Effects of a University Fitness Programme on Cardiorespiratory Fitness, Muscle Strength and Endurance, Body Composition, and Flexibility of Previously Sedentary Females.

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Abstract

Thirty-eight healthy females between the ages of 20 and 49 that had not undertaken any training for at least two months prior to the experiment were studied to determine the effects of six weeks of a combined circuit weight training and aerobic programme on estimated maximal oxygen consumption ($\dot{V}O_{2max}$), muscular strength, body composition and flexibility. Nineteen of the volunteers participated in the exercise programme while the remaining nineteen served as control subjects. Prior to the training programme each subject took part in two testing sessions. Further testing was conducted after 3 weeks (1 testing session) and at the conclusion of the training programme (two testing sessions). Estimated $\dot{V}O_2$max was determined from heart rate and oxygen uptake during a submaximal test using a cycle ergometer. Muscular strength was determined from an estimated one repetition maximum and maximum number of repetitions for a set weight for the bench press, leg press, leg extension and abdominal crunches. Body composition was evaluated from the sum of the triceps, subscapular, suprailiac, abdomen, thigh and calf skinfolds. Flexibility was evaluated for the hamstrings muscle group (using the sit and reach test), gastrocnemius and soleus muscles and shoulders. The training programme consisted of three 25-40 minute sessions a week on The Massey University Recreation Centre Supercircuit. The supercircuit consisted of thirty-six 40-second exercises which include 11 aerobic exercises and a variety of weight training and calisthenic exercises. Data was analysed using regression analysis and one factor ANOVA. There was no significant increase in the mean estimated VO_2max following the training period. The estimated 1RM increased by 40% and the maximum number of repetitions for a set weight increased by 100% for the bench press. The estimated 1RM increased by 16% for the leg press and the maximum number of repetitions for a set weight increased by 52% for the leg extension. The number of abdominal crunches completed in one minute increased significantly. There was no significant change in body mass or the sum of the skinfolds. There was a signficant increase in the flexibility of the hamstring muscle group but not of the gastrocnemius and soleus muscles and shoulders. Over the six weeks of the study period subjects felt they had significantly improved in stamina, muscle tone, strength, flexibility and general well being and had made small improvements in body shape. It was concluded that the supercircuit at the Massey University Recreation Centre is an effective means of improving musclar strength in sedentary females but it may not be as effective at improving cardiorespiratory fitness and body composition as some other forms of exercise.

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List of Abbreviations

CWT	circuit weight training
Load	the mass (kg) or amount of resistance against which a muscle works.
Repetition	a single complete action of an exercise from starting position to completion and back to the starting position.
1RM	One repetition maximum; the maximum load that can be lifted for one repetition only.
5RM	Five repetition maximum: the maximum load that can be lifted for five repetitions only.
5-10RM	Five - ten repetition maximum: the maximum load that can be lifted for between five and ten repetitions only.
bpm	heart rate in beats per minute
HRmax	maximum heart rate
HRR	heart rate reserve
L/min	litres per minute
ml/kg/min	millilitres/kilogram /minute
ml/kg LBW/min	millilitres/kilogram lean body weight/minute
pre-exercise HR	heart rate prior to participating in the cycle ergometer test
RMR	resting metabolic rate
RPE	rating of perceived exertion
R-hamstring	right hamstring muscle group
L-hamstring	left hamstring muscle group
R+L hamstring	right plus left hamstring muscle group
SKF-2	sum of the suprailiac and abdominal skinfolds
SKF-6	sum of the triceps, subscapular, suprailiac, abdominal, thigh and calf skinfolds
VO_2max	maximal oxygen uptake
C	regression variable representing training status
T	regression variable representing time
CT	regression variable representing training status x time
Tsq	regression variable representing time squared
CTsq	regression variable representing training status x time squared
ANOVA	analysis of variance

1. Introduction

People who are physically active gain some protection from coronary heart disease, respiratory diseases, some forms of cancer and death by unnatural causes such as accident and suicide (Paffenbarger *et al.*, 1984; Fox *et al.*, 1989), therefore maintaining reasonable levels of fitness should ideally be an essential part of normal life. However, too many people either lack the time or the motivation to develop reasonable standards of fitness. Circuit weight training is a form of resistance training which has been developed with the aim of improving not only muscular strength and endurance but also cardiorespiratory fitness. It may therefore be an attractive option to sedentary people who require a generalised conditioning programme.

1.1. Physical Fitness

There is no one definition of physical fitness which is universally accepted, with most definitions being descriptive rather than quantitative. For example, Clarke (1971), cited by Ong & Sothy (1986), defined fitness as:

> "the ability to carry out daily tasks with vigour and alertness, without undue fatigue, and with ample energy to enjoy leisure-time pursuits and to meet unforseen emergencies"

The American College of Sports Medicine (1990) defined fitness as:

> "The ability to perform moderate to vigorous levels of physical activity without undue fatigue, and the capability of maintaining such ability throughout life."

These definitions make it difficult to assess an individual's level of fitness. In order to quantify 'fitness' rather than describe it, fitness needs to be broken into measureable components which are generally agreed to be cardiorespiratory fitness, muscular strength and endurance, body composition and flexibility (O'Toole & Douglas, 1988; ACSM, 1990). Tables of Norms have been developed for these parameters but the Norm for each parameter will depend on the activity levels of the particular population studied and thus may vary from population to population. What is an appropriate level of fitness for a competitive endurance athlete will be quite different to that which is appropriate for a healthy adult who wishes to pursue active recreation.

The greatest increase in health benefits from exercise, such as a decreased risk of dying from heart disease, cancer and other causes, is found when comparing sedentary people to those people who exercise modestly by expending at least 2000kJ per week, i.e. the equivalent of a 70kg person walking briskly for approximately 60 minutes per week (Paffenbarger *et al.*, 1986; Blair *et al.*, 1989). Health benefits and possibly life expectancy, continue to increase as people spend more hours exercising but the increases in health benefits are not so great (Holloszy *et al.*, 1985; Paffenbarger *et al.*, 1986; Blair *et al.*, 1989). Exercising strenuously for more than 6-8 hours per week results in little or no increase in health benefits (Holloszy *et al.*, 1985; Paffenbarger *et al.*, 1986; Blair *et al.*, 1989).

Regular aerobic exercise may help prevent coronary heart disease by improving circulation and metabolism in the heart through enhanced vascularisation, increased glycogen stores and glycolytic capacity (Laughlin, 1985; Laughlin *et al.*, 1989; McArdle *et al.*, 1991); by enhancing the contractile properties of the heart muscle so that the heart can maintain or increase contractility during a specific challenge (McArdle *et al.*, 1991); by establishing more favourable blood clotting characteristics (Ferguson *et al.*, 1987); normalising blood lipid profiles (Wood, 1989); improving heart rate and blood pressure so that myocardial work is significantly reduced at rest and during exercise (Paffenbarger *et al.*, 1986); achieving a more desirable body composition (Katch & Katch, 1988); and providing a favourable outlet and response pattern to psychological stress and tensions (Dubbert, 1992; LaFountaine *et al.*, 1992; Crews & Landers, 1987).

Maximal oxygen uptake ($\dot{V}O_2max$), which is accepted as the most important indicator of an individual's cardiorespiratory fitness (Ong & Sothy, 1986), declines with age due to a decrease in muscle mass (Fleg & Lakatta, 1988), a decline in maximal heart rate (Hagberg *et al.*, 1985) and a decrease in peripheral bloodflow capacity (Parizkova *et al.*, 1971). However, exercise helps retain cardiovascular function in older individuals (Seals *et al.*, 1984; Meredith *et al.*, 1989) to such an extent that $\dot{V}O_2max$ declines twice as rapidly with age in sedentary individuals as it does in active individuals (Heath *et al.*, 1981).

Lean body mass not only tends to decrease with age due to a reduction in muscle mass but also due to a decrease in bone mass. Regular physical activity slows down the decline in muscle mass (Fleg & Lakatta, 1988) and retards bone loss (Smith, 1988) thus helping to prevent or reduce the incidence of injury in older individuals.

A desirable body composition is about 15% or less fat mass for men and 25% or less for women (McArdle *et al.*, 1991), although the optimum will vary from person to person depending mainly on genetic factors. For many people, achieving a desirable body composition means losing fat mass and either maintaining or gaining lean body mass. Exercise programmes can help induce fat loss and are important in maintaining a healthy weight (Wilfley & Brownell, 1994). With an increase in age, body fat levels tend to increase but the increase is not so great for those who maintain an active lifestyle (Brownell *et al.*, 1988).

1.1.1. Programmes for Improving Physical Fitness

Most activities are excellent for developing only one or two of the major components of fitness. For example, cycling and jogging are excellent for developing cardiorespiratory endurance and reducing body fat (Heath *et al.*, 1981; Meredith *et al.*, 1989; ACSM, 1990; Taylor *et al.*, 1991) but they are not good for developing flexibility and upper body strength. Resistance training is excellent for developing muscular strength and endurance but it is not good for developing cardiorespiratory fitness (Cunningham & Hill, 1975; Hickson *et al.*, 1980; Gettman & Pollock, 1981; Hurley *et al.*, 1984; Fleck & Kraemer, 1988a). Stretching will increase flexibility but it will not increase cardiorespiratory fitness, reduce body fat or increase muscular strength and endurance.

ACSM (1990) recommends that to develop and maintain a reasonable standard of fitness individuals should train three to five days per week at 60-90% of their maximum heart rate (or 50-85% of maximum oxygen uptake or heart rate reserve) for 20-60 minutes depending on the intensity of the exercise. The activity should use large muscle groups, be maintained continuously and be rhythmical and aerobic in nature. Also, an exercise programme should involve one set of 8-12 repetitions of eight to ten exercises that condition the major muscle groups at least two days per week.

1.1.1.1. Aerobic Training Programmes

Aerobic training programmes use large muscle groups continuously and rely primarily on aerobic metabolism for energy. Improvements in $\dot{V}O_2max$ as a result of aerobic or endurance training usually range from 5-30% (Astrand & Rodahl, 1986) and are directly related to the frequency, intensity and duration of the training, the initial level of fitness, the length of time that training has been undertaken (weeks/months) and the specificity of the testing in relation to the type of training. There are also genetic limitations on how much $\dot{V}O_2max$ can be improved (Klissouras, 1971).

The intensity and duration of exercise are inter-related, as it is the total amount of work accomplished which is an important factor in improving fitness (Kearney *et al.*, 1976; Wenger & Bell, 1986). Similar improvements in $\dot{V}O_2max$ have been shown for high intensity - short duration exercise as for low intensity - long duration exercise but work intensity does need to be over a certain threshold (Wenger & Bell, 1986). The recommended training intensity for apparently healthy individuals for improving cardiorespiratory fitness is 50-85% of maximal oxygen consumption, although the outside limits can be between 40-85%, or alternatively 55-90% of maximal heart rate (ACSM, 1990; Swain *et al.*, 1994). For all but the highly motivated, adherence to exercise programmes is much greater when the intensity is lower.

The recommended frequency for aerobic training is three to five times per week (ACSM, 1990) with the optimal frequency being four times a week (Wenger & Bell, 1986). Once the frequency of training is increased above three times per week the amount of improvement in $\dot{V}O_2max$ begins to plateau with little additional benefits being derived beyond a frequency of four times per week (Wenger & Bell, 1986). When training occurs less than twice per week there is generally no meaningful change in $\dot{V}O_2max$ (Wenger & Bell, 1986; ACSM, 1990). The mode of aerobic exercise, for example whether cycling, running or swimming, does not appear to have any effect on cardiorespiratory adaptations, provided the frequency, duration and intensity are similar and result in the same total energy expenditure (Lieber *et al.*, 1989; ACSM, 1990).

Generally, the lower the initial $\dot{V}O_2max$, the greater the percentage improvement in $\dot{V}O_2max$ (Ekblom *et al.*, 1968; Rowell, 1974). In sedentary people, a low intensity training programme of 30 minutes training three times a week demanding approximately 50% maximum oxygen uptake can increase $\dot{V}O_2max$ by 5-10% and a more intense programme of 70-80% $\dot{V}O_2max$ can increase $\dot{V}O_2max$ by 20% (Astrand & Rodahl, 1986). Significant improvements in aerobic capacity have been shown to occur in as short a time frame as 10 to 20 days in males (Hickson *et al.*,1981) and in sedentary females within six to seven weeks (Fox *et al.*, 1989).

The specificity of testing in relation to training can also affect values of $\dot{V}O_2max$. For example, if the individual has used running as the training mode and testing is done on a cycle ergometer, there will not be as great an apparent increase in $\dot{V}O_2max$ as when a treadmill is used for exercise testing (Hermansen & Saltin, 1969). In order to monitor improvements in $\dot{V}O_2max$ as a result of training, individuals should be tested using the same mode of exercise in which they have trained.

1.1.1.2. Resistance Training Programmes

Resistance training programmes are programmes that involve specific muscle groups overcoming a fixed resistance. The most popular form of resistance training is weight lifting, i.e. lifting or moving a fixed resistance in the form of a barbell, dumbbell or weight machine, but body weight can also be used as the fixed resistance. In traditional weight training programmes, various combinations of numbers of repetitions and amount of resistance are used. For example, low repetitions and high resistance are used for maximum strength development and high repetitions and low resistance are used for the enhancement of muscular endurance (Fleck & Kraemer, 1987; ACSM, 1990).

Resistance training programmes are effective in enhancing muscle strength and endurance but have little effect on cardiorespiratory fitness (Cunningham & Hill, 1975; Hickson *et al.*, 1980; Gettman & Pollock, 1981; Hurley *et al.*, 1984; Fleck & Kraemer, 1988a).

Body builders, power lifters and Olympic weight lifters who have used intense weight training programmes for a number of years tend to have values of $\dot{V}O_2max$ in the range of 41-55 ml/kg/min (average 48 ml/kg/min) which is slightly higher than the average sedentary male (44 ml/kg/min) but substantially below that of elite endurance trained athletes (70-80 ml/kg/min) (Hurley *et al.*, 1984; Fleck & Kraemer, 1988b). This suggests that weight training may have some effect on cardiorespiratory fitness but it is minimal.

The lack of improvement in $\dot{V}O_2max$ with resistance training is probably due to the relatively low metabolic cost of resistance training exercises as small muscle masses are used for short periods of time as compared with vigorous walking, running, cycling or swimming, where large muscle groups are used for long periods of time. The metabolic cost of an average 65kg women while weight training is 22.5kJ/min as compared with jogging which is 41kJ/min and cycling which is 34kJ/min (Watson & Mackle, 1995). The lower metabolic cost of resistance training will also make it less effective than aerobic exercise in weight control programmes.

Resistance training has been shown to be effective in reducing blood pressure, particularly in hypertensive subjects (Seals & Hagburg, 1984; McLatchie, 1993), but there are conflicting reports on whether or not it has a beneficial effect on blood lipid profiles and other heart-disease risk factors (Hagburg *et al.*, 1989; McArdle *et al.*, 1991).

The most effective means of increasing strength and power appears to be by completing a low number of repetitions (fewer than ten) using a resistance which requires maximal or nearly maximal tension development within the muscle group being trained (Berger, 1962; Atha, 1981; McDonagh & Davies, 1984; Fleck & Kraemer, 1987; ACSM, 1990). Extremely heavy loads in which the maximum number of repetitions able to be achieved is two or fewer result in smaller strength and power gains than a more moderate load (Fleck & Kraemer, 1987). Although four to six maximal repetitions repeated three to six times within a training session and completed three times a week is usually quoted as optimal for strength development, there does not appear to be a single combination of sets and repetitions that yields optimal strength gains for everyone (Berger, 1962; Atha, 1981; McDonagh & Davies, 1984; Fleck & Kraemer, 1987; ACSM, 1990). The development of muscular endurance requires lighter weights and more repetitions (greater than 12). Both strength and endurance are developed under each training regime but each regime favours either strength or endurance development. If the aim of a resistance programme is to improve both strength and endurance, most resistance training experts recommend that 8-12 repetitions are completed for each exercise (Astrand & Rodahl, 1986; Fleck & Kraemer, 1987; Fox *et al.*, 1989; ACSM, 1990).

Increases in strength can be difficult to assess and compare because a number of factors will influence strength development and how it is evaluated. These include initial strength of the individual and their genetic potential for strength development (ACSM, 1990) and the type of equipment used for testing and training (Fleck & Kraemer, 1987). There is a wide range of improvements in strength recorded in the literature but based on a review (Fleck & Kraemer, 1987), the average improvement in strength for sedentary young and middle aged men and women over a six month period is 25-30%.

1.1.1.3. Physical Fitness Programmes for Improving Body Composition

In order to attain an ideal body composition of 15% fat or less for men and 25% fat or less for women (McArdle *et al.*, 1991), most people need to decrease fat mass and either maintain or increase lean body mass.

ACSM (1990) has suggested that the threshold level for fat mass loss is an exercise intensity which requires an energy expenditure of 1260 kJ (or 63kJ/min) for a minimum of three exercise sessions per week of at least 20 minutes duration. When exercising four times a week this reduces to 840kJ per exercise session (or 42kJ per minute) (ACSM, 1990). For the average 65kg woman energy expenditure during resistance training is 22.5kJ/min, while casually cycling and doing aerobics it is 34kJ/min and jogging it is 41kJ/min (Watson & Mackle, 1995). Thus aerobic exercise is more likely to induce fat loss than resistance training.

Wilfley & Brownell (1994) have proposed that energy expenditure is only one of a number of mechanisms for inducing weight loss. Other mechanisms include minimisation of loss of lean body mass or an increase in lean body mass (Ballor *et al.*, 1988; Ballor *et al.*, 1990), suppression of appetite (Woo *et al.*, 1982), counteraction of a decline in resting metabolic rate (RMR) when weight loss is induced by a reduction in energy intake (Poehlman, 1989; Ballor & Poehlman, 1994), prevention of an increase in selecting foods which are higher in fat content especially over periods of time when weight fluctuates due to changes in diet and exercise (Gerardo-Gettens *et al.*, 1991) and positive psychological effects by improving mood, psychological well being, self concept and self esteem (Rodin & Plante, 1989; Wilfley & Brownell, 1994). Thus all exercise will be beneficial in aiding weight loss but aerobic exercise may be the most effective as energy expenditure is greater than other forms of exercise.

Although resistance training may not be as effective as aerobic exercise for inducing fat mass loss due to its lower metabolic cost, it is more effective at inducing an increase in lean body mass (MacDougall, 1986). High intensity resistance training programmes result in hypertrophy of both slow twitch and fast twitch fibres by increasing the number of myofibrils within each fibre (Faulkner & White, 1988), whereas endurance training results primarily in metabolic changes within the muscle fibre thus enhancing the ability of the fibre to oxidise fatty acids, conserve carbohydrates and delay metabolic acidosis during prolonged physical activity (Faulkner & White, 1988).

1.1.2. Circuit Weight Training as a means of Improving Physical Fitness

Traditional resistance training programmes are good for improving muscular strength and endurance but due to the relatively low cardiovascular and aerobic metabolic demands compared with aerobic forms of training, they are of little benefit to those wanting to improve cardiorespiratory fitness and induce weight loss (Cunningham & Hill, 1975; Hickson *et al.*, 1980; Hurley *et al.*, 1984). Logically, a training programme that could improve both cardiorespiratory fitness and strength within one programme would be a more efficient use of the training individuals time and it may be easier to motivate people to use this type of programme. By modifying the traditional approach to resistance training by decreasing the resistance which the muscle works against, increasing the number of repetitions for each exercise and allowing little (15-30 seconds) or no rest between exercises, the calorific cost of training can be increased making this type of training more suitable for developing reasonable levels of aerobic fitness, inducing fat loss, increasing strength and muscle endurance and improving 'muscle tone'. This approach, called circuit weight training (CWT), has been promoted by many Fitness Centres as an effective and efficient means of developing all of these major components of fitness.

1.1.2.1. Defining Circuit Weight Training

In circuit weight training (CWT) an individual lifts a weight of approximately 40-60% of a one repetition maximum (1RM) (the maximum resistance an individual can lift once but cannot lift a second time), for as many times as possible in a defined period of time e.g. 30 seconds (this usually involves 12-15 repetitions of each exercise), and then after a short rest interval (less than 30 seconds) proceeds to the next station. Some circuits will have only 8-12 exercises, with the circuit being repeated a number of times; other circuits will be made of a larger number of exercises and be repeated only once or twice. The focus of a circuit can be adjusted so that muscular strength and endurance, power, flexibility or improvements in cardiorespiratory fitness can be more specifically targeted. This is achieved by changing the exercises, the number of repetitions of each exercise, the approximate percentage of 1RM used and the duration of the rest period between stations.

Most weight training circuits use isotonic weight training machines such as those sold under the trade name of Universal Gym, Polaris, Nautilus and Fitness Works. These machines are either dynamic constant resistance or variable resistance machines.

Table 1. Review of Changes in Strength with Circuit Weight Training and Aerobic Circuit Weight Training

Study	sex	n	Type of Circuit	Equipment	Repetitions	Work/Rest ratio (sec/sec)	Length of Training (weeks)	Testing Procedure	Improvement Bench Press (%)	Improvement Leg Press (%)
Allen *et al.*, 1976	M	33	CWT	IT	5	30/60	12	aver tr wt	44	71
Wilmore *et al.*, 1978	M	16	CWT	IT	>12	30/15	10	1RM	8	7
	F	12	CWT	IT	>12	30/15	10	1RM	20	27
Gettman *et al.*, 1978	M	11	CWT	IT	>12	15reps/20	20	1RM	32	12
Gettman *et al.*, 1979	M	16	CWT	IK	>12	15reps/20	8	1RM	11	18
								IKfast	42	24
								IKslow	22	38
Gettman *et al.*, 1982	F	14	CWT	IT	>12	30/15	12	1RM	21	18
	M	16	CWT	IT	>12	30/15	12	1RM	14	16
	F	16	aerCWT	IT	>12	30/15	12	1RM	21	26
	M	16	aerCWT	IT	>12	30/15	12	1RM	21	22
Hurley *et al.*, 1984	M	13	CWT	IT	8-12	cont	16	1RM	50*	33*
Messier & Dill, 1985	M	12	CWT	IT	8-12UB >12LB	cont	10	IK	NSI	NSI
								aver tr wt	30*	46*
Katz & Wilson, 1992	F	13	CWT	IT	>12	cont	6	aver tr wt	31*	26*
Mosher *et al.*, 1994	F	17	aerCWT	IT	>12	30/30	12	1RM	21	26

CWT: circuit weight training
IK: isokinetic
1RM: one repetition maximim
aerCWT: aerobic circuit weight training
reps: repetitions
aver tr wt: average training weight
IT: isotonic
cont: continuous
NSI: no significant increase
* average of several upper or lower body exercises

Although isotonic muscle contractions are defined as muscular contractions in which the muscle exerts a constant tension, in reality the tension varies with the mechanical advantage of the joint involved in the movement (Fleck & Kraemer, 1987). When the external weight does not vary the machines are better referred to as dynamic constant resistance training (Fleck & Kraemer, 1987). Variable resistance equipment operates through a lever arm, cam or pulley arrangement so that the resistance is altered throughout the range of motion of an exercise in an attempt to match the increases and decreases in force exerted by the resistance throughout the range of movement. Nautilus equipment uses variable hydraulic cylinders to alter the resistance. More recently variable hydraulic machines have been developed which allow only concentric muscle contractions, with agonist and antagonist muscle groups being exercised alternately (Hydra-Fitness Industries Ltd). In these, the resistance is variable and the speed is kept relatively constant.

A few weight training circuits have used isokinetic training machines in which muscular contractions are performed at a set limb velocity. Any force applied to the machine results in an equal reaction force thus potentially resulting in maximal muscular contractions (Fleck & Kraemer, 1987).

In order to further increase the metabolic cost of training and thereby gain greater improvements in cardiorespiratory fitness, aerobic stations have been added to weight training circuits. In aerobic circuit weight training, alternate stations may be aerobic (Gettman *et al.*, 1982; Cheah, 1986; Hoevet, 1990) or groups of weight training exercises are followed by several minutes of aerobic activity (Mosher *et al.*, 1994).

1.1.2.2. The Effectiveness of Circuit Weight Training for Improving Strength

Circuit weight training and aerobic circuit weight training significantly improve strength (Allen *et al.*, 1976; Wilmore *et al.*, 1978a; Gettman *et al.*, 1978, 1979, 1982; Hurley *et al.*, 1984; Messier & Dill, 1985; Katz & Wilson, 1992; Mosher *et al.*, 1994). A summary of these studies is presented in Table 1. The increase in strength for the bench press ranged from 8% (Wilmore *et al.*, 1978a) to 44% (Allen *et al.*, 1976) and for the leg press from 7% (Wilmore *et al.*, 1978a) to 71% (Allen *et al.*, 1976). However, these studies are difficult to compare as each study used a slightly different type of training and there were variations in how strength was evaluated. Strength was evaluated from the weight which could be lifted for one repetition only (1RM), from an isokinetic dynamometer set at a particular angular velocity or from the average training weight.

When subjects trained isotonically such as when training on Universal Gym equipment and strength was evaluated using isokinetic machines which measure the maximum force that can be exerted at a constant angular limb velocity, improvements in strength were always less than when the subjects were tested by finding the weight which could be lifted for one repetition only (Gettman *et al.*, 1978). For example, when subjects were measured isotonically on the Universal Gym equipment used during the training protocol, Gettman *et al.* (1978) demonstrated an improvement of 50lb in the bench press (an improvement of 32%) for a group of subjects that underwent circuit weight training over 20 weeks, an improvement of 19lb (an improvement of 12%) in an equivalent running group who jogged for 30 minutes at 85% of their maximum heart rate and no significant change in strength in control subjects. However, when strength was evaluated using an isokinetic machine there was no significant difference between the running and the CWT groups.

The study of Wilmore *et al.* (1978a) in which subjects were both trained and tested using Universal Gym equipment, also showed significant improvements in strength over ten weeks. For women, the weight lifted on the bench press increased by 20%, and leg flexion and leg press improved by 51% and 27%. In comparison, men improved by 8% for the bench press and by 7% for both leg flexion and leg press. Wilmore *et al.*(1978a), thought the difference between the men and women in strength improvements was probably due either to the lower initial starting level of the women or to their more intense training programme.

When Gettman *et al.* (1979) used both isokinetic training and testing, the apparent increase in strength depended on the speed at which the isokinetic machine had been set. There was a 22% and 42% increase in bench press strength when tested at a slow speed (12^{o}/sec) and a fast speed (120^{o}/sec) respectively and a 38% and 24% increase in leg press strength. The speed at which the subjects trained was not stated. When strength was measured isotonically by finding the 1RM, bench press strength increased by 11% and leg press strength by 18%.

Hurley *et al.* (1984), used variable resistance equipment (Nautilus). Over 16 weeks there was a 50% average increase in 1RM for five upper body exercises and a 33% average increase in 1RM for three lower body exercises. Messier & Dill (1985) also used Nautilus equipment and found a 30% mean increase in upper body average training weight and a 46% increase in lower body training weight although there was no significant improvement when testing using an isokinetic dynamometer. Katz & Wilson (1992) demonstrated an increase of 31% in overall upper body strength and a 26% increase in overall lower body strength during training using Nautilus equipment.

Mosher *et al.* (1994) demonstrated increases in muscular strength ranging from 21% (for the bench press) to 26% for the leg extension measurement for their aerobic circuit training programme using a 1RM test on the Universal Gym equipment which the group used for training.

Table 2. Review of Changes in VO_2max with Circuit Weight Training.

Study	sex	n	type of training	Length of training (wk)	Average Duration of workout (min)	Work/Rest Ratio (sec/sec)	Intensity of Work (%1RM)	Change in VO_2max ml/kg/min (%)	Change in VO_2max ml/kgLBW/min (%)
Wilmore *et al.*, 1976	F	12	IT(>15)	10	25	30/15	40-55	6*	-
Allen *et al.*, 1976	M	33	IT(5)	12	30	30/60	-	-1	-
Wilmore *et al.*, 1978a	M	16	IT(>15)	10	22.5	30/15	40-55	-0.4	-2
	F	12	IT(>15)	10	22.5	30/15	40-55	11*	8*
Gettman *et al.*, 1978	M	11	IT(>15)	20	25	15reps/30	50	-	0.2
Gettman *et al.*, 1979	M	16	IK(>15)	8	24	15reps/30	-	3*	2*
Gettman *et al.*, 1982	F	14	IT(12-15)	12	22.5	30/15	40	13*	7.6*
	M	16	IT(12-15)	12	22.5	30/15	40	12*	9.1*
Hurley, 1984	M	13	IT(8-12)	16	-	8-12reps/0	-	5	5
Messier & Dill, 1985	M	12	IT(8-12UB) (12-15LB)	10	20	8-12repsUB/0 12-15repsLB/0	-	10.8*	7.1*
Petersen *et al.*, 1988	M	16	IT(>20)	5	-	20/40	-	-	9.5*
Haennel *et al.*, 1989	M	8	IT(>14)	9	27	20/20	70-85	11.3*	-
	M	8	IT(>16)	9	27	20/20	maxRM	12.5*	-

IT: isotonic weight machines used in training
(5), (8-12), (>15): number of repetitions of each exercise
UB: upper body. LB: lower body
* significant

IK: isokinetic weight machines used in training
reps: repetitions
maxRM: maximum number of repetitions possible

Circuit training therefore can result in an increase in strength but there are large variations between different studies depending on the type of training and the type of testing used making it difficult to compare many of the studies. Where similar testing procedures are used, it would appear that circuit weight training is just effective as aerobic circuit weight training for improving strength (Wilmore *et al.*, 1978a; Gettman *et al.*, 1978, 1982; Mosher *et al.*, 1994). Circuit weight training, however, is not as effective at improving strength as traditional strength training methods. The high levels of lactic acid produced and high levels of perceived exertion during circuit training (Noble *et al.*, 1984) tend to discourage or prevent the maximal exertion necessary for maximal gains in strength.

1.1.2.3. The Effectiveness of Circuit Training for Improving Cardiorespiratory Fitness

1.1.2.3.1. Circuit Weight Training

During CWT heart rate is maintained in the training zone for the duration of the training session. If it is done three times per week for at least 20 minutes, it appears to comply with the ACSM requirements for an improvement in cardiorespiratory fitness (ACSM, 1990), yet either no improvements or small to moderate improvements in $\dot{V}O_2max$ and heart rate and stroke volume at submaximal workloads have been reported. Some studies found small to moderate increases in $\dot{V}O_2max$ of between 3.5% and 13% (Wilmore *et al.*, 1976; Wilmore *et al.*, 1978a; Gettman *et al.*, 1979; Gettman *et al.*, 1982; and Messier & Dill, 1985; Petersen *et al.*, 1988; Haennel *et al.*, 1989) whereas others found no cardiorespiratory improvement (Allen *et al.*, 1976; Wilmore *et al.*, 1978a; Hurley *et al.*, 1984; Gettman *et al.*, 1978). The two critical factors for improving cardiorespiratory fitness appear to be (1) achieving a high number of repetitions within the work interval and (2) having a short rest interval between work intervals. Table 2 summarises the effects of CWT programmes on cardiorespiratory fitness.

Wilmore *et al.* (1976) demonstrated a small but significant increase of 6% in $\dot{V}O_2max$ in females during a 10 week programme of CWT using high repetitions on Universal Gym equipment. Subjects trained three times a week, 25 minutes per day, using a 30-second work to 15-second rest ratio. The weight lifted at each station was approximately 40-55% of 1RM and as many repetitions as possible were done in 30 seconds before moving onto the next station. Based on the work load (40-55% 1RM) in this study and the work load and repetitions completed in other studies (Gettman *et al.*, 1978, 1979, 1982; Haennel *et al.*, 1989), the number of repetitions achieved was probably greater than 15. A more complete study by Wilmore *et al.* (1978a) studied the effects of circuit weight training on both males and females over 10 weeks. At the completion of 10 weeks the experimental group had significantly increased lean body weight, flexibility, strength, decreased treadmill endurance time to exhaustion and, in females only, increased $\dot{V}O_2max$. Although both males and females decreased the time taken to reach exhaustion on a treadmill (5.8% in females and 5.2% in males), only the females showed an improvement in $\dot{V}O_2max$ (11%). Theories put forward by the authors to explain this were: (1) the females tended to work at a higher percentage of their maximum heart rate (87.6% vs 78.2%) and of their $\dot{V}O_2max$ (46.8% vs 41.1%) even though both groups exercised at 40-55% of their maximum strength, and (2) it was also possible that the threshold stimulus for increasing $\dot{V}O_2max$ was higher in men since their initial values of VO_2max were higher by 34.4%.

