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The effects of concurrent strength and muscular endurance resistance training on strength, endurance and body composition in previously untrained females

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**THE EFFECTS OF CONCURRENT STRENGTH AND MUSCULAR ENDURANCE
RESISTANCE TRAINING ON STRENGTH, ENDURANCE AND BODY
COMPOSITION IN PREVIOUSLY UNTRAINED FEMALES.**

by

Derek W Gibbins

A Thesis Submitted in Partial Fulfilment of the Requirements for the

Award of

Bachelor of Applied Science (Sports Science) Honours

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USE OF THESIS

The Use of Thesis statement is not included in this version of the thesis.

ABSTRACT

The number of females engaged in some form of sporting activity is growing rapidly, but many women still shy away from weight training because of their fear of excessive muscular hypertrophy and its accompanying loss of femininity. Because strength and muscular endurance play a vital role in most sporting endeavours, and weight training has proven to be one of the most effective methods to improve both attributes, any training regime that could achieve concurrent increases in both measures without noticeable increases in muscle size would be ideally suited to most women.

Changes in strength and endurance resulting from eight weeks resistance training of the non-dominant elbow flexors were followed in 11 females using either a high repetition low resistance training regime [Endurance], a low repetition moderate resistance training regime [Strength], or a combination routine alternating between the two regimes [Combined]. Changes in body weight, limb girth or skinfolds were also monitored. The occurrence and severity of any delayed onset muscle soreness (DOMS) based on the subjective assessment by each participant was also monitored. Strength gains [as measured by 1 RM preacher bench curls] were apparent in response to all training regimes [E: S: C], with mean pre-post increases of 11.9%, 12.0% and 10.5% respectively. Isometric peak torque tests produced only one statistically significant mean pre-post strength increase [20.5%], and that was achieved by the S group. Isokinetic peak torque measurements at 30° per second produced significant mean pre-post increases for both the S and C groups of 17.7% and 17.0% respectively, but when the assessment speed was increased to 90° per second only the 22.9% increase posted by the C group was found to fall within the selected ($p < .05$) level of statistical significance. Changes in muscular endurance were assessed using the total work produced during 25 continuous repetitions at 90° per second, and the only statistically significant increase was achieved by the C group.

The results of this study showed that gains in strength and muscular endurance can be made by previously untrained females in response to 8 weeks of alternating concurrent moderate (70-75% 1 RM) intensity / low (5 x 6 repetition) volume, and low (40-45% 1RM) intensity / moderate (5 x 25 repetition) volume training regimes, and that strength gains could be achieved without noticeable DOMS or any significant increases in muscle girth measurements.

DECLARATION

"I certify that this thesis does not incorporate, without acknowledgment, any material previously submitted for a degree or diploma in any institution of higher education, and that to the best of my knowledge and belief, it does not contain any material previously published or written by another person except where due reference is made in the text".

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CHAPTER 1

1.0. INTRODUCTION.

1.1 Background to the Study

In order to design and implement effective training programs for use in conjunction with various sporting pursuits it is vital for coaches to have reliable and relevant data concerning the physiological adaptations which occur in response to various types of training regimes. Research has demonstrated that adaptation of the human body is directly related to the training stimulus provided, and this holds true for both men and women (Hedrick, 1995).

The average woman is approximately 13 cm shorter, 15 kg lighter in total body mass, has 20 kg less lean body mass and significantly more adipose tissue than her male counterpart (Wilson, 1995b). Strength differences between the sexes vary from one muscle group to another, but in general women are approximately 40% weaker than men in the chest, shoulders and arms, but are only 30% weaker in terms of lower limb strength (Baechle, 1984).

Regardless of gender, exercise involving prolonged participation at submaximal workloads causes improvements in both maximal oxygen uptake ($\text{VO}_2 \text{ max.}$) and muscular endurance (Fox, Bowers & Foss, 1989, p. 323-324), whilst resistance training using heavy weights results in increased strength (Fleck & Kraemer, 1987, p. 25-27).

Muscle hypertrophy, which occurs in response to strength training, was until recently thought to be more obvious in males (Wells, 1991, p. 31), with research suggesting that the difference is possibly due to the lower levels of circulating testosterone found in females (Cureton, Collins, Hill & McElhannon, 1988). Recent studies using repeated muscle biopsies have demonstrated muscle fibre hypertrophy in previously untrained women during eight weeks of heavy resistance training despite little visible change in muscle girth (Staron, Karapondo, Kraemer, Fry, Gordon, Falkel, Hagerman, & Hikida, 1994).

Sporting activities often require the utilization of a combination of muscular attributes i.e. strength, power, and endurance in order to perform the different skills involved during participation in an event, and due to tight training schedules there is often the need to devise a training program that will address two or more attributes at once (Chromiak & Mulvaney, 1990):

1.2 Significance of the Study

Wells (1991, p.241) points out that “Most of the knowledge concerning adaptations to training comes from investigations involving non-humans or men. Relatively few well controlled training studies have been completed on either girls or women.” As the following literature review clearly shows a majority of the research studies have focused on the effects of concurrent strength and aerobic endurance training rather than muscular endurance, and only a very few of these investigations have used female participants. Most studies have confined their attention to lower limb adaptations to training, using the quadriceps muscle group to establish the variations in measured strength gains and VO_2 max. that result from combining both types of training simultaneously. Although most sports are predominantly lower limb orientated, there are some notable exceptions e.g. gymnastics, rowing, and swimming for which a high level of upper body strength and muscular endurance are necessary, and therefore to increase the general body of knowledge on this topic one of the most commonly recruited upper body muscle groups i.e. the elbow flexors was chosen as the focus area for this study.

1.3 Purpose of the Study

The purpose of this study was to evaluate the strength and endurance increases produced in the fifteen female participants as a result of eight weeks resistance training of the non-dominant elbow flexors using either a high repetition low resistance training regime, a low repetition moderate resistance training regime, or a combination routine alternating between both of the aforementioned routines, and to monitor any changes in body weight, limb girth or skinfolds which occur in response to training. The occurrence and severity of any delayed onset muscle soreness (DOMS) based on the subjective assessment by each participant was also monitored.

1.4 Hypotheses

This study was designed to test the following hypotheses:

- 1) An alternating concurrent strength and muscular endurance training regime will produce equivalent gains in elbow flexor muscle strength when compared to a strength only training regime.
- 2) An alternating concurrent strength and muscular endurance training regime will produce equivalent gains in elbow flexor muscular endurance when compared to an endurance only training regime.

To this end the subjects who volunteered for this study were allocated to one of three training groups i.e. 1)Endurance (E), 2) Strength (S) and 3)Concurrent Strength and Endurance (C). The results obtained were then compared to discover if there was any significant difference in the progress made by the participants as a result of the particular regimes they followed.

1.5 Thesis Organization

The first chapter provides a discussion of the background, significance and purpose of the study, along with the proposed hypotheses. The literature review that forms the basis of the second chapter, examines research in the areas of direct relevance to the study i.e. training methodology, adaptive processes, gender differences and the effects on strength and muscle endurance capacities of concurrent strength and endurance training. Chapter three describes the methodology used to conduct the study, and the results achieved are analyzed and presented in tabular and graphical form in chapter four. The fifth chapter discusses the findings in detail, and concludes with a summary.

CHAPTER 2.

LITERATURE REVIEW

2.1. Introduction

The human body possesses a remarkable ability to adapt to changing circumstances, and nowhere is this unique talent more apparent than in the area of muscular adaptation to specific training stimuli. Repeated systematic stress causes acute and chronic adaptations within the affected tissue which may be due to either neurological, morphological, biochemical or systemic changes either individually or in combination (Fox, Bowers & Foss, 1989, p. 194 - 195).

Research has shown that adaptation of the human body, including the neuromuscular system, is directly related to the training stimulus provided (Chromiak & Mulvaney, 1990). Anaerobic strength training using heavy weights results in muscle hypertrophy and increased strength (Fleck & Kraemer, 1987, p. 25-27), and aerobic exercise involving prolonged participation at submaximal workloads causes beneficial adaptations to both maximal oxygen uptake (VO_{2max}) and muscular endurance (Fox, et al., 1989, p. 323-374). This process is often referred to as the Specific Adaptation to Imposed Demands (SAID) Principle (Lillegard & Terrio, 1994). The nature and level of adaptation achieved is not only specific to the type of training employed, but is directly affected by the overload presented in terms of the frequency, intensity and duration of the training stimuli (Powers & Howley, 1997, p. 290).

This review will focus on the responses of human skeletal muscle to resistance training, using as its basis current research concerning the mechanisms involved in stimulating muscle growth and increasing force production, and will explore the variations in the adaptive processes which can be directly attributed to training specificity, trained versus untrained status, concurrent strength and endurance training and gender differences.

2.2. The Overload Principle.

The overload principle states that for a training effect to occur a system or tissue must be challenged with an intensity, duration or frequency of exercise to which it is unaccustomed

(Powers & Howley, 1994, p. 265). The elements which constitute overload will naturally vary according to the nature and degree of physiological, neurological and biochemical adaptations required, which will in turn be dictated by the skills and abilities necessary to excel in any given sporting activity (Bloomfield, Ackland, & Elliott, 1994, p. 125).

Frequency, Intensity and Duration are the variables normally manipulated to cause an overload, and progressive adjustments to each individual element are made as the body adapts to the current level of stimulus (Sharkey, 1990b, p. 72). Frequency refers to the number of training sessions per microcycle (which normally equates to a week). Intensity relates to the level of stress or resistance placed upon the system or tissue which is the target of the current phase of training (macrocycle). Duration is the term used to equate to the volume of training i.e. the length of time that the desired level of intensity is to be applied.

According to Fox et al. (1989) intensity is by far the most significant of the aforementioned tenants with respect to assuring a sufficient level of overload to stimulate adaptation (p. 296). Care must be taken to differentiate between progressive and excessive overload (overtraining), as this can result in tissue damage, illness, overtraining syndrome and performance decrements. Excessive training can lead to a situation where the body's ability to recover and adapt is exceeded, and more tissue breakdown (catabolism), than tissue building (anabolism) takes place. Worse still, the tissue's ability to recover is impaired leading to a downward spiral of further overtraining (Wilmore & Costill, 1994, p. 300). Programs must therefore be designed to include both rest, and variations in training volume and intensity to ensure optimal adaptation. This systematic application of overload is referred to as Periodization (Bompa, 1993, p. 61).

2.3. Training Induced Neurological Adaptations Affecting Human Skeletal Muscle.

Almost all skilled movements require a combination of muscular force and motor control, and during the early stages of training a majority of any apparent improvement in performance is due to the development of improved coordination and control of muscular activity (Sale, 1992b, p.263). The first time an activity is performed the task is novel and as a result there is suboptimal coordination between the relevant prime mover, synergist and antagonist muscles. Providing the activity is executed identically and repetitively on a number of occasions the neuromuscular system will become increasingly proficient resulting in improved performance (Rutherford &

Jones, 1986).

Neural adaptation involves both central and peripheral adjustments within the nervous system, and improved performance results from more efficient motor unit recruitment, increased neural activation, improved motor unit synchronization, enhanced motor neuron and/or motor end-plate excitability and decreased proprioceptive inhibition (Straton et al, 1994).

In theory, maximal muscular contraction requires the synchronized activation of every single motor unit at its highest possible firing frequency (Shield & Young, 1995, p. 49). According to Jones, Rutherford & Parker (1989) there is substantial evidence that untrained people cannot achieve full motor unit recruitment by voluntary effort at certain speeds or when limbs are held at certain angles. Specific training however has been shown to improve substantially a person's ability to recruit motor units voluntarily (Sale, 1992b, p.251).

2.4. Training Induced Physiological Adaptations in Human Skeletal Muscle.

Skeletal muscle is an extremely dynamic tissue which has a unique ability to adapt structurally to accommodate variations in functional demands. When confronted with repetitive workloads which exceed 60-70% of its maximum force generating capacity, such as the type of overloading typically presented by resistance training, skeletal muscle tissue will normally adapt by increasing in size (cross-sectional area) and strength. Theoretically, such gains could be jointly or severally attributed to increases in fibre size (hypertrophy), fibre numbers (hyperplasia), changes in fibre type (fibre transformation) and/or an increase in interstitial connective tissue (MacDougall, 1992, p.230). It has also been suggested by Jones et al. (1989) that changes in the angle of pennation, caused by increased fibre diameter, may account for part of any strength increase brought about in resistance trained penniform muscles.

2.4.1Hypertrophy.

Research has repeatedly concluded that in human muscle tissue hypertrophy is the major contributing factor to increased muscle size in response to repeated bouts of high intensity resistance training (Hedrick, 1995).

The primary physiological response to progressive overload is an increase in the

cross-sectional area of skeletal muscle fibers, which, in turn, is a direct consequence of increased volumes of contractile proteins (actin and myosin) deposited within the sarcomeres (Fox et al., 1989, p. 166 ; Bloomfield et al., 1994, p. 123).

An increase in protein synthesis and decrease in protein degradation are the first steps in muscle growth (Goldspink, 1992, p.219). Significant muscle overload can cause microscopic tears in the sarcomeres' structure and thereby provide a stimulus for repair and compensatory growth (Jones & Round, 1990, p.112). Remodelling of muscle involves the synthesis of new proteins and their orderly incorporation into or creation of new sarcomeres (Wilmore & Costill, 1994, p.75).

Muscle fibre hypertrophy does not occur at the same rate and to the same extent in the two main fibre types (I & II). Dudley and Harris (1994) cite research by Hather et al. (1991) as indicating that conventional resistance training causes a greater increase in the size of fast twitch fibers as compared to slow twitch fibers. The relative proportion of fast twitch fibers within a person's muscle may affect their potential for increasing size. Therefore people with a limited number of type II fibers may obtain reduced benefits from resistance training. This implicates genetics as a major contributing factor in muscle mass response to weight training, and may indicate that an individual's ability to respond to a particular training stimuli is also probably genetically determined irrespective of fibre type. Fleck and Kraemer (1987, p.152) concur with these assertions but allude to the possibility of selective hypertrophy of either Type I or Type II fibers based on the specificity of training.

MacDougall (1986) cites studies by Thorstensson (1976) and MacDougall et al. (1980) confirming increases in cross-sectional area of both fibre types in response to heavy resistance training but once again stressing the greater degree of hypertrophy of Type II fibers. According to Hedrick (1995) electron microscopic studies of muscle fibers exhibiting hypertrophy in response to heavy resistance training reveal that the overall increases in muscle cross-sectional area, and fibre area in particular, are a direct result of both a proliferation of myofibrils and an increase in their size. New myofilaments are added to the external layers of the myofibril resulting in their increased diameter. These adaptations appear to be cumulative and thus result in continual hypertrophy in response to progressive resistance overload. Jones and Round (1990) suggest that extreme muscle

overload (as can occur during heavy resistance training) has been shown to cause structural damage to the sarcomeres of myofibrils thereby providing a stimulus for repair and compensatory hypertrophy (p. 112).

The process which is said to account for such morphological adaptations involves the longitudinal splitting of individual myofibrils at their Z discs into two or more daughter myofibrils. This myofibrillar proliferation leads to subdivision of the fibre mass to such an extent that the sarcoplasmic reticulum and transverse tubular systems can invade the mass and gain access to the actin and myosin filaments. This results in a substantial increase in the myofibrillar content of the fibers and a resultant increase in their cross sectional area (Goldspink, 1992, p.215).

2.4.2. Hyperplasia

There is a great deal of controversy concerning the extent to which hyperplasia brought about in response to heavy resistance training contributes to increases in muscle mass in human subjects. Most research into hyperplasia involves non-human studies which allow the use of extremely invasive techniques to trigger muscle adaptation including such modalities as intermittent electrical stimulation, chronic stretching by immobilization or surgical intervention, ablation of synergist muscle and chronic muscular overloading (Lieber, 1992, p. 159-209).

According to a recent review by Antonio & Gonyea (1993) these techniques have been used to study skeletal muscle enlargement in adult animals to ascertain whether adaptation is primarily due to changes in fibre cross-sectional area (hypertrophy) or if other structural modifications i.e. increases in fibre number (hyperplasia) play a significant role.

Although animal studies provide reasonable proof of the occurrence of training induced hyperplasia, the invasive techniques used are inappropriate for the study of human subjects and consequently there is little evidence of this adaptation occurring in humans. Much of the support for hyperplasia in humans comes from studies of elite weight lifters and bodybuilders. Studies by MacDougall, Sale, Elder & Sutton (1982) and Tesch and Larsons (1982) found that despite having greater overall muscle mass, bodybuilders did not have relatively enlarged muscle fibre cross-sectional area. In

subsequent research Tesch (1988) found that fibre size in the deltoid and vastus lateralis muscles of elite bodybuilders were no larger than those of non-athletes and were smaller than those of weightlifters despite their greater mass. This led to speculation that hyperplasia and hypertrophy combined to produce increased cross-sectional area. Because there is evidence from postmortem examinations that significant individual variations in the number of muscle fibers exist within humans it may well be that in many strength athletes genetics have made them what they are and that they already possessed more fibers than normal (Hedrick, 1995).

