce hypertrophy in females. The extent of the hypertrophy will depend on the objective and/or design of the training program and, most likely, on genetic factors as well. Wilmore did note increases in lean body mass in his 1974 subjects, although no control group existed at that time for comparison. Moulds, Carter, Coleman and Stone found decreases in subcutaneous fat with no significant changes in circumference measures in female basketball players participating in a 14-week weight training and sprinting program (104). These findings suggest slight increases in muscle mass. No control

group, however, existed for this study. Cureton et al, using computerized axial tomography (CAT), have shown that while the absolute increase in muscle cross-sectional area of males to resistance training is greater, the relative response (percentage of change) is similar (24). This would suggest that given equal training, men and women would hypertrophy in relatively similar manners.

Simple observation of females who have participated in chronic resistance exercise provides ample empirical evidence that hypertrophy does occur in females. Women who participate in competitive weightlifting, power lifting, or bodybuilding, or women throwers or sprinters who use their weight training to enhance their performance often exhibit hypertrophied musculatures. This also is true of women in sports like gymnastics, where body weight is used as resistance.

Hormonal Considerations

In recent years, weight training has become a popular activity among females. Research into the short and long term hormonal adaptations to weight training in females is limited, however. In some cases, all that is known concerning the hormonal adaptations to exercise and training in females is derived from investigations of endurance activities.

Thus, it is difficult and risky to generalize about females from studies using male subjects or studies using endurance-type activities. Obviously, more research to assess the hormonal effects consequent weight training would have on female subjects is needed. In particular, data would be valuable in: (1) determining what type of strength training is either valuable or detrimental to the reproductive health of females; (2) determining the extent to which hormonal responses might actually be manipulated to produce enhanced training effects, specifically in females; (3) producing a greater number of comparative studies concerning different

modes of exercise.

Androgens in the Female

In the female, androgens are produced by the adrenal glands and the ovaries (45, 93). The adrenal cortex and ovaries contribute about equally to peripheral androgens, except at mid-cycle, when the peripheral androstenedione is double that of the production of adrenal cortex (1). Because testosterone and androstenedione are the more important androgens in the female, this discussion will be limited to testosterone and androstenedione variations in response to exercise and training.

In adult males, the production rate of testosterone and androstenedione have been found to be 5 to 10 mg/day and 1 to 2 mg/day, respectively. In adult females, the corresponding rates are less than 0.1 mg/day of testosterone and 2 to 4 mg/day of androstenedione (87). Vallette, Sereour and Boyer (143) report that plasma testosterone concentration during the menstrual cycle appears to be random. Numerous others, however (45, 79, 93), have reported a greater production of testosterone and androstenedione during the middle third of the menstrual cycle (the late follicular ovulatory and early luteal phases).

Hormonal Responses to Exercise and Training

Before examining specific hormonal responses to exercise, an important distinction needs to be made between the terms "exercise" and "training." In this discussion, exercise refers to a single period of activity. Training refers to prolonged, regular exercise.

Several studies have examined the androgen response to a single bout of weight training exercise in females. Fahey et al examined post-exercise serum testosterone concentrations in both genders and found serum testosterone concentrations increased in males, but not in females (36). The female subjects, however, were not experienced with weight training and

performed a different exercise program than the males, who were described as experienced weight trainers. Weiss, Cureton and Thompson also reported non-significant increases in testosterone and androstenedione in females and significant increases in males with equal weight training experience and controlled exercise intensities. These investigators reported that although resting testosterone levels were 10 times greater in males, the similar percentage increases in serum testosterone following weight training indicate that the changes were proportional to resting blood concentrations. Weiss and his colleagues concluded, "... men have a greater absolute testosterone response to weightlifting than females, whereas the absolute androstenedione response to weightlifting is similar in males and females" (147).

In one of the first longitudinal studies, Hetrick and Wilmore (64) examined the effect of training on plasma androgen concentrations in males and females following an eight-week training program. They found no significant differences between pre- and posttraining plasma androgen values for either males or females. They concluded that chronic androgen levels do not change significantly during the course of an eight-week training program (64). In contrast, prolonged weight training by males has been found to increase testosterone to cortisol ratios (60) and trained female endurance athletes have been found to possess significantly higher resting testosterone levels (though still within the normal range for females) when compared to controls (25).

Anabolic Steroid Use and Females

Because the NSCA has already published its position paper on anabolic drug use by athletes (160), it is necessary only to reiterate, with emphasis, the effects of anabolic steroids on females. Possible adverse side effects of anabolic steroid use by women are virilization, which includes hirsutism (growth of hair, particularly

facial hair), coarsening or deepening of the voice, clitoral enlargement, coarsening of the skin, development of male pattern baldness, menstrual irregularities, acne and behavioral changes (32, 87, 111, 128, 129, 159, 160). The major side effects—deepening of the voice, growth of facial hair and clitoral enlargement—may be only partially reversible (128). The other non-beneficial changes that occur in males may also occur in females. These changes include premature closure of the epiphyseal plates, changes in liver function (including hepatic tumors), pyrogenic effects, hypertension, inhibition of gonadotropins, changes in adrenocortical function, effects on serum lipids (including increased cholesterol and decreased high density lipoproteins), and such behaviors as increased aggression, psychoses, irregular sleep patterns and heightened libido (32, 87, 111, 128, 129, 159, 160).

Little statistical evidence is available to document the existence of steroid use or other drugs such as growth hormones by female athletes. It is widely believed, however, that a broad spectrum of athletes have experimented with anabolic steroids, and not only in the "power" sports (32). Because strength-power sports such as weightlifting, power lifting, swimming, sprinting and throwing events are based largely on physical size and/or strength, the temptation for female strength-power athletes to gain a winning edge by using anabolic steroids or other performance-enhancing substances in these particular events is especially great.

Along with the passage of Title IX in 1972 has come increased opportunities for U.S. women to participate in competitive athletics, to obtain athletic scholarships and to pursue sport-oriented careers. The heightened athletic environment created by Title IX, the many positive results on steroid drug tests for women in national and international competition, and the shift in emphasis in women's sports from participation to winning has led to the belief that there has been an increase in the number of female anabolic steroid users (32). The re-

search to date postulates that because natural testosterone levels in females are much lower than in males, the chance for females to increase muscle mass using steroids is probably better than that for males (32, 129). Whatever advantage exogenous steroids may offer males is most likely magnified in women. For this reason as well as the potential ill effects, female athletes need to be discouraged from using anabolic steroids or other performance-enhancing drugs. ●

Part II of this article will appear in Volume II, Number 5 of the NSCA Journal.

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