Gettman *et al.* (1978) also studied the effect of CWT using Universal Gym equipment. Subjects completed two sets of 15 repetitions with 30 seconds rest between each set before moving onto the next station. Training time reduced from 30 minutes to 23 minutes over the 20 weeks of the study. They found there was no significant increase in $\dot{V}O_2max$ when it was expressed in ml/kg lean body weight/min but there was if it was expressed in L/min (3.5% increase). They postulated that the increase in absolute $\dot{V}O_2max$ (L/min) was due to the increase in muscle mass which would presumably be able to metabolise more oxygen rather than an increase in the oxygen delivering potential of the individual. The 3.5% improvement was still substantially lower than a 17% improvement in $\dot{V}O_2max$ during a 20-week running programme conducted simultaneously. In the running programme subjects walked and jogged for 30 minutes maintaining an average heart rate of 85% of their maximal heart rate. In a further study, Gettman *et al.* (1982), reduced the rest interval of the circuit programme from 30 seconds to 15 seconds and this resulted in an increase in $\dot{V}O_2max$ (ml/kg/min) of 13% for females and 12% for males. The number of repetitions within each work interval were between 12 and 15. The reduction in the rest interval appears to be the important factor in creating increases in maximal aerobic power.

In contrast to these three studies, the study completed by Allen *et al.* (1976) in which subjects trained three times a week for 12 weeks using Universal Gym equipment, indicated no cardiorespiratory training effect with CWT. However, the study of Allen *et al.* (1976) did use high resistance and a low number of repetitions (five) with 30 seconds of work followed by 60 seconds of rest.

Subjects in the studies of Hurley *et al.* (1984) and Messier & Dill (1985) used a circuit of Nautilus equipment. In the study of Hurley *et al.* (1984) individuals completed 8-12 maximal repetitions of each exercise before moving immediately onto the next piece of equipment while Messier & Dill (1985) used 8-12 repetitions for the upper body and 15-20 repetitions for the lower body. After 16 weeks of training three to four times a week Hurley *et al.* (1894) found either no, or very little improvement in VO_2max while Messier & Dill (1985) reported an increase in $\dot{V}O_2max$ of 10.8% after 10 weeks of training. This increase was not significantly different from the increase in $\dot{V}O_2max$ demonstrated by

Table 3. Review of Changes in VO_2max with Aerobic Circuit Weight Training.

Study	sex	n	Type of training	Length of training (wk)	Duration of workout (min)	Work/Rest Ratio (sec/sec)	Intensity of Work (%1RM)	Change in VO_2max ml/kg/min (%)	Change in VO_2max ml/kg LBW/min (%)
Gettman *et al.*, 1982	M	16	IT/run	12	-	30/0	-	17*	10.6*
	F	16	IT/run	12	-	30/0	-	14.9*	12.7*
Cheah, 1986	M	12	IT/ex	10	30	30/15	40	7.9#*	-
Hoevet, 1990	F	19	IT/cycle	9	28	30/15	-	10*	-
Mosher *et al.*, 1994	F	17	IT/ex	12	45	30/30 (wts)	40-50	18*	-
						3m/1m(ex)	60%maxHR		

IT: isotonic weight machines used in training.
wts: weight machines
* significant

ex: aerobic exercise

% improvement in 1.5 mile run time

subjects who ran for 30 minutes at 60-90% of their heart rate reserve rather than participating in the CWT programme (Messier & Dill, 1985).

Haennel *et al.* (1989) used Hydra-fit hydraulic equipment to study cardiovascular function during CWT. This equipment allows only concentric muscle contractions with agonist and antagonist muscle groups being exercised alternately and provides variable resistance at constant speeds. The circuit consisted of 20-second work intervals at each station with a 1:1 work : rest ratio for 27 minutes, three times a week for nine weeks. One group completed the maximum number of repetitions possible within the 20 second work interval (an average of 16-17 repetitions), while another group exercised at 70-85% of the maximum number of repetitions possible (an average of 14-17 repetitions). Following training $\dot{V}O_2max$ increased significantly by 12.5% and 11.3% respectively compared with the control group. A group who trained concurrently at 70-85% of their heart rate reserve while cycling increased their $\dot{V}O_2max$ by 18.0%.

Development of resistance training equipment which allowed safe, high-velocity movements through variable hydraulic cylinders (Hydra-Fitness) led to a study by Petersen *et al.* (1988) which looked at the effect of a high-velocity resistance circuit on aerobic power. In five weeks a group of trained males increased their $\dot{V}O_2max$ by 9.5% by exercising for 40 minutes four times a week using 20-second sets of maximal exercise where greater than 20 repetitions were achieved and maintaining a work : relief ratio of 1:2. On average, the group exercised at 72% of their maximum heart rate reserve and at 59% of their $\dot{V}O_2max$.

1.1.2.3.2. Aerobic Circuit Weight Training

Other studies on circuit weight training have included aerobic activities within the weight training circuit (Gettman *et al.*, 1982; Cheah, 1986; Hoevet, 1990; and Mosher *et al.*, 1994). These studies have reported improvements in $\dot{V}O_2max$ of between 7.9% and 18%. The inclusion of aerobic stations as well as ensuring a high number of repetitions during each weight training station and short rest intervals appears to result in even greater gains in cardiorespiratory fitness. Table 3 summarises the effects of aerobic circuit weight training on cardiorespiratory fitness.

In 1979, Gettman *et al.* (1979) examined the interplay of circuit weight training and running (Table 2). In the first eight weeks of CWT, $\dot{V}O_2max$ improved by 3%. This was followed by an 8-week jogging programme at 85-90% of their maximum heart rate in which $\dot{V}O_2max$ improved by 8%. At the conclusion of the jogging programme half of the subjects returned to the CWT programme while the other half continued jogging for a further 8 weeks. Both groups maintained cardiorespiratory fitness equally well during the subsequent 8 weeks. This suggested to Gettman *et al.* (1979) that a circuit weight training programme may be more effective at maintaining cardiorespiratory fitness than improving it, as cardiorespiratory fitness can be maintained when the frequency of training is reduced provided the intensity is maintained (Fox *et al.*, 1989). It may therefore be that the intensity of CWT elicits the necessary physiological response to maintain cardiorespiratory fitness but not to improve it. In a subsequent study, Gettman *et al.* (1982) demonstrated a 15% increase in VO_2max in females and a 17% increase in VO_2max in males following a 12-week programme which combined 30-second weight training with 30-second interval running.

Cheah (1986) found that after 10 weeks of aerobic CWT there were significant improvement in aerobic power in his subjects with the average 1.5 mile run time improving by 7.9% (see Table 3) compared with 0.29% for the control group. Kangaroo jumps, shuttle runs, bench stepping, running on the spot and burpees were used for the aerobic stations and there was a 15 seconds rest between each weight training and aerobic station.

Hoevet (1990) studied the effects of 9 weeks of aerobic circuit weight training on females where subjects alternated between weight machines and cycling. Within the 30 seconds spent at each weight station, subjects performed 12-15 repetitions with the resistance set at 50% of their 5RM before moving on and doing 30 seconds of cycling at a resistance which elicited 65% of their maximum heart rate. Each 30 seconds of exercise was followed by a 15 second rest between each station. Subjects trained for 28 minutes three times a week. Hoevet observed a 10% improvement in VO_2max in his subjects. Unfortunately there was no parallel control group of subjects used in this study. The question of whether the changes in $\dot{V}O_2max$ he observed was due to the exercise programme or some other factor, therefore, remains equivocal.

A recent study by Mosher *et al.* (1994) on women who were not currently involved in any regular training showed an 18% improvement in $\dot{V}O_2max$ over 12 weeks. Training involved a 45 minute circuit of 30 activities made up of five 3-min aerobic exercises and twenty five 30-second weight training or calisthenic exercises. Subjects had a 1-minute rest after the aerobic activity and a 30-second rest after each set of 5 weight training exercises. Weights were increased when subjects could complete 20 repetitions correctly.

1.1.2.4. Problems of Testing for Cardiorespiratory Fitness

A major problem in evaluating a circuits weight training programme for changes in cardiorespiratory fitness is the specificity of testing in relation to the training programme. Gettman & Pollock (1981) have suggested that cycling and treadmill running as a test mode may not result in the highest possible increases in $\dot{V}O_2max$ as CWT involves training a variety of upper and lower body muscle groups, not just the lower body. When testing the effectiveness of CWT for improving cardiorespiratory fitness

Table 4. Changes in Body Composition with Circuit Weight Training and Aerobic Circuit Weight Training

Study	sex	n	type of training	Length of training (weeks)	Change in LBW (%)	Change in fat (%)
Wilmore *et al.*, 1978a	M	16	CWT	10	2.7	-1.5
	F	12	CWT	10	2.9	-1.8
Gettman *et al.*, 1978	M	11	CWT	20	2.8	-1.7
Gettman *et al.*, 1979	M	16	CWT	8	1.6	-0.9
Gettman *et al.*, 1982	F	14	CWT	12	3.9	-2.8
	M	16	CWT	12	2.6	-3.1
Gettman *et al.*, 1982	M	16	aer CWT	12	1.5	-3.2
	F	16	aer CWT	12	4.0	-4.1
Mosher *et al.*, 1994	F	17	aer CWT	12	3.8	-3.2

CWT: circuit weight training

aerCWT: aerobic circuit weight training

investigators have used treadmill running (Gettman & Pollock, 1981; Hurley *et al.*, 1984; Messier & Dell, 1985; Petersen *et al.*, 1988), the cycle ergometer (Marcinik *et al.*, 1985; Hoevet, 1990; Haennel *et al.*, 1989), arm cranking (Harris & Holly, 1987), Coopers 1.5 mile run (Cheah, 1986), recovery heart rate after a submaximal three-minute bench stepping test (Gettman & Pollock, 1981) and maximal rowing (Gettman & Pollock, 1981).

Apart from arm cranking, results were similar between the control and circuit training groups for all the modes of testing for cardiorespiratory fitness and it could be concluded that the specificity of testing does not bias the results. However, when arm cranking was used as the mode of testing, aerobic capacity was shown to increase by 21.1% as compared to an 11% increase when treadmill running was used as the mode of testing (Harris & Holly, 1987). As CWT involves a considerable amount of upper body exercise and arm cranking utilises the upper body musculature, it may be more specific for testing for improvements in cardiorespiratory fitness than the other modes of testing.

1.1.2.5. The Effectiveness of Circuit Training and Aerobic Circuit Weight Training for Improving Body Composition

Several studies have shown an increase in lean body mass and a decrease in fat mass with CWT and aerobic circuit weight training (Wilmore *et al.*, 1978a; Gettman *et al.*, 1978, 1979, 1982; Mosher *et al.*, 1994). Changes in body composition with CWT are summarised in Table 4.

In females, CWT has resulted in increases in lean body mass of between 2.9 and 3.9% (Wilmore *et al.*, 1978a; Gettman *et al.*, 1982) and for aerobic CWT between 3.8 and 4.0% (Gettman *et al.*, 1982; Mosher *et al.*, 1994). In males, CWT and aerobic CWT have resulted in increases of lean body mass of between 1.5 and 2.8% (Wilmore *et al.*, 1978a; Gettman *et al.*, 1978, 1982). Gettman *et al.* (1978) also compared running with CWT and found an increase of 2.6.% in lean body mass with running, compared with a 2.8% increase with CWT.

In females, CWT has resulted in decreases in body fat of between 1.8% and 2.8% (Wilmore *et al.*, 1978a; Gettman *et al.*, 1982) and for aerobic CWT between 3.2% and 4.1% (Gettman *et al.*, 1982; Mosher *et al.*, 1994). In males CWT and aerobic CWT have resulted in decreases in body fat of between 1.5% and 3.2% (Wilmore *et al.*, 1978a; Gettman *et al.*, 1978, 1982). Gettman *et al.* (1978) compared running with CWT and found a decrease of 2.6.% in body fat with running as compared with 1.7% in CWT. All these studies were completed over 10 to 20 weeks.

From these studies it would appear that CWT may be effective in altering body composition by increasing lean body mass and decreasing fat mass but it is probably not as effective as traditional strength training methods for increasing lean body mass. CWT is not as effective as aerobic exercises such as running and cycling for losing body fat as energy expenditure (oxygen consumption) is lower during CWT than running and cycling at the same level of perceived exertion (Wilmore *et al.*, 1978b; Hurley *et al.*, 1984; Petersen *et al.*, 1988; Ballor *et al.*, 1989). Wilmore *et al.* (1978b) reported that the average energy cost of CWT using a work (30-sec) to rest (15-sec) ratio of 2:1 and a total exercise time of 22.5 min for men and women was 37.8 and 25.2 kJ/min respectively. Ballor *et al.* (1989) reported an average energy cost of a hydraulic resistance circuit using a 30-sec work to 30-sec rest period, of 41.4 kJ/min and 27.6 kJ/min for men and women respectively. Mosher *et al.* (1994) increased the energy expenditure in their aerobic circuit to 36.5kJ/min for women by including five 3-minute aerobic activities.

1.1.3. The Physiological Basis of Circuit Weight Training

1.1.3.1. The Interaction of Strength and Endurance Training

In strength training a relatively small number of maximal or near-maximal muscle contractions are completed and in endurance training a large number of sub-maximal contractions are completed. Endurance training facilitates the transport and utilisation of oxygen with little or no increase in muscle strength while strength training elicits an increase in muscle strength with little or no change in the muscles ability to utilise oxygen (MacDougall, 1986; Schobersberger *et al.*, 1990). Circuit weight training involves a moderate number of sub-maximal contractions and could be seen to be a compromise between strength and endurance training as it attempts to improve both strength and oxygen utilisation.

Strength training combined with endurance training can compromise the development of strength but it does not compromise improvements in cardiorespiratory fitness (Dudley & Fleck, 1987; Hennessy & Watson, 1994). In high intensity strength training where the weight can be lifted for 5 or less repetitions there is fibre hypertrophy (particularly of the fast twitch fibres) which is associated with an increase in contractile protein and a change in myosin isoforms (Arnett, 1993) and a decrease in activity of the enzymes involved in aerobic pathways (Arnett, 1993). Strength training does not stimulate capillary growth and due to the increase in muscle fibre area it can lead to a decrease in capillary density and mitochondrial volume density (Saltin & Gollnick, 1983). In endurance training on the other hand, there is little increase in fibre size, a possible transformation of fast twitch to slow twitch characteristics and an increase in capillary density, mitochondrial volume density and activity of the oxidative enzymes (Arnett, 1993; Dudley & Fleck, 1987; Collins & Snow, 1993). The adaptive responses in skeletal muscle to strength and endurance training are thus different and sometimes opposite (Shield, 1992). It is possible, therefore, that skeletal muscle cannot adapt optimally to two contradictory stimuli when they are simultaneously imposed.

In contrast to maximal strength training, moderate or sub-maximal strength training where the weight can be lifted more than ten times results in similar adaptations to both strength and endurance training, although the strength gains are not as great as when maximal or near-maximal muscle contractions are used (Arnett, 1993). There is still hypertrophy of both the slow twitch and fast twitch fibres but there is also a possible increase in slow twitch characteristics with the fast myosin isoforms in the fast twitch fibres being replaced by isomyosin characteristic of slow twitch fibres (Arnett, 1993). By utilising moderate intensity high volume strength training, decreasing the rest period between work intervals thus increasing the metabolic cost of training and also including high intensity high volume aerobic or endurance training, as occurs in aerobic CWT, may be the best method for developing both strength and endurance.

Allen *et al.* (1976) used a protocol of high intensity low volume weight training for subjects using his circuit and found no increase in $\dot{V}O_2max$ but significant increases in strength. Wilmore *et al.* (1978a), Gettman *et al.* (1978, 1979, 1982), Hurley *et al.* (1984), Messier & Dill, (1985), Petersen *et al.* (1988) and Haennel *et al.* (1989), used moderate intensity high volume weight training but only found significant improvements in $\dot{V}O_2max$ if the rest interval between weight lifting was less than 30 seconds. The greatest increase in $\dot{V}O_2max$ was 12.5% (Haennel *et al.*, 1989). All the studies showed significant increases in strength. Gettman *et al.* (1982), Hoevet (1990) and Mosher *et al.* (1994) used moderate intensity high volume weight training combined with high intensity aerobic interval training and demonstrated increases in $\dot{V}O_2max$ of up to 18% (Mosher *et al.*, 1994). Strength increases were very similar to the studies using a circuit weight training protocol. However the CWT and aerobic CWT studies could not be compared with the protocol of Allen *et al.* (1976) as a different method was used to evaluate strength gains. It would therefore appear that the development of strength is not compromised by the endurance component of circuit weight training, although circuit weight training will probably still not result in as great strength gains as strength training using a high intensity, low volume programme because of high blood lactate levels (Noble *et al.*, 1984; Hurley *et al.*, 1984) which contribute to fatigue and prevent maximal training.

Although studies of concurrent strength and endurance training have shown that endurance training compromises strength gains, no studies have shown that strength training compromises endurance development (Dudley & Fleck, 1987; Bell *et al.*, 1991; Sale *et al.*, 1990a,b; Collins & Snow, 1993; Arnett, 1993; Hennessy & Watson, 1994), therefore it is unlikely that endurance development will be inhibited during CWT.

Table 5. Variations in the Relationship between %VO2max, %HRmax, and %HRR during Circuit Weight Training and Treadmill Running.

Study	sex	n	exercise	%VO_2max	%HRmax	%HRR
ACSM, 1990	-	-	-	40	55	40
	-	-	-	50	60	50
	-	-	-	85	90	85
Wilmore *et al.*, 1978	M	16	CWT	38.5	72	-
	F	12	CWT	44	82	-
Hurley *et al.*, 1984	M	13	CWT	45	-	80
	M	13	TM	45	-	45
Petersen *et al.*, 1988	M	16	CWT	58.5	-	72
Ballor, 1989	M	20	CWT	44	>80	-
	F	15	CWT	47	>80	-
Swain *et al.*, 1994	M	81	TM	40	62.5	-
	F	81	TM	40	63.9	-
	M	81	TM	85	91.5	-
	F	81	TM	85	91.9	-

CWT - circuit weight training
TM - treadmill running
HRmax - maximum heart rate
HRR - heart rate reserve

1.1.3.2. Reasons for Small Improvements in $\dot{V}O_2max$ with Circuit Weight Training

Some studies on the effects of CWT indicate either no or very little increase in $\dot{V}O_2max$ (Allen *et al.*, 1976; Gettman *et al.*, 1978, 1979; Hurley *et al.*, 1984), while others indicate increases of between 10% and 13% (Wilmore *et al.*, 1978a; Gettman *et al.*, 1982; Messier & Dill, 1985; Petersen *et al.*, 1988; Haennel *et al.*, 1989. This is in spite of the high sustained heart rate that occurs in most studies (greater than 80% of the subjects' maximum heart rate) and adequate duration and frequency of training. Hurley *et al.* (1984) proposes that the one stimulus that is missing is a high enough oxygen consumption.

Heart rate monitoring is an indirect way of estimating oxygen utilisation by the body as heart rate and oxygen consumption are generally related in a linear fashion over a wide range of values (Fox, 1973; Swain *et al.*, 1994). When compared on a percentage of maximum basis, during most modes of exercise 60% of an individuals maximum heart rate occurs at 50% $\dot{V}O_2max$ or 50% HRR (heart rate reserve) and 90% of maximum heart rate occurs at 85% $\dot{V}O_2max$ or 85% HRR (ACSM, 1990; see Table 5). However, the use of different sized muscle groups (Stenberg *et al.*, 1967), the use of different muscle groups of the same size (Vokac *et al.*, 1975; Toner *et al.*, 1990), variations in emotional factors (Vokac *et al.*, 1975; Toner *et al.*, 1990), ambient temperature (Brouha *et al.*, 1963) and the amount of static muscle contraction (Sanchez *et al.*, 1979), can all modify the relationship between heart rate and oxygen uptake. Variations in $\%\dot{V}O_2max$, %HRmax and %HRR from different studies using varying modes of exercise are presented in Table 5. Swain *et al.* (1994) found that when treadmill running at $40\%\dot{V}O_2max$, subjects were working at 63%HRmax as compared with the 55%HRmax stated by ACSM (1990) as the average for most modes of exercise. %HRmax or %HRR at the same relative oxygen uptake are even greater during CWT (Wilmore *et al.*, 1978b; Hurley *et al.*, 1984; Petersen *et al.*, 1988; and Ballor *et al.*, 1989). For example, circuit weight training and running on the treadmill at 45% VO_2max resulted in subjects working at 80% HRR when CWT and at 45% HRR when running on the treadmill (Hurley *et al.*, 1984).

ACSM (1990) states that an increase in $\dot{V}O_2max$ can only occur when the intensity of training is greater than 50% $\dot{V}O_2max$. During most modes of exercise this is equivalent to greater than 60% HRmax. In CWT programmes where oxygen uptake has been measured, the oxygen consumption was about 45% of $\dot{V}O_2max$ (which is less than the threshold necessary for stimulating an increase in $\dot{V}O_2max$) but heart rate was greater than 70%HRmax (Wilmore *et al.*, 1978a; Hurley *et al.*, 1984; and Ballor *et al.*,1989). The exception to this was the study of Petersen *et al.* (1988) who reported an average oxygen uptake of 59% $\dot{V}O_2max$. However, he used a high velocity circuit and his moderately fit males had an average heart rate greater than 80% of HRmax during training. Such a high intensity probably would not be sustainable by a more sedentary person. As ratings of perceived exertion are extremely high during circuit training, much higher than walking at the same oxygen requirement (Hurley *et al.*, 1984), it would be difficult for a subject to work harder in order to achieve greater oxygen uptake values.

Four possible factors have been speculated to be responsible for the high heart rate in relation to oxygen uptake seen during CWT; (1) a decrease in stroke volume or failure to increase stroke volume in proportion to the exercise demands (Allen *et al.*, 1976; Petersen *et al.*, 1988), (2) a smaller muscle mass associated with upper body exercises (Vokac *et al.*, 1975), (3) a larger static exercise component (Allen *et al.*, 1976; Toner *et al.*, 1990) and (4) the release of catecholamines (Hurley *et al.*, 1984).

In the study by Hurley *et al.* (1984), the oxygen pulse (oxygen uptake per heart beat) was found to be much lower during a Nautilus exercise session than walking at the same oxygen uptake. As oxygen pulse is a relative indicator of stroke volume (Astrand & Rodahl, 1986), this suggests that stroke volume is not increased to the same extent during CWT training as in other forms of exercise such as walking.

Heart rate values have been shown to be higher and stroke volume lower for arm exercises than for leg exercises alone and combined arm and leg exercises at a given oxygen uptake (Stenberg *et al.*, 1967; Toner *et al.*, 1990). This suggests that lower body exercise may augment venous return thereby maintaining cardiac output. There is normally a very close relationship between oxygen uptake and cardiac output and except under exceptional conditions, such as hypoxia, if stroke volume is reduced there is a compensatory increase in heart rate in an attempt to maintain cardiac output (Rowell, 1974; Astrand & Rodahl, 1986).

The smaller muscle mass associated with upper body exercises, in particular arm exercises, may contribute to the high heart rate in relation to oxygen uptake seen during CWT. The smaller muscle mass used during CWT will also reduce the training stimulus for the oxygen transport system and this may partly explain the low improvement in cardiorespiratory fitness after a programme of CWT (Toner *et al.*, 1990).

Catecholamines may play a role in the high heart rate relative to oxygen uptake by stimulating an increase in heart rate. Hurley *et al.* (1984) and Noble *et al.* (1984) showed that CWT results in a very large stress response. During the Nautilus CWT used by Hurley *et al.* (1984), noradrenaline was found to be 7 fold greater and adrenaline 4.5 fold greater than treadmill walking at the same oxygen uptake. Noble *et al.* (1984) also showed that a large increase in noradrenaline and adrenaline as well as cortisol occurred in their high intensity weight training circuit. On a cycle ergometer noradrenaline only increases markedly when the exercise intensity is greater than 60% VO_2max but during isometric exercise, noradrenaline is significantly higher than high intensity cycling even though the energy cost is lower (Hurley *et al.*, 1984). Thus, when the exercising muscle occludes the circulation during isometric exercise, the accumulated trapped metabolites may contribute to the sympathetic drive (Astrand & Rodahl, 1986), thus increasing the level of catecholamines.

Increases in $\dot{V}O_2max$ are not only associated with increases in cardiac output but also with increases in oxidative capacity of the muscle which is reflected by changes in mitochondrial volume density. Resistance training results in a decrease in mitochondrial volume density as there is no parallel increase in mitochondrial volume alongside the hypertrophy of muscle fibers (MacDougall *et al.*, 1979). It would therefore appear that resistance training (and possibly CWT) does not enhance endurance characteristics of the muscle fibres themselves and may even be detrimental.

In CWT each muscle group is exercised for a very short duration (30-40 seconds) so that although a high heart rate is sustained the duration is too short to be effective at promoting aerobic conditioning at the muscle level. Aerobic metabolism responds very slowly to increases in energy requirements and it may take one to three minutes or more before all the peripheral components (aerobic enzyme activities, capillary dilation, etc) and central components (cardiac output) are operating at full efficiency at the new work level or within the new muscle group being utilised. During the exercise process, anaerobic metabolic processes, primarily the lactic acid energy system must meet most of the energy demands. This results in a rapid accumulation of lactic acid causing muscle fatigue and thereby significantly reducing the intensity at which the exercise can be performed.

The degree of improvement in cardiorespiratory fitness as a result of CWT will depend largely on the type of circuit used. CWT may result in increases in $\dot{V}O_2max$ of between 10 and 13 % when the repetitions are kept high at each station (between 12 and 20) and the rest period between stations is less than 30 seconds (Wilmore *et al.*, 1978a; Gettman *et al.*, 1982; Messier & Dill, 1985; Petersen *et al.*, 1988; Haennel *et al.*, 1989). With lower repetitions and rest periods of 30 seconds or longer between exercise sets there is little or no improvement in VO_2max (Allen *et al.*, 1976; Gettman *et al.*, 1978, 1979; Hurley *et al.*, 1984). When aerobic exercises are included in the circuit, improvements in $\dot{V}O_2max$ are higher, from 10-18% (Gettman *et al.*, 1982; Hoevet, 1990, Mosher *et al.*, 1994). However the aerobic circuits still produce less improvement than other aerobic forms of exercise such as running done over the same period of time where $\dot{V}O_2max$ can improve by 15-20% (Gettman *et al.*, 1978; Haennel *et al.*, 1989). The smaller increase in $\dot{V}O_2max$ despite the high sustained heart rate is probably due to the relatively low oxygen uptake while circuit training (about 45% VO_2max) (Wilmore *et al.*, 1978b; Hurley *et al.*, 1984; Petersen *et al.*, 1988; Ballor *et al.*, 1989).

1.1.4. Summary

A variety of different circuit weight training programmes have been studied to find how effective they are at improving fitness (Allen *et al.*, 1976; Wilmore *et al.*, 1978a; Gettman *et al.*, 1978, 1979, 1982; Hurley *et al.*, 1984; Messier & Dill, 1985; Cheah, 1986; Petersen *et al.*, 1988; Haennel *et al.*, 1989; Hoevet, 1990, Mosher *et al.*, 1994). The programmes range from CWT with varying work : rest ratios, varying repetitions and intensity of training and utilise different equipment (Allen *et al.*, 1976; Wilmore *et al.*, 1978a; Gettman *et al.*, 1978, 1979; Hurley *et al.*, 1984; Messier & Dill, 1985; Petersen *et al.*, 1988; Haennel *et al.*, 1989), to aerobic weight training circuits which incorporate various aerobic activities into the circuit (Gettman *et al.*, 1982; Cheah, 1986; Hoevet, 1990, Mosher *et al.*, 1994). All the circuits studied have been effective at improving strength, although they are not quite as effective as traditional strength training methods. Improvements in cardiorespiratory fitness range from no effect (Allen *et al.*, 1976; Wilmore *et al.*, 1978a; Gettman *et al.*, 1978; Hurley *et al.*, 1984), to significant improvements (Gettman *et al.*, 1979, 1982; Messier & Dill, 1985; Petersen *et al.*, 1988; Haennel *et al.*, 1989; Hoevet, 1990; Mosher *et al.*, 1994) although the improvements are not as great as programmes such as running and cycling. Factors which appear to be important in circuit weight training programmes for increases in cardiorespiratory fitness are the number of repetitions completed for each exercise, the duration of the rest period between exercises, the inclusion of aerobic stations, oxygen uptake while exercising and the number of weeks the subject follows the programme.

1.2. The Present Study

The aim of this study was to find how effective exercising using the 'supercircuit' developed at The Massey University Recreation Centre is at improving cardiorespiratory fitness, muscle strength and endurance, body composition and flexibility.

The 'supercircuit' was developed to offer people a generalised conditioning programme for developing muscular strength and endurance, cardiorespiratory fitness and induce weight loss if required, but its layout and design was limited by the equipment and the space available at The Massey University Recreation Centre.

The 'supercircuit' is used by a large number of students and staff at Massey University to help improve and maintain their fitness and it could be utilised more effectively to help people develop the best exercise programme for their needs if its effectiveness was known.

2. Methods

2.1. Subjects

Females volunteers who had not done any regular exercise for at least two months were sought by advertisement in the Massey University newsletter. Of the 101 women who initially responded to the advertisements, 44 of these volunteered to take part in the study as either controls or to take part in the supercircuit programme. Thirty eight completed the study. Each subject completed a PAR-Q questionnaire (Physical Activity Readiness Questionaire - see Appendix A.1) (ACSM, 1991) to ensure there were no apparent contraindications to their participation in the fitness tests and the exercise programme. The project was approved by The Massey University Human Ethics Committee and an informed consent form was completed prior to the first fitness test.

2.2. Experimental Design

Each subject underwent two initial fitness tests, one fitness test three weeks later, and two final fitness tests after six weeks. In 1994, prior to her first fitness test, each subject filled in a questionnaire on her perceived level of fitness (see Appendix A.2). At the completion of the six weeks she completed a second questionnaire on her perceived level of fitness and a further questionnaire on perceived changes in various aspects of fitness (see Appendix A.3).

Nineteen of the subjects took part in the supercircuit programme while the other nineteen (controls) did not take part in any regular exercise. All the subjects were asked to maintain their normal eating habits and activities. The study took place over two separate time periods. The first group (made up of six individuals who did supercircuit training and six individuals who acted as controls) took part in the study at the beginning of 1993, while the remaining group (13 supercircuit and 13 controls) took part in 1994. A further six subjects started the supercircuit programme but did not complete the six weeks of training. All of these were from the second (1994) group. The protocols for the two groups were identical except where specifically noted.

2.3. Supercircuit Training

The supercircuit group had one session where each participant was instructed in the correct use of the equipment, how the supercircuit sessions were organised and how to do the stretches correctly. She then attended supercircuit training three times a week for six weeks under the supervision of Recreation Centre staff. Each session lasted between

Table 6. Mean Heart Rate during One exercise Session of Each Subject from the 1994 Group while Participating in the Supercircuit Programme

Subject Code Number	Estimated Maximum Heart Rate (220-age)	Mean Heart Rate	% of estimated Maximum Heart Rate
01	198	151	76
02	181	145	80
03	199	157	79
04	178	153	86
05	165	142	86
06	176	139	79
07	172	141	82
08	188	147	78
09	193	158	82
10	193	137	71
11	188	141	75
12	186	145	78
13	189	149	79

For one exercise session, each subject wore a Polar Sports Tester which recorded the mean heart rate every minute. At the completion of the supercircuit session the mean heart rate for the entire session was calculated from the mean heart rate each minute.