Antonio and Gonyea (1993) asserted that the difficulties in determining the presence of hypertrophy and/or hyperplasia in humans are mainly technical and ethical. It is unacceptable in human studies to remove whole muscles from living subjects in order to carry out direct fibre counts. The most widely used technique to determine changes in the size and structure of humans is muscle biopsy, and these only give a small sample of the total muscle mass.

2.5. Training Specificity.

The concept of specificity relates to the fact that the most noticeable improvements in performance actually occur in response to training which closely mimics the skills required to participate in any selected activity (Bloomfield et al., 1994, p. 127.; Jones, Rutherford & Parker, 1989; Sale & MacDougall, 1981)

The principle of specificity of training can be analysed in terms of:-

- 1) The major muscle groups utilised.
- 2) The type of muscle contraction utilised i.e. Isometric, Dynamic (Concentric and/or Eccentric) or Isokinetic.
- 3) The required speed of execution.
- 4) Movement patterns required during performance.

2.5.1. Muscle Group Utilization.

At a basic level muscle group specificity simply means that training programs must include exercises which target the major muscles and/or muscle groups that are recruited during the performance of the activity for which training is being undertaken (Fleck & Kraemer, 1987, p. 8). If a muscle group is subjected to endurance exercise certain

metabolic adaptations occur in response to this specific type of overload. The major muscular adaptations cited in current research are increases in capillary density, mitochondrial volume density (size & number), myoglobin content and oxidative enzyme activity (Chromiak & Mulvaney 1990; Miller 1992; Sale, MacDougall, Jacobs & Garner, 1990b).

Since endurance activities predominantly stress the slow twitch (ST) muscle fibres, the majority of changes occur in this area, but there can also be an overall shift in the oxidative characteristics of the whole fibre spectrum from fast twitch type 'b' fibres (FTb) through fast twitch type 'a' fibres (Fta) towards ST fibres (Abernethy, Jurimae, Logan, Taylor & Thayer, 1994).

It should be noted that although strength training has little or no effect on max VO_2 , it has been shown to actually cause decreases in mitochondrial volume density, capillary density and oxidative enzyme activity resulting in an overall reduction in muscular endurance capabilities. Any apparent reduction in max VO_2 is normally only a relative decrease due to increased body mass resulting from hypertrophy being used in the calculation.

2.5.2. Muscle Contraction Modes.

Muscular actions can be classified as either static, that is where no movement occurs at the related joint, or dynamic where joint angle is either increased or decreased (Knuttgen & Komi, 1992, p. 4). Static and dynamic muscle actions are notably different physiological and mechanical phenomena, especially in terms of the neural patterning that occurs during their execution. Highly efficient motor unit recruitment speeds achieved during static muscle actions may not be transferable to dynamic contraction modes (Baker, 1995).

All training is aimed at achieving improvements in functional performance and emphasising muscle actions during training that are identical or relatively similar to those required during competitive performance will facilitate appropriate neural adaptation (Sale & MacDougall, 1981). In order to make accurate comparisons of the effectiveness of different training modes on strength and endurance parameters, test protocols should attempt to mimic training activities (Sale, 1992a).

There are few absolute standards available for the assessment of strength, and therefore during the course of various research studies a wide variety of procedures have been employed, thus making direct comparison very difficult. In their review of the

specificity and effectiveness of the various resistance training modes Morrissey, Harman & Johnson (1995) noted that when comparing static (isometric) versus dynamic concentric training the evidence suggested that research supports the notion of exercise type specificity when similar training and testing modes are used, but that concentric training may be superior to static training for enhancing functional performance. A possible exception to the established norm occurs in circumstances where so called 'sticking points' are encountered at certain angles during a particular movement e.g. the bicep curl, and the inclusion of isometric training at the particular angle in question can produce better results than traditional dynamic training. This type of training is called Functional Isometrics and Wilson (1995a) cites a study by O'Shea et al. (1989) which reported that this type of training resulted in a 16% greater increase in strength than conventional resistance training.

One of the most common comparisons made in research literature focuses on the results achieved during isometric exercise versus conventional weight training i.e. alternating concentric and eccentric movements. Evidence is conflicting and makes it impossible to make a definitive statement at this time, but the weight of argument supports exercise-mode specificity (Wilson, 1995a). When study is restricted to the comparison of concentric versus eccentric training there appears to be a much clearer consensus supporting specificity of training (Morrissey et al., 1995). Sale and MacDougall (1981) suggest that when overall strength is a prerequisite for superior performance, some additional advantage may be gained by supplementary eccentric training even if the activity in question involves predominantly concentric muscle contractions. They hypothesized that the greater tension capabilities apparent during eccentric movements may stimulate additional muscle hypertrophy.

2.5.3. Velocity Specificity.

According to Sale (1992a) research has suggested that velocity specificity may be the result of a combination of muscular and neural adaptations, which facilitates an increased rate of force development resulting from a high initial motor neuron firing rate, selective activation of fast twitch motor units within muscles during high velocity contractions and selective activation of fast muscles within a synergistic group.

Jones & Round (1990), suggest that the speed at which a muscle can contract is dependant on the proportions of the different fibre types it contains, and the contraction velocity of the individual fibre types is determined by enzymatic reactions affecting the

actomyosin cross-bridge activity rates. The genetic information required to produce the different myosin isoforms and other proteins which differentiate the various fibre type characteristics are present in all fibres, and it should therefore be theoretically possible for slow to fast and fast to slow twitch conversion to occur in response to appropriate training stimuli, but to date there has been no definitive proof of this phenomenon occurring in humans (p. 100).

The power output potential of human muscle is determined by its overall size and strength and its velocity of shortening. Within the limits of its potential, a muscle has an inherent capacity to adjust the amount of tension it produces to exactly match the force it is required to overcome in order to contract. If the resistance is too great the muscle will generate its maximal force isometrically. When faced with light loads, the muscle modifies its force production by increasing the speed of contraction, but above a certain velocity known as V_{max} , the muscle ceases to be able to generate force (Edman, 1992, p. 105).

2.5.4. Movement Pattern Specificity.

Movement pattern specificity is best established by selecting training exercises which closely resemble those necessary to execute the required skill in terms of the muscles, joints, velocity, direction and range of motion utilized (Harman, 1994, p. 44). The closer the movement pattern mimics the actual performance the greater the benefit that will accrue to the athlete (Wilmore & Costill, 1994, p. 84). Bell & Jacobs (1992) cite research by Hakkinen & Komi (1986) and Thorstensson et al. (1976) indicating that strength gains are very movement pattern specific.

Jones, Rutherford & Parker (1989) quote early research by Rasch & Morehouse (1957) which assessed subjects elbow flexor strength in the standing and supine positions and then required them to train the elbow flexors in the standing position only. The subsequent retests showed that the subjects' strength had only improved in the position in which they trained ie. standing. The apparent lack of transfer of training between the movement patterns used in the aforementioned study points to skill acquisition playing an important role in training induced strength gains (Jones et al., 1989) and that significant as it may appear in relation to single joint muscle actions, its ramifications become significantly more pertinent to more complex movement patterns (Sale & MacDougall, 1981). Sale (1988) suggests that in multifunctional muscles the recruitment order of some motor units is task dependent, and that preferential recruitment of certain motor

units within both the prime mover and it's synergists may take place to achieve a specific task. This may well be the basis for the specificity of movement pattern associated with strength training.

In their review of movement pattern training specificity Sale & MacDougall (1981) refer to the (1976) study by Thorstensson et al. in which subjects took part in an 8 week barbell squat training program. Pre and post-tests of 1 RM squat performance showed significant increases in the amount of weight lifted, but comparison of the subject's isometric leg press evaluations, which theoretically targeted the same muscle groups, revealed a much smaller improvement.

2.6. Gender Specific Variations in Adaptation to Strength and Endurance Training.

Although a majority of the research studies which focus on strength development use non-humans or males as their primary subjects there has been sufficient research in the areas of strength differences, trainability and adaptations to strength training to be able to draw some conclusions about the results which can be expected to occur when women engage in strength training.

2.6.1. Strength Differences Between Males and Females.

The obvious anatomical, and less obvious physiological differences between the sexes favour males in all activities that rely on size and strength capabilities (Bloomfield, Fricker, & Fitch, 1995, p. 528). These differences between males and females should be considered under three main headings i.e. (1) Absolute strength, (2) Strength in relation to body size and composition and (3) Strength in relation to muscle size (Fox et al., 1989, p. 389).

2.6.1.1. Absolute Strength.

Fleck & Kraemer (1987) cite statistics by Lambach (1976) indicating that women's mean total absolute strength is only 63.5% of their male counterparts, and that there is a great deal of variation between muscle groups (p. 189). The difference is greatest in the upper body where men appear to be 50% stronger than women (Powers & Howley, 1997, p. 400). These observations are supported by Fox et al. (1989, p. 390), Holloway (1994, p. 152) and Fleck & Kraemer (1987, p. 189).

2.6.1.2. Strength Relative to Body Composition.

When strength differences are calculated using lean body mass as opposed to total body weight the gap between men and women narrows considerably, and leg and hip strength has been shown on occasions to be even greater in women (Brown & Wilmore, 1974).

2.6.1.3. Strength in Relation to Muscle Size.

Research to date suggests that when the force production capabilities of each sex are compared on the basis of muscle cross-sectional area, the apparent male superiority is all but eliminated. According to Fox et al. (1989, p. 391) this fact was clearly shown in the study undertaken by Ikai & Fukunago (1970) which compared the strength and cross-sectional area of male and female elbow flexors and concluded on the basis of their findings that the force exerted by equal sized muscles is the same for both sexes, and that the quality of the muscle fibres, in terms of their force production capabilities are concerned, is independent of sex.

2.6.2. Trainability of Females.

A majority of the early research into the physical capabilities of women involved the use of totally untrained subjects, and because of their poor exercise tolerance it was assumed that females could not train hard enough to benefit from resistance training (Bloomfield et al., 1995, p. 529). Subsequent research by O'Shea & Wegner (1981) cited by Wells (1991)) shows women to have the same ability as men to tolerate and adapt to the demanding physical stresses associated with training for, and competing in, powerlifting (p. 242). In fact in the 1985 USA Women's Powerlifting Championships a contestant weighing only 82.5kg Squatted 242.5kg, Deadlifted 250kg and Bench-pressed 122.5kg (Fleck & Kraemer, 1987, p. 192).

The trainability of women is also supported by Fox et al. (1989, p. 393), Fleck & Kraemer (1987, p. 192) and Powers & Howley (1997, p. 400) who all cite Wilmore (1974) who compared the strength of a group of untrained men and women before and after 10 weeks of isotonic weight training and concluded that little or no differences existed between the sexes in the percent of strength gained as a result of the specified training.

Bloomfield et al. (1995, p. 529) concluded from their review of current literature that there is less difference in the physiological capabilities of trained women versus trained men, than between the average male and female, and that this is possibly due to the lower exercise participation rates amongst women in general.

2.6.3. Adaptations to Strength Training.

There has always been a reluctance amongst women to pursue intensive resistance training programs due to the misconception that they would hypertrophy to the same degree as men, and as a result lose their femininity due to the development of unsightly muscle bulk (Baechle, 1984). This myth has now largely been dispelled by the weight of subsequent research which has indicated that despite significant increases in strength over pre-training values there has been little or no increase in the circumference of the targeted muscle groups during the early stages of training (Fleck & Kraemer, 1987, p. 193). Any increase in muscle mass is usually balanced out by a concomitant reduction in adipose tissue thus yielding little or no change in circumference (Hunter, 1985).

The significant initial increases in women's strength, especially in the arms, are normally attributed to the fact that the average female starts training at a lower level of fitness, and is therefore not as close to her genetic potential as her male counterpart may be (Fleck & Kraemer, 1987, p. 192; Powers & Howley, 1997, p. 394).

Females who participate in heavy resistance training programs will not exhibit the same visible degree of muscle hypertrophy as their male counterparts (Bell & Jacobs, 1990), but when muscle hypertrophy is assessed by a more direct method, such as computed axial tomography or muscle biopsy the increase in the size of the individual muscle fibres can be clearly seen (Staron; Karapondo; Kraemer; Fry; Gordon; Falkel; Hagerman & Hikida, 1994). These researchers further concluded from their study, which involved male and female subjects in an eight week progressive resistance training program, that there is a slow but definite size increase in all three fibre types in both sexes but a more rapid fibre type conversion IIb to IIa was shown to occur in women.

2.7. Effects of Concurrent Strength and Endurance Training.

Many sports require participants to utilize a combination of several muscular attributes e.g. strength, power and endurance in order to perform the different skills involved during participation in a particular event, and due to tight training schedules there is often the need to devise a training program that will address multiple attributes simultaneously. It is therefore important to understand the effects of combined training on the development of each individual muscular attribute (Chromiak & Mulvaney, 1990).

The search to establish optimal training regimes for strength and muscular endurance has been going on for decades, and ever since the early pioneering work of DeLorme (1945) most researches have based their studies around the concept of training specificity he advocated as a result of his research into the restoration of strength in injured war veterans. DeLorme's so called Strength/Endurance Continuum Theory suggested that strength and endurance exercises were at the opposite ends of a training continuum and that the volume and intensity combinations required to produce gains in strength and power were diametrically opposed to those necessary to bring about improvement in muscular endurance capacity. This concept is still supported by many authors and researchers (Anderson & Kearney, 1982; Baechle, 1984; McArdle, Katch, & Katch, 1996; Stone & Coulter, 1994).

Adaptations caused by strength training are in some respects diametrically opposed to those required to improve endurance capabilities. Strength requires adaptation of contractile tissue, whilst it is metabolic adaptations that contribute to enhanced endurance capabilities, and both processes are induced by distinctly different genes (Goldspink, 1992, p. 211).

According to Sale et al. (1990b) "Whether the interaction between concurrent strength and endurance training results in antagonism or addition of training response probably depends on several factors including the initial state of training of the trainees; the intensity, volume and frequency of training; and the way the two forms of training are integrated."

Several researchers have investigated the effects of concurrent strength and cardiorespiratory endurance training on strength and endurance adaptations, and the majority of these studies concluded that strength gains were compromised to some degree by concurrent training (Hickson, 1980; Dudley & Djamil, 1987; Sale et al., 1990a; Sale et

al., 1990b; Bell et al., 1991; Abernethy, 1993; Abernethy & Quigley, 1993; Collins & Snow, 1993; Hennessy & Watson, 1994).

Despite all these studies there is still very little definitive proof of the positive and/or negative effects of concurrent training for strength and endurance, and even less about the possible variability from one muscle group to another, as most research to date has focused on adaptations in the quadriceps femoris muscle group (Abernethy & Quigley, 1993). There is also a marked lack of evidence concerning possible gender specific variations as male subjects have predominated in most studies.

Very little attention has been focused on the effects of high volume muscular endurance training on maximal strength capabilities or on the optimal methods of training novice females during the early stages of weight training programs aimed at rectifying apparent upper body strength deficits. Even though Anderson & Kearney (1982) specifically studied the effect of three different resistance training programs on upper body strength and absolute and relative muscular endurance their conclusions that high resistance-low repetition exercise builds strength, whereas low-resistance high volume training results in increased muscular endurance capabilities, only went part way towards addressing the problem in that, once again, only male subjects were used.

2.8 Summary.

Muscle has been shown to have an innate capacity to adapt to appropriate stimuli, and the extent of adaptation appears to be dependent on the frequency, duration and intensity of overload, and the allowance of optimum periods for rest and recovery. The physiological adaptations expected as a result of various training protocols have been, and indeed are still being, systematically studied world wide, but despite all this research we do not yet fully understand some of the adaptive processes which occur in response to different training regimes. A wealth of data exists which seems to support the concept of training specificity, but it is unclear to what extent the results of these studies have been influenced by shortcomings in their design.

There appears to be very little difference between male and female relative strength levels when the effects of the differences in overall muscle mass are eliminated, and women's relative strength increases in response to resistance training are at least equivalent and in some cases even superior to those of their male counterparts. Women can increase their strength levels with little or no apparent increase in body weight or girths which is probably due to changes in body composition i.e. increase in muscle mass matched by a compensatory decrease in body fat.

Simultaneous training for strength and muscular endurance may inhibit the normal adaptive processes which would accrue if each specific training regime were applied individually, and the extent of the antagonism caused by concurrent training may depend on the volume and intensity of training, the training status of the individual and the sequence of training.

CHAPTER 3.

METHODS:

3.1.SAMPLE.

Participants for the proposed study were drawn from members of the local community as well as interested staff and students from within the various departments of the University. In order to be allowed to participate in this study volunteers were asked to complete a pre-activity questionnaire to ensure that they were healthy females within the age range of 17-45 years who were not currently engaged in regular weight training activities or heavy manual work. In an attempt to maintain three equally balanced groups as recommended by Wilks (1995) the fifteen volunteers were assigned to one of the three training groups [Endurance, Strength or Concurrent] based on their age, body weight and their 1 RM performance during the pretest familiarization session. All participants were carefully briefed on the nature of the study and any risks involved, and were then asked to signed informed consent statements (Appendix A).