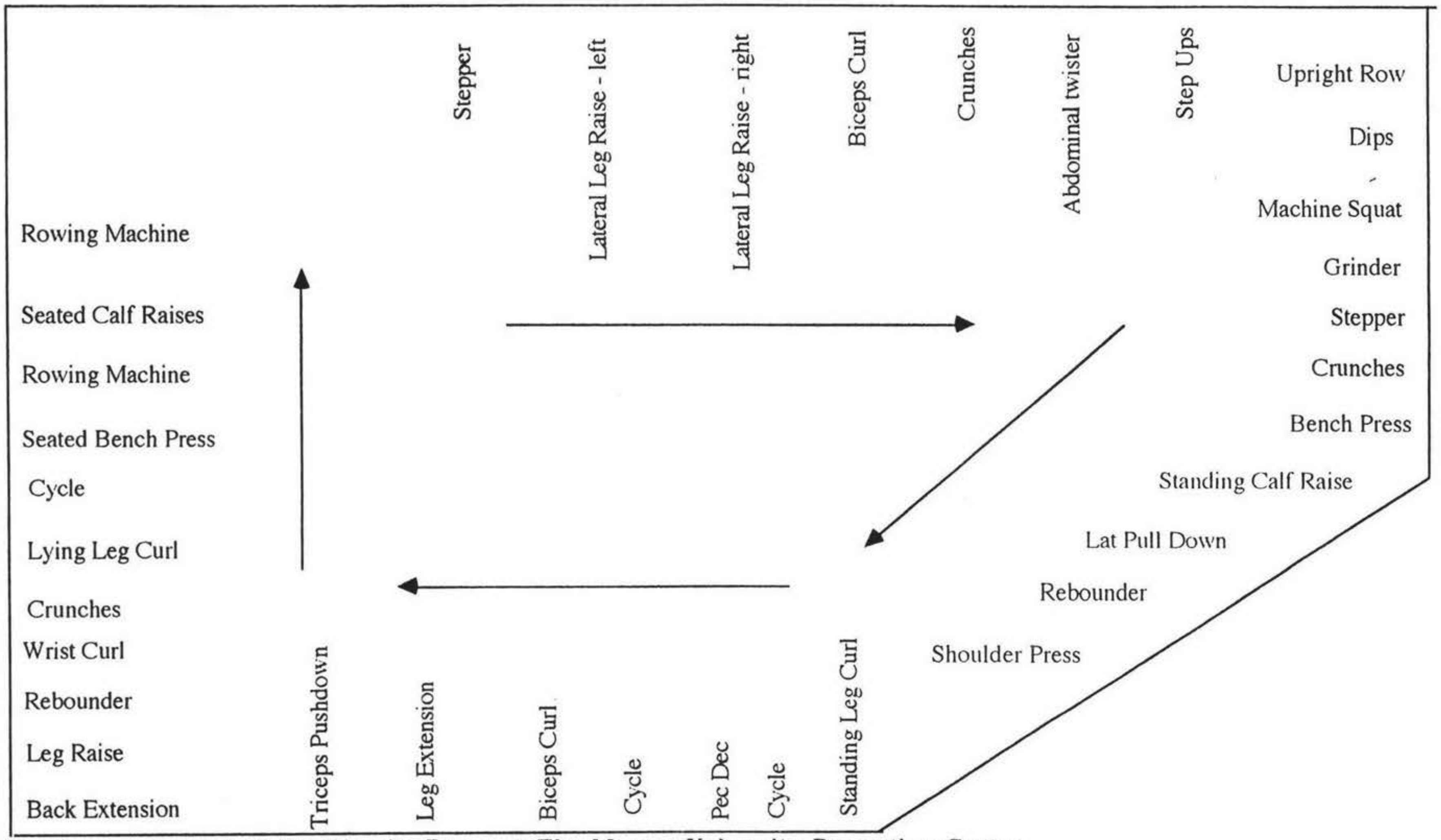

Fig 1. Layout of the Circuits Room at The Massey University Recreation Centre.
Participants start at a cardiovascular station and move in a clockwise direction, exercising for forty seconds at each station.

25 and 40 minutes. Initially, individuals completed a minimum of 25 minutes of training but each individual was encouraged to extend this time after two to three weeks. During each exercise session each subject checked her pulse rate after completing an aerobic station such as cycling to ensure she were training in the range of 55-90% of her estimated maximum heart rate as recommended by ACSM (1990). An approximate working heart rate was obtained by palpating her radial artery for 10 seconds and converting the number to beats/minute. Each subject from the 1994 group also wore a heart rate monitor (Polar Sport Tester, Kimpele, Finland) for one exercise session for the duration of the supercircuit to ensure her heart rate was in the correct training zone. The average heart rate and percentage of estimated maximum heart rate (calculated from 220-age; Astrand & Rodahl, 1986) for each subject while completing a supercircuit training session with a Polar Heart Rate Monitor is shown in Table 6. The individual average heart rate for the duration of a training session ranged from 71% to 86% of her estimated maximum heart rate.

The 'supercircuit' at The Massey University Recreation Centre was made up of a series of weight training exercises using weight machines, calisthenic exercises and cardiovascular exercises, which was comprised of 17 weight training stations (Polaris, and Fitness Works), eleven stations of aerobic exercises (eg rowing, cycling, step ups) and eight calisthenic exercises (e.g. crunches, back extensions) (Fig 1). Of the 36 exercises in the circuit, 11 were cardiovascular and the remaining 25 were muscular endurance/strength exercises with five for the abdominal muscles, two for the back, six for the upper legs, two for the lower legs, three for the shoulders, three for the chest and four for the arms. The circuit was designed such that the upper body exercises alternated either with lower body exercises or antagonistic muscle groups. For example, the biceps curl was followed by the calf raise and the leg extension was followed by a triceps press. If two upper (or lower body) exercises were placed consecutively, the exercises used antagonistic muscles (eg biceps curl followed the bench press which involved the use of the triceps muscle). Aerobic exercises were included at regular intervals. The major training effect of each exercise is shown in Appendix A.4. Subjects exercised at each station for 40 seconds and then moved immediately on to the next station. A buzzer signalled when the 40 seconds was completed. The subjects were instructed to complete 15-20 repetitions at each weight training station with the weight set such that they could complete no more than 15-20 repetitions (15-20RM, or approximately 40-50% of their 1RM). Some exercises, such as the back extension and crunches, which were performed slowly resulted in fewer repetitions occurring within the 40 seconds. Participants began each exercise session with two to three minutes of exercise at a cardiovascular station and then moved around the circuit. After completing the circuit training, participants spent three to five minutes stretching, following the 'Saw Series' stretching charts prepared by the Accident Compensation Corporation for the lower and upper calves, hamstrings, quadriceps, lower back and shoulders.

2.4. Fitness Testing

The following variables were measured in this order for each subject: height, body mass, blood pressure, skinfolds, pre-exercise heart rate, estimated maximum oxygen uptake, recovery heart rate, flexibility of the hamstring muscle group, soleus muscle, gastrocnemius muscle and shoulders, and strength/endurance of the abdominal muscles, upper body and lower body.

2.4.1. Body Composition

2.4.1.1. Height and Body Mass

Height was measured to the nearest 0.5cm using a stadiometer fixed to the wall. Body mass was assessed (to the nearest 0.1kg) using electronic scales (Tanita, Japan).

2.4.1.2. Skinfolds

Skinfold thickness was measured with a Lafayette skinfold caliper (model 01127, Layfayette Instrument Comp., Illinois, U.S.A.) at the following sites: (1) triceps - the vertical fold midway between the tip of the elbow and the tip of the shoulder, (2) subscapular - the oblique fold just below the bottom tip of the scapular, (3) suprailiac - the slightly oblique fold just above the hip bone, (4) abdomen - the vertical fold 2cm to the right of the umbilicus, (5) anterior thigh - the vertical fold at the midline of the thigh, two-thirds of the distance from the knee cap to the hip, and (6) medial calf - the vertical fold at the widest point of the calf. These sites are shown in Appendix A.5 and are the same sites that were used in the Life in New Zealand survey (Wilson *et al.*, 1993). All the measurements were taken on the right hand side of the body with the subject standing. One measurement was made at each site, this was then repeated and if any measurement was more than 1mm different from the first reading, a third measurement was taken. The skinfold score for each site was the average of the two closest measurements (McArdle *et al.*, 1991).

To obtain an indication of the relative amount of body fat among the individuals, the skinfold scores were summed and presented as (i) the sum of six skinfolds (SKF-6) which is indicative of total body fat and (ii) the sum of two trunk skinfolds (SKF-2) which is indicative of central fat distribution (Wilson *et al.*, 1993).

2.4.2. Flexibility and Strength Measures

2.4.2.1. Flexibility of the Hamstring Muscle Group

Flexibility of the hamstring muscle group (and lower back) was assessed using the sit-and-reach test (Wells & Dillon, 1952; Hoeger & Hopkins, 1992; Handcock, 1994). Each subject assumed a sitting position on the floor with her feet up against a box with a metre ruler on it. Keeping her knees flat on the floor the subject reached forward as far as possible down the metre rule and held the position for two seconds. The score or distance reached on the third attempt was recorded. This was then repeated first with one foot placed up against the box and the other leg moved to the side, and then the alternate foot placed up against the box and the other leg moved to the side.

2.4.2.2. Flexibility of the Gastrocnemius and Soleus Muscles

Flexibility of the gastrocnemius and soleus muscles was assessed by measuring the vertical distance between the base of the knee and the floor while stretching either the gastrocnemius or soleus muscle group . The base of the knee was first marked with the subject standing upright. Each subject was then asked to assume the stretching position for the gastrocnemius muscle group while in bare feet and without lifting the heel off the floor (Saw Series, Accident Compensation, Corporation) and the vertical distance between the base of the knee and the floor was measured with a tape measure. This was repeated for the opposite leg. Each subject was then asked to assume the stretching position for the soleus muscle group (Saw Series, Accident Compensation, Corporation) and the vertical distance between the base of the knee and the floor was measured with a tape measure. This was repeated for the opposite leg.

2.4.2.3. Flexibility of the Shoulders

Flexibility of the shoulders was assessed by the Apley Scratch Test (Handcock, 1994). Placing one arm behind the back and reaching upwards and the other hand over the shoulder and reaching downwards and attempting to contact the opposite hand gives a crude measure of internal shoulder rotation and adduction for one limb (the lower hand) and of external rotation and abduction for the other limb (the upper hand). The overlap or distance between finger tips was measured.

2.4.2.4. Abdominal Muscle Strength/Endurance

Abdominal muscle strength (endurance) was measured by counting the number of correct crunches each subject could do in a maximum time of one minute (Handcock, 1994).

able 7. Method of Estimating a One Repetition Maximum from the Maximum Load which can be Lifted Less than Ten Times

Maximum number of repetitions	Proportion of Maximum Load	
	% maximum of 1RM	Fraction of 1RM
1	100	1
2	94.3	.94
3	90.6	.91
4	88.1	.88
5	85.6	.86
6	83.1	.83
7	80.7	.81
8	78.6	.79
9	76.5	.77
10	74.4	.74

To determine the estimated 1RM divide the final weight lifted by the fraction of 1RM corresponding to the number of repetitions achieved. From Paterson & Poliquin, (1987). eg if 10kg is lifted 8 times, the estimated 1RM would be 10kg divided by 0.79 or 12.7kg.

The subject lay supine on the floor with knees bent such that the heels were approximately 30cm from the buttocks and her hands were resting on her thighs. Each subject curled up in a controlled manner with relaxed shoulders and arms until her hands touched her knees. After two or three practice crunches to ensure correct technique each subject completed as many crunches as possible in one minute. If the subject no longer maintained correct technique she was stopped before the minute was completed.

2.4.2.5. *Upper and Lower Body Strength*

Upper and lower body strength were assessed either by estimating the maximum weight each subject could lift once only (1RM) (1993 group) (Paterson & Poliquin, 1987; Hoeger *et al.*, 1987; 1990; Mayhew *et al.*, 1992), or by determining the maximum number of repetitions each subject could achieve at a set weight (1994 group). For upper body strength the Polaris bench press machine was used and for lower body strength the Fitness Works leg press machine in 1993 and the Fitness Works leg extension machine in 1994.

Estimation of a One Repetition Maximum

After an initial warm up set of 10 repetitions with a light weight, the weight was increased and each subject was asked to complete a further 10 repetitions. If the subject completed 10 correct repetitions and felt she could do more, the weight was increased by 2.2kg and each subject was asked to attempt a further 10 repetitions. This was repeated until the subject could no longer complete 10 repetitions. All subjects were given a rest of 2-3 minutes between each set of repetitions. The estimated 1RM was then calculated from the last weight attempted and the number of repetitions achieved. See Table 7 (from Paterson & Poliquin, 1987).

Maximum Repetitions for a Set Weight.

After an initial warm up set of 10 repetitions with a light weight, the weight was increased and the subject was asked to do as many repetitions as possible. The weight chosen for the second set depended on how hard the subject found the warm up set of weights. The aim was to choose a weight such that the subject could do somewhere between 5 and 15 repetitions for the second set. In subsequent tests on each subject, the weight was kept the same.

2.4.3. Cardiorespiratory Fitness

2.4.3.1. Cycle Ergometer Test

Systolic and diastolic blood pressure measurements were taken prior to the cycle ergometer test using a Riester portable sphygmomanometer to the nearest 2mm of Hg. Heart rate was monitored prior to, throughout the test, and for three minutes after the test, with either an electrocardiogram (ECG) using three precordal leads and a commercial isolated ECG and heart rate monitor (NT 117 isolated ECG. manufactured by Neomedix Systems, Sydney, Australia) or a heart rate monitor (Polar Sport Tester, Kimpele, Finland). The recorded heart rate was the average heart rate over 10 seconds. Prior to the test, subjects sat on the cycle ergometer (Monark Ergomedic 818E), adjusted to the correct seat height until three consecutive heart rate readings taken five seconds apart were within five beats of each other. This was recorded as the pre-exercise heart rate. Subjects then cycled for 12 minutes at 60rpm with the work load being increased every 4 minutes. The pedal frequency of 60rpm was controlled by subjects reading the pedal frequency directly from the control panel on the ergometer and adjusting the pedal rate as necessary. The first work load was set at 45 watts, the second at 75 watts, and the third at either 90 watts or 105 watts depending on the heart rate achieved at the end of the second work load. The target heart rate for the third work load was 70-80% of the subjects estimated maximum heart rate which was calculated as 220-age (Astrand & Rodahl, 1986). The work loads used for the first test were used for all subsequent tests. There were three exceptions to this: for one supercircuit subject, who weighed 38.5kg, the 3 work loads used were 0, 30, and 45 watts; and for a supercircuit subject and a control subject whose heart rates were greater than 75% of their estimated maximum heart rate at the second work load (Astrand & Rodahl, 1986), only two work loads of 45 and 75 watts were used. Expired gases were collected in a Douglas Bag for the last minute of each work load. The average heart rate over the last 10 seconds of each work load was recorded. Subjects also gave a subjective rating of perceived exertion (Rating of Perceived Exertion) based on the Borg scale (see Appendix A6; Borg, 1982) at the completion of each work load. After the completion of the last work load, the work load was decreased to zero and subjects pedalled at 40rpm for a further two minutes, and then sat on the ergometer for a further one minute. The average heart rate over the final 10 seconds of each minute was recorded i.e. at one, two, and three minutes after the completion of the third work load. In the latter stages of the study a fault developed with the cycle ergometer resulting in the work load decreasing to approximately 30 watts rather than zero.

The oxygen and carbon dioxide content of the expired air in each Douglas Bag was analysed using a Datex Normocap gas analyzer (London, U.K.) modified to provide one decimal place of accuracy on the percentage oxygen scale, and the volume measured with a standard 'dry' gas volume meter (Harvard Apparatus, United Kingdom). The gas analyzer was calibrated both against gas (N.Z.I.G., Wellington) containing 15.5% oxygen and 3% carbon dioxide, and against air. Oxygen uptake was calculated from the fraction of oxygen and carbon dioxide in the expired air according to the Draft International Standard (1993). Estimated VO_2max was estimated from heart rate, and either external work load or oxygen uptake during the final work load from the nomagram of Astrand & Rodahl (1986) (see Appendix A.7). This value was then adjusted by multiplying it by an age correction factor (Astrand & Rodahl, 1986) (see Appendix A.7).

2.4.4. Statistical Analysis

Statistical analysis was completed using 'Statview', a programme for the MacIntosh computer. The mean, standard deviation, and standard error were computed at zero, three, and six weeks for both the supercircuit and control groups.

Multiple regression, one factor analysis of variance (ANOVA), and 2-tailed t-tests were used to compare the supercircuit and control groups (Thomas & Nelson, 1990). The variables used in the multiple regression equations were T (time, where T=0, 1, or 2, for 0, 3, or 6 weeks), C (condition or training status, in which the control group = 0, and the supercircuit group = 1), CxT (the linear interaction of training with time), Tsq (time squared), and CxTsq (the quadratic interaction of training with time). When the regression analyses were performed the least significant variables were eliminated from the equation one at a time until only the significant variables ($p<.05$) remained.

Table 8. A Comparison of the Characteristics of the 1993 and 1994 Subjects using ANOVA.
The results are from the first two tests which were done prior to starting supercircuits.

	1993 Group		1994 Group		ANOVA
Variable	Mean	SD	Mean	SD	F
Age (yrs)	28.3	8.2	29.8	5.8	1.2
Height (cm)	165.9	5.3	164.8	10.3	0.2
Body Mass (kg)	67.8	7.5	67.5	11.8	0.2
Systolic Blood Pressure (mm Hg)	114.2	7.2	111.9	8.9	4.8*
Diastolic Blood Pressure (mm Hg)	77.8	5.0	71.5	7.6	8.4*
SKF-2 (mm)[1]	51.2	15.5	55.5	18.3	0.0
SKF-6 (mm)[2]	146.2	37.6	166.5	42.1	0.3
Right + Left Hamstring (cm)	21.2	7.6	22.5	12.6	0.8
Right Hamstring (cm)	22.3	8.0	24.3	11.5	1.6
Left Hamstring (cm)	21.4	7.7	23.8	12.0	1.7
Right Soleus (cm)	31.7	3.5	30.1	3.2	0.6
Left Soleus (cm)	33.4	3.5	30.4	3.3	5.3*
Right Gastrocnemius (cm)	32.0	4.2	32.9	2.6	1.2
Left Gastrocnemius (cm)	33.5	3.7	33.3	2.8	0.3
Right Shoulder (cm)	0.1	6.2	2.8	5.4	0.5
Left Shoulder (cm)	1.8	6.1	5.4	3.9	0.6
Crunches (repetitions)	22.5	7.3	35.3	6.6	12.2*
Pre-exercise Heart Rate (bpm)	84.8	13.7	80.0	7.7	1.3
Perceived Exertion (RPE)[3]	15.7	2.1	13.8	1.6	2.3
Estimated VO_2max (ml/kg/min)[4]	38.1	8.0	35.4	5.1	2.3

Sum of the suprailiac and abdominal skinfolds.

Sum of the triceps, subscapular, suprailiac, abdominal, thigh, and calf skinfolds.

Rating of Perceived Exertion at the final work load for the cycle ergometer test (Borg, G.A., 1982).

Estimated VO_2max determined from heart rate and external work done (watts) at the final work load.

Significant difference between the two groups (F must be greater than 4.1 for $p<.05$). The summary tables for ANOVA are shown in Appendix C.1.

Table 9 continued.

Variable	Supercircuit Group		Control Group		ANOVA
	Mean	SD	Mean	SD	F
Pre-exercise HR (bpm)	81.5	10.1	80.8	10.3	0.06
Rating of Perceived Exertion[3] (n=18), (n=18)	14.5	2.0	14.8	1.8	0.24
Estimated VO_2max (ml/kg/min)[4] (n=17), (n=19)	34.5	5.2	32.4	7.4	1.07
Estimated VO_2max (ml/kg/min)[5]	36.2	6.2	34.2	7.7	0.84

n=19 for both the supercircuit group and control group for all variables except Bench Press repetitions, Bench Press estimated 1RM (repetition maximum), Leg Extension repetitions, Leg Press estimated 1RM, estimated VO_2max, and Rating of Perceived Exertion. For these variables, the number in the supercircuit and control groups are written under the variable.

1 Sum of the suprailiac and abdominal skinfolds.
2 Sum of the triceps, subscapular, suprailiac, abdominal, thigh, and calf skinfolds.
3 Rating of Perceived Exertion at the final work load for the cycle ergometer test (Borg, G.A., 1982).
4 Estimated VO_2max determined from heart rate and oxygen uptake (litres/min) at the final work load.
5 Estimated VO_2max determined from heart rate and external workload (watts) at the final work load.

There was no significant difference between the two groups (F must be greater than 4.1 for $p<.05$). The summary tables for ANOVA are shown in Appendix C2.

Table 9. A Comparison of the Characteristics of the Supercircuit and Control Groups using ANOVA.
The results are from the first two tests undertaken prior to starting supercircuits.

	Supercircuit Group		Control Group		ANOVA
Variable	Mean	SD	Mean	SD	F
Age (yrs)	29.4	6.5	31.8	7.5	1.13
Height (cm)	165.1	8.9	164.4	5.9	0.07
Body Mass (kg)	67.6	10.5	65.5	7.5	0.48
SKF-2 (mm)[1]	54.2	17.4	50.6	12.7	0.49
SKF-6 (mm)[2]	160.1	41.4	157.8	32.6	0.03
Systolic Blood Pressure (mm Hg)	112.6	8.4	111.5	10.6	0.18
Diastolic Blood Pressure (mm Hg)	73.5	7.4	74.1	6.7	0.10
Right + Left Hamstring (cm)	22.1	11.1	26.3	10.2	1.34
Right Hamstring (cm)	23.7	10.5	27.3	8.8	1.33
Left Hamstrings (cm)	23.1	10.9	26.1	10.7	0.71
Right Gastrocnemius (cm)	32.6	3.1	33.7	3.5	1.03
Left Gastrocnemius (cm)	33.4	3.1	34.8	3.1	2.16
Right Soleus (cm)	30.6	3.3	31.7	3.5	1.03
Left Soleus (cm)	31.4	3.6	33.0	3.3	2.16
Right Shoulder (cm)	2.0	5.7	3.6	4.8	0.94
Left Shoulder (cm)	4.3	4.9	5.5	4.5	0.67
Bench Press 1RM (kg) (n=6), (n=6)	25.5	4.4	29.6	6.4	0.43
Bench Press (repetitions) (n=13), (n=13)	11.8	5.2	9.2	4.7	1.89
Leg Press 1RM (kg) (n=6), (n=6)	75.8	9.9	75.2	15.1	0.98
Leg Extension (repetitions) (n=13), (n=13)	18.2	6.3	19.8	6.8	0.40
Crunches (repetitions)	31.2	9.0	26.9	9.5	2.29

3. Results

The raw data from each subject from the two tests prior to supercircuit training, the one test at 3 weeks and the two tests at the completion of supercircuit training is presented in Appendix B. Twelve subjects (six of whom were controls) participated in 1993, and a further 26 (13 of whom were controls) participated in 1994.

3.1. Characteristics of the 1993 and 1994 Groups Prior to Supercircuit Training

In order to test whether the 1993 and 1994 groups came from the same population, the group means of each characteristic from the first two tests were compared statistically using ANOVA. A comparison of the characteristics of the 1993 and 1994 groups is shown in Table 8. A summary of the calculations to determine F for the ANOVA of each characteristic is shown in Appendix C.1.

There were no significant differences between the two groups for age, height, body mass, sum of two and six skinfolds, flexibility of the hamstring muscle group, flexibility of the gastrocnemius muscle, flexibility of the soleus muscle of the right leg, flexibility of the shoulders, heart rate prior to testing, perceived exertion at the third work load on the cycle ergometer and estimated VO_2max. However, mean systolic and diastolic blood pressure were significantly lower in the 1994 group than the 1993 group, mean flexibility of the left soleus muscle was significantly smaller and the mean number of crunches completed in one minute was significantly greater. Strength of the upper and lower body could not be compared as different methods were used to assess strength.

3.2. Characteristics of the Supercircuit and Control Groups Prior to Supercircuit Training

In order to test whether the supercircuit and control groups came from the same population, the mean of each characteristic from the first two tests was compared statistically using ANOVA. A comparison of the characteristics from the supercircuit and control groups is shown in Table 9. A summary of the calculations to determine F for the ANOVA of each variable is shown in Appendix C.2.

There were no significant differences between the two groups for all the characteristics measured.

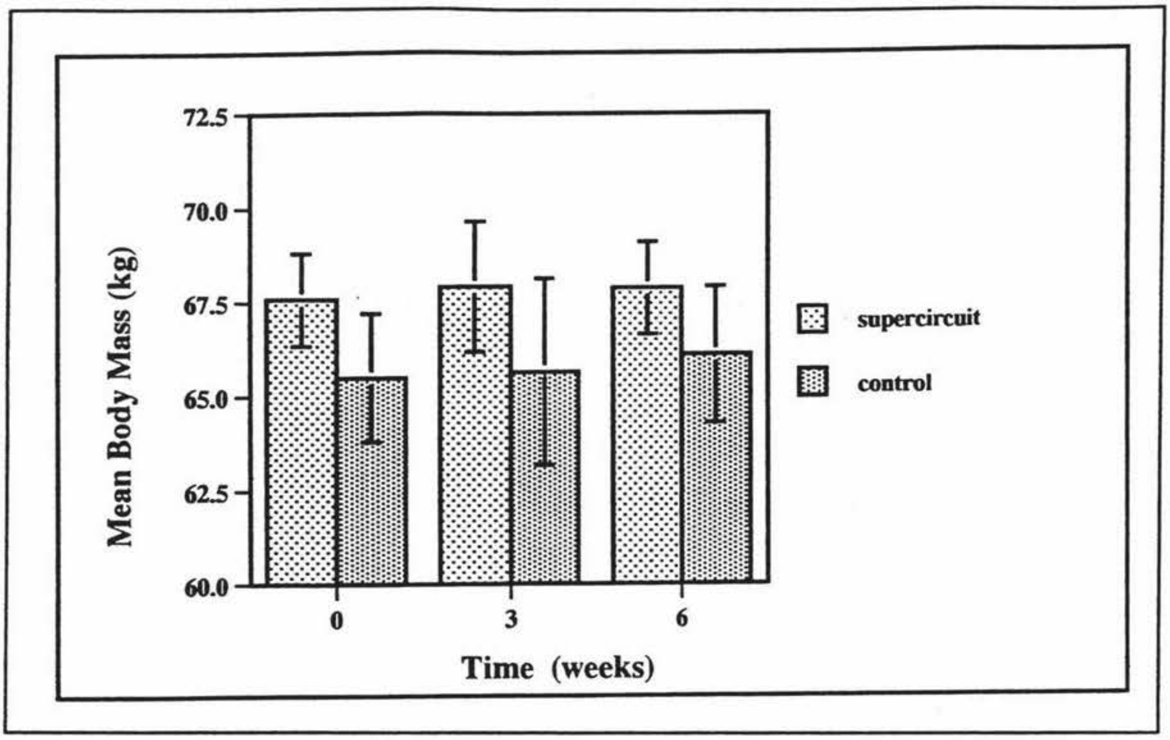

Fig 2. Body Mass Measurements of the Supercircuit and Control Groups at Zero, Three, and Six Weeks (mean ± S.E.M.). There was no significant difference between the supercircuit and control groups and no significant change with time.

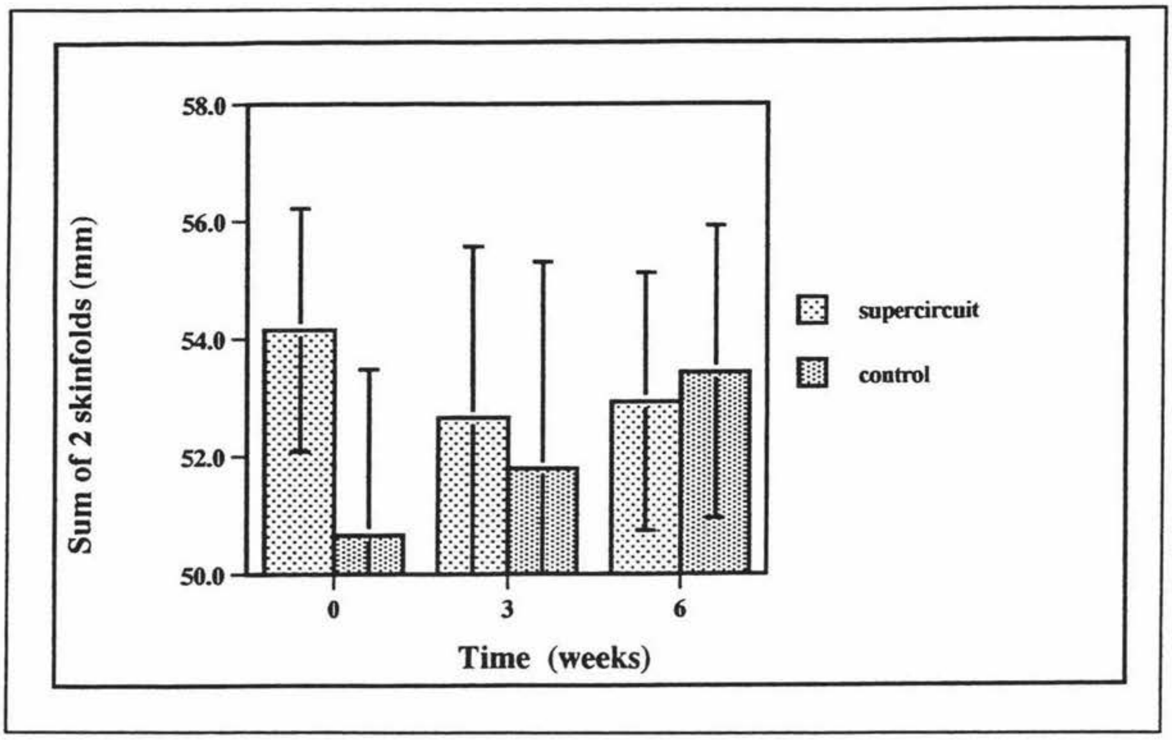

Fig 3. Sum of the Suprailiac and Abdominal Skinfolds of the Supercircuit and Control Groups at Zero, Three, and Six Weeks (mean ± S.E.M.). There was no significant difference between the supercircuit and control groups and no significant change with time.

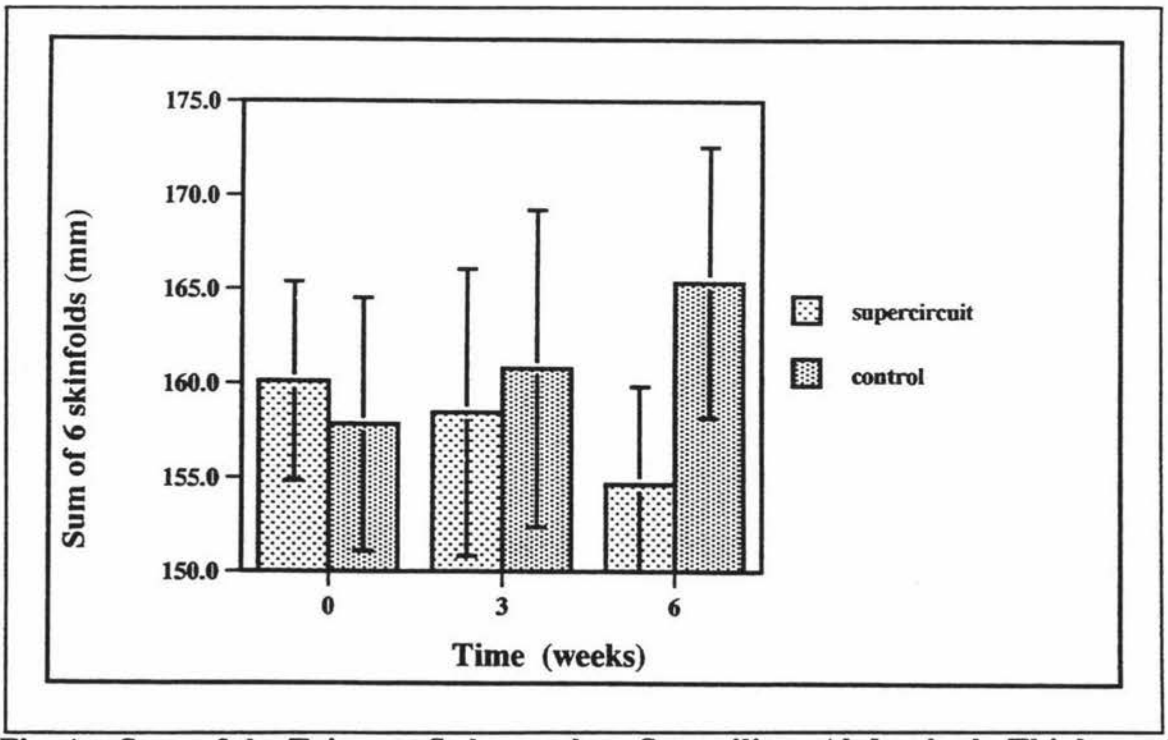

Fig 4. Sum of the Triceps, Subscapular, Suprailiac, Abdominal, Thigh, and Calf Skinfolds of the Supercircuit and Control Groups at Zero, Three, and Six Weeks (mean ± S.E.M.). There was no significant difference between the supercircuit and control groups and no significant change with time.

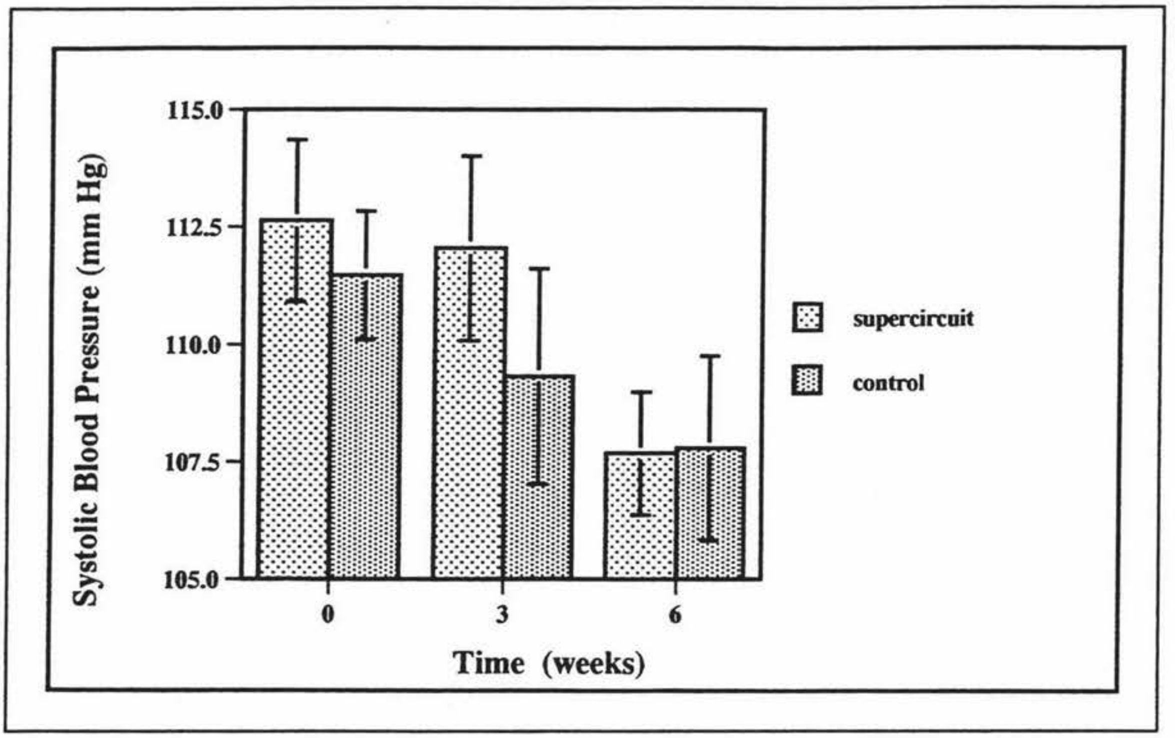

Fig 5. Systolic Blood Pressure of the Supercircuit and Control Groups at Zero, Three, and Six Weeks (mean ± S.E.M.). The decrease in systolic blood pressure was significant (T, p=.007) but there was no significant difference between the two groups (CT, >.05).

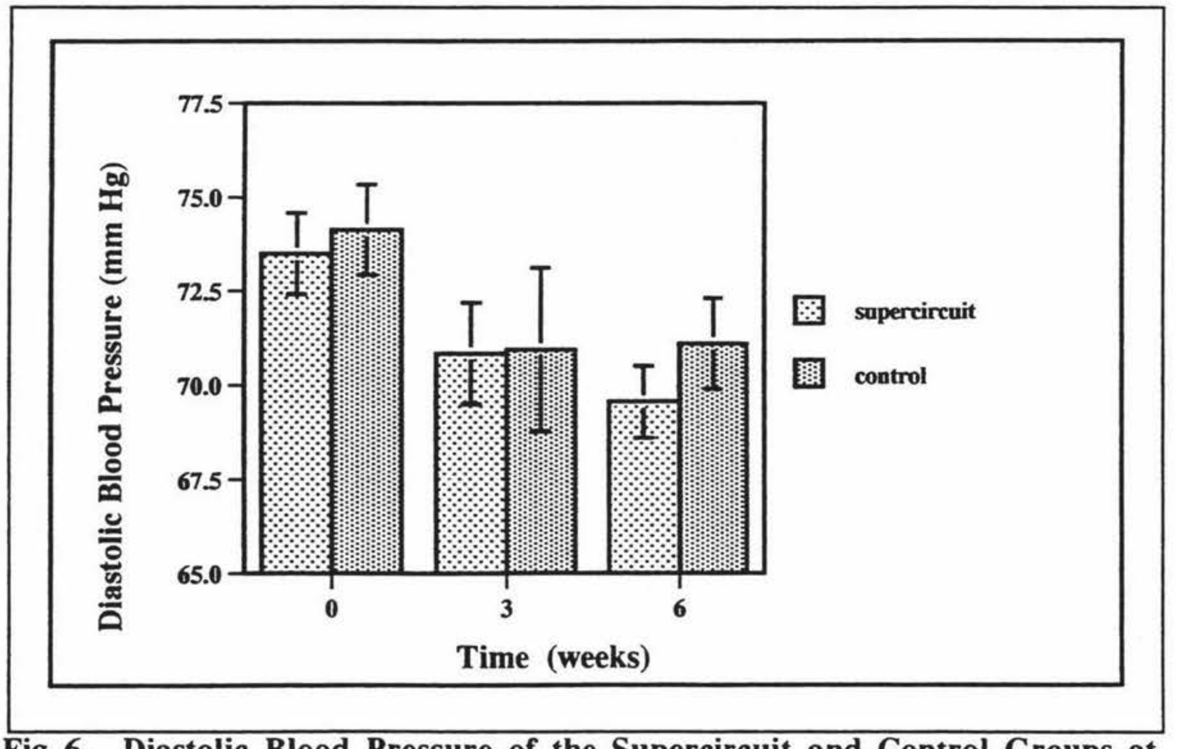

Fig 6. Diastolic Blood Pressure of the Supercircuit and Control Groups at Zero, Three, and Six Weeks (mean ± S.E.M.). The decrease in systolic blood pressure was significant (T, p=.003) but there was no significant difference between the two groups (CT>.05).

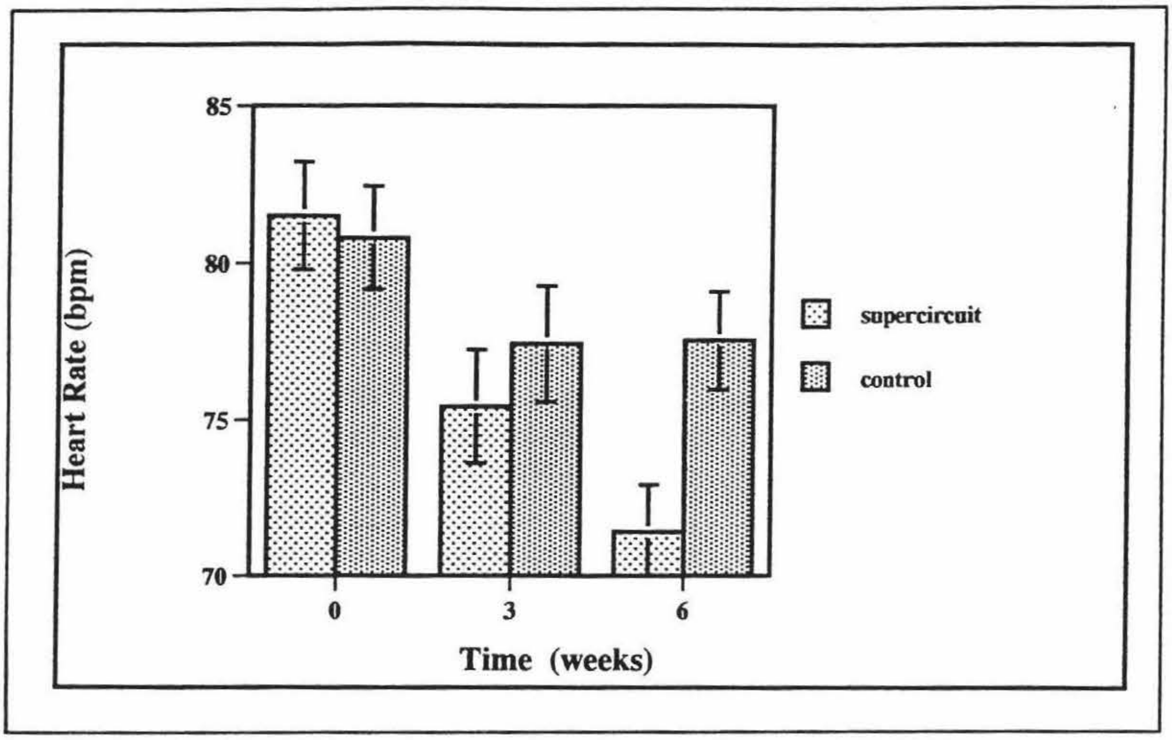

Fig 7. Pre-exercise Heart Rate of the Supercircuit and Control Groups at Zero, Three, and Six Weeks (mean ± S.E.M.). The decrease in heart rate over the six weeks was significant (T, p=.04) with the supercircuit group showing a significantly greater decrease (CT, p=.005) than the control group.

3.3. A Comparison of the Supercircuit and Control Groups over the Six Weeks of the Supercircuit Training Programme

The effect of six weeks of supercircuit training on different characteristics was assessed by comparing the results from the supercircuit and control groups using regression analysis.

The multiple regression equations for each characteristic are shown in Appendix E.

3.3.1. Body Composition

The effect of supercircuit training on body composition was assessed by measuring body mass, the sum of two skinfolds (SKF-2; suprailiac and abdomen) and the sum of 6 skinfolds (SKF-6; triceps, subscapular, suprailiac, abdomen, thigh and calf). The raw data from these measurements for the supercircuit and control groups at zero, three and six weeks is presented in Appendix B.1. The means and standard deviations are shown in Appendix D, Table 1. The means of these results are shown graphically in Figures 2, 3 and 4. The multiple regression equations for body mass, SKF-2 and SKF-6 are shown in Appendix E, Table 1.

When body mass (Fig 2), SKF-2 (Fig 3) and SKF-6 (Fig 4) were regressed against C (training status), T (time), CT (the linear interaction of training with time), Tsq (time squared) and CTsq (the quadratic interaction of training with time) (Appendix E, Table 1), there was no significant change in body mass ($p>.05$), SKF-2 ($p>.05$) and SKF-6 ($p>.05$) over the 6 weeks of the study although the mean values of SKF-2 and SKF-6 appeared to decrease for the supercircuit group by 2.7mm and 5.5mm respectively, and appeared to increase for the control group by 2.7mm and 7.6mm respectively.

3.3.2. Blood Pressure and Heart Rate Prior to Fitness Testing

Appendix D, Table 2, summarises the means and standard deviations of systolic blood pressure, diastolic blood pressure and heart rate prior to testing (pre-exercise HR) at zero, three and six weeks. The raw data is presented in Appendix B.1. These measurements were made prior to the cycle ergometer test. The means of these results are shown graphically in Figures 5, 6 and 7. The multiple regression equations for systolic blood pressure, diastolic blood pressure and pre-exercise HR are shown in Appendix E, Table 2.

When systolic and diastolic blood pressure were regressed against C, T, CT, Tsq and CTsq, there was a significant decrease in systolic blood pressure (T, $p=.007$) and diastolic blood pressure (T, $p=.003$) over the 6 weeks of the study but the decrease in systolic and diastolic blood pressure in the supercircuit group was not significantly

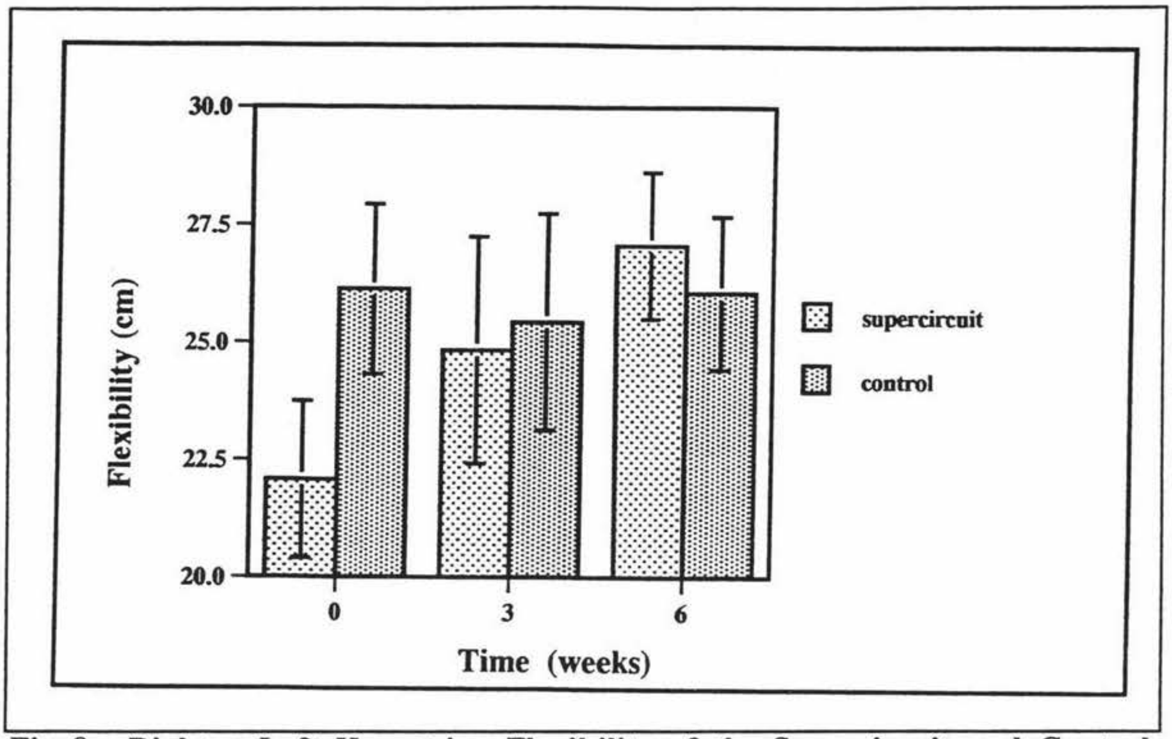

Fig 8. Right + Left Hamstring Flexibility of the Supercircuit and Control Groups at Zero, Three, and Six Weeks (mean ± S.E.M.). The supercircuit group showed a significantly (CT, $p=.04$) greater increase in flexibility than the control group. There was also a significant (C, $p=.04$) difference between the supercircuit and control groups.

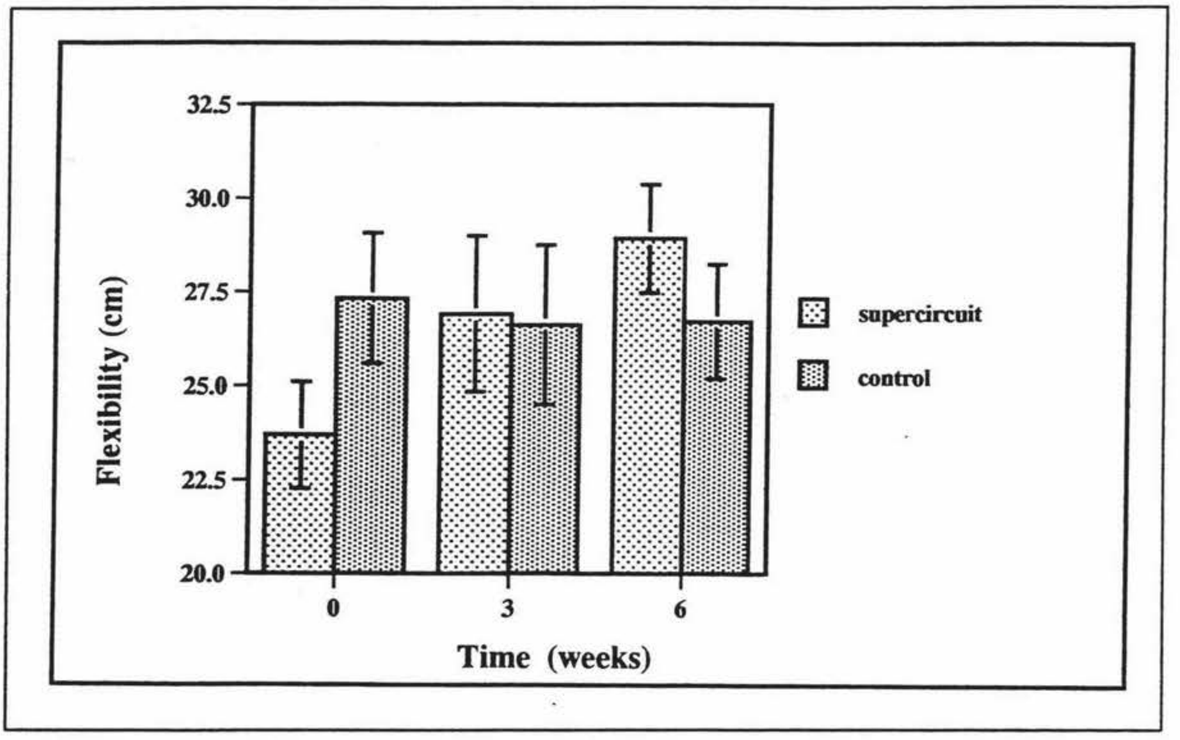

Fig 9. Right Hamstring Flexibility of the Supercircuit and Control Groups at Zero, Three, and Six Weeks (mean ± S.E.M.). The supercircuit group showed a significantly greater (CT, p=.02) increase in flexibility than the control group.

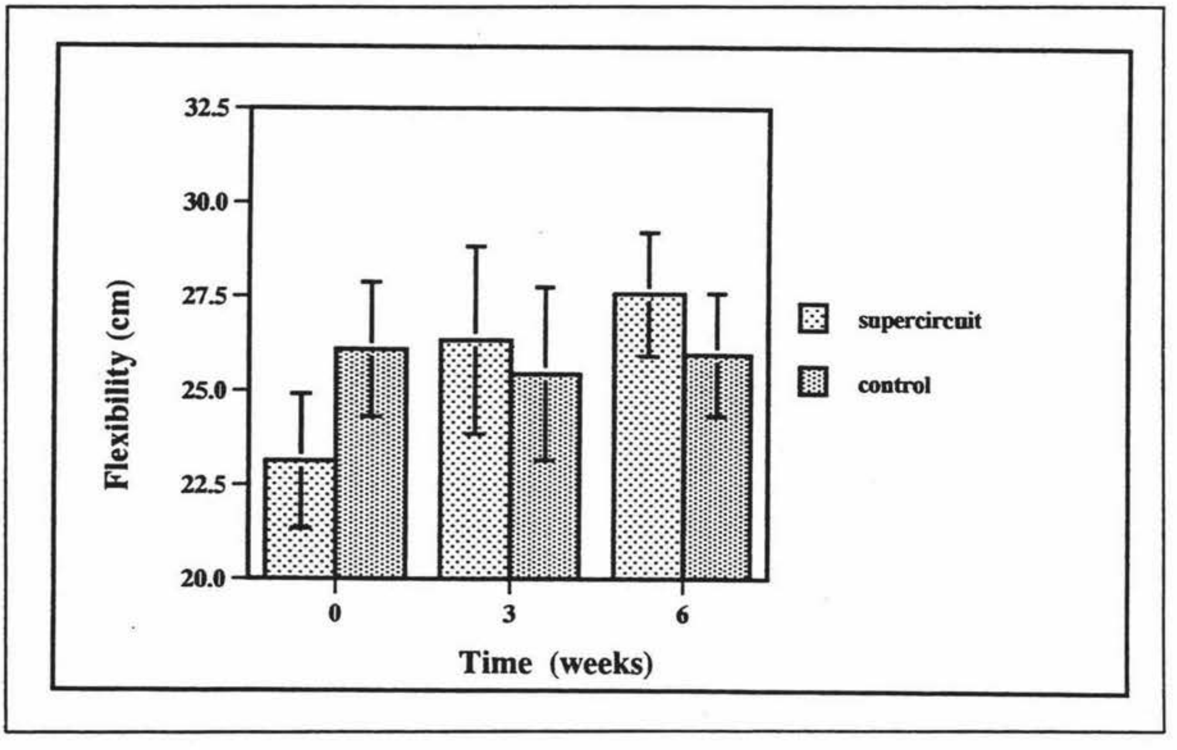

Fig 10. Left Hamstring Flexibility of the Supercircuit and Control Groups at Zero, Three, and Six Weeks (mean ± S.E.M.). There was no significant difference (CT, p>.05) in flexibility between the two groups.

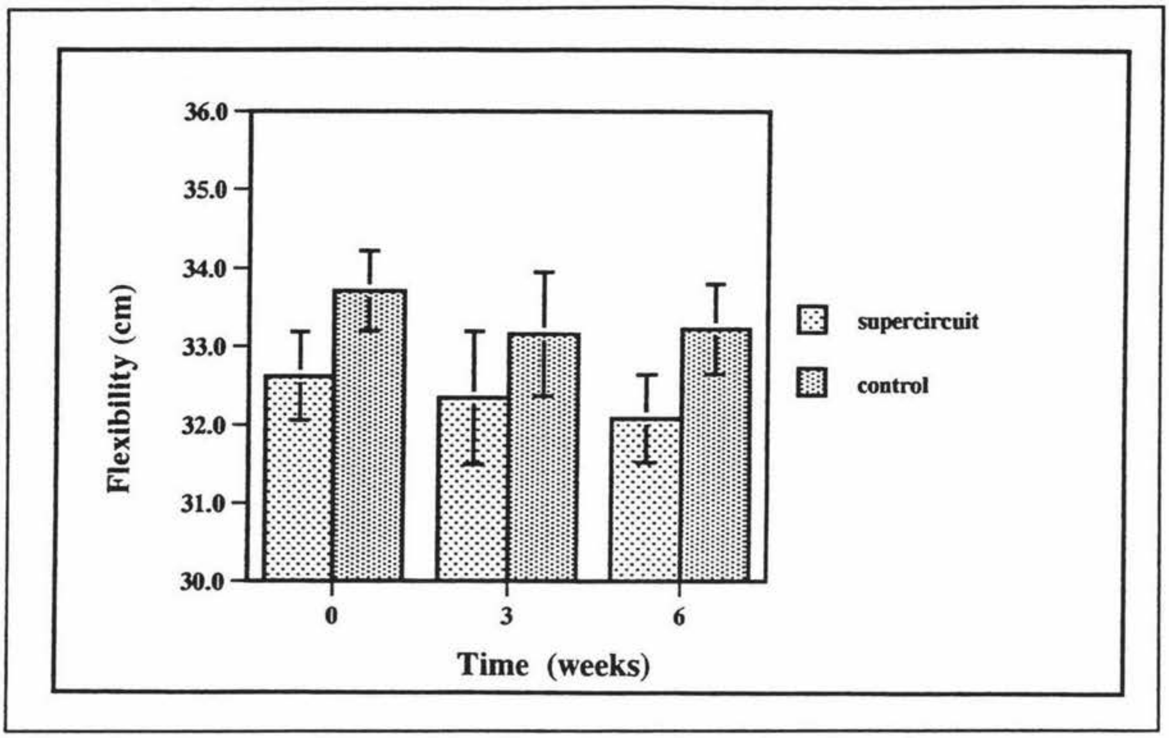

Fig 11. Right Gastrocnemius Muscle Flexibility of the Supercircuit and Control Groups at Zero, Three, and Six Weeks (mean ± S.E.M.). There was a significant (C, p=.04) difference between the supercircuit and control groups but no significant changes with time (CT, T, p>.05).

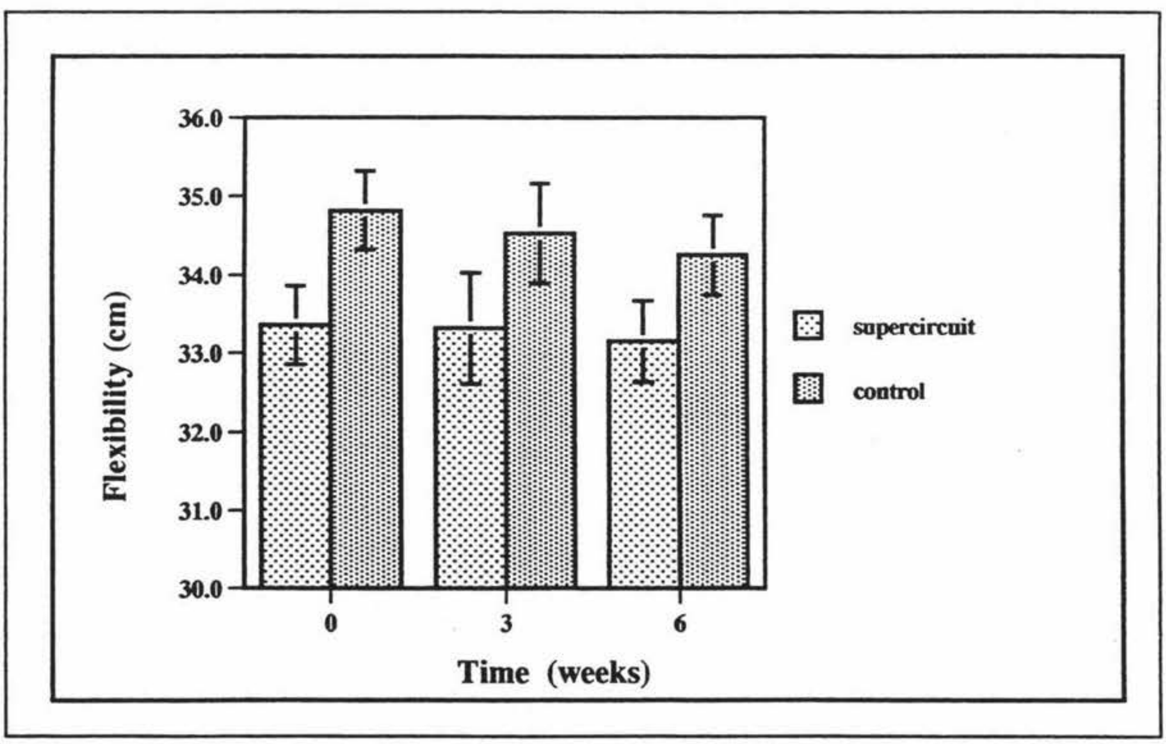

Fig 12. Left Gastrocnemius Muscle Flexibility of the Supercircuit and Control Groups at Zero, Three, and Six Weeks (mean ± S.E.M.). There was a significant (C, p=.005) difference between the supercircuit and control groups but no significant changes with time (CT, T, p>.05).

greater than the decrease shown by the control group (p>.05 for CT and CTsq). The mean systolic blood pressure decreased by 4.9mm Hg in the supercircuit group and by 3.7mm Hg in the control group (Fig 5). The mean diastolic blood pressure decreased by 3.9mm Hg and 3.0mm Hg respectively (Fig 6).

When pre-exercise HR was regressed against C, T, CT, Tsq and CTsq, there was a significant decrease in pre-exercise HR (T, p=.04) over the 6 weeks of the study with the supercircuit group showing a significantly greater decrease than the the control group (CT, p=.005). The mean pre-exercise HR decreased by 10.1 beats per minute (bpm) for the supercircuit group and by 3.3 bpm for the control group (Fig 7).

3.3.3. Flexibility

Flexibility measurements were made of the hamstring muscle groups, gastrocnemius muscles, soleus muscles, and shoulders at zero, three and six weeks. The raw data is presented in Appendix B.2 and the means and standard deviations of the raw data is presented in Appendix D, Table 3. These means of these results are shown graphically in Figures 8-16. Multiple regression equations for the flexibility of each muscle group over the six weeks of the study are shown in Appendix E, Table 3.

The sit and reach test to assess the flexibility of the hamstring muscle group was done with legs together (R + L hamstring, Fig 8) and for the right leg (R-hamstring, Fig 9) and left leg (L-hamstring, Fig 10). Over the 6 week training period, flexibility of the hamstring muscle group in the supercircuit group increased by 5.0cm when flexibility was measured with both legs together (R+L hamstring), it increased by 5.3cm for the right leg (R-hamstring) and by 4.5cm for the left leg (L-hamstring). Flexibility of the control group decreased by 0.6cm for the R-hamstring, by 0.1cm for the L-hamstring and there was no change in flexibility for R+L hamstring. When the hamstring muscle group flexibility was regressed against C, T, CT, Tsq and CTsq, over the six weeks of the study the supercircuit group showed a significantly greater increase in flexibility than the control group for R+H hamstring (CT, p=.04) and for R-hamstring (CT, p=.02), but not for L-hamstring (CT, p>.05). There was also a significant difference between the supercircuit and control groups for R+L hamstring (C, p=.04). None of the other variables were significant.

Flexibility of the gastrocnemius muscle was assessed by measuring the vertical distance between the base of the knee and the floor with the knee straight and the gastrocnemius muscle stretched as much as possible. Mean values for the right gastrocnemius muscle are shown graphically in Fig 11 and for the left gastrocnemius muscle in Fig 12. Over the six week training period the right gastrocnemius muscle group increased in flexibility by 0.5cm for both the supercircuit and control groups. The left gastrocnemius muscle

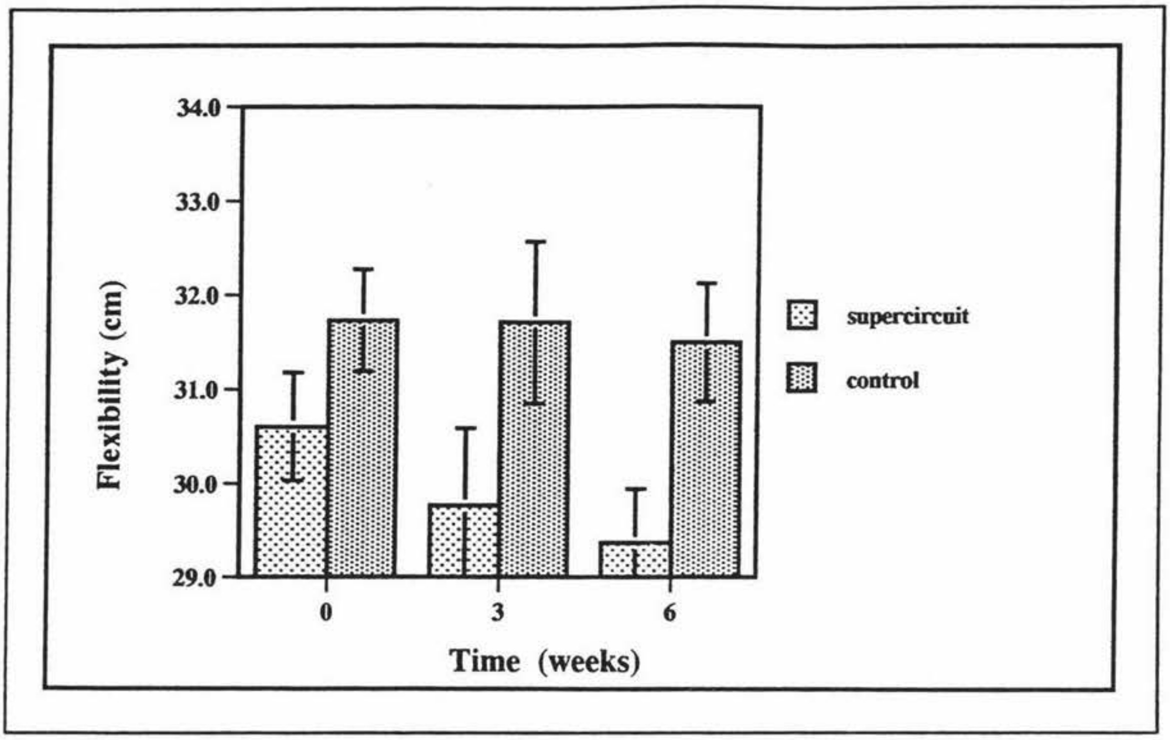

Fig 13. Right Soleus Muscle Flexibility of the Supercircuit and Control Groups at Zero, Three, and Six Weeks (mean ± S.E.M.). There was a significant (C, p=.001) difference between the supercircuit and control groups but no significant changes with time (T, CT, p>.05).