3.2 EQUIPMENT.

The following equipment was used for testing and training purposes:-

Anthropometric Measurements. [Body Weight, Girths and Skinfolds] Metler Platform Scale [Model ID1], Lufkin Constant Tension Tape, Lufkin Segmometer, Skin Marker Pen, Harpenden Skinfold Calipers.

Warm Up. Concept II Rowing Ergometer (Concept II Inc., Morrisville, VT), PE4000 Heart Rate Monitor (Polar Inc., Finland).

Training. Preacher Bench Free ,Weight Dumbbell, Spinlock Collars, Weight Discs [30 grams-5 Kgs], Cadence Timer.

Testing. Preacher Bench Free ,Weight Dumbbell, Spinlock Collars, Weight Discs [30 grams-5 Kgs], Preacher Curl Range of Movement Gauge [See Illustration 1](Kash Fabrications), Cybex 6000 isokinetic dynamometer (Lumex Inc., New York).

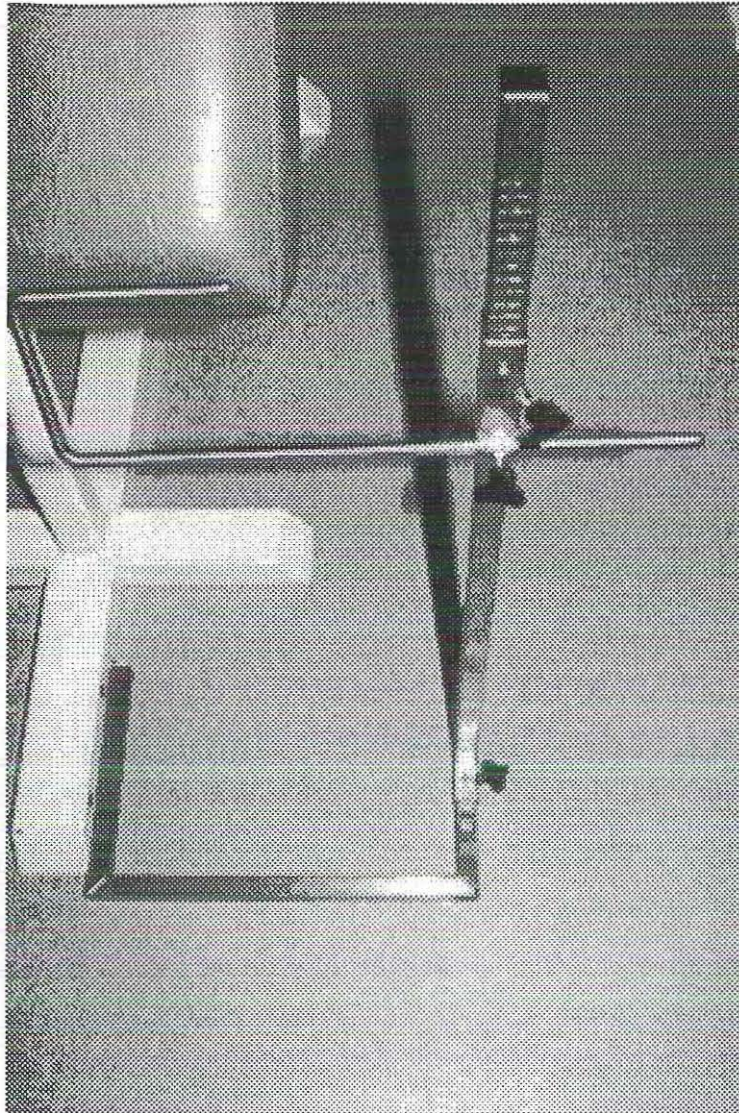


Illustration 1 Preacher Bench Curl Range of Movement Gauge

3.3.SAFETY.

In order to minimise the risk of injury during testing and training, the following routine was completed by all participants prior to every testing and training session. Each participant performed a 5 minute warm-up using a rowing ergometer at an intensity designed to elicit 65% of age predicted maximum heart rate ($220 - \text{age}$). Heart rate responses to exercise were monitored using a PE4000 Heart Rate Monitor, and distance travelled recorded to ensure that workloads remained constant. A series of static stretches of the elbow flexors, elbow extensors, wrist flexors, wrist extensors, shoulder flexors and horizontal adductors (duration 15 seconds each) were then performed. A muscle group specific warm up was then completed consisting of 3 sets of 3 repetitions of Preacher Bench curls performed continuously without rest between sets using progressively increasing submaximal workloads.

3.4. Pretest Familiarization Session.

During the two weeks prior to commencement of the study familiarization sessions were held for all participants. During these sessions they were given the opportunity to experience all aspects of the testing and training protocols, and the preliminary results obtained were used as a basis for group formation, and for estimating both warm-up poundage and 1 RM attempt starting weights.

3.5. Testing.

The first testing session was scheduled for a Monday, and participants were requested to refrain from all upper body exercise or rigorous activity for a period of 48 hours prior to the tests, in order to minimise any residual fatigue that may have resulted from such activity. Although no formal controls were enforced on the participants, they were requested not to radically change their training or eating patterns during the 8 week study period. Anthropometric measurements consisting of each participant's Body Weight, Biceps Girth (Relaxed and Flexed) and Biceps and Triceps Skinfolts were made in accordance with the techniques specified by Norton & Olds (1996, p. 44-55). Measurements were taken whilst the participant's were 'cold' i.e. prior to any warm-up exercise. After a warm-up the three strength assessments were made followed by the muscular endurance assessment. Every attempt was made to consistently assess all participants at the same time of day to minimise any diurnal effects on performance, and the same assessor was used during all testing sessions to avoid the incidence of inter-tester errors.

Measurement of elbow flexor **1 RM strength** of each participant's non-dominant arm was made using a preacher bench with a specifically designed range of movement gauge attached, and a free weight dumb-bell with spinlock collars which was assembled using a range of pre-weighed discs [See illustration 2]. Three to five trials were carried out using progressively heavier 1 RM attempts separated by 1 minute recovery intervals, as recommended by Volpe, Walberg-Rankin, Rodman & Sebolt (1993) & Weir, Wagner

& Housh (1994). Failure to succeed with a particular poundage at two consecutive attempts resulted in the previous highest successful lift being recorded as that participant's 1 RM (Cureton, Collins, Hill & McElhannon Jr., 1988).

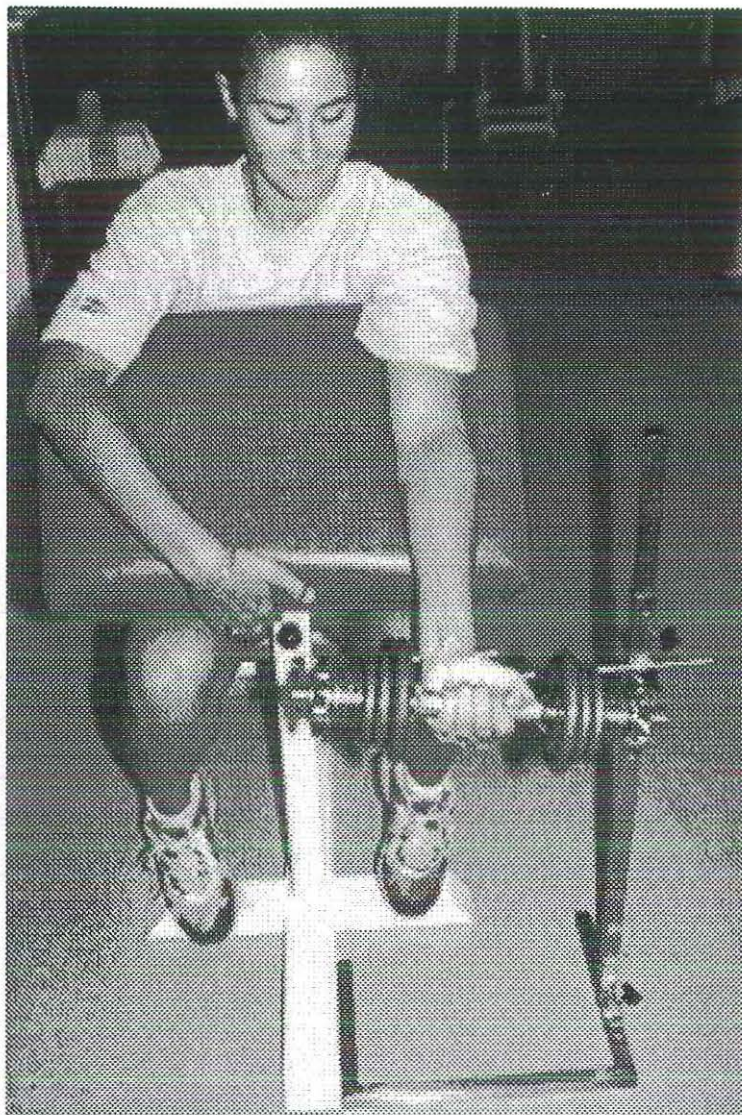


Illustration 2 1 RM Testing Procedure.

Measurements of elbow flexor **isometric strength** of each participant's non-dominant arm were made using a Cybex 6000 isokinetic dynamometer. The participants were firmly restrained by inextensible straps in a sitting position in the preacher bench with the dynamometer axle positioned at the centre of rotation of the elbow. The lever arm was attached to the wrist whilst the arm was held in the saggital plane, with 90 degrees of flexion at the elbow, and the humerus held flexed against the preacher bench [see illustration 3]. The torque measurements produced by the Cybex were digitised using the manufacturer's software, and concurrently recorded on the integral Intel 386 DX

microprocessor. Participants were requested to exert maximal force against the dynamometer arm on 3 occasions, separated by 1 minute recovery periods, and the average of the three peak torque levels achieved was used. Prior to the actual measurements being taken, a single practice trial was given.



Illustration 3 Cybex Isometric and Isokinetic Assessments

Measurement of Elbow Flexor **Dynamic concentric strength** was carried out 60 seconds after the Isometric measurements had been completed. Dynamic concentric strength was assessed using the Cybex Isokinetic Dynamometer at a velocity of 30 degrees per second. Prior to the measurement of torque at 30 degrees per second a practice trial set of three repetitions was performed, and the participants were advised to use progressively increasing sub-maximal efforts during this practice set. This was followed by a series of 3 consecutive maximum efforts with no rest between repetitions. The peak torque measurements produced by the Cybex dynamometer were digitised by the software and concurrently recorded on the integral Intel 386 DX microprocessor.

Measurement of elbow flexor **muscular endurance** of each participant's non-dominant arm was also made using the Cybex Isokinetic Dynamometer in the same position as that used for isometric strength testing. The participants were asked to perform 25 continuous repetitions whilst exerting maximum force, and verbal encouragement and visual feedback were provided to encourage compliance as suggested by Perrin (1993, p. 49). Measurements of peak torque and total work produced during the 25 maximal repetitions were automatically digitised by the software and concurrently recorded on the integral Intel 386 DX microprocessor.

3.6 Reliability.

All equipment was calibrated on a regular basis throughout the duration of the study, and as a majority of the measurement systems are computer software controlled there was a very high degree of reproducibility between participant measurements. Perrin (1993, p: 31) suggests that intertester and intratester reliability can be enhanced by adhering to established protocols, especially with respect to participant set-up and tester training, and therefore in order to ensure maximum possible accuracy both participant and equipment positioning were noted and stored on a specifically designed form during the initial assessment, and then precisely replicated for subsequent tests to maintain measurement accuracy.

3.7 Training.

All training sessions took place in the laboratory, and were fully supervised. Every attempt was made to ensure the standardization of all sessions, and to this end separate trainers were allocated to each group of participants and remained with them throughout the study.

Baechle (1984) suggests training loads of 70-90% of 1 RM for strength and 40-60% of 1 RM for muscular endurance. Participant's starting weights were set at the lower ends of the suggested scales due to their lack of training experience, and to minimise the severity of any acute or delayed onset muscle soreness that may occur.

Strength training [see illustration 4] consisted of 5 sets of 6 repetitions of preacher bench curls, at a cadence of 3 seconds concentric and 5 seconds eccentric per repetition, with a resistance equal to 70 - 75% of each participant's established 1 RM Preacher Bench Curl poundage. Participants were only required to train their non-dominant arm, and were allowed 1 minute rest between sets. Participants performed their training Preacher Bench curls in the same position as that used to establish their 1 RM. Training took place at the same time on 3 days per week with a minimum of 48 and a maximum of 72 hours between training sessions.

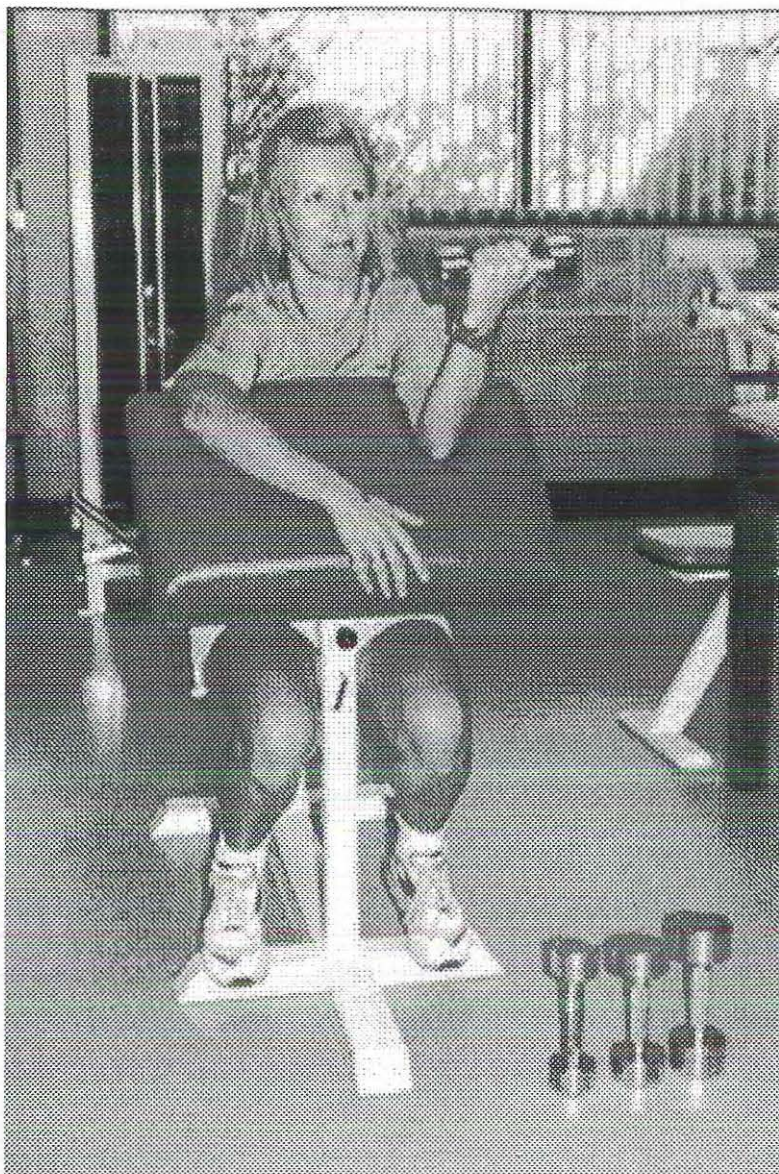


Illustration 4 Protocol Used for all Training

Endurance training consisted of 5 sets of 25 repetitions of preacher bench curls, at a cadence of 1 second concentric and 1 second eccentric per repetition, with a resistance equal to 45 - 50% of each participant's established 1 RM Preacher Bench Curl poundage. Participants only trained their non-dominant arm, and were allowed 60 seconds rest between sets. Participants performed their training Preacher Bench curls in the same position as that used to establish their 1 RM. Training took place at the same time on 3 days per week with a minimum of 48 and a maximum of 72 hours between training sessions.

The **Concurrent Training** Group also trained at the same time on 3 days per week with a minimum of 48 and a maximum of 72 hours between training sessions, but alternated between

strength and endurance training so that in any one week they either performed 2 strength workouts (as above) separated by 1 endurance (as above) or 2 endurance workouts with 1 strength session in between.

3.8 Statistical Analysis.

All data were analyzed using SPSS for WINDOWS software (Release 6.0), and graphical representations were prepared using Microsoft EXCEL (Release 7.0). Mean, standard deviation and standard error of means were calculated for all subject anthropometrical measurements and performance variables. A series of 3(GROUP: Endurance[E]; Strength[S] and Combined[C]) x 3(MEASUREMENT OCCASION: Pre, Mid and Post) ANOVAs with repeated measures on the measurement occasion variable were used to ascertain the overall effects of the three training regimes on the anthropometric measurements and performance variables used during the study, and the significance level was set at $p < .05$. Further analysis of significant effects for measurement occasions were carried out using t-tests of paired samples Pre-Mid; Mid-Post and Pre-Post for all three ([E]; [S]; [C]) Groups. The results of all significant main effects for all analyses are shown in Appendix B.