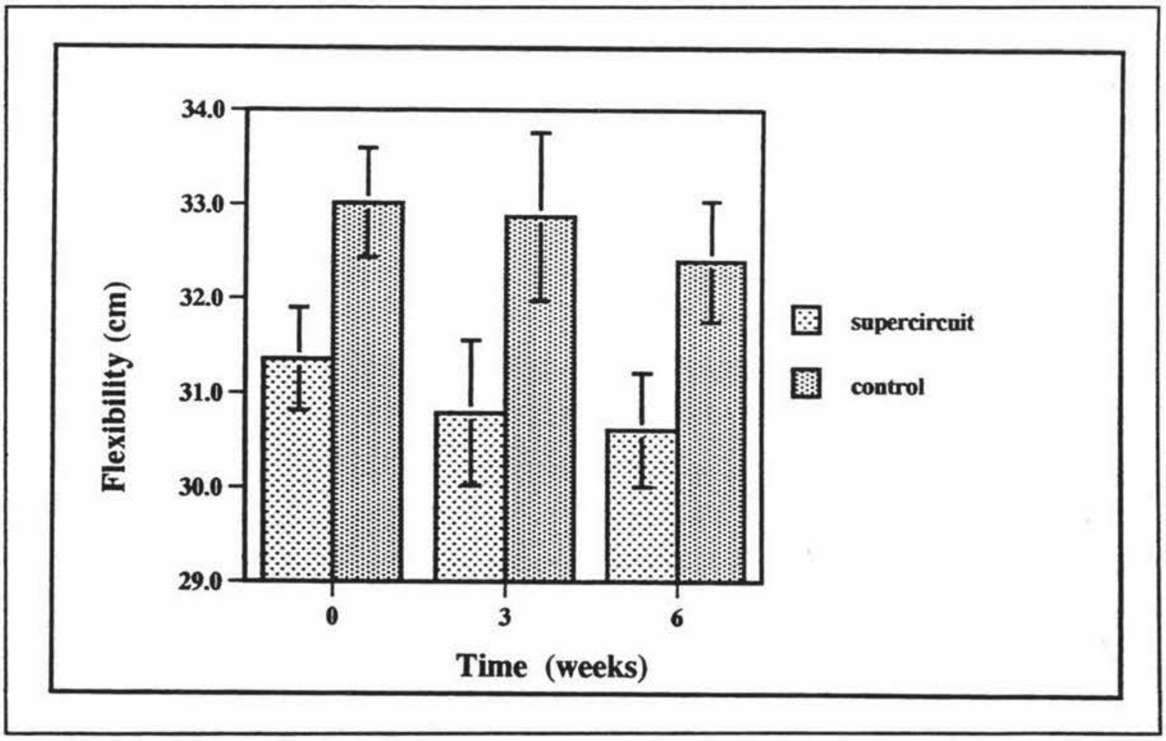

Fig 14. Left Soleus Muscle Flexibility of the Supercircuit and Control Groups at Zero, Three, and Six Weeks (mean ± S.E.M.). There was a significant (C, p=.0008) difference between the supercircuit and control groups but no significant changes with time (T, CT, p>.05).

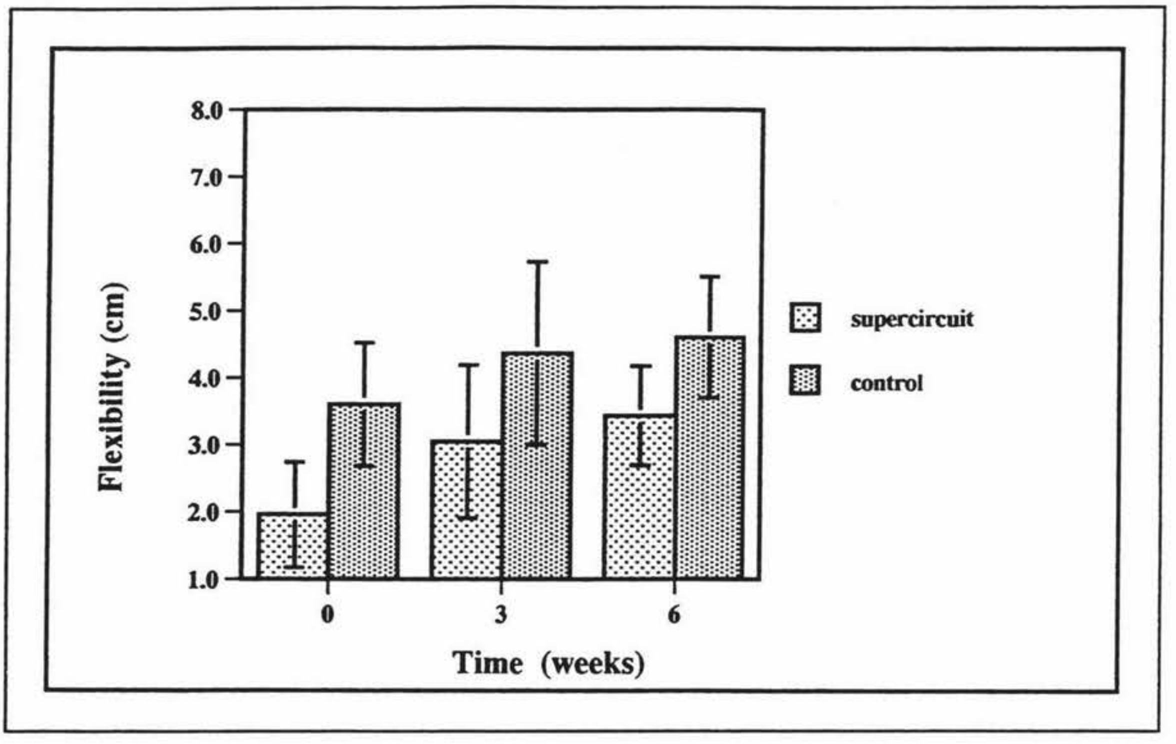

Fig 15. Right Shoulder Muscle Flexibility of the Supercircuit and Control Groups at Zero, Three, and Six Weeks (mean ± S.E.M.). There was no significant difference between the supercircuit and control groups and no significant change with time.

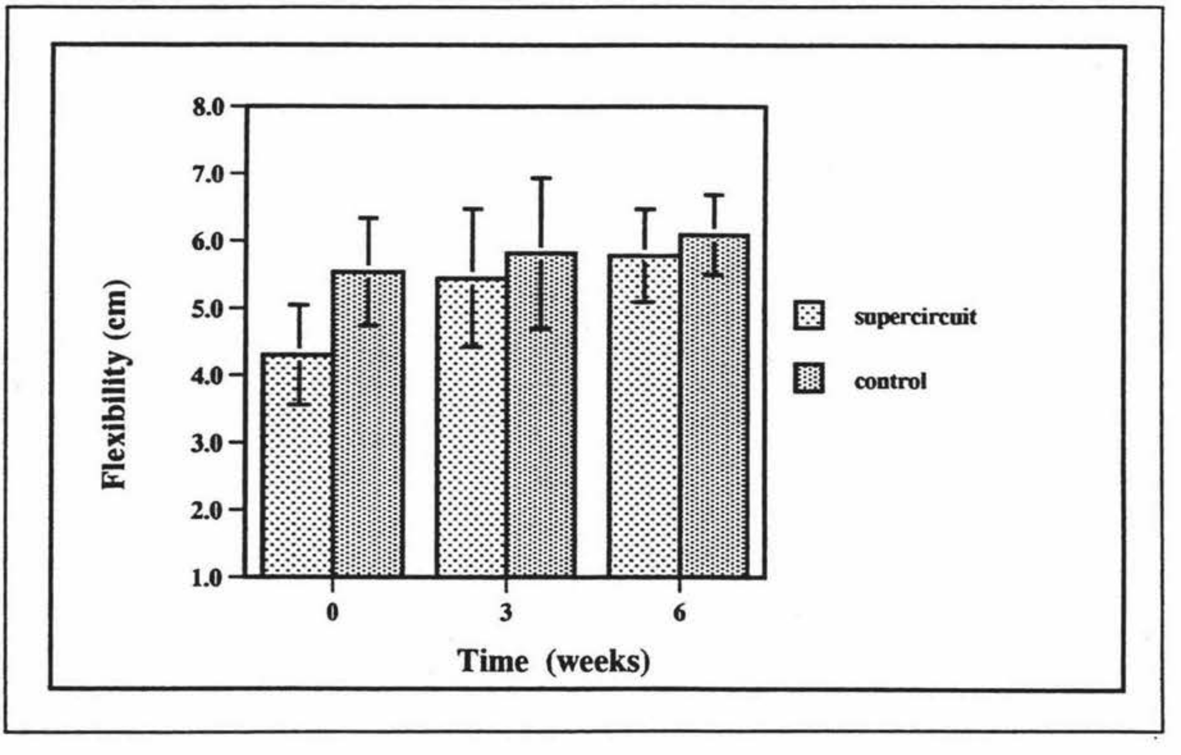

Fig 16. Left Shoulder Muscle Flexibility of the Supercircuit and Control Groups at Zero, Three, and Six Weeks (mean ± S.E.M.). There was no significant difference between the supercircuit and control groups and no significant change with time.

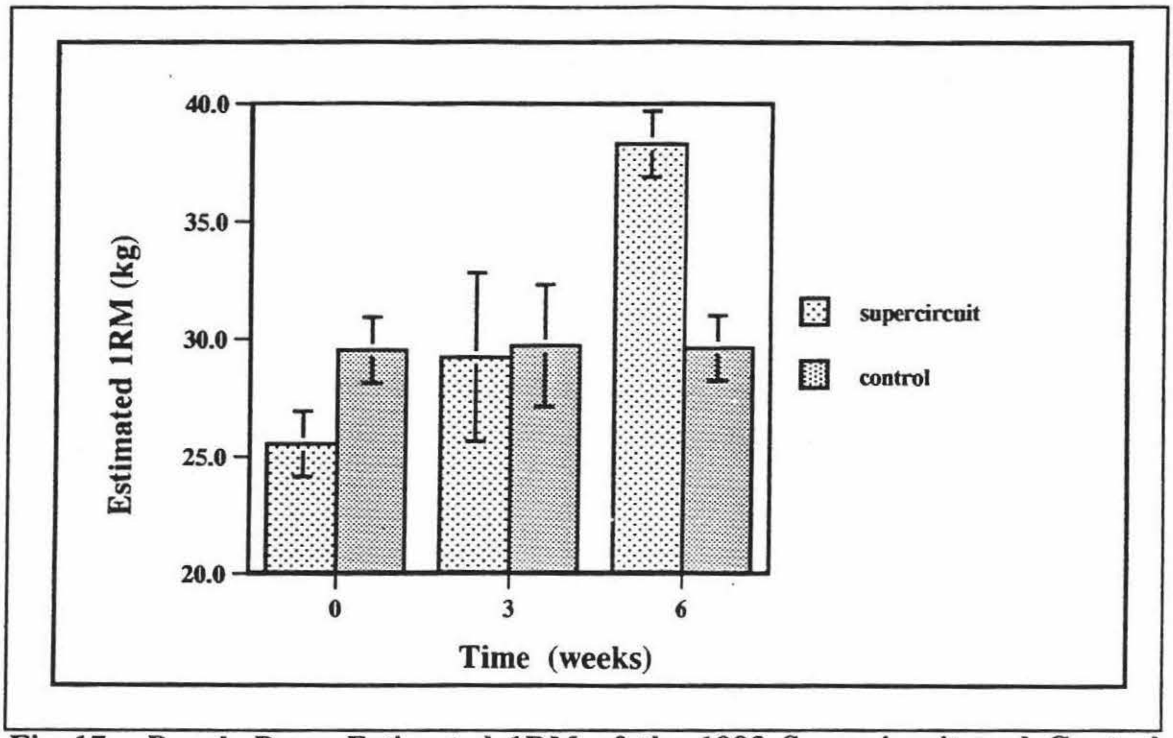

Fig 17. Bench Press Estimated 1RM of the 1993 Supercircuit and Control Groups at Zero, Three, and Six Weeks (mean ± S.E.M.). The supercircuit group showed a significantly (CT, p=.0001) greater increase in strength than the control group. There was also a significant (C, p=.006) difference between the supercircuit and control groups.

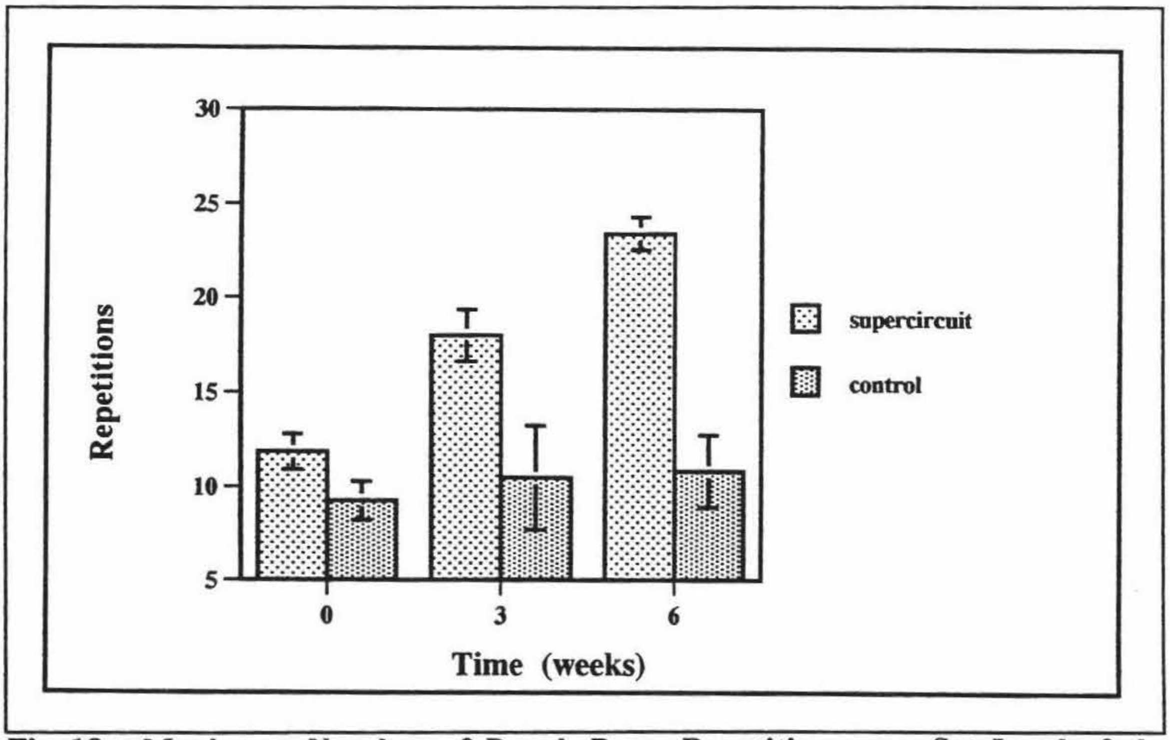

Fig 18. Maximum Number of Bench Press Repetitions at a Set Load of the 1994 Supercircuit and Control Groups at Zero, Three, and Six Weeks (mean ± S.E.M.). The supercircuit group showed a significantly (CT, p=.0001) greater increase in strength than the control group.

group increased in flexibility by 0.3cm for the supercircuit group and by 0.6cm for the control group. When the gastrocnemius muscle flexibility measures were regressed against C, T, CT, Tsq and CTsq, there were no significant changes in flexibility over the six weeks of the study (T, CT, Tsq, CTsq, p>.05). There was a significant difference between the supercircuit and control groups (C, p<.05) but it was not as a result of training as there was no significant interaction of training with time (CT, CTsq, p>.05).

Flexibility of the soleus muscle was assessed by measuring the vertical distance between the base of the knee and the floor with the knee bent and the soleus muscle stretched as much as possible. Mean values for the right soleus muscle are shown graphically in Fig 13 and for the left soleus muscle in Fig 14. Flexibility mean values of the right and left soleus muscles decreased by 1.3cm and 0.8cm respectively for the supercircuit group and by 0.3cm and 0.6cm for the control group. When the soleus muscle flexibility measures were regressed against C, T, CT, Tsq and CTsq, the decreases in mean values over the six weeks were not significant for either group (T, Tsq. p>.05) nor was the greater decrease seen in the supercircuit group significant (CT, CTsq, p>.05). The supercircuit group, however, was significantly more flexible than the control group for both right soleus muscle (C, p=.001) and left soleus muscle (C, p=.0008).

Right shoulder flexibility increased by 1.4cm and 1.0cm respectively for the supercircuit and control groups (Fig 15) and left shoulder flexibility increased by 1.5cm and 0.6cm (Fig 16). When the shoulder flexibility measurements were regressed against C, T, CT, Tsq and CTsq, none of these variables were significant.

3.3.4. Muscle Strength and Endurance

Appendix D, Table 4, summarises the means and standard deviations of all the strength/endurance characteristics measured in the supercircuit group and control group at zero , three and six weeks. The raw data is presented in Appendix B.2. Upper body strength was assessed using the bench press, lower body strength was assessed using either the leg press or the leg extension machine and abdominal strength/endurance was assessed by the number of crunches completed in one minute. These means of these results are shown graphically in Figures 17-21. The multiple regression equations for each strength/endurance characteristic are presented in Appendix E, Table 4.

3.3.4.1. Upper Body Strength/Endurance

In 1993, upper body strength was assessed by estimating each subjects bench press one repetition maximum (1RM) (Fig 17) from their 10RM (10 repetition maximum). In 1994, it was assessed by counting the maximum number of bench press repetitions achieved at a set weight (Fig 18).

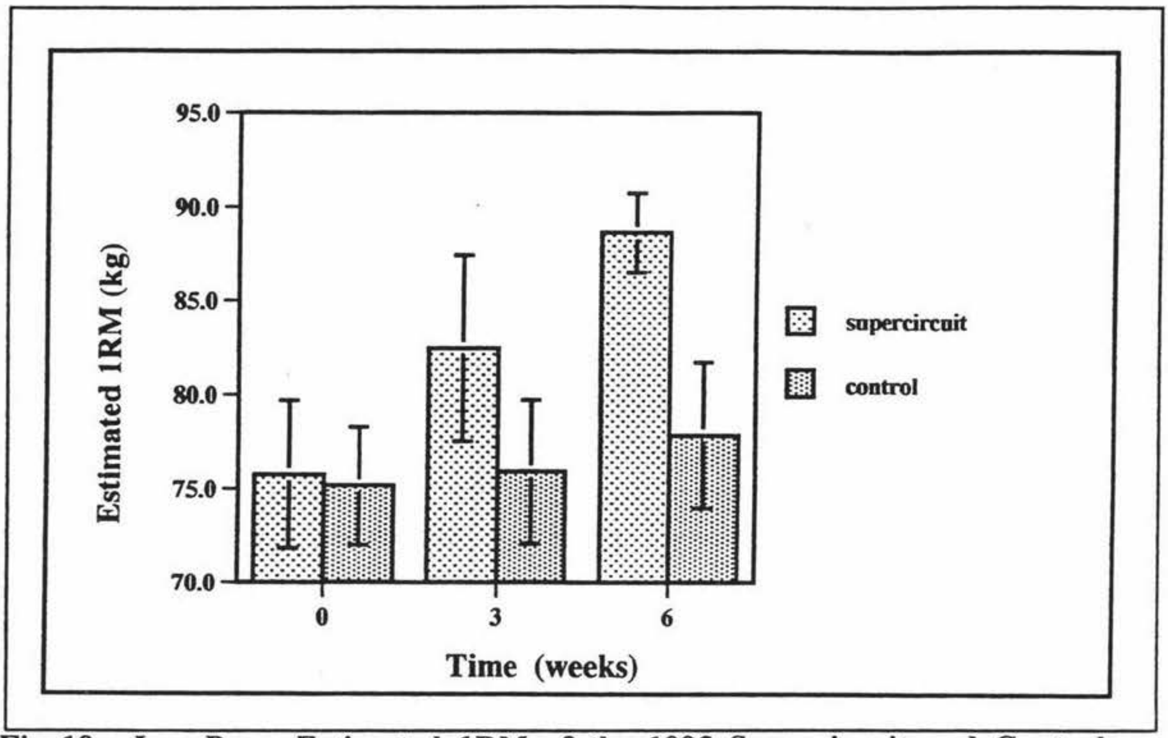

Fig 19. Leg Press Estimated 1RM of the 1993 Supercircuit and Control Groups at Zero, Three, and Six Weeks (mean ± S.E.M.). The supercircuit group showed a significantly (CT, p=.001) greater increase in strength than the control group.

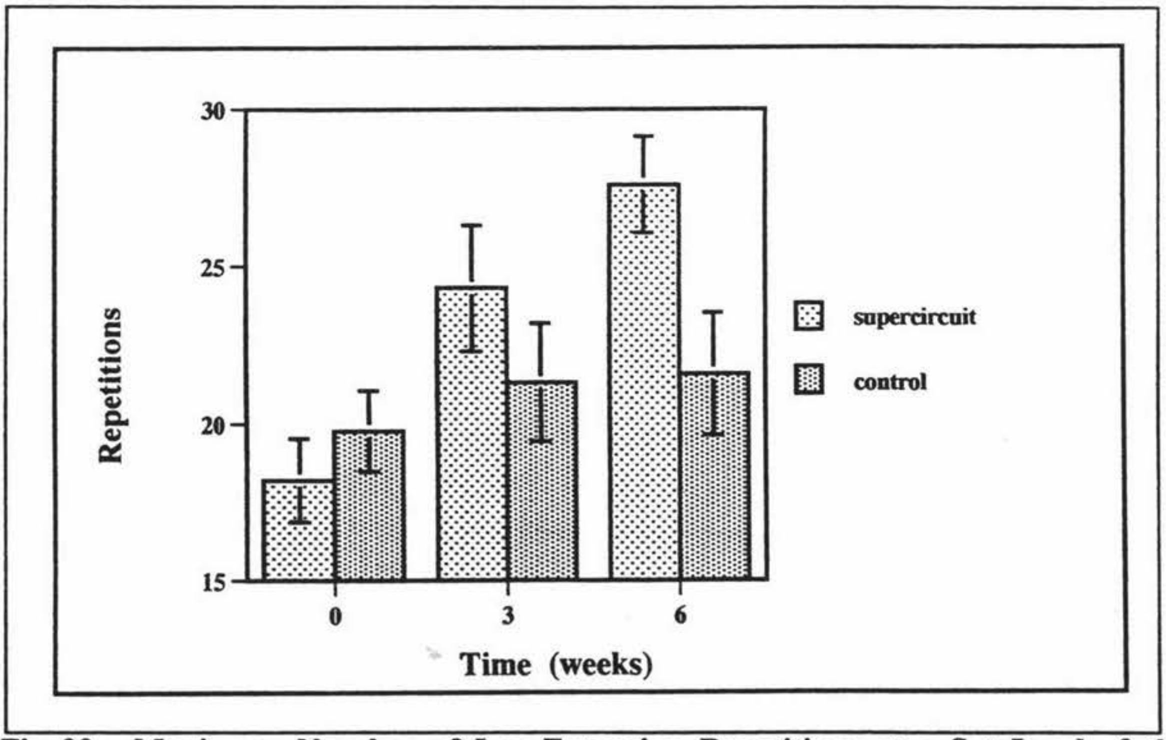

Fig 20. Maximum Number of Leg Extension Repetitions at a Set Load of the 1994 Supercircuit and Control Groups at Zero, Three, and Six Weeks (mean ± S.E.M.). The supercircuit group showed a significantly (p=.0001) greater increase in strength than the control group.

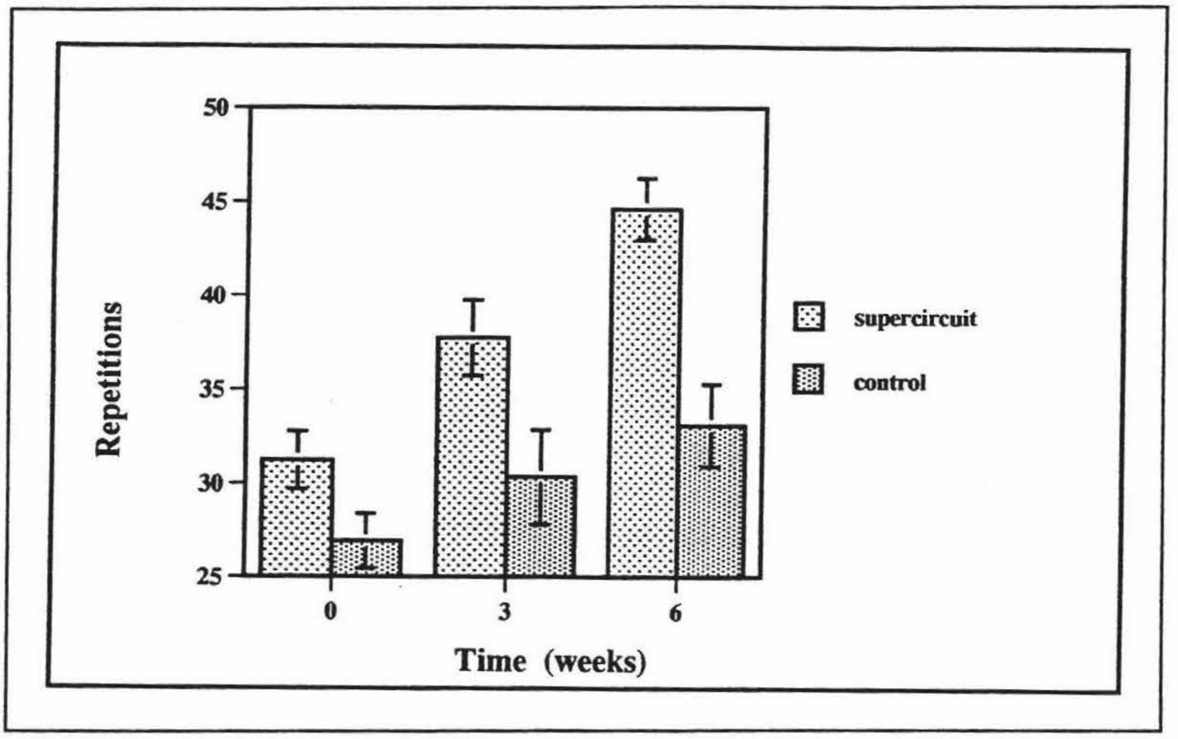

Fig 21. Maximum Number of Repetitions in One Minute of Abdominal Crunches of the Supercircuit and Control Groups at Zero, Three, and Six Weeks (mean ± S.E.M.). The supercircuit group showed a significantly (CT, p=.0001) greater increase in abdominal strength than the control group.

Following six weeks of supercircuit training the estimated 1RM of the supercircuit group increased by 50% from 25.5 ± 4.4 kg to 38.3 ± 4.7 kg and the maximum number of repetitions achieved increased by 98% from 11.8 ± 5.2 to 23.4 ± 9.8 repetitions. The control group increased their estimated 1RM by 0.9% from 29.6± 4.6 to 29.9 ± 4.8 kg and the maximum number of repetitions by 17% from 9.2 ± 4.7 to 10.8 ± 9.8 repetitions. When these results were regressed against C, T, CT, Tsq and CTsq, the increase in estimated 1RM (CT, p=.0001) and maximum number of repetitions (CT, p=.0001) in the supercircuit group was significantly greater than the control group over the time course of the study. In the 1993 group there was also a significant difference between the supercircuit and training groups (C, p=.006).

3.3.4.2. Lower Body Strength/Endurance

In 1993, lower body strength was assessed by estimating each subjects 1RM from their 10RM on the leg press machine (Fig 19). In 1994, it was assessed by counting the maximum number of repetitions achieved at a set weight on a leg extension machine (Fig 20).

Following six weeks of supercircuit training the supercircuit group's estimated 1RM increased by 17% from 75.8 ± 9.9 to 88.6 ± 11.6 kg and the maximum number of repetitions achieved increased by 52% from 18.2 ± 6.2 to 27.6 ± 9.8 repetitions. The control group increased their estimated 1RM by 4% from 75.2 ± 13.1 to 77.8 ± 7.3 kg and the maximum number of repetitions by 9% from 19.8 ± 6.8 to 21.6 ± 7.8 repetitions. When these results were regressed against C, T, CT, Tsq, and CTsq, the increase in estimated 1RM (CT, p=.001), and maximum number of repetitions (CT, p=.0001) was significantly greater in the supercircuit group than the control group over the time course of the study.

3.3.4.3. Abdominal Strength/Endurance

The supercircuit group increased the number of crunches completed in one minute by 43% from 31.2 ± 9.0 to 44.6 ± 13.3 and the control group increased the number of crunches by 23% from 26.9 ± 9.5 to 33.1 ± 9.9 (Fig 21). When these results were regressed against C, T, CT, Tsq and CTsq, (Appendix E, Table 4), the increase in the number of crunches shown by the supercircuit group was significantly greater (CT, p=.001) than that of the control group. Although the control group also showed an increase in the mean number of crunches achieved in one minute, this increase was not significant (T, p>.05).

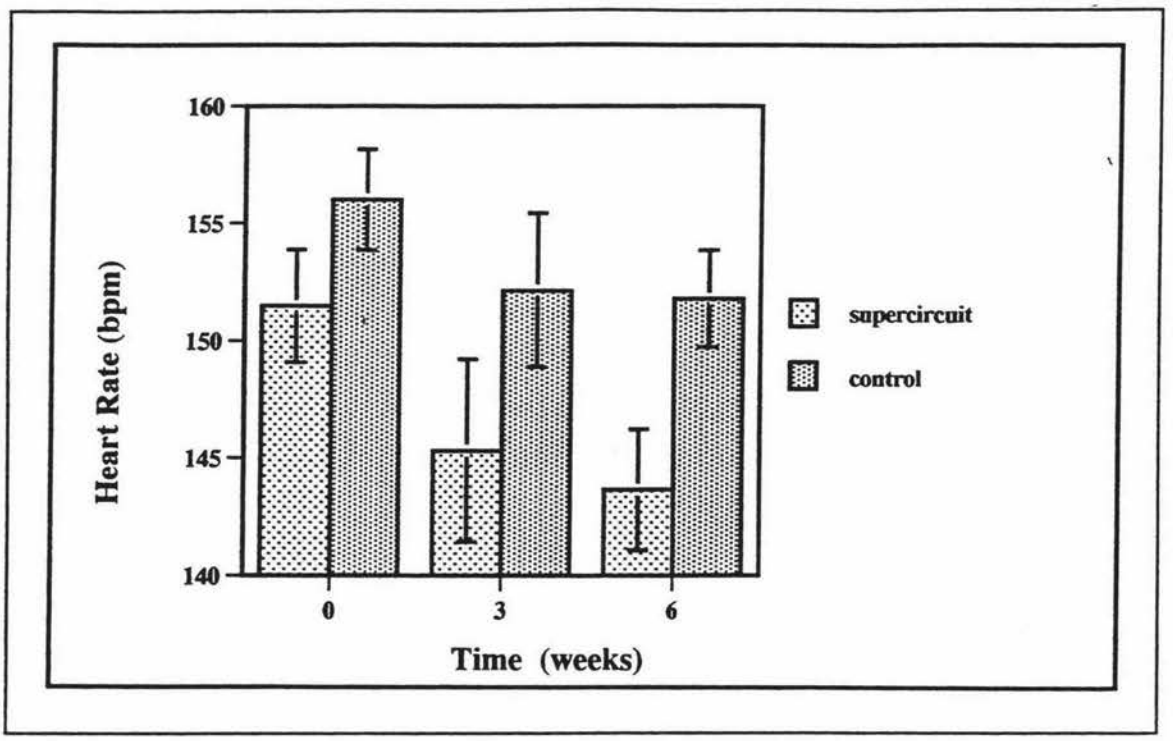

Fig 22. Heart Rate at the Third Workload on the Cycle Ergometer of the Supercircuit and Control Groups at Zero, Three, and Six Weeks (mean ± S.E.M.). The decrease in heart rate was significant (T, p=.01) but the supercircuit group did not decrease significantly more than the control group. There was a significant difference (C, p=.003) between the supercircuit and control groups.

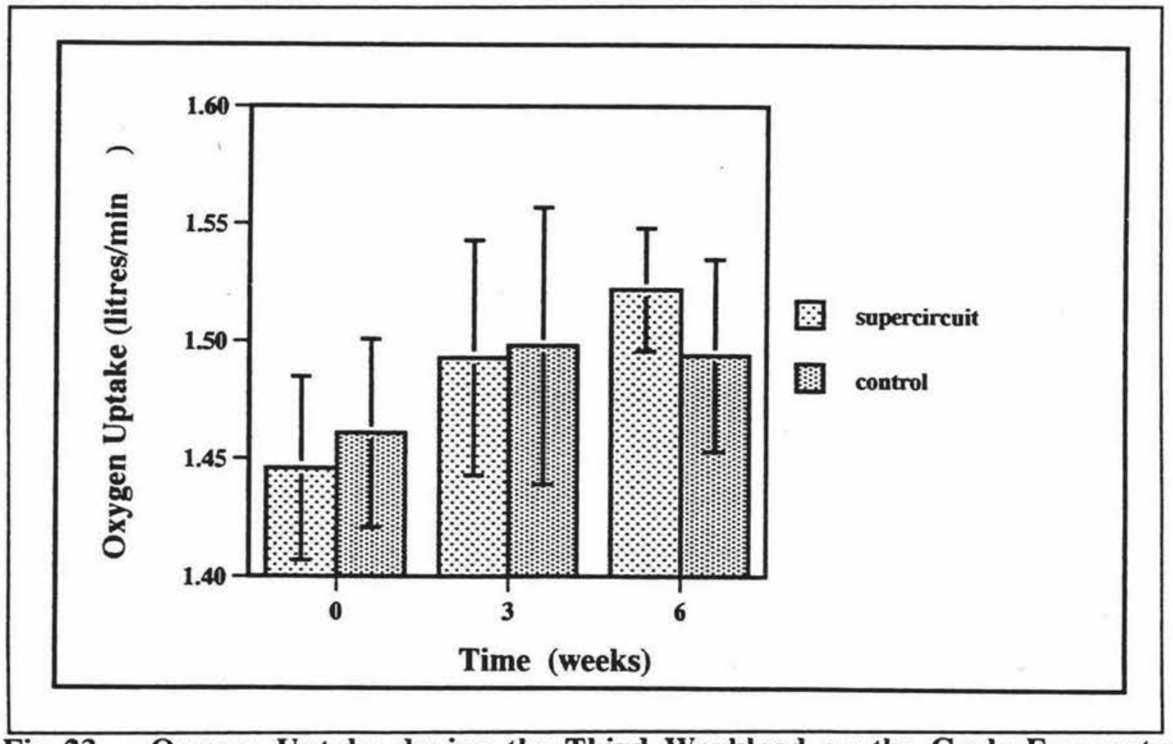

Fig 23. Oxygen Uptake during the Third Workload on the Cycle Ergometer of the Supercircuit and Control Groups at Zero, Three, and Six Weeks (mean ± S.E.M.). There was no significant difference between the supercircuit and control groups and no significant change with time.

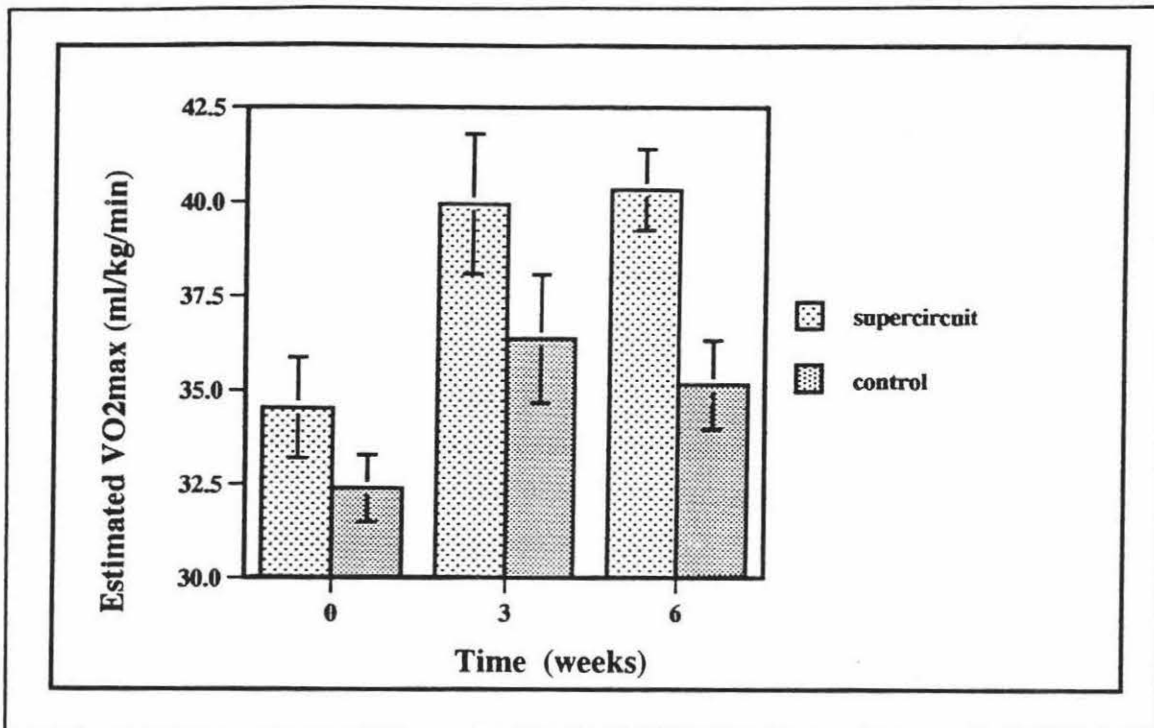

Fig 24. Estimated $\dot{V}O_2$max Calculated from Oxygen Consumption of the Supercircuit and Control Groups at Zero, Three, and Six Weeks (mean ± S.E.M.). There was a significant (T, p=.006; Tsq, p=.045) increase in estimated $\dot{V}O_2$max with time, and a significant (C, p=.0004) difference between the supercircuit and control groups.

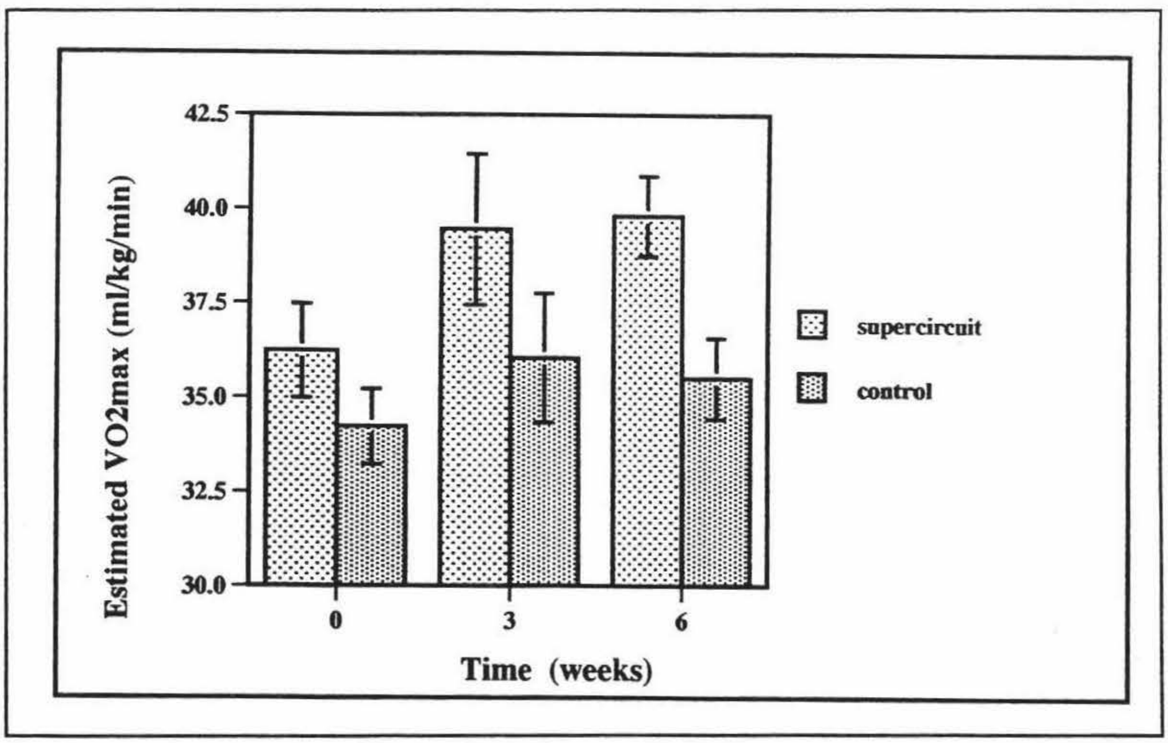

Fig 25. Estimated $\dot{V}O_2$max Calculated from External Work (watts) of the Supercircuit and Control Groups at Zero, Three, and Six Weeks (mean ± S.E.M.). There was a significant (T, p=.04) increase in estimated $\dot{V}O_2$max with time, and a significant (C, p=.002) difference between the two groups.

3.3.5. Cardiorespiratory Fitness

Cardiorespiratory fitness was monitored by estimating $\dot{V}O_2max$ from (1) heart rate and oxygen uptake over the last minute of the final work load on the cycle ergometer and (2) heart rate and external work (watts) for the final work load. The rate of decline in heart rate after completing the final work load on the cycle ergometer was assessed by recording the subjects' heart rate one, two and three minutes after completion of the final work load. The raw data from each subject is presented in Appendix B.3.

3.3.5.1. Heart Rate and Oxygen Uptake

The heart rate at the completion of the third work load on the cycle ergometer decreased from 151.4 $\pm$ 13.2 bpm to 143.6 $\pm$12.6 bpm for the supercircuit group (Fig 22; Appendix D, Table 5). For the control group the heart rate decreased from 156.0 $\pm$ 14.7 bpm to 151.8 $\pm$ 15.6 bpm. When heart rate was regressed against C, T, CT, Tsq and CTsq (Appendix E, Table 5), the decrease in heart rate over the six weeks was significant (T, $p=.01$) for both groups. The supercircuit group had a significantly (C, $p=.0025$) lower mean heart rate than the control group but although the supercircuit group showed a greater decrease in heart rate over the six weeks, this was not significant (CT, $p>.05$).

There was a small increase in oxygen uptake at the third work load on the cycle ergometer for both the supercircuit group and control group (Fig 23; Appendix D, Table 6). When oxygen uptake was regressed against C, T, CT, Tsq and CTsq (Appendix E, Table 6), none of these variables were found to have a significant influence on oxygen uptake.

3.3.5.2. Estimated $\dot{V}O_2max$

Appendix D, Table 7, summarises the mean estimated $\dot{V}O_2max$ for each group at zero, three and six weeks, calculated from oxygen consumption and external work at the final work load. The estimated $\dot{V}O_2max$ means calculated from oxygen consumption are shown graphically in Fig 24, and estimated $\dot{V}O_2max$ calculated from external work (watts) is shown graphically in Fig 25. Multiple regression equations for changes in estimated $\dot{V}O_2max$ over six weeks are presented in Appendix E, Table 7.

Estimated $\dot{V}O_2max$ calculated from oxygen consumption

When estimated $\dot{V}O_2max$ was calculated from oxygen consumption and heart rate at the final work load (Fig 24), estimated $\dot{V}O_2max$ increased by 16.8% from 34.5 $\pm$ 5.2 ml/kg/min to 40.3 $\pm$6.9 ml/kg/min for the supercircuit group. For the control group, estimated $\dot{V}O_2max$ increased by 8.6% from 32.4 $\pm$ 7.4 ml/kg/min to 35.2 $\pm$ 6.6 ml/kg/min. When estimated $\dot{V}O_2max$ was regressed against C, T, CT, Tsq and CTsq (Appendix E, Table 7), the mean estimated $\dot{V}O_2max$ of the supercircuit group was

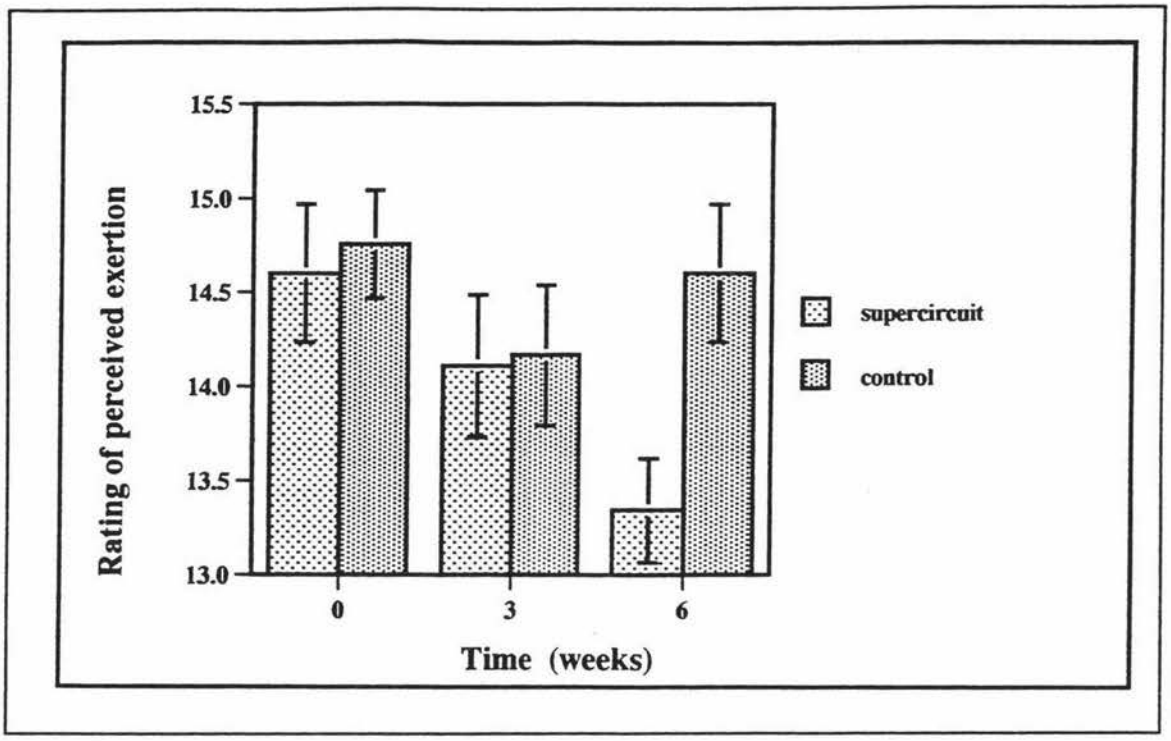

Fig 26. Rating of Perceived Exertion for the Third Workload of the Supercircuit and Control Groups at Zero, Three, and Six Weeks (mean ± S.E.M.). Subjects were asked to give a Rating of Perceived Exertion (Borg G.A., 1982) at the end of the third workload on the cycle ergometer. The decrease in Rating of Perceived Exertion of the supercircuit group was significantly (CTsq, p=.0006) different to the control group.

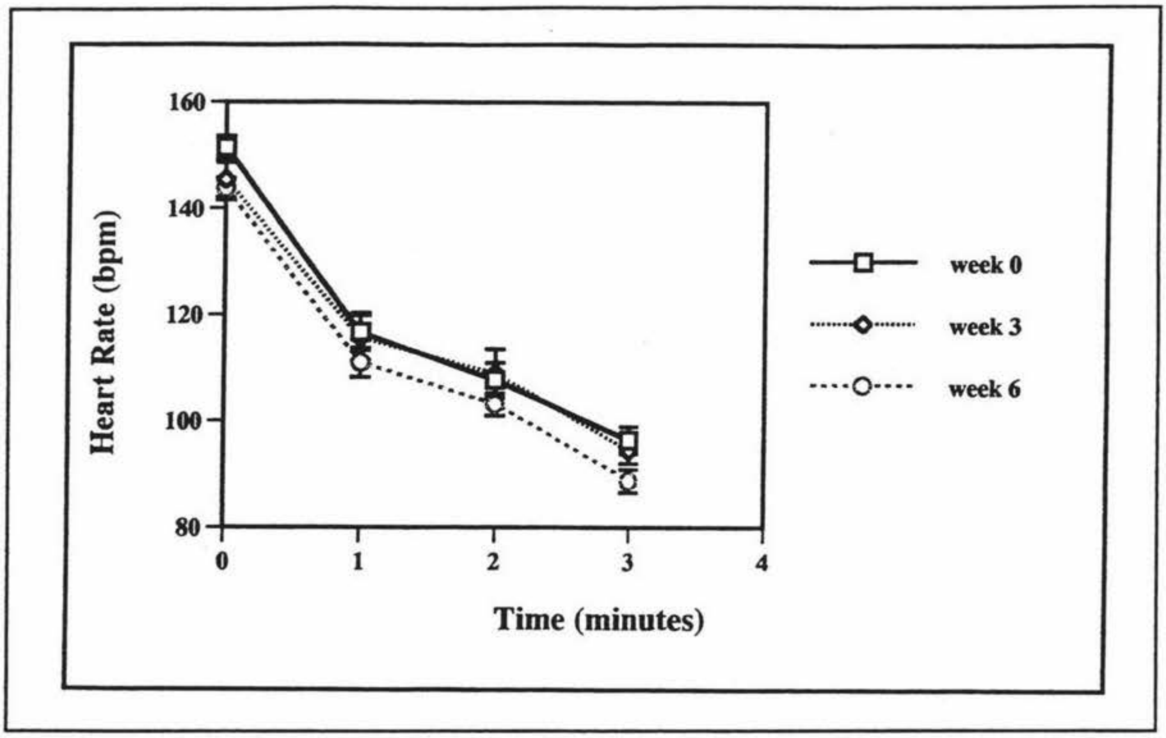

Fig 27. Rate of Decline in Heart Rate after the Completion of the Third Workload of the Supercircuit Group at Zero, Three, and Six Weeks (mean ± S.E.M.). Heart rate was recorded one minute, two minutes and three minutes after the completion of the third workload.

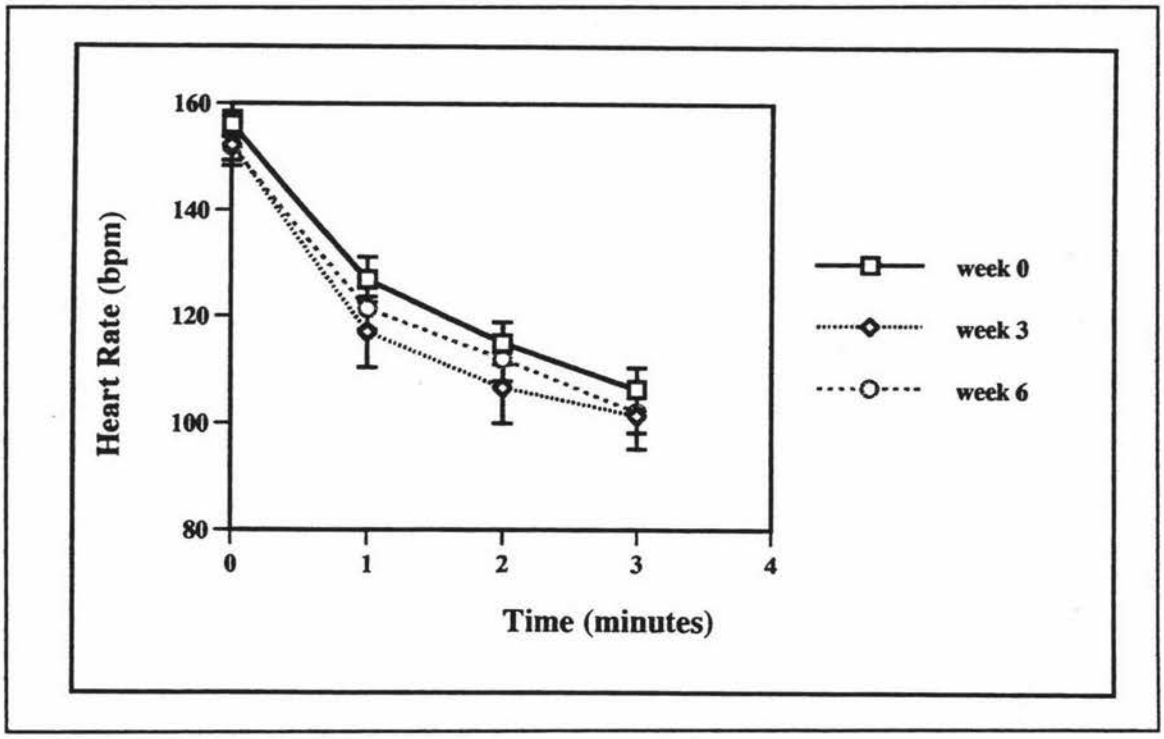

Fig 28. Rate of Decline in Heart Rate after the Completion of the Third Workload of the Control Group at Zero, Three, and Six Weeks (mean ± S.E.M.). Heart rate was recorded one minute, two minutes and three minutes after the completion of the third workload.

significantly higher than the control group (C, p=.0004) and there was a significant increase in estimated $\dot{V}O_2max$ over the six weeks of the study in both groups, (T, p=.006; Tsq, p=.045) but the increase shown by the supercircuit group was not significantly greater than the increase shown by the control group (CT, p>.05).

Estimated $\dot{V}O_2max$ calculated from external work load.

When estimated $\dot{V}O_2max$ was calculated from the external work load (watts) and heart rate at the final work load (Fig 25), estimated $\dot{V}O_2max$ increased by 9.9% from 36.2 ± 6.1 ml/kg/min to 39.8 ± 6.5 ml/kg/min for the supercircuit group. For the control group, estimated $\dot{V}O_2max$ increased by 5.8% from 34.2 ± 7.6 ml/kg/min to 36.2 ± 6.1 ml/kg/min. When estimated $\dot{V}O_2max$ was regressed against C, T, CT, Tsq, and CTsq (Appendix E, Table 7) the mean estimated $\dot{V}O_2max$ of the supercircuit group was significantly higher than the control group (C, p=.002) and there was a significant increase in estimated $\dot{V}O_2max$ over the six weeks of the study in both groups, (T, p=.04), but the increase shown by the supercircuit group was not significantly greater than the increase shown by the control group (CT, p>.05).

3.3.5.3. Rating of Perceived Exertion

The decrease in heart rate at the final work load was accompanied by a decrease in rating of perceived exertion (RPE) (Fig 26; Appendix E, Table 8). After six weeks of supercircuit training the RPE of the supercircuit group decreased from 14.6 ± 2.0 to 13.3 ± 1.6 while the control group decreased from 14.8 ± 1.7 to 14.6 ± 2.2. When RPE was regressed against C, T, CT, Tsq and CTsq (Appendix E, Table 8), there was a significantly greater (CTsq, p=.0006) decrease in RPE shown by the supercircuit group than the control group.

3.3.5.4. Rate of Decline in Heart Rate after the Completion of the Final Work Load on the Cycle Ergometer

Heart rate was recorded at one, two and three minutes after the completion of the third work load on the cycle ergometer for the 1994 group only. The results of the supercircuit and control groups are summarised in Appendix D, Table 9, and the means are shown graphically in Fig 27 and Fig 28.

Following six weeks of supercircuit training, the mean heart rate one minute after completion of the final work load on the cycle ergometer (while pedalling with no load) decreased from 116.8 ± 17.8 to 111.0 ± 13.9 for the supercircuit group (a decrease of 5.0%) while the control group decreased from 127.0 ± 21.5 to 121.4 ± 19.9 (a decrease of 4.4%). When heart rate was regressed against C, T, CT, Tsq and CTsq, there was a

Table 10. Changes in the Mean Response to a Questionaire on Perceived Levels of Fitness of the Supercircuit and Control Groups in 1994.
Prior to and after supercircuit training both the supercircuit and control groups were asked to rate the following aspects of fitness on a scale between 1 and 5 (Appendix A2). Changes in the mean response are shown in the following Table.

	Supercircuits Group		Control Group		
	Mean Change	SD	Mean Change	SD	P (2-tailed)
Body Fat	-.08	.96	-.18	.69	.82
Muscle Tone	1.15	.69	-.18	.60	.004*
Stamina	1	.58	-.09	.30	.0004*
Arm Strength	1	.71	-.091	.54	.0004*
Leg Strength	.39	.96	0	.45	.27
Arm Flexibility	.62	1.12	-.27	.91	.07
Leg Flexibility	.54	.66	-.46	.93	.0004*

* significant (p<.05).

significant (C, p=.01) difference between the supercircuit and control groups (Appendix E, Table 8).

The heart rate two minutes after completion of the final work load on the cycle ergometer (while pedalling with no load) decreased from 107.7 ± 15.9 to 103.2.0 ± 10.6 for the supercircuit group (a decrease of 4.2%) while the control group decreased from 115.0 ± 20.1 to 112.0 ± 19.7 (a decrease of 2.6%) over the six weeks of the study. When heart rate was regressed against C, T, CT, Tsq and CTsq, there was a significant (C, p=.05) difference between the supercircuit and control groups.

The heart rate three minutes after completion of the final work load on the cycle ergometer decreased from 96.4 ± 12.4 to 88.7.0 ± 11.0 for the supercircuit group (a decrease of 8.0%) while the control group decreased from 106.4 ± 20.7 to 102.0 ± 18.8 (a decrease of 4.1%). When heart rate was regressed against C, T, CT, Tsq and CTsq, there was a significant (C, p=.00003) difference between the supercircuit and control groups.

3.3.6. Questionnaires

3.3.6.1. Changes in Perceived Levels of Fitness

Prior to beginning supercircuit training, the 1994 supercircuit and control groups were asked to rate various aspects of their fitness on a scale between 1 and 5 (Appendix A.2). At the completion of supercircuit training and prior to the last two testing sessions, both groups were again asked to rate the same aspects of their fitness. The raw data is presented in Appendix B.4. The changes in the mean responses of each group is summarised in Table 10. t-tests (two-tailed) were used to compare the changes in the mean response of the supercircuit and control groups.

After six weeks of supercircuit training, the supercircuit group, in comparison to the control group, had a significantly greater increase in their perceived level of muscle tone (p=.004), stamina (p=.0004), arm strength (p=.0004) and leg flexibility (p=.0004), but not in body fat, leg strength and arm flexibility. Both groups no longer considered their body fat levels to be as high after six weeks, although this was not significant, with the control group's perception of their body fat level appearing to be lower than that of the exercise group.

3.3.6.2. Perceived Changes in Levels of Fitness

In 1994, at the completion of supercircuit training and prior to the final two testing sessions, both the supercircuit and control groups were asked if they felt there had been any changes in various aspects of fitness over the six weeks of the study (Appendix A.3).

Table 11. Perceived Changes in Levels of Fitness Over the Six Weeks of the Study of the Supercircuit and Control Groups in 1994 .
The subjects rated their changes in fitness on a scale of 1 to 5 where 1 was no change and 5 was a very large amount of improvement. A negative score indicated a decrease in fitness.

	Supercircuits		Control		
	Mean	SD	Mean	SD	P (2-tailed)
Body Shape	2	.71	.64	1.21	.015*
Muscle Tone	2.85	.80	.64	1.2	.003*
Stamina	2.77	.93	.64	1.2	.005*
Leg Strength	3	.91	.64	1.2	.002*
Arm Strength	3.54	.66	.64	1.2	.0001*
Shoulder Flexibility	2.31	.86	.64	1.2	.005*
Leg Flexibility	2.39	1.0	.64	1.2	.007*
General Physical Feeling	3.15	1.07	.64	1.2	.0015*

* significant ($p<.05$)

The raw data is shown in Appendix B.4 and summarised in Table 11. The supercircuit group felt they had significantly improved in body shape (p=.015), muscle tone (p=.003), stamina (p=.005), leg strength (p=.002), arm strength (p=.0001), shoulder flexibility (p=.005), leg flexibility (p=.007) and overall general physical feeling (p=.0015), whereas the control group felt that they had either remained the same or got worse.

4. Discussion

The purpose of this investigation was to study the effects of six weeks of training using a continuous circuit which included both aerobic and weight training stations, on body composition, muscle strength and endurance, flexibility and cardiorespiratory fitness. Nineteen previously sedentary females ranging in age from 20 to 44 years trained three times a week for 30-40 minutes while a further 19 previously sedentary females ranging in age from 21 to 49 years acted as controls.

4.1. Characteristics of the 1993 and 1994 Groups Prior to Supercircuit Training

Both the 1993 and 1994 groups came from the staff and student population at Massey University and volunteered in response to an advertisement in a Massey University newsletter. There was no significant difference between the two groups in age, height, body mass, body composition, eight of the nine flexibility measures, pre-exercise heart rate and estimated $\dot{V}O_2max$. The 1994 group had a significantly lower mean systolic and diastolic blood pressure than the 1993 group although the difference in the means for each year was less than the mean error of $\pm$ 8mm of Hg expected in individual readings of systolic and diastolic blood pressure when using the auscultatory method (Brobeck, 1973). The number of crunches completed in one minute was significantly greater in the 1994 group. However, crunches are not a very good method of assessing abdominal strength (see section 4.3.4). Strength of the upper and lower body could not be compared as different methods were used to assess strength.

The significant differences between the two groups in three of the 20 measured characteristics may have been due to variability in the population and the small number of subjects in each group, especially the 1993 group in which only 12 subjects participated. Another source of variability may have been that subjects were tested between February and April in 1993, and between May and October in 1994. The time of year may have had an effect on levels of activity and stress in the subjects and also probably resulted in differences in room temperature where the testing was done. However, as room temperature was not monitored it was not possible to directly relate room temperature to the test results.

4.2. Characteristics of the Supercircuit and Control Groups Prior to Supercircuit Training

When ANOVA was used to compare the results from the first two tests for the supercircuit and control groups there were no significant differences between the two groups for all the characteristics measured. However, when the results of the two groups were compared over the five tests using regression analysis some mean differences did become significant. These are discussed in the relevent sections.

4.3. A Comparison of the Supercircuit and Control Groups over the Six Weeks of the Supercircuit Training Programme

4.3.1. Body Composition

Body composition may have changed slightly in the supercircuit group over the six weeks of this study as there was a small increase in body mass in the supercircuit group and a small decrease in the sum of two and six skinfolds. This would indicate a decrease in body fat levels and an increase in lean body weight. However, these changes were not significant.

Regular exercise has been shown to promote weight loss (Perri *et al.*, 1986; Pavlou *et al.*, 1989; Ballor & Poehlman, 1994), but the energy expended during exercise has been proposed to be only one of a number of mechanisms that links exercise to weight loss (Wilfley & Brownell, 1994). Other mechanisms include minimisation of loss of lean body mass or increasing lean body mass (Ballor *et al.*, 1988, 1990), suppression of appetite (Woo *et al.*, 1982), counteraction of a decline in resting metabolic rate (RMR) (Poehlman, 1989; McArdle *et al.*, 1991), prevention of an increase in selecting dietary fat during weight cycling (Gerardo-Gettens *et al.*, 1991) and positive psychological effects by improving mood, psychological well being, self concept and self esteem (Rodin & Plante, 1989; Wilfley & Brownell, 1994). Several of these mechanisms are more applicable to those who are combining a decrease in calorie intake with exercise in order to lose weight (i.e. minimising loss of lean body mass, counteracting a decline in RMR, and preventing an increase in dietary fat selection). In this study subjects were asked not to consciously change their diet therefore the main mechanisms for changes in body composition for these subjects was likely to be an increase in energy expenditure, an increase in lean body mass and suppression of appetite.