CHAPTER 4

RESULTS

It was proposed to have 5 members in each study group, and 15 participants were recruited and took part in the pre-test familiarisation program. Unfortunately prior to the commencement of the study 3 participants were forced to withdraw due to sickness reducing the study groups to 4 members each. It was subsequently discovered that one member of the Endurance group was pregnant and for this reason her data was not included in the study.

The results for the remaining participants of all three study groups ['E' Endurance: 'S' Strength: 'C' Combined] collected during the three test and measurement sessions (Pre; Mid; Post) have been presented under two main headings viz:-

- 1) Anthropometric Measurements
- 2) Performance Variables.

Mean, standard deviation and standard error of means were calculated for all anthropometrical and performance data, and all charts are of means and standard error of means. Statistical significance was set at $p < .05$ and full details of the statistically significant effects identified during the ANOVA and 't-tests' are given in Appendix B.

4.1 ANTHROPOMETRIC MEASUREMENTS

Table 1 shows statistical data relevant to all five anthropometrical measurements (Body Weight, Relaxed Upper Arm Girth, Flexed Upper Arm Girth, Biceps and Triceps Skinfolts) for the three measurement occasions. There were no significant differences between groups for 4 of the 5 measurements, but in the case of triceps skinfolts the mean pre-test readings of the E group were significantly higher ($p < .05$) than those of the other two groups.

In terms of statistical significance the only result of note pertained to the pre-post comparison within the E Group in respect of tricep skinfold measurements. Figure 1 shows the percentage change in mean tricep skinfold measurements for each group on all three measurement occasions and the significant pre-post change in the E Group figures can be clearly seen.

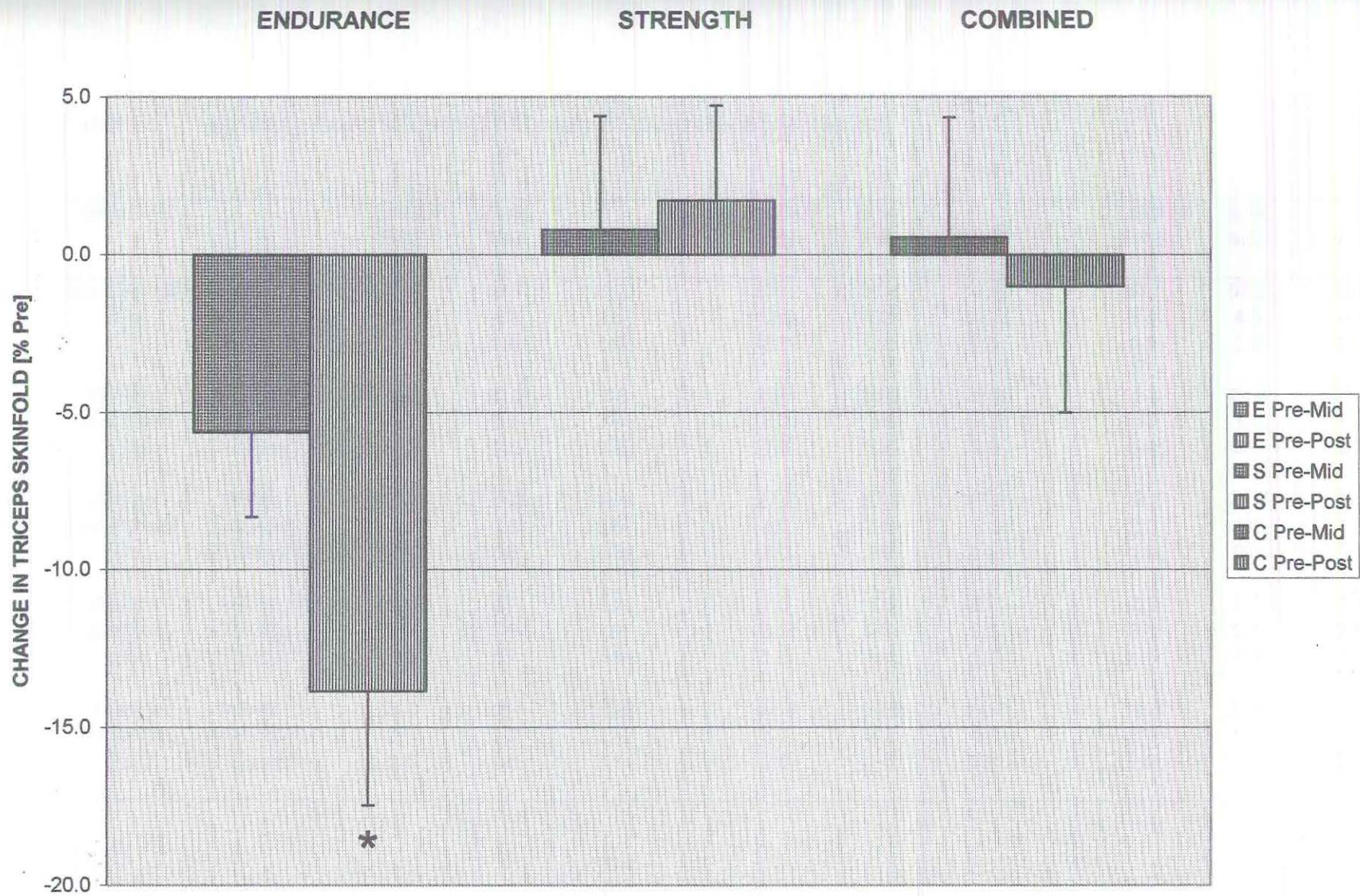


Figure 1. Changes to participant's non-dominant arm triceps skinfold measurements.

Table 1 Anthropometric Data by Group Measurement Occasion.

MEASURE		E GROUP	[N=3]		S GROUP	[N=4]		C GROUP	[N=4]	
		PRE	MID	POST	PRE	MID	POST	PRE	MID	POST
Body Weight [Kg]	MEAN	62.8	62.7	61.2	57.4	57.4	57.3	56.7	57.2	56.9
	STDDEV	5.0	4.9	4.5	12.3	10.6	12.0	5.0	4.5	4.8
	STDerror	2.9	2.8	2.6	6.1	5.3	6.0	2.5	2.2	2.4
Relaxed Arm Girth [cm]	MEAN	29.2	29.2	28.6	25.6	25.9	25.8	27.1	27.3	27.2
	STDDEV	0.6	0.6	0.7	3.7	3.6	3.2	1.7	1.7	1.4
	STDerror	0.4	0.4	0.4	1.9	1.8	1.6	0.9	0.9	0.7
Flexed Arm Girth [cm]	MEAN	29.8	29.8	29.4	27.2	27.4	27.6	28.1	28.2	28.3
	STDDEV	0.3	0.3	0.6	4.0	3.8	3.6	2.0	1.6	1.6
	STDerror	0.2	0.2	0.3	2.0	1.9	1.8	1.0	0.8	0.8
Biceps Skinfold [mm]	MEAN	8.6	8.7	8.2	7.0	6.6	6.7	7.3	7.3	7.6
	STDDEV	3.3	3.6	3.4	3.0	2.7	2.5	3.1	2.6	2.8
	STDerror	1.9	2.1	2.0	1.5	1.4	1.3	1.5	1.3	1.4
Triceps Skinfold [mm]	MEAN	24.0	22.7	20.8	14.4	14.5	14.7	18.6	18.8	18.5
	STDDEV	2.6	3.2	3.7	3.7	3.2	4.0	4.4	5.1	5.0
	STDerror	1.5	1.8	2.1	1.8	1.6	2.0	2.2	2.5	2.5

Table 2 Performance Variable Data by Group Measurement Occasion.

MEASURE		E GROUP [N=3]			S GROUP [N=4]			C GROUP [N=4]		
		PRE	MID	POST	PRE	MID	POST	PRE	MID	POST
1RM										
[Kg]	MEAN	7.7	8.2	8.6	7.0	7.3	7.8	6.8	7.0	7.5
	STDDEV	1.3	1.4	1.2	2.3	2.4	2.2	1.1	0.6	0.6
	STDError	0.8	0.8	0.7	1.1	1.2	1.1	0.6	0.3	0.3
Isometric										
Peak	MEAN	31.0	34.7	34.3	29.3	32.3	34.8	26.3	30.0	31.8
Torque	STDDEV	4.0	4.5	7.1	9.3	9.3	8.8	5.4	3.6	3.0
[Nm]	STDError	2.3	2.6	4.1	4.7	4.6	4.4	2.7	1.8	1.5
30 Degrees										
Peak	MEAN	22.3	24.3	24.0	21.3	23.8	24.8	17.8	21.3	20.8
Torque	STDDEV	6.7	5.5	7.8	8.0	7.0	8.3	1.3	4.3	2.2
[Nm]	STDError	3.8	3.2	4.5	4.0	3.5	4.2	0.6	2.1	1.1
90 Degrees										
Peak	MEAN	16.0	18.7	17.3	17.5	20.0	21.3	14.8	17.0	18.0
Torque	STDDEV	3.5	4.0	4.9	6.6	6.9	6.7	3.3	2.4	3.3
[Nm]	STDError	2.0	2.3	2.8	3.3	3.5	3.4	1.7	1.2	1.6
Total Work										
[J]	MEAN	517.7	576.3	543.0	590.3	613.5	682.8	457.0	539.8	558.3
	STDDEV	82.8	91.0	99.5	230.6	252.2	283.8	89.0	92.8	105.5
	STDError	47.8	52.5	57.5	115.3	126.1	141.9	44.5	46.4	52.8
End Ratio										
[%]	MEAN	73.7	69.3	68.0	76.8	74.8	69.5	79.0	77.0	74.5
	STDDEV	3.2	10.1	3.5	7.2	3.9	7.4	9.9	3.9	4.4
	STDError	1.9	5.8	2.0	3.6	1.9	3.7	5.0	2.0	2.2

Table 3 Percentage differences in Performance Variable Data between Group Measurement Occasions.

MEASURE		E GROUP [N=3]			S GROUP [N=4]			C GROUP [N=4]		
		Pre-Mid	Mid-Post	Pre-Post	Pre-Mid	Mid-Post	Pre-Post	Pre-Mid	Mid-Post	Pre-Post
1RM										
	MEAN	7.0	4.6	11.9	5.1	6.6	12.0	3.1	7.2	10.5
	STDDEV	0.5	10.7	11.5	0.4	4.7	5.2	7.5	2.3	8.3
	STDerror	0.3	6.2	6.7	0.2	2.4	2.6	3.8	1.1	4.2
Isometric										
Peak	MEAN	11.8	-1.6	10.1	10.9	8.8	20.5	16.6	6.1	23.2
Torque	STDDEV	1.0	8.0	8.7	8.4	9.6	12.6	19.9	4.5	16.9
	STDerror	0.6	4.6	5.0	4.2	4.8	6.3	9.9	2.3	8.4
30 Degrees										
Peak	MEAN	10.6	-1.9	7.0	13.8	4.4	17.7	19.2	-2.4	17.0
Torque	STDDEV	13.9	16.6	6.1	12.5	13.2	7.4	18.9	26.7	10.3
	STDerror	8.0	9.6	3.5	6.3	6.6	3.7	9.5	13.3	5.1
90 Degrees										
Peak	MEAN	16.9	-7.4	7.4	15.1	7.7	24.4	17.1	6.2	22.9
Torque	STDDEV	10.8	12.8	7.5	4.0	16.9	23.7	12.8	10.4	6.1
	STDerror	6.3	7.4	4.3	2.0	8.5	11.9	6.4	5.2	3.0
Total Work										
	MEAN	11.4	-6.0	5.0	4.8	12.4	15.5	18.6	3.4	22.4
	STDDEV	5.8	6.2	12.4	15.1	21.5	10.9	8.0	2.2	8.3
	STDerror	3.4	3.6	7.2	7.6	10.7	5.5	4.0	1.1	4.2
End Ratio										
	MEAN	-6.0	-1.0	-7.6	-2.0	-7.1	-9.0	-1.1	-2.7	-4.4
	STDDEV	11.2	10.1	4.9	10.3	7.0	11.7	16.0	7.3	14.1
	STDerror	6.4	5.9	2.8	5.2	3.5	5.9	8.0	3.6	7.0

4.2 PERFORMANCE VARIABLES

Absolute values and percentage changes for all performance variables are presented in Tables 2 & 3 respectively.

4.2.1 1RM DUMBBELL PREACHER BENCH CURLS.

Figure 2a reveals what appears to be a similar pattern of steady increase in strength across all three study groups. When viewed in terms of percentage changes between measurement occasions (fig 2b) the only areas of inter-group commonality are in terms of the pre-post increases achieved by all groups [E = 11.9% ; S = 12.0%; C = 10.5%], but when considered on the basis of statistical significance ($p < .05$) the E Group showed merely a single significant instance viz a pre-mid strength increase of 7%, and only the S Group showed consistency for both measurements ie pre-mid 5.1% increase; and a pre-post 12% increase.

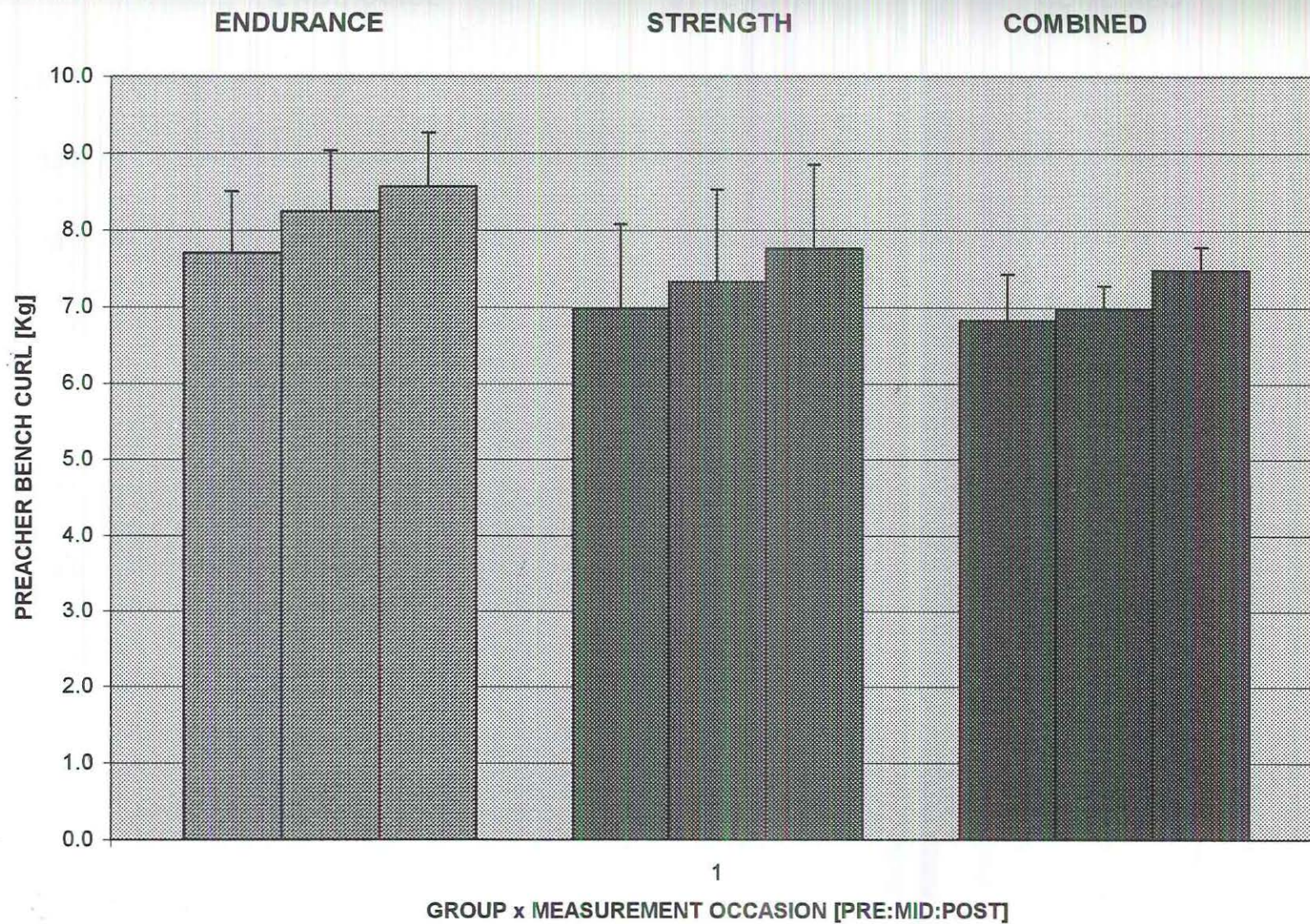


Figure 2a. 1 RM Preacher Bench Curl.