In order to induce fat loss by exercising three times a week while maintaining the same energy intake, it has been suggested that energy expenditure within an exercise session needs to be at least 1260kJ for 20 minutes or 63kJ per minute (ACSM, 1990). Energy expenditure while doing supercircuits was not measured in this study but other studies on CWT have shown energy expenditure during CWT to be between 25 and 36.5kJ per minute (Wilmore *et al.*, 1978b; Ballor *et al.*, 1989; Mosher *et al.*, 1994). Wilmore *et al.* (1978b) and Ballor *et al.* (1989) used weight training circuits where 30 seconds of work was followed by 30 seconds and 15 seconds of rest respectively. The average energy expenditure for the circuit used by Wilmore *et al.* (1978b) was 25kJ/min and for the circuit used by Ballor *et al.* (1989) was 27.6kJ/min. Mosher *et al.* (1994) included five 3 minute aerobic sessions within their weight training circuit in which 30 seconds of weight training was followed by 30 seconds of rest. The average energy expenditure during this circuit was 36.5kJ/min. The energy expenditure by the average 65kg woman during weight training (22.5kJ/min: Watson & Mackle, 1995) is lower than the average energy expenditure while doing aerobic exercise (eg aerobics is 34kJ/min, casual cycling is 34kJ/min, jogging is 41kJ/min: Watson & Mackle, 1995) which would account for the increase in energy expenditure in the circuit of Mosher *et al.* (1994). The supercircuit in the present study included eleven 40 second aerobic stations - a total of 7 minutes of aerobic exercise. As the circuit was a predominantly weight training circuit, it was therefore likely that the average energy expenditure was somewhere between 25kJ and 36kJ per minute although by having no rest periods between stations, energy expenditure may have been slightly higher. (The intensity of training is likely to be lower where training is continuous as compared to training interspersed with rest periods). However, energy expenditure is unlikely to be as high as 63kJ/min, the minimum thought to be required to induce fat loss when exercising three times a week for 20 minutes. One would, therefore, not expect to see a decrease in body fat due to energy expenditure alone while circuit weight training, particularly over a short period of six weeks. Subjects were asked not to modify their diets during the six week training period, however, it is possible that some of the subjects may have modified their diets and this combined with the increase in energy expenditure may have resulted in the apparently small but insignificant decrease in skinfolds seen in this study.

Lean body mass in females has been shown to increase by 3-4% over 10-12 weeks for both circuit weight training (Wilmore *et al.*, 1978a; Gettman *et al.*, 1982) and aerobic circuit weight training (Mosher *et al.*, 1994). This study indicated a 3.5% decrease in total body skinfolds (SKF-6) and a 2% decrease in trunk skinfolds (SKF-2) while body mass remained the same or increased slightly. Sum of skinfolds was used in this study in preference to predicting percentage body fat from the skinfold measurements as equations for the calculation of percentage body fat from skinfolds have not been developed for the

New Zealand population. Also, there are a number of assumptions when predicting fat content of the body from skinfolds, the validity of which have been questioned (Wilson *et al.*, 1993).

Although the changes in skinfolds and body mass were insignificant in this study, it does suggest there may have been a small increase in lean body mass during the six weeks of the study.

4.3.2. Blood Pressure

There was a significant decrease in both systolic and diastolic blood pressure for both the supercircuit group and the control group over the six weeks of this study with systolic blood pressure decreasing by 4-5 mm of Hg and diastolic blood pressure decreasing by 3-4 mm of Hg. However, these decreases, although significant, are insignificant on a physiological scale as there is a mean error of $\pm$ 8 mm of Hg expected in individual readings of systolic and diastolic blood pressure (Brobeck, 1973). Blood pressure decreased more for the supercircuit group, particularly the systolic pressure but there was no significant difference between the two groups. Other studies on circuit weight training have also not been able to demonstrate a training effect on blood pressure, even over periods of as long as 12 weeks (Allen *et al.*, 1976; Haennel *et al.*, 1989; Katz & Wilson, 1992) although both weight training and endurance training are well known to decrease blood pressure (Seals & Hagburg, 1984; McLatchie, 1993). All the blood pressure measurements were in the normal range for this study and it has been suggested that a fall in blood pressure with aerobic training would be unlikely as it is not possible to reduce blood pressure in the normal range by a large amount (Grant *et al.*, 1992).

A significant decrease in blood pressure of 7-11 mm of Hg in control groups has been shown in other studies (Seals & Hagburg, 1984) although these were hypertensive subjects. The cause of the decrease in blood pressure in this study is not clear but it may be because the subjects became less 'stressed' by the fitness testing. Fear, excitement, and related emotional stress can all elevate blood pressure.

4.3.3. Flexibility

In this study changes in flexibility of the hamstring muscle group, calf muscles (gastrocnemius and soleus) and shoulders were assessed. Prior to the study the supercircuit group was less flexible for the hamstring muscle group than the control group, as assessed by the sit and reach test, but after six weeks of supercircuit training which involved five minutes of stretching at the completion of training, there was a significant improvement in their flexibility and they became more flexible than the control group. There was no significant improvement in any of the other flexibility tests.

Few studies on CWT have attempted to assess changes in flexibility. Wilmore *et al.* (1978a) did not appear to include stretching as part of the exercise routine but found that females improved slightly (by 2.5cm) but significantly in the sit and reach test while males did not. Marcinik *et al.* (1985) found no improvement in males in the sit and reach test even though 10 minutes of stretching was included in the exercise programme. The 5cm improvement in the sit and reach test shown in this study is similar to an improvement of 6cm shown by males (Grant *et al.*, 1992), after an aerobic type fitness programme run over ten weeks which included five minutes of stretching within the programme.

The increase in flexibility of the supercircuit group in the present study is probably attributable to the stretching exercises included at the end of the exercise programme as long duration static stretching carried out with elevated body temperatures is optimal for improvements in flexibility (Sapega *et al.*, 1981). Although this study does not indicate that supercircuits alone can increase flexibility, supercircuits followed by a stretching routine appears to.

4.3.4. Muscle Strength and Endurance

The bench press, leg press and leg extension were the exercises chosen to assess upper and lower body strength as they are relatively safe exercises when performed with submaximal loads and they are representative of upper and lower body strength. Evaluating strength by finding the load which can be lifted once only (1RM) was not used in this study as these exercises are potentially dangerous when attempting a 1RM. This is particularly true for the leg extension where a lot of stress is put on the knee joint, and the leg press where a lot of stress is put on the knee and lower back.

In 1993 the strength of each subject was assessed by finding the maximum weight each subject could lift five to ten times (5-10RM) and converting it to an estimated 1RM (Paterson & Poliquin, 1987; Hoeger et al., 1987, 1990; Mayhew et al., 1992). The results from the 5-10RM were converted to a 1RM in order to monitor improvements more readily and to collate group results (Paterson & Poliquin, 1987). Monitoring the increase in number of repetitions at a set load was used in the second year as it was felt that (provided the number of repetitions was under ten initially) it may be a more accurate way to measure strength gains as subjects were often not prepared to attempt a heavier load if they did achieve 10 repetitions when strength was assessed from a 5-10 RM test.

All supercircuit subjects significantly improved their strength. The percentage of improvement ranged from 40-100% for the bench press depending on whether it was assessed using an estimated 1RM or an increase in the number of repetitions for a set load, and by 16% for the leg press using an estimated 1RM and 52% for the leg extension using the maximum number of repetitions possible. Over the same six week period the control group increased their bench press estimated 1RM by 0.9% and the maximum number of repetitions possible by 17%, the leg press estimated 1RM by 3.4% and leg extension repetitions by 9%. The changes in the control group were not significant. These results appear to indicate a greater increase in strength as a result of using The Massey University Recreation Centre supercircuit than in other circuits studied (Wilmore *et al.*, 1978a; Gettman *et al.*, 1982; Mosher *et al.*, 1994) which showed increases in 1RM of 20-21% for the bench press and 18-27% for the leg press for females, particularly as these latter studies were done over 12 weeks as compared to six weeks in the present study. However, the 1RM was estimated in the present study rather than measured directly which may have led to an overestimate of the increases in strength.

Abdominal strength and endurance as measured by the number of crunches each subject could do in a minute increased by 43% for the supercircuit group which was significantly greater than the 23% increase shown by the control group. The large increase in apparent abdominal strength shown by the control group suggests that there may be a large learning component in the number of crunches that can be achieved in one minute and it is therefore a test that needs to be interpreted cautiously.

Although a few studies have shown that simultaneous strength and endurance training reduces the ability to increase muscular strength (Hennessy & Watson, 1994; Sale *et al.*, 1990b) it appears that it is only in high intensity, low volume strength programmes combined with high intensity endurance programmes that development of strength and power is impeded. In moderate-low intensity strength programmes combined with high intensity endurance training there are enhanced gains in strength and endurance (Arnett, 1993). In The Massey University Recreation Centre supercircuit, strength training is low intensity (approximately 40-50% 1RM) and high volume (a high number of repetitions), so although it would not be the best type of training for those who wish to improve strength and power, the aerobic/endurance component of the circuit should not impede strength development.

Although large strength gains were made as a result of supercircuit training it is unlikely that they would be as great as those made during conventional strength training programmes. To achieve optimal strength gains loads should be high, approximately 5RM to 6RM, and each set of exercises should be followed by at least one minute rest (Atha, 1981; Fleck & Kraemer, 1987). During circuit training high levels of blood lactate occur (Noble *et al.*, 1984; Hurley *et al.*, 1984), approximately 16-fold greater than walking at the same oxygen uptake level which may contribute to fatigue and preclude the high intensity training necessary for optimal strength gains.

The gains in strength could be attributed to three possible factors: (1) muscle hypertrophy, (2) biochemical adaptations, and (3) neural adaptations (Enoka, 1988). An increase in lean body mass would indicate that muscle hypertrophy had occurred. In this study there appeared to be a small increase in body mass and a small decrease in the sum of the skinfolds which may indicate an increase in lean body mass, but these changes were not significant. Biochemical changes such as increases in creatine, phosphocreatine, ATP and glycogen are small and often inconsistent (Saltin & Gollnick, 1983; McDougall, 1986) therefore it is likely that neural mechanisms are largely responsible for the increases in strength. Changes in neural mechanisms could result in improved coordination or learning (Jakeman *et al.*, 1994) or from changes in recruitment patterns and synchronisation of motor units (Thorstensson, 1976, Enoka, 1988).

4.3.5. Cardiorespiratory Fitness

4.3.5.1. The Effectiveness of the Supercircuit Programme for Improving Cardiorespiratory Fitness

With an improvement in cardiorespiratory fitness it would be expected that estimated $\dot{V}O_2max$ would increase, heart rate would recover more rapidly after exercise, heart rate at a given submaximal work load would decrease, and subjects would feel that their stamina had increased. In the supercircuit group there was a significant increase of 17% in estimated $\dot{V}O_2max$ (ml/kg/min) over the six weeks of the study but it was not signficantly different to the 8.5% increase shown by the control group, pre-exercise heart rate decreased significantly more than the control group, heart rate at the final work load appeared to decrease (but the decrease was not significant), subjects' ratings of perceived exertion at the final work load decreased significantly, and subjects felt that their was a significant improvement in their 'stamina'. The control group, in contrast, showed no significant changes in perceived exertion, heart rate at the final work load or in stamina. The decrease in estimated $\dot{V}O_2max$ and pre-exercise heart rate shown by the control group demonstrates the importance of a non-exercising control group, because without a control group these reductions would have been ascribed solely to the effects of supercircuit training.

Although there was no significant difference in estimated $\dot{V}O_2max$ between the supercircuit and control groups based on the measurements from the first two tests and using ANOVA to compare the two groups, when regression analysis was used over the five tests there was a significant difference between the two groups. This could be due to the control group mean estimated $\dot{V}O_2max$ being lower than the supercircuit group throughout the five tests. There was a significant increase in estimated VO_2max over the time course of the study for both groups, but the greater decrease shown by the supercircuit group was not significantly greater than that of the control group. As the interaction of training with time was not significant, there was therefore no significant training effect.

Improvements in $\dot{V}O_2max$ with CWT have ranged from as high as 18% (Mosher *et al.*, 1994) to no improvement (Allen *et al.*, 1976) depending on the type of circuit used. Studies which have used lower repetitions (less than 12) and longer rest intervals (30 seconds or more) have shown little or no change in VO_2max (Allen *et al.*, 1976; Gettman *et al.*, 1978, 1979; Hurley *et al.*, 1984). Studies on weight training circuits which have used high repetitions (greater than 12) and very short rest periods between sets (less than 20 seconds) have shown increases in VO_2max of between 10% and 13% (Wilmore *et al.*, 1978a; Gettman *et al.*, 1982; Messier & Dill, 1985; Haennel *et al.*, 1989; Petersen *et al.*, 1988). The increase in estimated $\dot{V}O_2max$ shown in this study is of a similar magnitude to studies done by Mosher *et al.* (1994) and Gettman *et al.* (1982) who both used aerobic weight training circuits. Mosher *et al.* (1994) showed an increase of 18% and Gettman *et al.* (1982) showed an increase of 17% in $\dot{V}O_2max$ in females after 12 weeks of training. However, neither of these studies showed any increase in VO_2max in the control groups.

The fast recovery of heart rate after exercise in trained people has been well established (Astrand & Rodahl, 1986), but in this study there was no apparent improvement in recovery heart rate over the six weeks of supercircuit training in the 1994 group despite an increase in estimated $\dot{V}O_2max$, decrease in pre-exercise heart rate, and a feeling of increased stamina. The inability to measure a more rapid decrease in heart rate may have been due to the subjects continuing to cycle for 2 minutes after completing the last work load on the cycle ergometer and the failure of the ergometer to drop back to zero load in the latter part of the 1994 study, or it may have been because there was not a big enough improvement in cardiorespiratory fitness.

Although the results of this study indicate there may have been an improvement in cardiorespiratory fitness as a result of supercircuit training, as there was a significant improvement in perceived stamina, a significant decrease in pre-exercise heart rate, and a significant decrease in perceived exertion at a submaximal work load on the cycle ergometer, the results were not conclusive as the increase in estimated $\dot{V}O_2max$ shown by the supercircuit group was not signficantly greater than the increase shown by the control group. An increase in $\dot{V}O_2max$ is usually thought to be the most reliable indicator of an improvement in the cardiorespiratory fitness of an individual.

4.3.5.2. Problems of Demonstrating an Improvement in Estimated VO_2max

The inability of this study to establish a significant difference between the increase in estimated $\dot{V}O_2max$ in the supercircuit and control groups could be due to a number of factors. (1) There was relatively little increase in estimated $\dot{V}O_2max$ as oxygen uptake during supercircuit training was too low to elicit an adaptive response despite the high heart rate while doing supercircuits. (2) The test procedure used to estimate $\dot{V}O_2max$ may not have been sensitive enough to pick up an increase in estimated VO_2max due to biological and technological variability. (3) The study may have been conducted over too short a time frame to allow a significant increase in VO_2max. (4) There were not enough participants in the study for the results to be statistically significant. (5) Cycling may not have been the most appropriate mode for testing for an increase in $\dot{V}O_2max$.

4.3.5.2.1. Oxygen Uptake While Training

In order to achieve an increase in $\dot{V}O_2max$, ACSM (1990) has suggested that aerobic conditioning needs to be performed for at least 20 minutes, at least three times a week at a work level which elicits either a heart rate of at least 55% of the maximum heart rate or where the intensity of training requires an oxygen uptake of greater than 50% $\dot{V}O_2max$. Subjects in this study trained three times a week for at least 20 minutes a session with their heart rates greater than 55% of their estimated maximum heart rate. Although heart rate was monitored during the supercircuit training (either by palpation or heart rate monitor) to ensure subjects were working in the correct heart rate range, oxygen uptake was not measured so a true account of the intensity at which the subjects were working was not possible.

Heart rate monitoring is an indirect method of estimating oxygen uptake by the body but there is not always a direct relationship between the two (Fox, 1973; Swain *et al.*, 1994). A number of studies have shown that oxygen uptake while circuit training is less than running or walking at the same percentage of maximum heart rate and rate of perceived exertion (See Table 5; Wilmore *et al.*, 1978b; Hurley *et al.*, 1984; Petersen *et al.*, 1988; Ballor *et al.*, 1989). However, none of these circuits included aerobic exercises and are therefore somewhat different to the supercircuit in this study. Wilmore *et al.* (1978b) used a work to rest ratio of 30/15 seconds, Petersen *et al.* (1988) used a work to rest ratio of 20/40 seconds, Ballor *et al.* (1989) used a work to rest ratio of 30/30 seconds, and although Hurley *et al.* (1984) used a continuous circuit, the number of repetitions completed at each station were low (8 - 12 repetitions) in contrast to the 15 - 20 repetitions used at each station in the present supercircuit. Oxygen uptake while training using the The Massey University Recreation Centre supercircuit should be greater than in the above studies as a higher number of repetitions increases oxygen uptake (Petersen *et al.*, 1988), there were no rest periods and the circuit also included a number of aerobic stations which would further increase oxygen uptake. It is, therefore, likely that participation in this supercircuit programme results in an oxygen uptake greater than the 45% of maximum oxygen uptake found during the circuit training studied to date (Wilmore *et al.*, 1978b; Hurley *et al.*, 1984; Petersen *et al.*, 1988; Ballor *et al.*, 1989). However, oxygen uptake may still be below the 50% of maximum oxygen uptake suggested as necessary to improve cardiorespiratory fitness (ACSM, 1990).

4.3.5.2.2. Testing Procedure

In this study $\dot{V}O_2max$ was estimated from heart rate and either oxygen uptake or external work (watts) at a submaximal work load on a cycle ergometer. However, the standard error of this method for predicting $\dot{V}O_2max$ can be as high as 15% (Astrand & Rodahl, 1986). This method depends on a linear increase in heart rate with an increase in oxygen uptake (or external work load), a maximal heart rate which is the same for people of the same age and declines with age at a set rate and, where $\dot{V}O_2max$ is predicted from work load alone, it also depends on a constant mechanical efficiency. Estimating $\dot{V}O_2max$ from oxygen uptake rather than external work load thus removes one error in the method. Because $\dot{V}O_2max$ is predicted from heart rate, it is also dependent on heart rate at a given submaximal work load not being affected by extraneous factors such as stress, and variations in room temperature.

Variability in Heart Rate

The increase in estimated $\dot{V}O_2max$ found for both the supercircuit and control groups is due mainly to a decrease in heart rate. There was a significant decrease in heart rate for both the supercircuit and control groups over the six weeks of the study with the supercircuit group demonstrating a greater decrease than the control group. Pre-exercise heart rate also decreased for both groups with the supercircuit group showing a significantly greater decrease than the control group. The cause of the decrease in heart rate prior to testing and at each submaximal work load is not clear, but possible causes include a change in activity levels of the control group and/or both groups of subjects becoming less 'stressed' or apprehensive of the fitness testing procedureπ. Wilmore *et al.* (1978a) and Grant *et al.* (1992) also showed significant drops in heart rate at rest and at submaximal work loads in control subjects over the ten weeks of their studies.

As well as an overall decrease in heart rate for both supercircuit and control subjects, there was also a lot of individual variability in heart rate. Individual heart rates (recorded on a heart rate monitor) varied by as much as 10 beats per minute on consecutive days in both groups for a given level of external work (some decreasing on consecutive days and others increasing). This is a similar variation to that shown by Becque *et al.* (1993) who demonstrated an average day to day within subject variability of 3.2% for heart rate and a reliability ranging from r=0.69 to r=0.97 at three submaximal work loads for four males.

In other words, if the mean heart rate is 130, 95% of the time heart rate will be within 8 beats per minute at a given work rate. If work load is measured by oxygen consumption, according to Astrand & Rodahl (1986), for a specific oxygen uptake heart rate should vary less than 5 beats/minute under standardised conditions. In this study heart rate at the same oxygen uptake varied by as much as 10 beats per minute although conditions were not standardised.

Factors that could cause a variation in heart rate are stress, circadian variation in heart rate, stage of the menstrual cycle, room temperature variation, and variability in cycling efficiency. Variability in heart rate may also be more frequent in untrained subjects as exceptions to a linear increase in heart rate with increasing exercise intensity may be more frequent in untrained subjects (Astrand & Rodahl, 1986). Although all subjects were tested at the same time of the day where possible to avoid possible daily variations in heart rate, there were sometimes large variations in room temperature (for some morning tests the temperature was very low) and cold conditions can either depress or elevate heart rate (LeBlanc *et al.*, 1978). Heart rate has been shown to increase during the luteal phase of the menstrual cycle but the alterations are not substantial (LeBrun, 1993). It is postulated that the higher core temperature and plasma volume shifts during this phase may cause a secondary increase in cardiovascular strain during prolonged exercise.

Maximal Heart Rate

In order to estimate $\dot{V}O_2max$, the oxygen uptake value obtained from the nomogram of Astrand & Rodahl (1986), was corrected by multiplying it by an age correction factor (Astrand & Rodahl, 1986). However, the standard deviation for maximal heart rate within an age group is approximately ± 10 beats per minute (Astrand & Rodahl, 1986) and can thus lead to a reasonable error when estimating VO_2max.

Other studies which have demonstrated significant increases in $\dot{V}O_2max$ have used maximal tests which require subjects to exercise at or close to their maximal heart rate (Gettman *et al.*, 1979, 1982; Messier & Dill, 1985; Petersen *et al.*, 1988; Haennel *et al.*, 1989; Mosher *et al.*, 1994) thus removing some of the variability in heart rate seen at sub-maximal work loads. During repeated maximal exercise the standard deviation in heart rate was said to be ± 3 beats per minute (Astrand & Saltin, 1961).

Mechanical Efficiency

In this study oxygen uptake whilst working at 105 watts varied by up to 0.3 litres of oxygen per minute for an individual. This is within the range shown by Becque *et al.* (1993) who demonstrated an average day to day, within subject, variability in oxygen uptake of 4.3% for cycling at a set submaximal work load. Oxygen uptake can vary due to changes in mechanical efficiency which can vary by as much as ± 6% on a cycle ergometer (Astrand & Rodahl, 1986). A mean oxygen uptake of 2.1 litres/minute could lead to a variation of 0.4 litres/minute. Different conditions such as a hot environment should have little effect on oxygen uptake at a given submaximal rate of exercise (Astrand & Rodahl, 1986), although cold conditions which result in a decrease in body temperature can increase oxygen uptake (Holmer & Bergh, 1974; Davies *et al.*, 1975; Bergh, 1980). Changes in individual mechanical efficiency over the course of a training period should be small or insignificant (Astrand & Rodahl, 1986) with fitness having no apparent effect on the reliability of oxygen uptake (Becque *et al.*, 1993). If anything, one might perhaps expect a slight increase in cycling efficiency with sedentary subjects in response to a series of fitness tests, but in this study both the control and supercircuit groups demonstrated a small, insignificant increase in oxygen uptake which suggests a decrease rather than an increase in cycling efficiency.

Technological Variability

A small part of the error in predicting $\dot{V}O_2$max will be due to technological variability. However this source of error is likely to be small compared to the biological variability. Some error is likely to occur in measuring the volume of air collected, analysis of the gas samples, and setting the work load. When measuring oxygen uptake, air was collected for one minute. Opening or closing the valve during various stages of the inspiratory and expiratory phases of breathing could lead to a variation in the volume of air collected. The gas analyser was calibrated regularly against both air and a gas containing a known concentration of oxygen and carbon dioxide, which should have resulted in very little error in the gas analysis. Repeated sampling of expired gas from Douglas bag once the gas analyzer had stabilisd resulted in a maximum error of approximately 0.1% of oxygen which resulted in a maximum error of approximately 2.5% of the total amount of oxygen extracted by the lungs. This is less than the 4-6% error which could be expected from variations in cycling efficiency (Astrand & Rodahl, 1986; Becque *et al.,* 1993), therefore is unlikely to be a large source of error. Accuracy could have been increased by calibrating the gas analyser to two decimal places rather than to one decimal place.

4.3.5.2.3. Duration of the Exercise Programme

In this study subjects trained over a period of six weeks. Although significant responses to training may require as much as 15-20 weeks of training for some individuals (Seals et al., 1984), the present study was only over a period of six weeks, to ensure maximum compliance with the exercise programme. It was also felt that because of the sedentary background of the subjects, most improvements would occur within the first six weeks. Most studies which have shown significant increases in $\dot{V}O_2$max have trained individuals for 8-16 weeks (Gettman *et al.*, 1979, 1982; Messier & Dill, 1985; Haennel *et al.*, 1989; Mosher *et al.*, 1994), although Petersen *et al.* (1988) showed a 9.5% increase in VO_2max in five weeks in subjects who trained four times a week at a very high intensity. Improvements in $\dot{V}O_2max$ are said to occur linearly up to 10-11 weeks after which point there is less improvement, no matter what the initial fitness level, intensity, duration or frequency of training (Wenger & Bell, 1986). Thus, if the length of the study had been extended there may have been a greater increase in estimated $\dot{V}O_2max$ resulting in a significant difference between the control and supercircuit group but increased non-compliance with the exercise schedule may have confounded the observations.

4.3.5.2.4. Number of subjects

The mean estimated $\dot{V}O_2max$ of the supercircuit group increased over the six weeks of the study but the increase was not significantly different to that shown by the control group. By increasing the number of subjects in both the supercircuit and control groups it is possible that the differences between the two groups may have become significant.

4.3.5.2.5. Mode of Testing

Improvements in $\dot{V}O_2max$ are the result of adaptations which can occur at any point within the pathway of oxygen from the air via the lungs and circulatory system to the mitochondria, and within the mitochondria itself (Sutton, 1992). However, at the peripheral level, the changes from physical training are specific to the muscles involved and to the pattern in which they are used (Gettman *et al.*, 1981). As the The Massey University Supercircuit used in this study exercised both upper body and lower body muscle groups, cycling, which exercises predominantly the lower body may not be the best mode of testing for an increase in $\dot{V}O_2max$. Most studies reviewed here have assessed $\dot{V}O_2max$ using the treadmill (Wilmore *et al.*, 1978a; Gettman *et al.*, 1978, 1979, 1982; Hurley *et al.*, 1984; Messier & Dill, 1985; Petersen *et al.*, 1988; Mosher *et al.*, 1994), with only two using the cycle ergometer (Marcinik *et al.*, 1985; Haennel *et al.*, 1989), and one using arm ergometry (Harris & Holly, 1987). All of these studies have shown small to modest increases in $\dot{V}O_2max$ apart from Harris & Holly (1987), who showed a 21% increase in $\dot{V}O_2max$ using arm ergometry but only an 8% increase when using the treadmill. Arm ergometry may therefore be a better mode of testing for improvements in $\dot{V}O_2max$ than either the treadmill or cycle ergometry.

4.3.6. Perception of Fitness Levels

All subjects were asked to fill in two questionnaires. The first questionnaire (perceived level of fitness) asked subjects to rate their body fat, muscle tone, stamina, strength of their arms and legs, and flexibility of their arms and legs on a scale between 1 and 5. This questionnaire was filled in both before and after the six weeks of the study. At the completion of six weeks the control group rated themselves very much the same, but the supercircuit group had a significant increase in their ratings for muscle tone, stamina, arm strength, and leg flexibility. There was no significant change in their ratings for body fat, leg strength, and arm flexibility.

The second questionnaire (perceived changes in fitness) was completed after the six week supercircuit programme. Subjects were asked if they felt various aspects of fitness had improved and by how much. The control group felt they had remained the same or had become less fit whereas the supercircuit group felt they had improved in all the variables. Arm strength showed the greatest improvement followed by muscle tone, stamina, leg strength, shoulder flexibility, leg flexibility and overall general physical feeling. Body shape showed the least improvement.

4.4. Summary

Six weeks of training using the supercircuit developed at The Massey University Recreation Centre significantly altered several aspects of fitness in sedentary females. Upper and lower body strength, abdominal strength, and flexibility of the hamstring muscle group increased significantly. A significant improvement in pre-exercise heart rate, perceived exertion at a submaximal work load and perceived stamina; a decrease in heart rate at a submaximal work load, and a 17% increase in estimated $\dot{V}O_2max$ (although insignificant), all indicated an increase in cardiorespiratory fitness. Although there was a small increase in body weight and decrease in the sum of the skinfolds in the supercircuit group, possibly suggesting an increase in lean body mass and a decrease in body fat, these changes were not significant.

The supercircuit developed at the Massey University Recreation Centre was a continuous circuit of weight training and aerobic exercises, but although similar to other circuits developed to improve both strength and cardiorespiratory fitness, there were not as many aerobic stations, nor were there several minutes of aerobic activity after groups of weight training exercises. Also, there was a variety of modes of aerobic exercise, rather than just cycling or running. Based on this study, which indicates significant changes in nearly all aspects of fitness, supercircuit training as used in the present study would appear to offer a good generalised conditioning programme for sedentary females.

5. Conclusion

The continuous weight training circuit developed at The Massey University Recreation Centre, in which a high number of repetitions (15 - 20) is completed at each 40 second station and in which approximately one in every three stations is aerobic, is effective for improving strength in sedentary women if it is undertaken for 20 - 30 minutes three times a week. If stretching is included as part of the programme, flexibility will also be increased. The results also demonstrated an increase in cardiorespiratory fitness although the increase in estimated $\dot{V}O_2max$ was not signifcantly different to the increase shown by the control group. The circuit may also be effective for improving body composition.

The failure of this study to demonstrate a significant increase in $\dot{V}O_2max$ and a decrease in body fat may have been because (1) the testing protocol and methodology used were not sensitive enough to detect small changes, (2) the duration of the study was not long enough and/or there were not enough subjects, and (3) the circuit was not very effective for increasing cardiorespiratory fitness and decreasing body fat.

In order to clarify the potential effectiveness of the circuit for improving cardiorespiratory fitness and body composition the following are recommended:

1. Oxygen uptake should be measured while completing a supercircuit programme in order to assess whether (a) oxygen uptake is above or below the recommended oxygen uptake necessary to stimulate improvements in VO_2max, and (b) to monitor energy expenditure.
2. The diets of subjects should be analysed to establish whether energy intake changes over the time frame of the study.
3. A positive control made up of subjects who participated in a more aerobic programme such as jogging which is known to be one of the best exercises for both improving cardiorespiratory fitness and inducing fat loss, should be included.
4. The duration of the study should be extended to 10 - 12 weeks.
5. Participants should complete a fitness test prior to the commencement of the study in order to familiarise them with the testing protocol.
6. All participants in the study should complete daily activity diaries in order to ensure that control groups do not change their activity levels, and the training group only increases their activity levels by circuit training.

The circuit could probably be made more effective for improving cardiorespiratory fitness and decreasing body fat by either increasing the number of the aerobic stations such that one in every two stations are aerobic, or by increasing the duration of the aerobic stations so that approximately half of the time doing circuits is aerobic exercise, and half the time is weight training. However, although this may be more effective in increasing cardiorespiratory fitness and fat loss, it may compromise increases in strength.

As the tests used in this study are used in many Fitness Centres to monitor improvements in fitness, the 'Perceived Level of Fitness' questionnaires demonstrate how important it is to consult participants partaking in an exercise programme on how they feel as the result of an exercise programme rather than relying solely on physiological measures to monitor improvements in fitness. Feeling better about one's self should be a good enough reason for individuals to participate in an exercise programme.

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Appendix A.

1. Physical Activity Readiness Questionnaire (PAR-Q)
2. Questionnaire: "Perceived Level of Fitness"
3. Questionnaire: "Perceived Changes in Fitness Levels"
4. Primary Training Effect of Each Exercise in The Massey University Recreation Centre Supercircuit
5. Skinfold Sites
6. Rating of Perceived Exertion
7. Nomogram from Astrand & Rodahl (1986) for the Calculation of Maximal Oxygen Uptake

Appendix A.

1. Physical Activity Readiness Questionnaire (PAR-Q)

Massey University Recreation & Sports Centre

Preassessment Questionnaire

Please answer the following questions with a
YES or NO

1. Have you ever been diagosed by a doctor as having heart trouble? ....
2. Have you ever had any symptoms of heart trouble (pains in your chest, feeling faint or spells of severe dizziness)? ....
3. Has your doctor ever said your blood pressure was too high? ....
4. Do you have any family history of heart attacks, high blood pressure, or any heart/lung abnormality? ....
5. Do you get asthma? ....
6. Do you smoke? ....
7. Do you consider yourself overweight or underweight? ......
8. Has your doctor ever told you that you have a bone or joint problem that has been aggravated by exercise, or might be made worse with exercise? ....
9. Do you know of any other good physical reason that would make the undertaking of a fitness assessment or exercise programme undesirable? ......
10. Are you currently on any medication? ....
11. Are you over 40? ....
12. Are you unaccustomed to vigorous exercise? ....