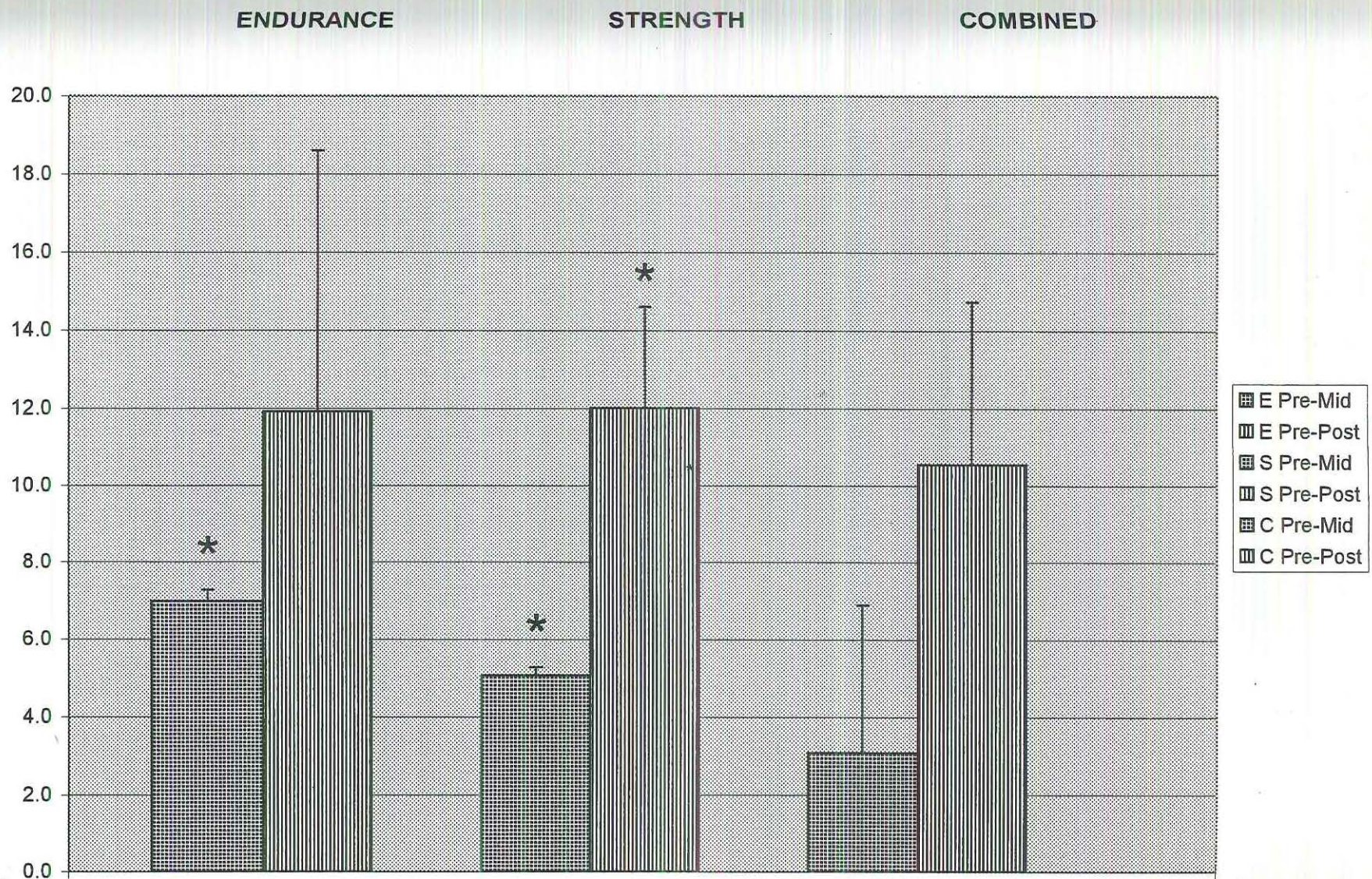


Figure 2b Percentage Variations in 1 RM Preacher Bench Curl.

4.2.2 ISOMETRIC PEAK TORQUE.

The test results for this assessment are shown in figure 3a, and although some evidence of strength increases can be seen in the pre-post gains achieved by all groups, the pattern displayed by the E Group differs from the other two groups in that the rate of increase in peak torque seen during the first four weeks of training [pre-mid] was not sustained during the final four weeks of the study.

The differences between the groups become more obvious when expressed as percentage changes. Figure 3b clearly shows the difference between the pre-mid to pre-post performance trend displayed by the E Group compared to those of the other two groups. Although the strength gains recorded by the S & C groups gave rise to somewhat similar performance patterns the pre-post 23.2% gain shown by the C Group was not quite statistically significant ($p = .059$), whereas the smaller increase [20.5%] of the S Group was significant ($p < .05$). The E Group, despite its apparently poor performance in the pre-post comparison did none the less post the only significant [11.8%] pre-mid strength increase ($p < .05$).

4.2.3 ISOKINETIC PEAK TORQUE @ 30° PER SECOND:

This first isokinetic assessment, like the two previous tests, revealed a similar pattern of pre-post strength increases made by all groups (fig. 4a), but only the S group appears to demonstrate a measure of consistency across all three measurement occasions.

When viewed in terms of percentage changes in peak torque (fig. 4b) the E & C groups showed gains during the pre-mid phase that were not sustained during the latter half (weeks 4-8) of the study. In pure percentage terms the largest gain during weeks 1-4 was made by the C group (19.2%), but this did not prove to be statistically significant. However the 17.7% and 17% increases posted by the S & C groups respectively did fall within the chosen level of significance.

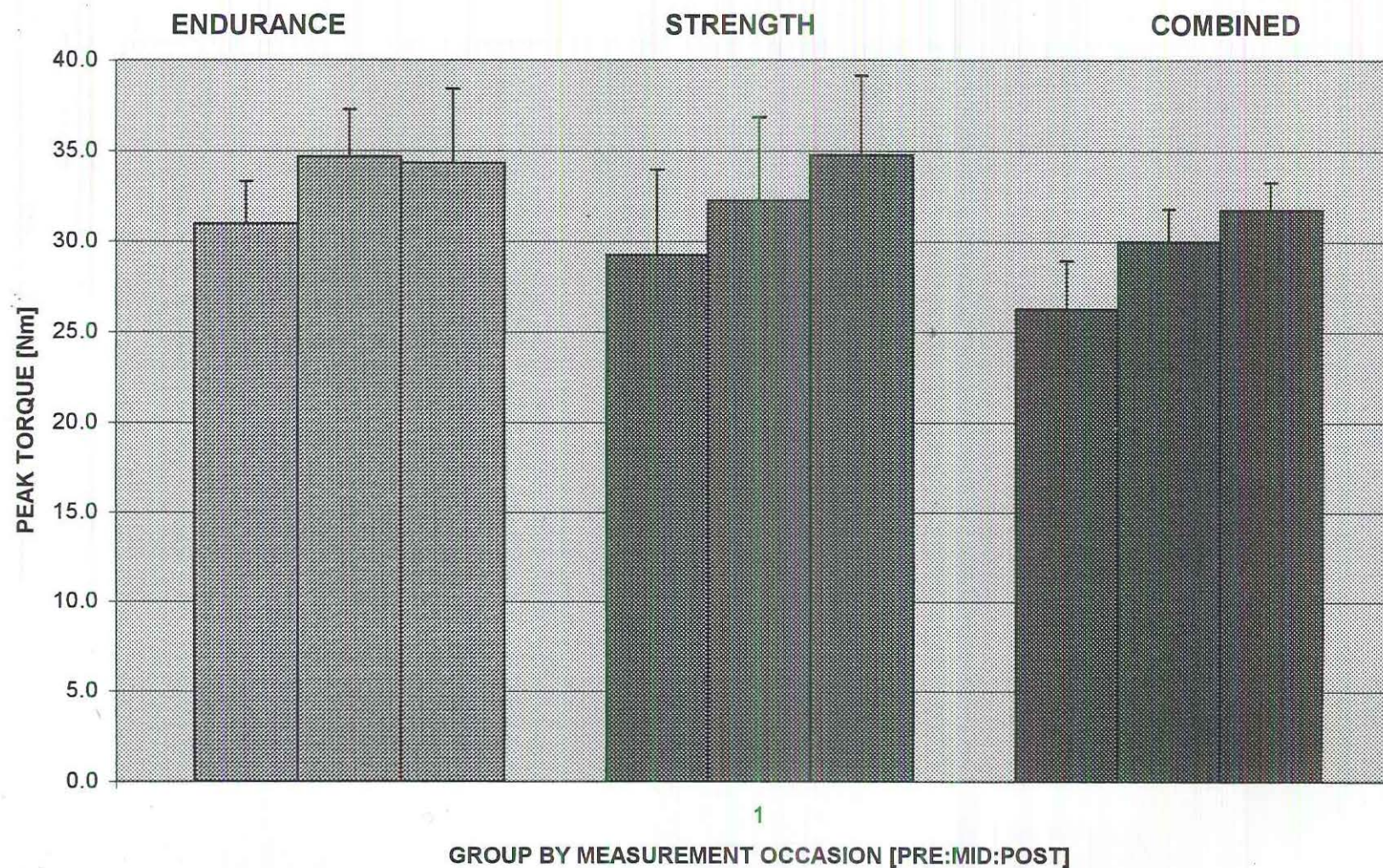


Figure 3a. Non-Dominant Arm Flexor Isometric Peak Torque.

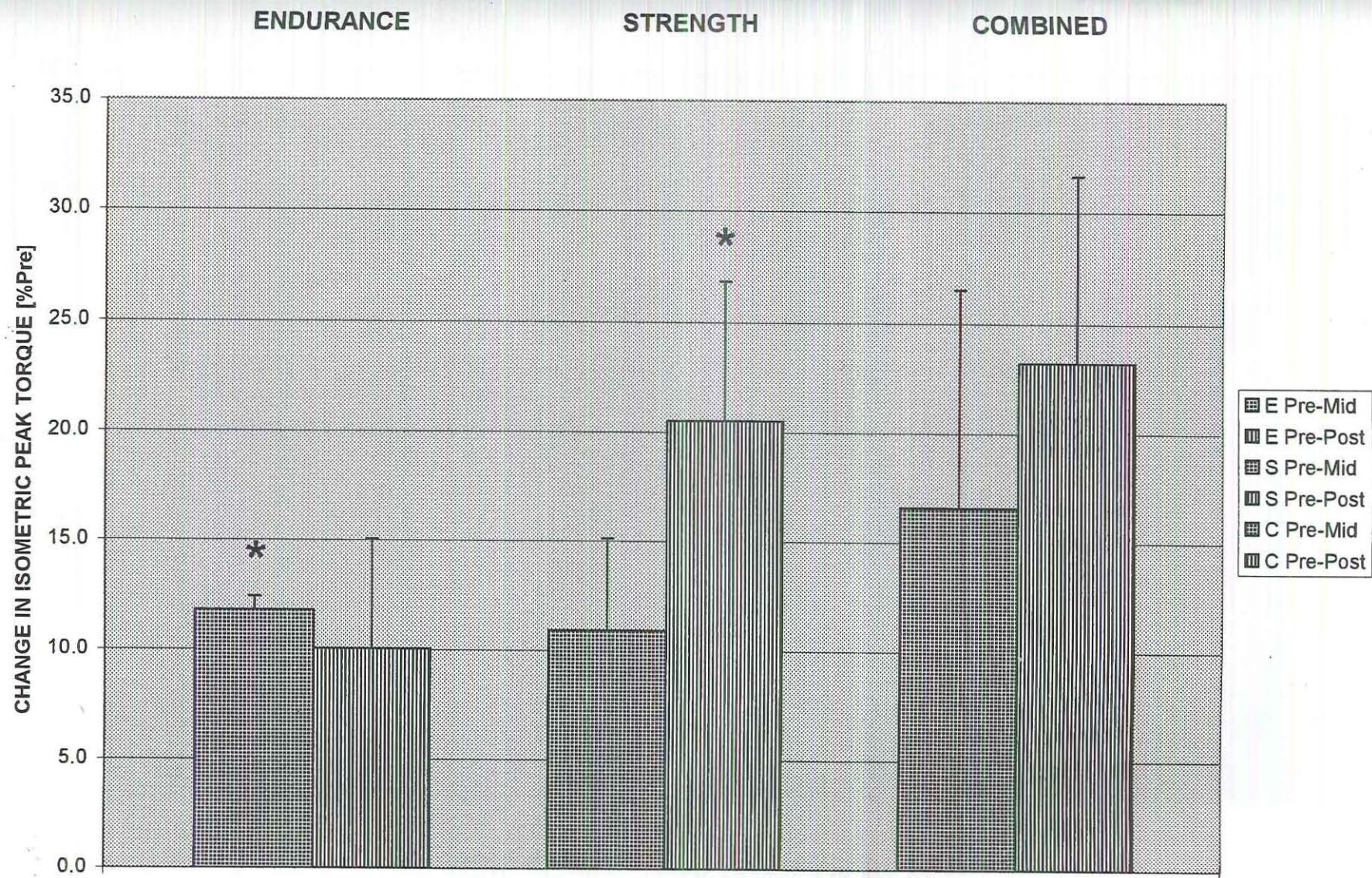


Figure 3b. Percentage Variations in Isometric Peak Torque.

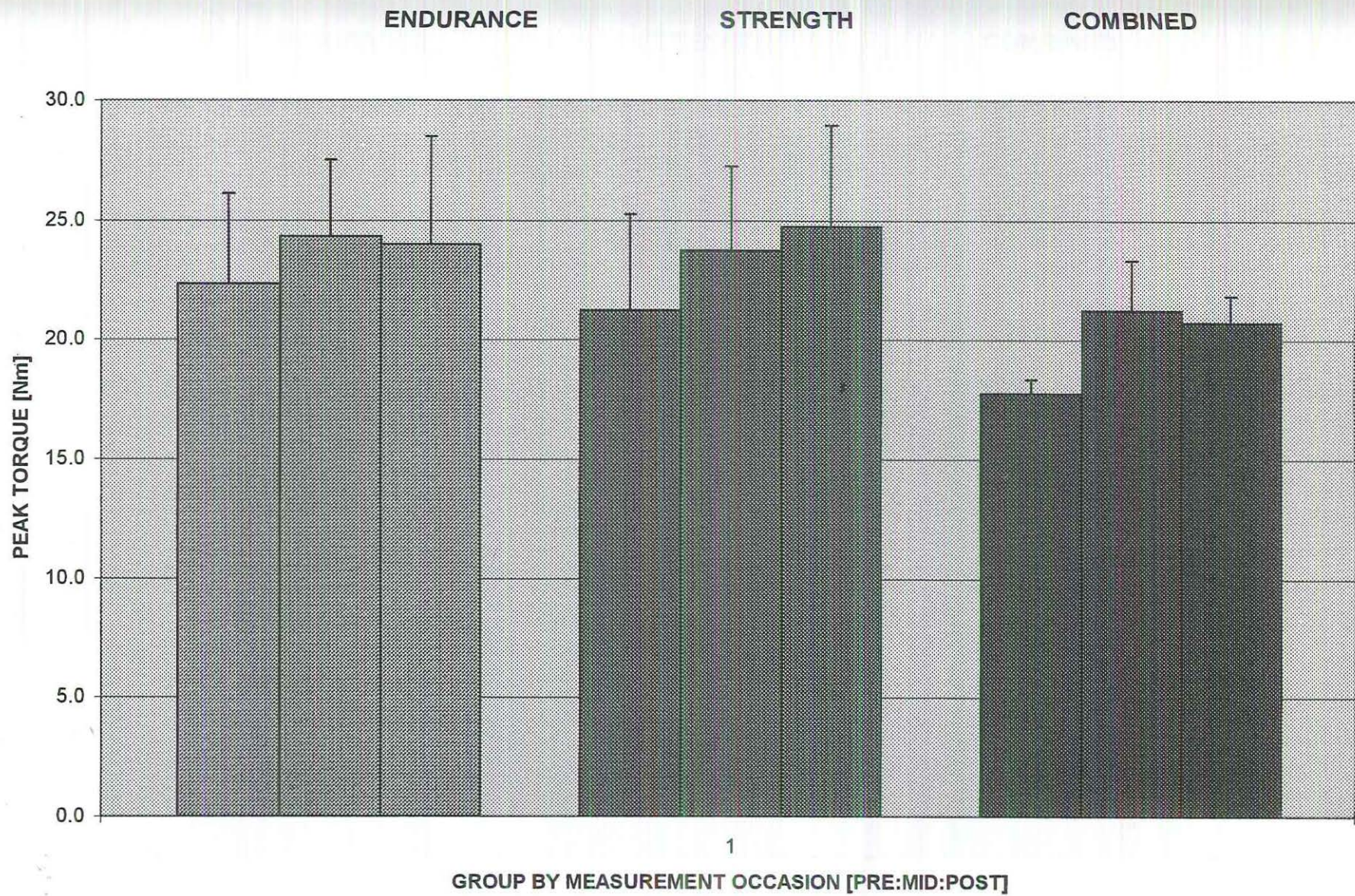


Figure 4a. Non-Dominant Arm Flexor Isokinetic Peak Torque @ 30° per second

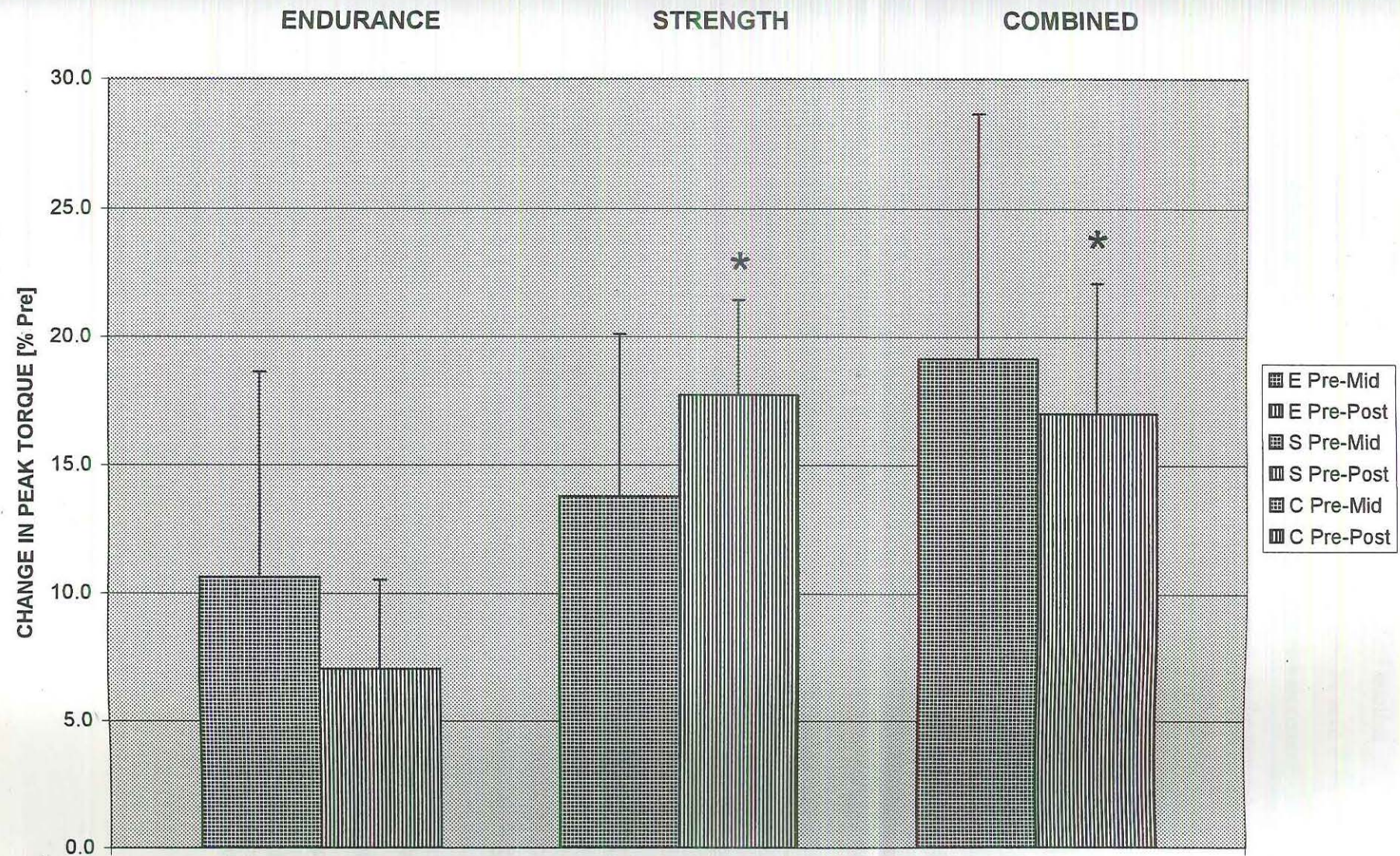


Figure 4b. Percentage Variations in Isokinetic Peak Torque @ 30° per second.

4.2.4 ISOKINETIC PEAK TORQUE @ 90° PER SECOND:

This faster speed of contraction produced another variant in the inter-group pattern of apparent strength increases, and as can be seen from Figure 5a. only the S & C groups demonstrated a consistent step-like increment throughout the range of measurements, with the largest of these occurring in the pre-mid phase.

Figure 5b confirms the aforementioned overall pattern variation between the groups, but also clearly shows some areas of parity in percentage strength gains during the first four weeks (pre-mid phase) of training. When subjected to statistical analysis only two measurements proved to be significant i.e. the S Group pre-mid increase of 15.1% and the C Group pre-post increase of 22.9%.

4.2.5 WORK PRODUCED DURING 25 REPS @ 90° PER SECOND.

Endurance capabilities (as measured by 25 continuous maximal contractions @ 90° per second) produced a different pattern of adaptation for each group (fig 6a). The E & C groups showed an initial increase in performance which was not sustained during the second half of the study, whereas the S Group showed very little early adaptation, but a more noticeable improvement during the last four weeks of training.

Once again comparison of percentage change (fig. 6b) more clearly highlights the differences in endurance adaptation to training during the course of the study. The E Group appeared to show little similarity to the other groups in this first measure of endurance capabilities, in fact, as with the strength assessments, although subjects showed an initial improvement in performance the rate of increase was not sustained during the latter stage of training.

The S Group displayed a small initial increase [4.8%] followed by a substantial improvement during the last four weeks bringing their overall pre-post figure up to 15.5%. By way of contrast the C Group made a large [18.6%] first phase improvement, but did not make a notable increase in the last half of the study finishing with a pre-post change of 22.4%. The C group increases proved to be the only two statistically significant changes ($p < .05$).

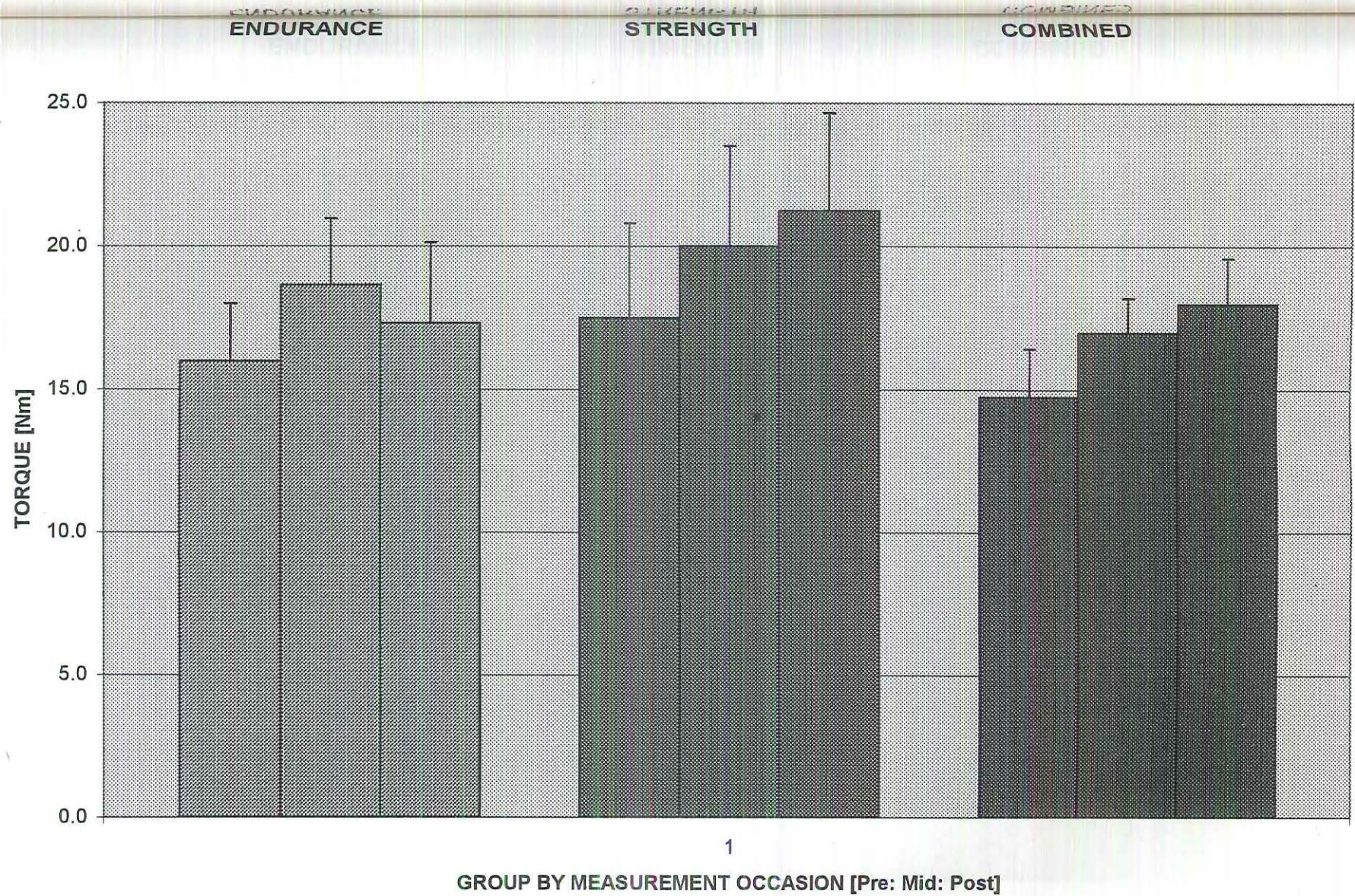


Figure 5a. Non-Dominant Arm Flexor Isokinetic Peak Torque @ 90° per second.

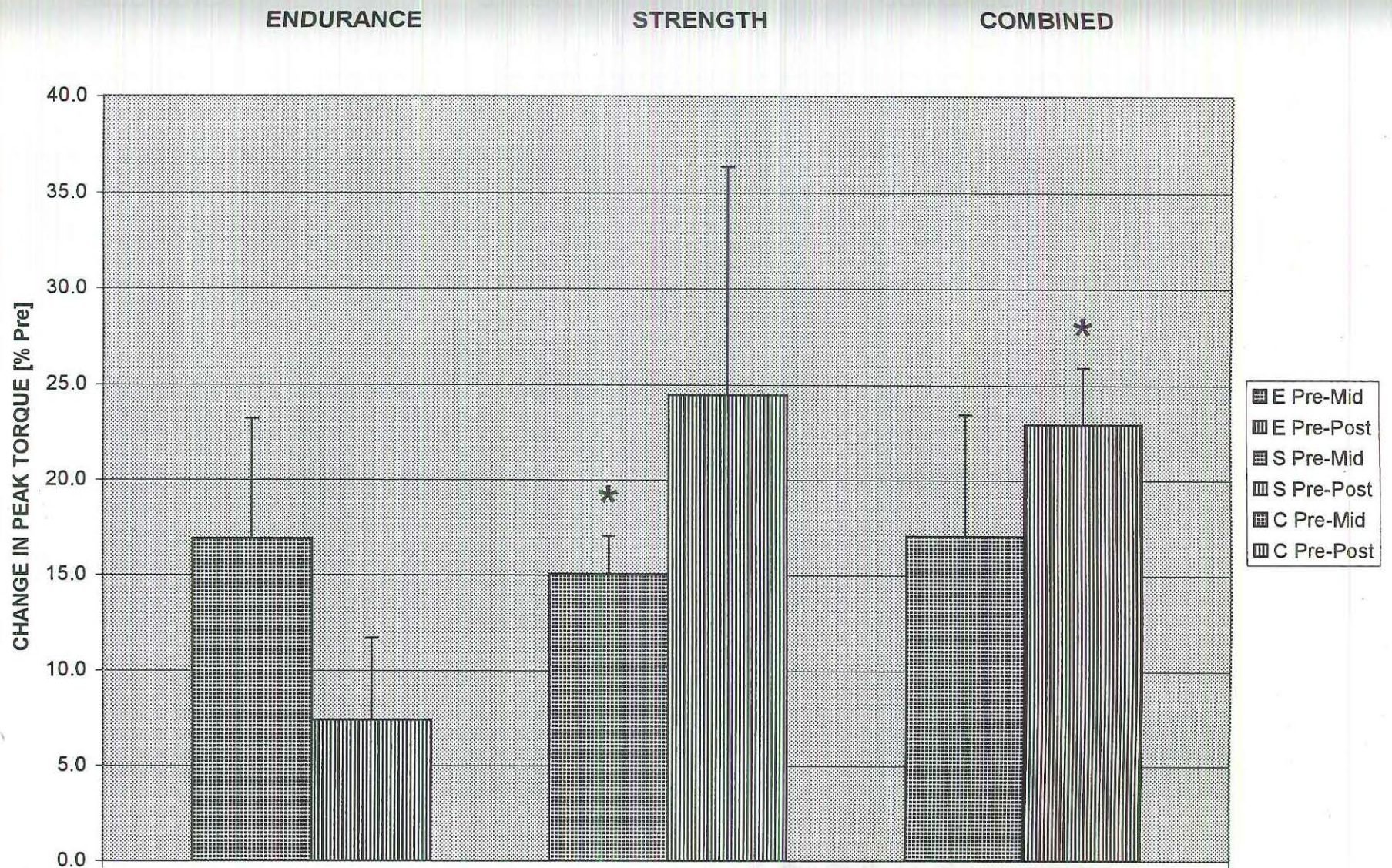


Figure 5b. Percentage Variations in Isokinetic Peak Torque @ 90° per second.

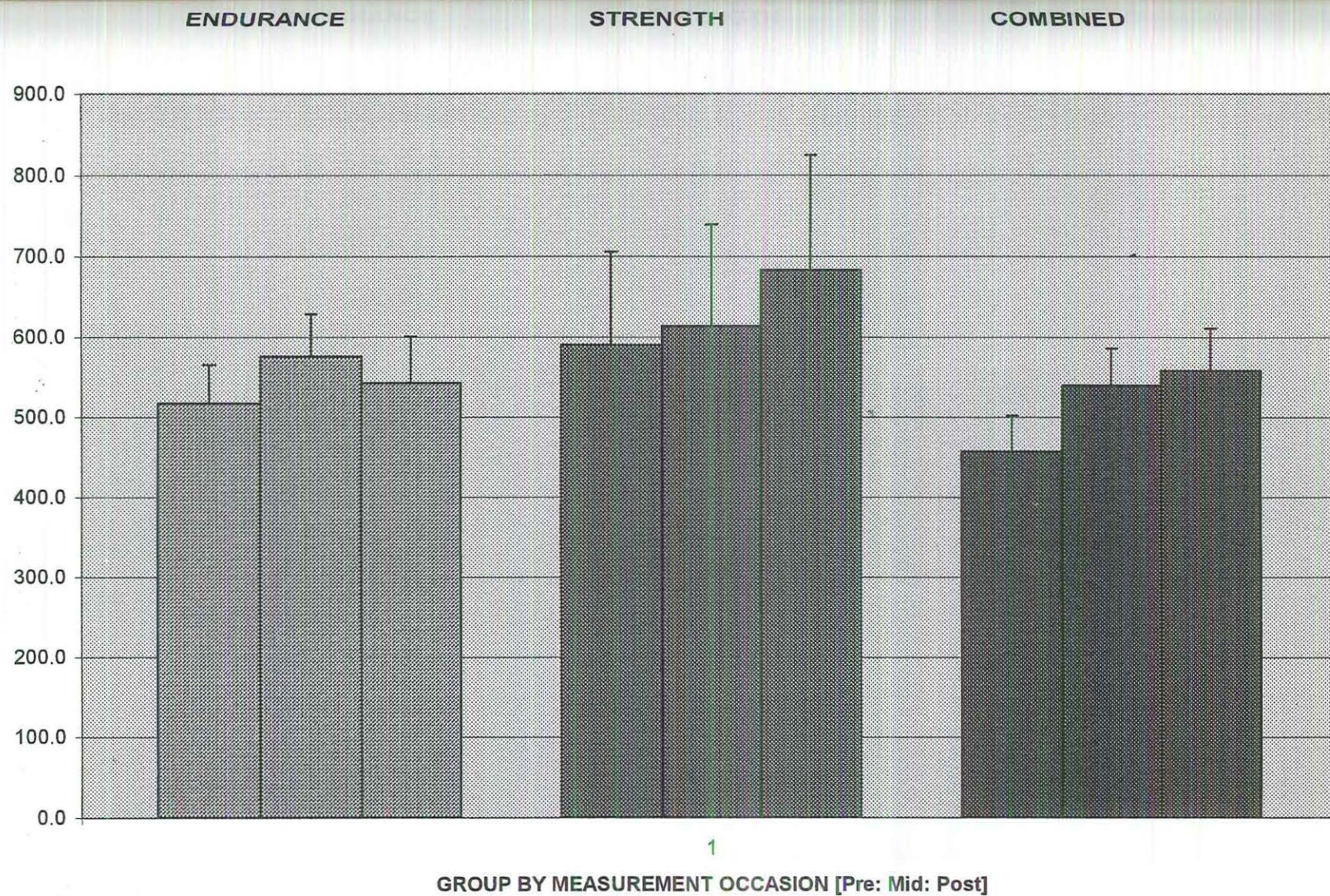


Figure 6a. Total Work Produced During 25 Continuous repetitions @ 90° per second.

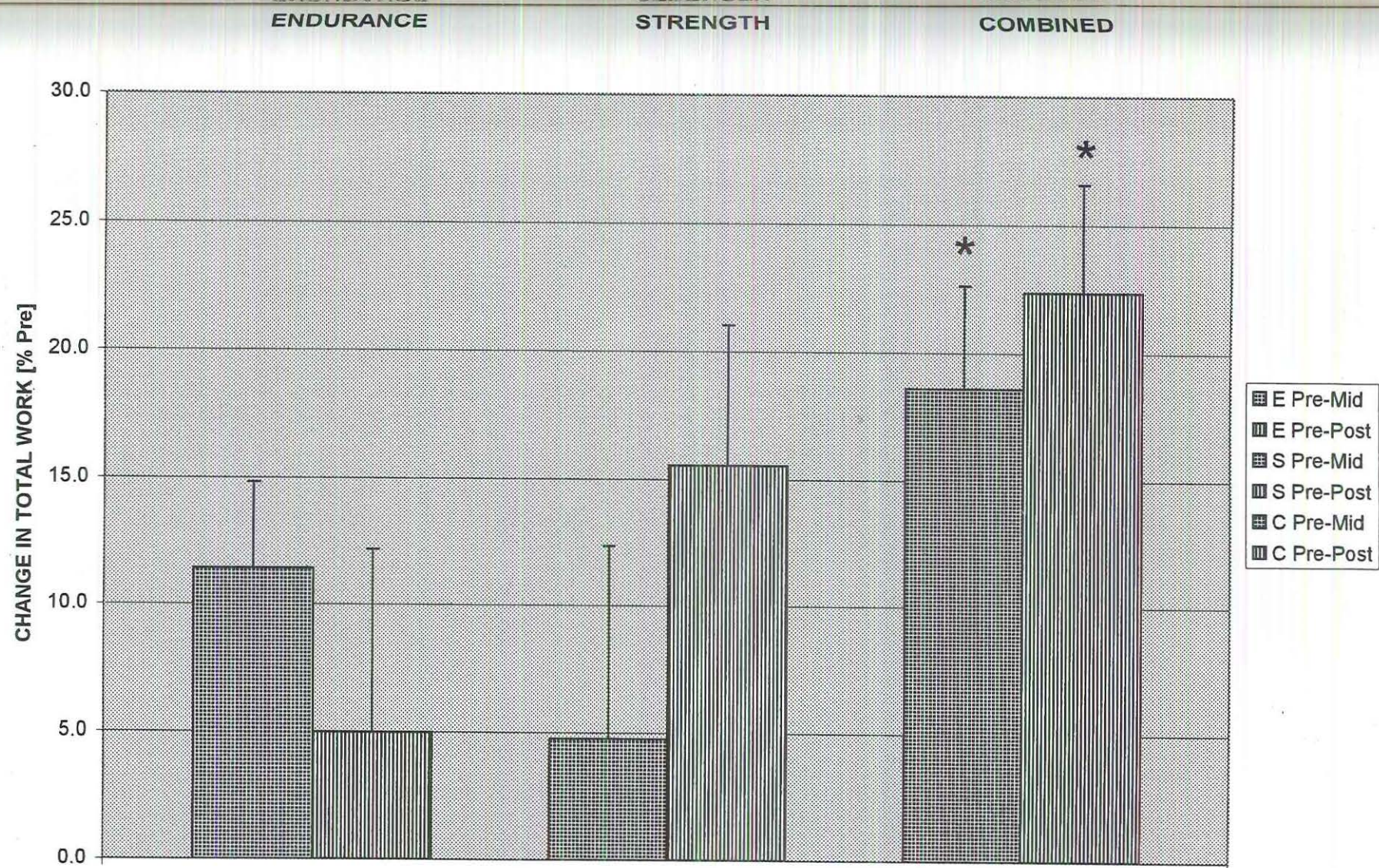


Figure 6b. Percentage Variations in Total Work Produced During 25 Continuous repetitions @ 90° per second

4.2.6 ENDURANCE RATIO BASED ON 25 REPS @ 90° PER SECOND.

A similar pattern emerged across all three groups in respect of changes in endurance ratio [Total work during the last 5 of 25 continuous repetitions / Total work during the first 5 continuous repetitions] and figure 7a shows the decline from pre to post measurements in all cases.

Figure 7b paints a slightly different picture when the changes are viewed in percentage terms, and as can be clearly seen from the magnitude of the standard error bars there was obviously considerable intra-group variability, but no significant trends were observed.

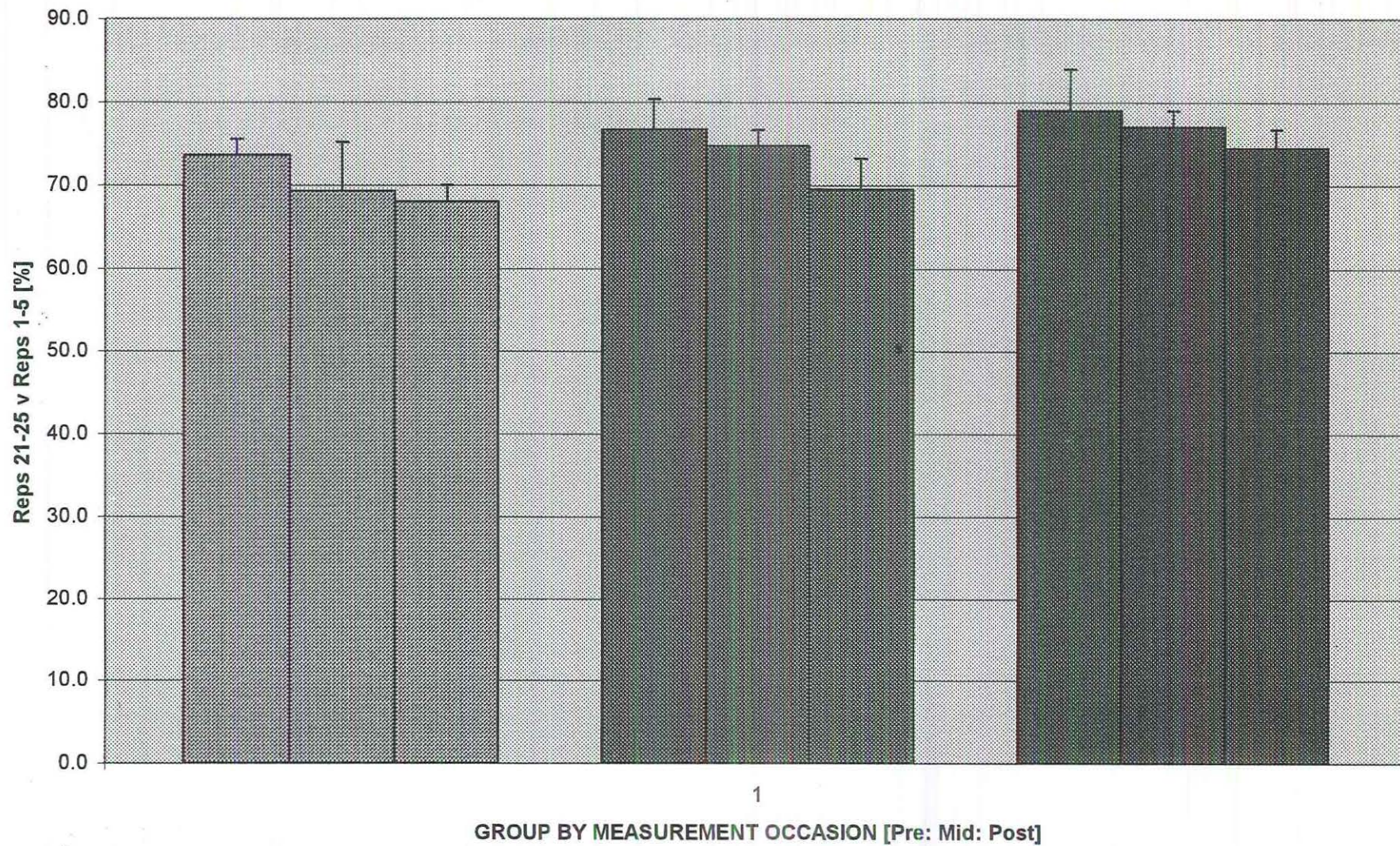


Figure 7a. Ratio of Work Produced during the First 5 and Last 5 of 25 Continuous Repetitions @ 90° per second

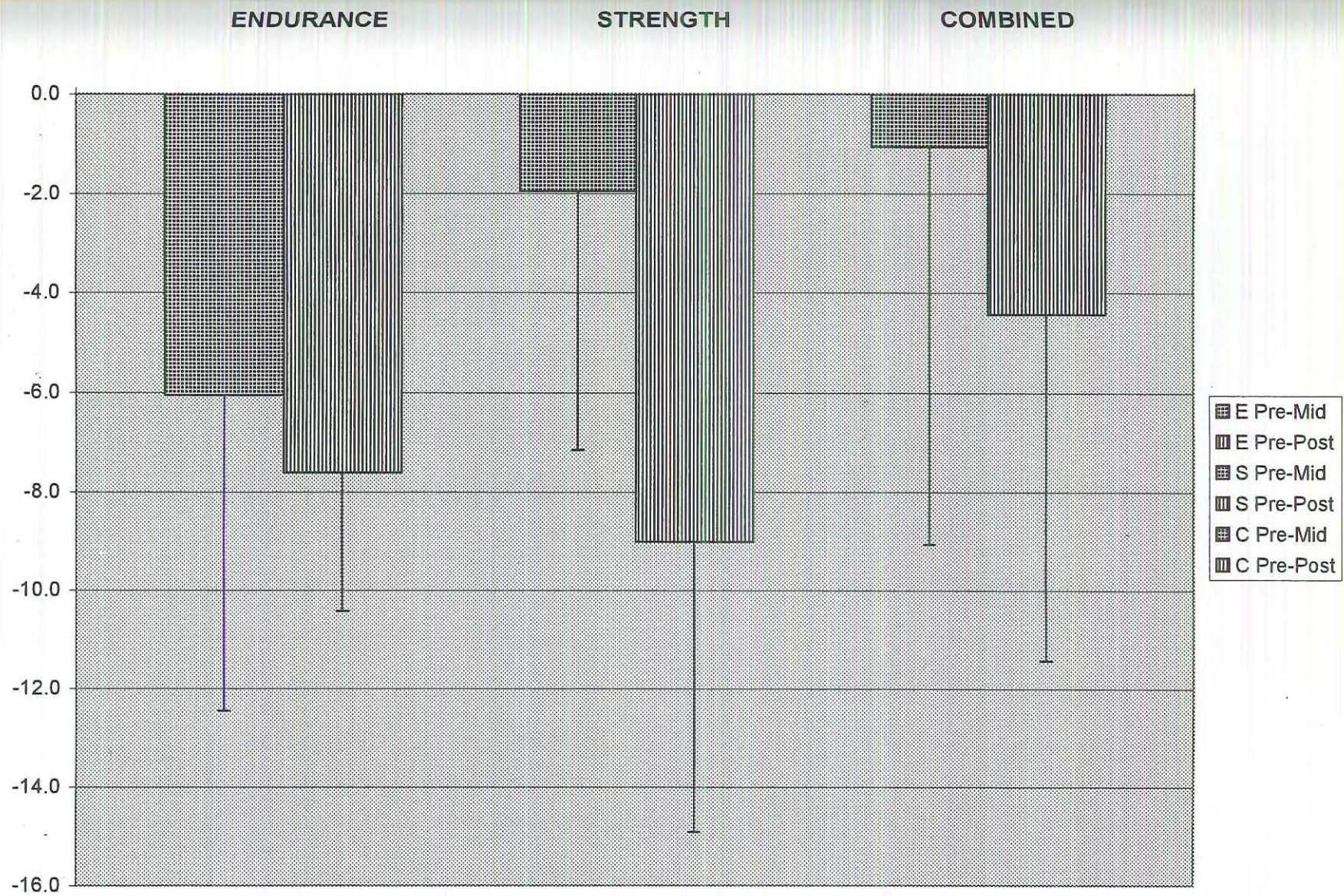


Figure 7b Percentage Variations in Endurance Ratios..

CHAPTER 5.

DISCUSSION.

The number of females engaged in some form of sporting activity is growing rapidly (Powers & Howley, 1997, p. 410). This surge in participation, plus the ever increasing push for excellence is creating greater demands on coaching staff to provide effective and time efficient training programs. Resistance training is now widely accepted as an integral part of almost all training regimes, but despite copious research aimed at defining the perfect weight training regime coaches are still currently having to use trial and error methods to identify the correct frequency, intensity and duration of the various training phases. According Jones et al. (1989) only limited guidance is available regarding the feasibility of utilizing time efficient techniques such as concurrent training for strength and muscular endurance.

This study attempted to address an area in which research is still limited i.e. responses of untrained females to short term intensive weight training programs specifically targeting upper-body musculature, and whether it is possible to train for increases in strength and muscular endurance concurrently. Related changes to body composition, and the occurrence of any training induced muscle soreness were also monitored due to concerns, often expressed by females when they first engage in resistance training, about excessive muscle hypertrophy, and/or discomfort in the target muscle groups.

Despite the fact that according to the results of the various isotonic, isometric and isokinetic assessments used in this study all participants posted some level of strength increase, there was little significant change in body composition, and no recorded episodes of muscle soreness.

The results of the various performance tests carried out as part of this study indicated that the strength training [S] group increased their performance level in all the strength tests, and the combined training [C] group showed increases in both strength and endurance tests, but the endurance training [E] group recorded no significant increase in endurance. Examination of the test data revealed a pattern indicating that the S group, who followed a moderate intensity low repetition regime, made the greatest gains in strength when measured by the 1 RM and isometric methods, both the S and C groups made equal gains when assessed isokinetically at 30° per second, and that the C group, (who alternated between the

programs used by the E and S groups, showed the greatest gains at both the faster isokinetic assessment speed of 90° per second, and in endurance, as measured by the total work produced during 25 continuous repetitions at 90° per second.

The two hypotheses that this study proposed to test were firstly, that an alternating concurrent strength and muscular endurance training regime would produce similar gains in strength to a strength only training regime, and secondly, that an alternating concurrent strength and muscular endurance training regime would produce similar gains in muscular endurance to an endurance only training regime. Whilst not fully supporting the proposed hypotheses these test results do at least demonstrate the apparent effectiveness of the concurrent strength and muscular endurance regime followed by the C group, for achieving isometric and isokinetically measured strength and endurance gains that were equivalent to, and in some respects greater than, those achieved in response to the other individual training regimes. It was only during isotonic 1 RM preacher bench curl assessment that the S group appeared to make superior gains.

5.1 STRENGTH.

Isotonic strength gains [as measured by 1 RM preacher bench curls] were apparent in response to all training regimes [E: S: C], with mean pre-post percentage increases of 11.9%, 12.0% and 10.5% respectively. The fact that the E group showed similar strength gains to those achieved by the S group, and superior gains to those of the C group, both of whom were following more intensive protocols was quite unexpected, and contrary to the well established principles of training specificity and the Strength/Endurance Continuum Theory advanced by DeLorme (1945) and confirmed by numerous other authors and researchers including Anderson & Kearney (1982) Baechele (1984) and Stone & Coulter (1994).

This apparent anomaly may be explained in part by the structure of the E group which contained the only two previously sedentary participants. The study groups were formed to be comparable in terms of age, body weight and preliminary 1 RM strength (as established during the pre-test familiarization sessions), and despite

the fact that all participants were screened to ensure that they were not actively engaged in weight training, their current activity level was not checked. Research has indicated that previously sedentary subjects may have greater potential to increase their baseline measures in response to any form of training, than those who participate in some form of regular exercise (Sharkey, 1970), and this, coupled with the reduction in number, brought about by the exclusion of the pregnant participant from the same group, rendered the group mean percentage gains atypical.

The percentage increases in isotonic strength demonstrated by the S & C groups were smaller than those achieved by previous training studies which also utilized the elbow flexors (Mayhew & Gross, 1974; Cureton et al., 1988; Davies et al., 1988). This may be due in part to the use in the current study of an exercise i.e. preacher bench curl, which unlike the standing barbell curl used in other research studies does not allow the recruitment of other muscle groups to assist in completing the movement, or may just reflect the low intensity of the selected training weight used during the first 4 weeks[70% of pre-test 1 RM score] and the small increment used during the last 4 weeks[5% of pre-test 1 RM score]. The 70% starting level was selected for two reasons, firstly because of the very strict nature of the mode of exercise both in terms of the isolation of the target muscles by the equipment and the very slow cadence used [3 second concentric 5 second eccentric], and the fact that previous research by Cureton et al. (1988) had suggested a 70% of 1 RM starting point for untrained participants.

In deference to their subject's lack of weight training experience, other studies using untrained females have also chosen to use starting workloads at the lower end of the spectrum normally associated with strength development which, according to research cited by Wathan (1994, p. 442), should be in excess of 80% of 1 RM. Ben-Sira, Ayalon & Tavi (1995) selected a training load of 65% of 1 RM for the women participating in their training study after their pilot study had found that many of the women were unable to complete the proposed training regime with higher loads.

According to Jones et al. (1989) the training process can be divided into a number of distinct but overlapping phases. During the first of these there is often a rapid improvement in the subject's ability to perform the training exercise, and this appears to be the result of a learning process in which the correct sequence of muscle

contractions is laid down as a motor pattern in the central nervous system, and this phase is associated with little or no increase in the size and contractile strength of individual muscles. During phase two increases in the neural drive take place, and individual muscle strength increases but there is still little change in the anatomical cross-sectional area of the muscle. It is during phase three when the first signs of hypertrophy start to occur, and this normally coincides with the end of most training studies which usually only run for 8-12 weeks.

A great deal has been written about the specificity of training and the fact that training and testing modalities need to be similar to provide accurate evaluations. According to McArdle et al. (1996, p. 430) most research suggests that dynamically trained muscle is likely to show more significant strength increases when evaluated by some form of dynamic assessment than if tested isometrically (Clarke, 1994, p. 65). The results produced by the isometric peak torque evaluations carried out during this study tend to conflict with these assertions in that both the S & C groups posted apparently larger strength gains than those recorded during the 1 RM tests i.e. pre-post gains of 20.5% and 23.2% respectively, but these may have been due in part to adaptations caused by the super slow training cadence [3 seconds concentric : 5 seconds eccentric] used in every training session, or may have resulted from a problem often associated with the 1 RM preacher bench curl test procedure i.e. during this assessment the participants have to hold the weight whilst extending and flexing the forearm, and this creates the possibility of the movement becoming a two joint action if the wrist is allowed to extend as the forearm comes in contact with the end of the preacher bench. This extended wrist position makes it harder to initiate the concentric curling action required to complete the attempt, and can fatigue the participant significantly, causing them to either fail in the current attempt, or the subsequent attempts, thus adversely affecting their final result. This effect cannot occur during the Cybex isometric peak torque assessments as the load arm is secured by means of a strap attached to the lower end of the participant's forearm just proximal to the wrist joint, and this may account for the apparent superiority of the isometric strength gains.

The first of the isokinetic assessments were made at a speed of 30° per second which was designed to approximate to the concentric training cadence utilized during the low repetition high intensity regime assigned to the S & C groups. This

may account for the significant pre-post strength gains of 17.7% and 17.0% respectively, achieved by those groups. There is little research available comparing the type of training and testing regimes used in this study, but based on their study of previously untrained females, Doherty & Campagna (1993) concluded that similar increases in maximal force production will be displayed during tests at fast and slow speeds regardless of the velocity at which training was performed.

Ninety degrees per second was chosen for the subsequent isokinetic assessment as this speed was similar to the high repetition low intensity training cadence [1 second concentric : 1 second eccentric] used by the E & C groups, but because the assessment requires the participant to perform a maximal contraction the loading is different to the light weights used during training and therefore it was not particularly applicable to the endurance training group which may have accounted for their relatively insignificant 7.4% pre-post improvement. The C group however showed a statistically significant pre-post percentage increase of 22.9% from which it could be inferred that the alternating strength training sessions had more of an influence on the outcome of this particular assessment than their endurance training sessions.

5.2 MUSCULAR ENDURANCE.

According to Kannus (1994), "there is no universally accepted or standardized testing protocol for the assessment of muscular endurance.", and therefore in light of this assertion it was decided to use the procedures recommended by the manufacturers of the Cybex isokinetic dynamometer. Their protocol consists of performing a set of 25 continuous maximal repetitions at a preset speed which for the purposes of this study was set at 90° per second. From the measurements taken during each set the integral software produces data reflecting the total work produced during the 25 repetitions, and an endurance ratio representing the work produced during the last 5 of the 25 divided by the work produced during the first 5 of the 25 expressed as a percentage. Burdett & Van Swearingen (1987) assessed both of these

measurements as part of their review of muscular endurance tests and concluded that the reliability of these tests was greater than the value of 0.8 needed for a clinically significant test, but that the endurance ratio had a lower reliability than either peak torque or total work measurements.

The results of the total work assessments showed that the E group, who might have been expected to have made the most significant gains because of the high repetition low intensity training regime only achieved a 5% pre-post increase, as opposed to the 15.5% and 22.4% increases registered by the S & C groups respectively. This appears to conflict with the well established strength/endurance continuum theory, but this unexpected result could be due to the nature of the chosen endurance assessment as opposed to a lack of specific adaptation on the part of the E group participants. The total work test requires the participants to complete 25 maximal repetitions which although resembling the training volume bares no relationship to the light workloads used consistently in training. Stone & Coulter (1994) used free weights to assess absolute muscular endurance so that the test protocol would more closely resemble the technique and workloads used in training. For the purpose of their assessment they used a fixed weight for all subjects and merely counted the number of repetitions that could be completed at a preset cadence whilst maintaining correct technique. The inclusion of a similar test during this study may well have provided the E group with a more valid assessment of their adaptation to training.

The apparently superior results posted by the S & C groups could be attributed to the fact that the strength training regime that both groups utilized, with its heavier workloads and slower cadence, may have better prepared them to meet the test requirement for maximal exertion during all the 25 repetitions than the faster and lighter training regime followed by the E group, but without some corroborating research this can only be supposition.

Kannus (1994), although recommending the use of the Cybex isokinetic muscular endurance assessment based on total work, did not support the use of the endurance ratio in a clinical setting since he suggested that there was very little pre-post change in the ratios produced by his participants because both the numerator (work during the last 5 reps) and the denominator (work during the first 5 reps) improved at the same rate keeping the ratios virtually unchanged. The pre-post

changes recorded in the endurance ratios produced during the present study did not prove to be statistically significant, and thus it is not prudent to draw any conclusions. All groups did show a decrease in their ratios indicating an increase in peak torque during the first 5 repetitions that could not be sustained throughout all 25 repetitions. The fact that the decline in performance applied to all groups, but was least pronounced in the C group figures could suggest a more sustainable force output in response to combined training.

5.3 MUSCLE SORENESS.

According to Wells (1991, p. 242) it is often suggested that women do not have the same capacity as men to tolerate the rigors of intense weight training, but this premise is totally unfounded. However women are still often reluctant to engage in weight training because of reported incidents of acute and delayed onset muscle soreness (DOMS) experienced by novice trainers. Teague & Schwane (1995) suggest that high intensity eccentric contractions are most often associated with DOMS, and as the strength training protocol used throughout this study included slow eccentric contractions, one of the major considerations in the selection of the initial training loads assigned to participants was the minimization of muscle soreness.

Participants were questioned regarding the levels of post training soreness they had experienced prior to the start of the following training session, and no significant effects were reported by any group throughout the course of the 8 weeks training. Isolated incidents of soreness were however reported after testing sessions during which maximal efforts were required. This suggests that the 70% of 1 RM initial loading chosen for the participants is light enough to minimise muscle soreness whilst still promoting small yet significant strength increases.

5.4 BODY COMPOSITION.

Many women still shy away from weight training because of their fear of excessive muscular hypertrophy and its accompanying loss of femininity, and early research studies by Mayhew & Gross (1974) and Hunter (1985) fueled these concerns with their reports of significant increases in girth measurements, but with the bulk of current research indicating that with appropriate training strength increases are not necessarily associated with large increases in muscle size, this fear has started to diminish.

The results of the present study revealed no significant change in either relaxed or flexed bicep girth for any of the participants irrespective of training group despite the pre-post strength gains posted by all groups.

In their study of female hypertrophy Mayhew & Gross (1974) assessed the effects of high resistance weight training on the body composition of 17 college aged subjects. Their results indicated that the strength increases posted by their subjects were accompanied by statistically significant increases in flexed biceps girth measurements in response to 9 weeks weight training. In contrast, the women who took part in the 6 week elbow flexor training study carried out by Davies et al. (1988) showed no significant increase in upper arm girth despite increased isometric strength and significant increases in muscle cross-sectional area of the biceps as assessed by computed tomography scanning (CT Scan).

These findings were confirmed by Cureton et al. (1988) who studied the effects of weight training on muscle hypertrophy in men and women, using CT Scans in addition to upper arm circumference to assess increases in muscle size in response to 16 weeks heavy resistance weight training. The results of their study showed that despite a 59% improvement in elbow flexor strength and a 23% increase in muscle cross-sectional area there was no significant increase in upper arm girth. Similar results were reported by Boyer (1990) who assessed body composition changes in women as part of his 12 week training study to evaluate the effectiveness of three different modes of resistance training. Although all subjects displayed significant increases in 1 RM bench press and press behind neck strength levels no significant increases in arm girth were recorded.

Morehouse & Miller (1976) cited in Baechle (1984) discuss the process of muscle mass increase being accompanied by a commensurate reduction in intramuscular adipose tissue and suggested that “there may be a 30% increase in mean fibre diameter without a noticeable increase in the girth of the limb”. This may possibly account for why both men and women can experience increased strength and lean body mass without visible hypertrophy.

Changes in body mass and body fat percentages brought about in response to various weight training regimes have also attracted their fair share of research coverage. Cureton et al. (1988) used body composition, as measured by hydrostatic weighing, as one of the dependent variables in their study and noted no significant pre-post changes in the body composition of any subjects in spite of considerable strength increases. Volpe et al. (1993) also used hydrostatic weighing to assess changes in the body composition of the 25 sedentary women who took part in their 9 week training study. Despite recording significant gains in 1 RM leg strength (56-66%) no significant changes were recorded in body composition.

Although this study used only simple body weight and bicep and tricep skinfold measurements to gauge body composition changes in response to the various weight training regimes, the results produced supported the previously established pattern reported by the aforementioned research.

No changes were seen in the pre-post mean body weight levels of the S & C groups, and only an insignificant 2.5% decrease was posted by the E group. Bicep skinfold measurements followed a slightly different pattern with both the E & S groups showing pre-post decreases of 4.6% & 4.3% respectively, but in stark contrast the C group recorded a 4.1% increase. Despite the apparent disparity of results none of these figures proved to be statistically significant.

The only area of controversy arose in respect of tricep skinfold measurements where in contrast to the minor (<2%) pre-post variations recorded by the S & C groups the pre-mid decrease of 5.4% , the mid-post decrease of 8.3% and 13.3% pre-post decrease of the E group appeared completely out of step. The biased composition of the E group [eluded to in section 5.1], may well have been implicated in this abnormal result.

A downward trend in body fat levels without an accompanying reduction in body weight is a well recognised primary adaptation displayed by previously sedentary

subjects who embark upon a program of regular exercise (McArdle et al. 1996, p. 597). The mere fact of training three times per week for 8 weeks of this study may well have been enough stimulus to bring about this significant decrease in body fat, and a concomitant increase in muscle mass with the net result of little or no alteration in overall body mass.

Some clarification as to when hypertrophy can be expected to occur in untrained females was given by the work of Staron et al. (1994) who reported significant increases in the cross-sectional areas of all three major fibre types [as detected by biweekly muscle biopsies] in response to only 6 weeks of high intensity resistance training.

5.5.SUMMARY.

The results of this study showed that gains in strength and muscular endurance can be made by previously untrained females in response to 8 weeks of alternating concurrent moderate (70-75% 1 RM) intensity / low (5 x 6 repetition) volume, and low (40-45% 1RM) intensity / moderate (5 x 25 repetition) volume training regimes. Analysis of the test data also suggested that concurrent training was superior to using either regime independently. These findings support the proposed hypotheses, but care must be taken however in attempting to generalise the outcomes to the population at large due to the small numbers of participants in each of the study groups, the untrained status of the selected participants and the noted deficiencies in the training and testing protocols.

The test outcomes seem to question the reliability of the well supported strength/endurance continuum theory, but because the training regimes used only moderate intensity strength training and moderate volume endurance training it does not preclude the possibility of measurably different adaptations being observed if intensity and/or volumes were increased to near maximal levels.

The fact that the participants were able to achieve significant strength gains without noticeable muscle hypertrophy or DOMS should allay the fears of women concerning the excessive discomfort, or unacceptable increases in muscularity thought to be associated with short term weight training programs.

With small samples like those used in the three study groups, and particularly the E group which was reduced to only 3 members, certain issues need to be considered in terms of the significance and reliability of the results viz:-1) With a small population the data for one individual can have a significant effect on the group mean results either causing or preventing a statistically significant result. 2) A difference between means is more likely to be statistically significant when a larger sample is used.

Further research is necessary before any firm conclusions can be reached as to the most efficient training regime to provide optimum strength and muscular endurance gains, and it would be useful to repeat the present study using training groups with similar previous activity levels, and including an isotonic endurance assessment. The inclusion in future studies of either muscle biopsies or CT scans would help to more accurately assess the degree of muscle hypertrophy which may have occurred in response to training. It would also worth while including more frequent increases in training load to ascertain if this would contribute significantly to the rate of strength increase without any apparent increase in DOMS.

In order to broaden the applicability of the findings of this study, future investigations should focus on the effects of concurrent training on subjects with previous weight training experience to ascertain if the adaptations noted in the present study are comparable with those of trained participants. No attempt was made in the present study to monitor any cross-training effect which may have occurred in the untrained limb, and this would also be a suitable area for future research.

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APPENDIX A

INFORMED CONSENT FORM

The aim of this research is to determine the magnitude of any changes which occur in the strength and muscular endurance capabilities of the elbow flexor muscles of each participant's non-dominant arm(left, in the case of right handed people) in response to various weight training regimes. The results of this investigation have the potential to effect the design of training programs used to promote increases in muscle size, strength and power.

The study will be conducted over an eight week period at the Exercise Physiology Laboratory in the Joondalup campus of Edith Cowan University. As a participant, you will be randomly assigned to one of three groups. Group A will perform low repetition high intensity strength training consisting of 5 sets of 5 repetitions with 65-80% of their pre-established 1 Repetition Maximum. Group B will perform high repetition low intensity endurance training consisting of 5 sets of 25 repetitions with 40-45% of their pre-established 1 Repetition Maximum and Group C will perform the aforementioned strength and endurance routines in rotation. All groups will train three times per week with a minimum of 48 and a maximum of 72 hours between training sessions.

Due to the fact that the participants' arm muscles will be subjected to unfamiliar work loads, they may experience some localized muscle soreness resulting in mild discomfort following the initial training sessions. This will be carefully monitored by the testing staff.

All testing and training information is confidential and will only be used for the purpose of this study. Information will be kept under lock and key. Your data will be identifiable only through a number coding system held by the principle researchers. Data used for analysis will not include any names.

We ask that you refrain from making any major changes to diet or exercise habits throughout the study. Participation in the study is voluntary and you may withdraw at any time, for any reason.

Any questions concerning the study can be directed to:

Derek Gibbins
Principle Investigator.

300 5078 / 400 5054

Dr. Paul Sacco
Exercise Physiologist, Human Movement Dept.
Edith Cowan University

400 5642

I (the participant) have read the above informed consent and any questions have been answered to my satisfaction.
I agree to participate in this study realising that I may withdraw at any time.
I agree that the research data obtained in this study may be published, provided that I am not identifiable.

I understand and agree that the Edith Cowan University Human Movement Department will not be held responsible for any injury or permanent damaged sustained.

Participant

Date

Investigator

APPENDIX B

STATISTICALLY SIGNIFICANT EFFECTS ($P < .05$)

MEASUREMENT/PERFORMANCE VARIABLE	ANOVA RESULT	PAIRED 't-test' RESULT
TRICEPS SKINFOLD	[F(2,16) = 3.82, $p = .044$]	E Group Pre-Post [$t(2) = -4.51$, $p = .044$]
1 RM PREACHER BENCH CURL	[F(2,16) = 16.19, $p = .000$]	E Group Pre-Mid [$t(2) = 16.00$, $p = .004$] C Group Mid-Post [$t(3) = -7.07$, $p = .006$] S Group Pre-Mid [$t(3) = 7.00$, $p = .006$]; S Group Mid-Post [$t(3) = -3.23$, $p = .048$]; S Group Pre-Post [$t(3) = -6.99$, $p = .006$];
ISOMETRIC PEAK TORQUE	[F(2,16) = 16.19, $p = .000$]	E Group Pre-Mid [$t(2) = 11.00$, $p = .008$] S Group Pre-Post [$t(3) = -4.16$, $p = .025$]
ISOKINETIC PEAK TORQUE @ 30° per second	[F(2,16) = 26.14, $p = .011$]	S Group Pre-Post [$t(3) = -7.00$, $p = .006$] C Group Pre-Post [$t(3) = 13.29$, $p = .046$]
ISOKINETIC PEAK TORQUE @ 90° per second	[F(2,16) = 12.03, $p = .001$]	S Group Pre-Mid [$t(3) = 8.66$, $p = .003$] C Group Pre-Post [$t(3) = -13.00$, $p = .001$]
TOTAL WORK DURING 25 REPS @ 90° per second	[F(2,16) = 8.31, $p = .003$]	C Group Pre-Mid [$t(3) = 5.76$, $p = .010$] C Group Pre-Post [$t(3) = -5.90$, $p = .010$]