If the answer is YES to any of these questions please comment.

....

....

Appendix A.

2. Questionnaire: "Perceived Level of Fitness"

Fitness Questionnaire Number One

Code Number: ....

Rate the following aspects of your fitness.
Circle a number between 1 and 5 with 1 being the lowest grade and 5 the highest.

Body Fat	low	1	2	3	4	5	high
Muscle Tone	Poor	1	2	3	4	5	excellent
Stamina	Poor	1	2	3	4	5	excellent
Strength							
arms	Poor	1	2	3	4	5	excellent
legs	Poor	1	2	3	4	5	excellent
Flexibility							
arms	Poor	1	2	3	4	5	excellent
legs	Poor	1	2	3	4	5	excellent

3. Questionnaire: "Perceived Changes in Fitness Levels

Fitness Questionnaire Number two

Code Number: ....

Rate how you feel the following aspects of fitness have changed over the last 6 weeks.
Circle a number between 1 and 5 where:
1 = no improvement
2 = a little improvement
3 = quite a bit of improvement
4 = a lot of improvement
5 = a very large amount of improvement

Have you noticed a change in body shape?	1	2	3	4	5
Do you feel more toned?	1	2	3	4	5
Do you feel you have more stamina?	1	2	3	4	5
Do you feel stronger in the legs?	1	2	3	4	5
in the arms?	1	2	3	4	5
Do you feel more flexible in the shoulders?	1	2	3	4	5
in the legs?	1	2	3	4	5

Do you feel better about yourself from a physical point of view than you did 6 weeks ago? 1 2 3 4 5

Do you plan to continue a fitness programme? yes/no

If so, what?
....

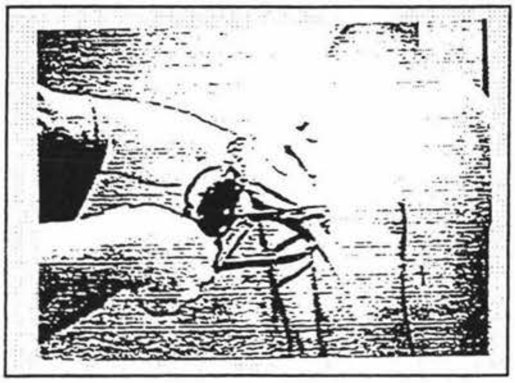
4. Primary Training Effect of Each Exercise in the Massey University Recreation Centre Supercircuit

Exercise	Training effect
Stepper	Cardiovascular
Lateral leg raise	Strength/endurance upper leg
Biceps Curl	Strength/endurance arms
Crunches	Strength/endurance abdominals
Abdominal twister	Strength/endurance abdominals
Step Ups	Cardiovascular
Upright Row	Strength/endurance shoulders
Dips	Strength/endurance arms and shoulders
Machine Squat	Strength/endurance upper legs
Grinder	Cardiovascular
Bench Press	Strength/endurance arms and chest
Standing Calf Raise	Strength/endurance lower legs
Lat Pulldown	Strength/endurance upper back
Rebounder	Cardiovascular
Shoulder Press	Strength/endurance shoulders
Standing Leg Curl	Strength/endurance upper legs
Cycle	Cardiovascular
Pec Dec	Strength/endurance chest
Leg Extension	Strength/endurance upper legs
Triceps Extension	Strength/endurance upper arms
Back Extension	Strength/endurance shoulders
Leg Raise	Strength/endurance abdominals
Lying Leg Curl	Strength/endurance upper legs
Seated Bench Press	Strength/endurance arms and chest
Rowing	Cardiovascular
Seated Calf Raises	Strength/endurance lower legs

Appendix A.

. Skinfold Sites

. Triceps Skinfold

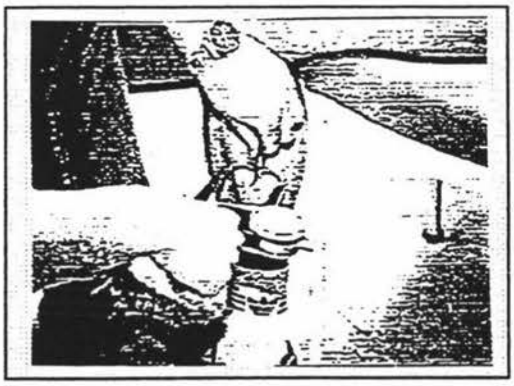


2. Subscapular Skinfold

. Suprailiac Skinfold

4. Abdominal Skinfold

5. Thigh Skinfold



6. Calf Skinfold

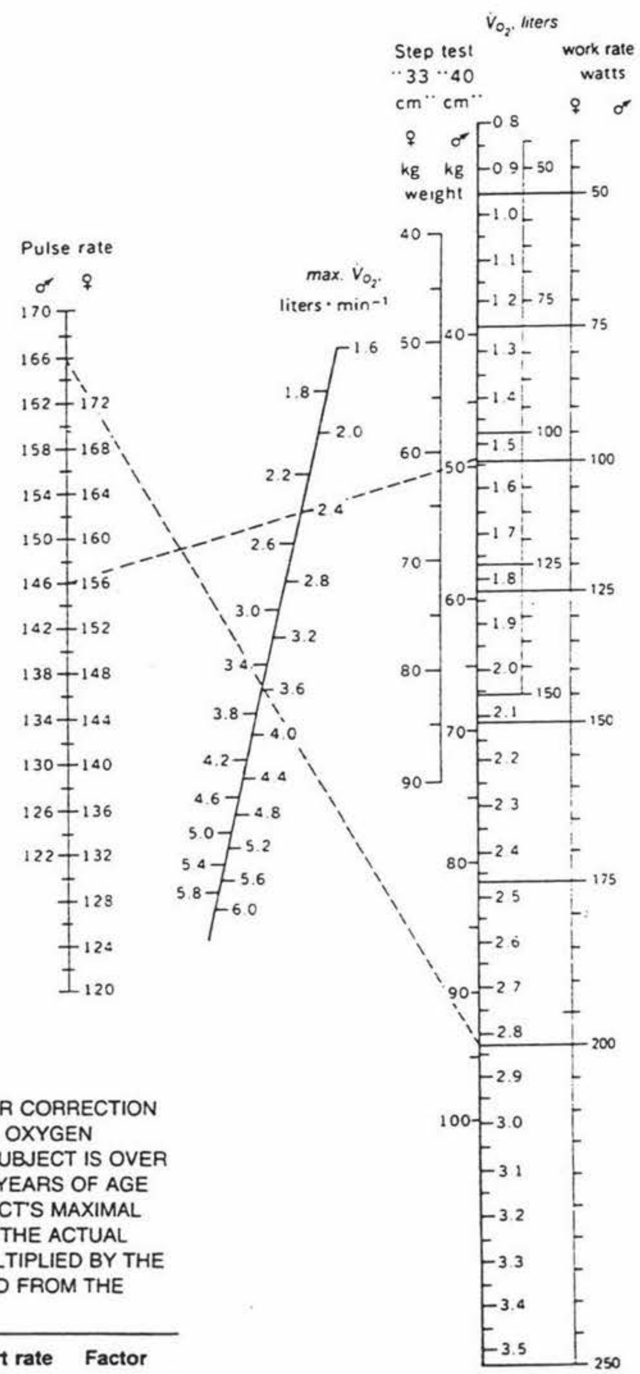
Appendix A

6. Rating of Perceived Exertion

Rating of Perceived Exertion Scale	
6	
7	Very, very light
8	
9	Very light
10	
11	Fairly light
12	
13	Somewhat hard
14	
15	Hard
16	
17	Very hard
18	
19	Very, very hard
20	

From Borg (1982).

7. **Nomogram from Astrand & Rodahl (1986) for the Calculation of Maximal Oxygen Uptake**



FACTOR TO BE USED FOR CORRECTION OF PREDICTED MAXIMAL OXYGEN UPTAKE (1) WHEN THE SUBJECT IS OVER THIRTY TO THIRTY-FIVE YEARS OF AGE OR (2) WHEN THE SUBJECT'S MAXIMAL HEART RATE IS KNOWN. THE ACTUAL FACTOR SHOULD BE MULTIPLIED BY THE VALUE THAT IS OBTAINED FROM THE NOMOGRAM

Age	Factor	Max heart rate	Factor
15	1.10	210	1.12
25	1.00	200	1.00
35	0.87	190	0.93
40	0.83	180	0.83
45	0.78	170	0.75
50	0.75	160	0.69
55	0.71	150	0.64
60	0.68		
65	0.65		

Appendix B.

1. Age, Height, Body Mass, Blood Pressure, Pre-exercise Heart Rate, and Skinfold Measurements obtained from 38 Subjects.

Abbreviations:

ht:	height
wt:	body mass
sbp:	systolic blood pressure
dbp:	diastolic blood pressure
pre-HR:	pre-exercise heart rate
tri:	triceps skinfold
sca:	subscapular skinfold
sup:	suprailiac skinfold
abd:	abdominal skinfold
thi:	thigh skinfold
cal:	calf skinfold
∑SKF-2:	sum of abdominal and suprailiac skinfolds
∑SKF-6:	sum of triceps, subscapular, suprailiac, abdominal, thigh, and calf skinfolds.
S33 - S49:	supercircuit subjects in 1994
C1 - C13:	control subjects in 1994
S211 - S216:	supercircuit subjects in 1993
C201 - C206:	control subjects in 1993

code	age	ht	Wt	sbp	dbp	pre-HR	tri	sca	sup	abd	thi	cal	∑SKF-2	∑SKF-6
s33	28	166.5	73.4	106	72	70	38.50	24.00	24.00	30.00	56.00	23.50	54.00	196.00
	28	166.5	72.6	118	72	80	36.50	24.00	23.50	30.00	57.50	24.50	53.50	196.00
	28	166.5	72.0	118	72	68	36.00	21.00	20.50	25.25	53.00	22.75	45.75	178.50
	28	166.5	72.2	110	78	67	35.50	23.75	17.25	27.00	50.50	25.25	44.25	179.25
	28	166.5	72.0	104	78	75	33.50	23.00	18.50	25.50	54.00	25.25	44.00	179.75
s34	22	159.5	62.0	114	70	90	25.00	17.00	23.00	29.50	34.00	20.50	52.50	149.00
	22	159.5	62.0	114	72	85	25.50	18.00	18.00	28.00	26.50	17.50	46.00	133.50
	22	159.5	62.4	118	79	85	27.00	19.00	24.00	29.50	31.50	19.00	53.50	150.00
	22	159.5	61.8	106	70	85	27.00	20.50	24.50	30.00	31.00	19.00	54.50	152.00
	22	159.5	61.4	106	70	90	26.00	21.75	25.00	30.00	32.50	20.50	55.00	155.75
s35	37	167.5	78.0	122	86	90	25.50	19.50	24.50	35.50	40.50	24.50	60.00	170.00
	37	167.5	78.2	130	82	84	24.50	22.00	33.50	32.00	42.25	23.00	65.50	177.25
	37	167.5	79.8	118	90	95	23.25	23.75	25.00	35.00	45.50	28.00	60.00	180.50
	37	167.5	78.8	130	84	77	25.50	20.00	27.50	36.25	46.50	28.50	63.75	184.25
	37	167.5	79.0	118	82	80	25.00	20.00	20.75	36.25	43.75	23.00	57.00	168.75
s36	31	183.0	74.8	108	70	80	21.50	13.00	16.50	20.50	24.50	17.00	37.00	113.00
	31	183.0	74.8	112	64	70	22.00	13.00	14.25	21.00	26.00	17.50	35.25	113.75
	31	183.0	75.0	110	68	80	22.50	14.00	18.50	23.75	29.75	18.50	42.25	127.00
	31	183.0	76.2	102	62	58	25.50	17.25	18.00	23.00	27.00	17.75	41.00	128.50
	31	183.0	76.4	112	64	55	26.00	17.75	18.00	23.00	30.50	18.00	41.00	133.25
S37	42	166.5	74.2	106	68	70	19.00	18.75	23.50	30.00	25.75	25.50	53.50	142.50
	42	166.5	74.8	106	70	70	19.50	17.50	24.00	33.00	26.25	27.50	57.00	147.75
	42	166.5	74.4	104	70	63	18.75	16.50	25.50	32.50	28.00	25.75	58.00	147.00
	42	166.5	74.6	104	72	62	18.75	18.00	25.50	32.25	27.50	29.00	57.75	151.00
	42	166.5	74.6	106	66	71	18.00	17.25	22.25	32.75	26.75	26.75	55.00	143.75
s40	20	175.0	63.0	104	72	83	26.50	18.00	19.50	26.50	29.25	21.00	46.00	140.75
	20	175.0	62.8	112	68	83	26.00	19.00	19.50	29.50	32.00	24.00	49.00	150.00
	20	175.0	62.2	106	68	79	28.00	18.50	18.50	25.25	30.00	24.50	43.75	144.75
	20	175.0	63.4	98	70	75	26.00	17.50	18.00	25.75	30.00	20.50	43.75	137.75
	20	175.0	63.2	82	58	66	26.00	18.00	18.50	26.50	34.50	23.00	45.00	146.50

Appendix B.1. Height, Weight, Blood Pressure, Pre-exercise Heart Rate, and Skinfold Measures

code	age	ht	Wt	sbp	dbp	pre-HR	tri	sca	sup	abd	thi	cal	∑SKF-2	∑SKF-6
s41	26	171.0	69.8	112	76	83	32.00	23.00	19.50	32.50	43.50	26.00	52.00	176.50
	26	171.0	70.6	124	68	85	30.00	27.75	20.50	32.50	48.50	25.50	53.00	184.75
	26	171.0	70.0	124	72	75	32.75	25.75	18.50	32.00	42.50	25.75	50.50	177.25
	26	171.0	71.6	120	66	76	33.25	28.50	17.25	32.00	43.00	27.50	49.25	181.50
	26	171.0	71.4	124	66	76	32.75	28.00	18.75	32.50	47.25	27.50	51.25	186.75
s42	26	168.5	75.8	112	64	85	30.75	29.50	34.00	47.00	51.00	37.50	81.00	229.75
	26	168.5	77.4	106	62	90	32.00	30.75	32.00	43.00	56.00	37.25	75.00	231.00
	26	168.5	78.4	102	56	78	31.75	30.50	34.50	44.50	57.75	36.50	79.00	235.50
	26	168.5	78.0	100	64	58	31.00	30.50	35.50	39.75	49.75	39.50	75.25	226.00
	26	168.5	78.0	110	58	64	29.75	30.25	37.00	42.75	56.00	40.25	79.75	236.00
s43	33	165.5	60.2	112	66	80	19.50	15.00	19.25	27.25	31.75	22.00	46.50	134.75
	33	165.5	59.8	104	70	73	19.25	14.75	18.00	28.75	31.50	20.25	46.75	132.50
	33	165.5	59.6	110	68	68	19.75	17.00	17.00	25.00	30.50	19.75	42.00	129.00
	33	165.5	58.6	102	62	58	19.00	16.50	17.50	23.75	31.50	18.50	41.25	126.75
	33	165.5	•	104	68	64	19.50	16.25	17.50	24.00	31.75	24.00	41.50	133.00
s44	32	155.5	53.6	124	80	73	18.50	18.00	10.00	9.75	32.25	16.25	19.75	104.75
	32	155.5	53.2	98	62	70	19.00	14.75	11.25	11.25	32.00	17.00	22.50	105.25
	32	155.5	52.8	108	70	70	19.00	17.50	11.50	11.50	36.50	17.50	23.00	113.50
	32	155.5	53.2	96	70	78	20.00	16.25	13.50	12.25	37.00	19.75	25.75	118.75
	32	155.5	52.8	98	60	70	20.25	16.75	13.25	11.75	37.50	20.00	25.00	119.50
s46	32	163.5	82.0	118	80	93	30.50	44.00	43.50	50.50	40.00	34.00	94.00	242.50
	32	163.5	83.2	124	92	78	32.50	44.75	46.50	51.50	37.75	30.25	98.00	243.25
	32	163.5	83.0	124	82	74	27.75	44.00	37.00	46.75	36.50	29.00	83.75	221.00
	32	163.5	82.4	124	82	68	27.00	38.50	35.80	45.00	34.50	29.25	80.80	210.05
	32	163.5	81.8	126	72	74	26.00	42.25	34.00	44.75	33.00	28.50	78.75	208.50
s47	32	138.5	38.2	98	68	92	25.00	23.00	18.50	32.50	28.50	19.75	51.00	147.25
	32	138.5	38.4	94	60	72	24.75	24.25	23.00	32.50	27.25	23.50	55.50	155.25
	32	138.5	39.0	88	50	70	23.50	23.50	20.25	31.75	31.50	23.00	52.00	153.50
	32	138.5	38.0	84	52	72	23.25	23.50	19.75	32.25	27.00	20.50	52.00	146.25
	32	138.5	38.4	88	64	73	19.00	23.25	20.25	31.75	29.00	23.00	52.00	146.25

Appendix B.1. Height, Weight, Blood Pressure, Pre-exercise Heart Rate, and Skinfold Measures

code	age	ht	Wt	sbp	dbp	pre-HR	tri	sca	sup	abd	thi	cal	∑SKF-2	∑SKF-6
s49	27	161.5	71.0	118	76	80	30.00	31.00	31.25	39.25	49.25	24.50	70.50	205.25
	27	161.5	71.2	114	70	70	29.25	32.25	30.25	39.00	50.00	26.00	69.25	206.75
	27	161.5	73.0	112	62	67	28.00	27.75	29.50	34.50	47.50	23.75	64.00	191.00
	27	161.5	72.8	102	62	66	28.00	31.75	32.00	39.00	48.50	25.50	71.00	204.75
	27	161.5	72.8	110	74	64	30.25	31.25	31.50	42.25	51.00	25.50	73.75	211.75
c1	27	161.5	69.8	104	70	60	25.00	29.50	22.50	37.00	44.50	23.00	59.50	181.50
	27	161.5	70.4	104	68	80	29.50	30.00	29.50	36.50	44.50	23.00	66.00	193.00
	27	161.5	70.4	100	70	80	29.00	30.25	29.75	44.50	51.00	23.50	74.25	208.00
	27	161.5	71.0	118	76	80	30.00	31.00	31.25	39.25	49.25	24.50	70.50	205.25
	27	161.5	71.2	114	70	70	29.25	32.25	30.25	39.00	50.00	26.00	69.25	206.75
c2	33	165.5	59.2	118	80	80	19.00	17.50	20.00	25.50	30.50	18.50	45.50	131.00
	33	165.5	59.8	104	70	100	18.00	17.00	20.00	25.50	32.00	20.00	45.50	132.50
	33	165.5	60.0	110	78	85	19.00	13.25	19.75	26.00	29.75	21.50	45.75	129.25
	33	165.5	60.2	112	66	80	19.50	15.00	19.25	27.25	31.75	22.00	46.50	134.75
	33	165.5	59.8	104	70	73	19.25	14.75	18.00	28.75	31.50	20.25	46.75	132.50
c3	21	169.0	74.2	120	70	80	36.00	25.50	30.00	38.50	49.00	31.50	68.50	210.50
	21	169.0	74.6	118	76	85	35.00	24.00	29.00	36.00	49.50	30.50	65.00	204.00
	21	169.0	74.4	122	80	86	34.50	29.00	30.25	39.00	50.00	32.50	69.25	215.25
	21	169.0	74.4	118	78	102	39.00	29.00	31.25	40.25	49.50	31.50	71.50	220.50
	21	169.0	74.6	104	70	85	34.00	29.00	28.50	37.00	50.50	31.00	65.50	210.00
c4	32	155.5	51.4	100	70	82	15.50	16.50	8.00	10.50	30.00	14.00	18.50	94.50
	32	155.5	51.4	100	70	80	16.50	15.50	8.50	11.50	30.50	16.50	20.00	99.00
	32	155.5	51.4	94	62	75	18.50	17.50	12.50	12.50	31.00	15.50	25.00	107.50
	32	155.5	53.6	124	80	73	18.50	18.00	10.00	9.75	32.25	16.25	19.75	104.75
	32	155.5	53.2	98	62	70	19.00	14.75	11.25	11.25	32.00	17.00	22.50	105.25
c5	32	156.0	66.0	104	60	85	28.00	18.50	17.50	25.00	37.00	19.50	42.50	145.50
	32	156.0	66.4	106	58	68	29.75	18.50	16.75	23.50	36.75	20.00	40.25	145.25
	32	156.0	65.4	96	60	72	26.75	17.50	17.00	21.50	35.50	20.75	38.50	139.00
	32	156.0	67.8	94	60	75	30.00	21.00	23.25	30.25	44.00	21.25	53.50	169.75
	32	156.0	67.2	98	68	78	30.00	19.50	21.25	30.00	44.00	21.50	51.25	166.25

Appendix B.1. Height, Weight, Blood Pressure, Pre-exercise Heart Rate, and Skinfold Measures

code	age	ht	Wt	sbp	dbp	pre-HR	tri	sca	sup	abd	thi	cal	∑SKF-2	∑SKF-6
c6	49	173.5	67.2	104	68	70	20.00	11.75	16.00	31.50	32.00	16.50	47.50	127.75
	49	173.5	66.8	104	74	65	18.75	11.75	14.50	31.50	32.25	19.25	46.00	128.00
	49	173.5	67.6	110	70	75	21.00	12.75	13.50	32.00	33.50	20.00	45.50	132.75
	49	173.5	66.2	106	68	78	23.25	12.75	17.50	35.50	34.50	22.00	53.00	145.50
	49	173.5	66.2	112	78	68	21.25	12.25	17.25	33.75	33.00	21.00	51.00	138.50
c7	43	170.5	61.6	110	70	90	21.25	13.75	16.25	29.00	36.50	24.25	45.25	141.00
	43	170.5	61.6	102	70	90	23.75	16.50	15.00	30.00	35.50	25.00	45.00	145.75
	43	170.5	61.2	114	70	85	22.00	17.75	16.50	31.00	37.25	23.50	47.50	148.00
	43	170.5	61.6	108	80	73	26.25	16.00	17.25	29.75	36.00	23.75	47.00	149.00
	43	170.5	61.8	120	70	93	23.50	15.00	17.50	30.00	40.00	23.50	47.50	149.50
C8	43	166.5	73.6	120	80	78	27.50	32.25	29.75	38.75	43.50	21.50	68.50	193.25
	43	166.5	73.6	110	78	73	27.25	36.50	29.25	50.00	45.50	25.25	79.25	213.75
	43	166.5	73.6	114	68	74	27.00	36.50	26.50	41.50	39.00	26.50	68.00	197.00
	43	166.5	74.6	108	64	64	27.50	34.00	26.75	46.25	41.00	25.25	73.00	200.75
	43	166.5	74.2	102	68	77	27.75	34.75	32.00	47.50	42.00	22.50	79.50	206.50
c9	38	159.5	72.2	126	88	76	37.75	23.00	23.00	34.00	50.00	24.50	57.00	192.25
	38	159.5	70.6	110	80	72	41.00	21.00	21.00	33.00	50.00	31.00	54.00	197.00
	38	159.5	70.2	110	72	70	36.50	21.25	21.00	32.50	51.00	29.50	53.50	191.75
	38	159.5	69.8	124	76	69	36.25	19.50	17.75	29.50	47.00	29.75	47.25	179.75
	38	159.5	70.4	102	72	66	36.25	19.00	19.75	31.75	57.75	34.50	51.50	199.00
c10	26	166.5	58.0	100	70	82	23.00	19.50	12.75	24.50	31.25	23.75	37.25	134.75
	26	166.5	57.6	106	70	75	22.50	17.00	13.25	26.00	33.50	25.50	39.25	137.75
	26	166.5	57.4	108	68	67	19.75	15.00	11.25	24.50	28.50	23.25	35.75	122.25
	26	166.5	58.2	98	58	75	23.00	17.00	15.00	24.75	30.00	24.75	39.75	134.50
	26	166.5	59.4	108	68	70	23.00	17.25	15.00	25.75	31.50	25.00	40.75	137.50
C11	32	172.0	74.8	106	76	93	30.00	22.50	26.50	29.25	43.00	27.50	55.75	178.75
	32	172.0	74.6	118	80	101	31.75	21.75	21.25	31.00	43.75	26.00	52.25	175.50
	32	172.0	74.0	108	78	86	32.25	25.25	25.00	31.00	44.00	27.25	56.00	184.75
	32	172.0	75.4	118	68	93	32.50	21.25	24.00	26.50	44.00	27.50	50.50	175.75
	32	172.0	74.0	102	66	94	32.00	20.75	27.00	28.00	43.00	29.00	55.00	179.75

Appendix B.1. Height, Weight, Blood Pressure, Pre-exercise Heart Rate, and Skinfold Measures

code	age	ht	Wt	sbp	dbp	pre-HR	tri	sca	sup	abd	thi	cal	∑SKF-2	∑SKF-6
c12	28	159.5	59.8	100	70	74	25.50	14.50	26.00	25.50	41.50	25.00	51.50	158.00
	28	159.5	59.0	112	78	66	25.50	16.50	24.00	29.25	34.25	22.25	53.25	151.75
	28	159.5	60.8	108	66	72	24.00	16.75	27.50	25.50	41.00	26.00	53.00	160.75
	28	159.5	60.6	112	66	75	24.50	17.75	27.00	28.50	40.75	27.00	55.50	165.50
	28	159.5	60.4	120	78	75	25.25	17.50	31.75	32.25	36.00	26.00	64.00	168.75
c13	39	153.0	53.2	114	72	92	24.00	18.00	17.50	24.50	19.25	17.25	42.00	120.50
	39	153.0	54.0	98	68	90	23.50	16.50	18.25	23.50	18.75	17.50	41.75	118.00
	39	153.0	54.2	118	70	94	23.50	17.75	19.50	25.00	20.50	17.00	44.50	123.25
	39	153.0	54.0	100	70	87	23.75	18.50	20.00	25.00	18.75	17.00	45.00	123.00
	39	153.0	54.4	104	68	86	24.00	18.50	18.50	25.75	20.25	19.25	44.25	126.25
s211	44	157.0	73.0	118	80	65	35.00	23.00	27.00	45.00	42.50	32.00	72.00	204.50
	44	157.0	72.6	117	78	60	30.50	26.00	25.50	46.50	43.50	29.50	72.00	201.50
	44	157.0	72.4	102	70	70	34.50	23.00	29.50	44.50	38.50	31.00	74.00	201.00
	44	157.0	72.0	110	70	52	33.50	26.00	27.50	45.50	42.50	31.00	73.00	206.00
	44	157.0	71.6	108	74	60	34.50	26.00	24.00	47.00	46.50	30.00	71.00	208.00
s212	32	166.5	66.6	128	80	95	15.50	15.00	11.50	23.50	24.00	10.00	35.00	99.50
	32	166.5	66.8	118	82	92	14.50	13.00	12.50	24.00	25.00	14.00	36.50	103.00
	32	166.5	67.4	130	84	83	13.00	15.00	14.00	25.00	25.00	12.00	39.00	104.00
	32	166.5	66.8	104	78	76	13.00	15.50	16.00	23.50	20.50	11.50	39.50	100.00
	32	166.5	67.0	108	70	80	14.00	15.00	12.50	27.00	21.50	13.50	39.50	103.50
s213	26	167.0	56.8	118	80	90	23.00	11.00	11.00	18.00	32.50	13.00	29.00	108.50
	26	167.0	57.6	110	65	78	25.00	12.50	10.00	19.00	32.00	14.00	29.00	112.50
	26	167.0	57.8	120	70	75	21.50	11.00	12.50	18.50	31.50	15.50	31.00	110.50
	26	167.0	57.6	110	70	80	25.50	13.00	12.00	17.50	32.50	14.50	29.50	115.00
	26	167.0	57.2	110	70	92	24.00	11.50	11.00	18.50	31.00	13.00	29.50	109.00
s214	22	163.0	60.0	108	70	90	19.50	21.50	23.50	35.50	24.00	15.00	59.00	139.00
	22	163.0	59.8	118	80	100	23.00	25.00	22.50	42.00	26.50	16.50	64.50	155.50
	22	163.0	60.8	105	65	88	22.50	24.00	21.00	32.00	34.50	16.00	53.00	150.00
	22	163.0	60.8	98	74	80	21.50	25.50	24.50	32.00	23.50	13.50	56.50	140.50
	22	163.0	61.2	104	74	78	20.50	24.00	22.50	34.00	22.00	13.50	56.50	136.50

Appendix B.1. Height, Weight, Blood Pressure, Pre-exercise Heart Rate, and Skinfold Measures

code	age	ht	Wt	sbp	dbp	pre-HR	tri	sca	sup	abd	thi	cal	∑SKF-2	∑SKF-6
s215	25	173.5	76.8	118	80	107	17.50	17.00	20.50	29.50	29.50	22.50	50.00	136.50
	25	173.5	76.8	105	78	83	16.50	19.50	19.00	35.00	27.00	19.50	54.00	136.50
	25	173.5	76.6	110	70	72	18.50	14.00	19.50	30.50	30.50	22.00	50.00	135.00
	25	173.5	77.2	102	64	82	16.50	14.50	23.00	36.00	25.50	19.00	59.00	134.50
	25	173.5	•	•	•	•	•	•	•	•	•	•	0.00	0.00
s216	21	168.5	73.0	110	80	82	25.50	18.50	23.50	35.50	40.50	40.50	59.00	184.00
	21	168.5	73.4	102	80	76	26.50	17.00	22.00	32.00	38.00	38.00	54.00	173.50
	21	168.5	73.8	120	80	73	25.00	18.00	24.00	32.00	37.00	25.50	56.00	161.50
	21	168.5	74.4	130	78	70	24.50	17.00	23.00	31.50	35.00	24.50	54.50	155.50
	21	168.5	73.8	134	78	70	24.00	18.00	21.00	29.50	32.00	27.00	50.50	151.50
c201	28	173.0	58.8	117	78	100	19.75	9.50	11.50	25.00	37.50	16.50	36.50	119.75
	28	173.0	59.0	110	78		19.00	11.00	11.00	27.00	39.50	18.00	38.00	125.50
	28	173.0	58.8	105	75	85	18.50	10.50	11.50	27.50	39.00	20.50	39.00	127.50
	28	173.0	58.8	100	80	85	18.50	11.50	8.00	27.00	36.00	19.00	35.00	120.00
	28	173.0	58.6	110	70	73	19.00	12.00	10.50	24.00	41.00	19.50	34.50	126.00
c202	28	165.5	71.6	120	85	85	13.00	16.00	17.50	32.50	32.00	23.50	50.00	134.50
	28	165.5	70.6	102	78	•	14.50	19.00	20.50	34.00	31.50	20.00	54.50	139.50
	28	165.5	72.4	120	78	80	15.00	19.00	23.00	37.00	35.50	22.50	60.00	152.00
	28	165.5	76.0	120	80	78	15.50	20.50	26.50	41.50	40.50	25.00	68.00	169.50
	28	165.5	76.6	110	70	82	16.00	21.00	29.50	39.50	44.00	27.00	69.00	177.00
c203	25	166.5	69.4	117	78	71	28.50	27.50	22.00	38.00	42.00	27.00	60.00	185.00
	25	166.5	69.8	110	70	90	29.50	28.50	19.50	37.50	43.00	25.50	57.00	183.50
	25	166.5	70.2	100	70	70	26.50	26.00	22.50	40.00	43.50	23.00	62.50	181.50
	25	166.5	69.4	102	70	85	29.50	27.00	22.00	38.00	44.50	21.50	60.00	182.50
	25	166.5	69.6	100	76	85	31.50	25.00	23.00	36.50	40.00	20.00	59.50	176.00
c204	21	168.5	73.6	142	90	76	27.50	19.50	23.00	33.00	34.50	34.50	56.00	172.00
	21	168.5	73.8	138	78	75	24.50	20.00	23.50	36.50	36.50	36.50	60.00	177.50
	21	168.5	74.2	120	80	70	27.50	22.00	22.50	33.00	35.00	35.00	55.50	175.00
	21	168.5	73.0	110	80	82	25.50	18.50	23.50	35.50	40.50	40.50	59.00	184.00
	21	168.5	73.4	102	80	76	26.50	17.00	22.00	32.00	38.00	38.00	54.00	173.50

Appendix B.1. Height, Weight, Blood Pressure, Pre-exercise Heart Rate, and Skinfold Measures

code	age	ht	Wt	sbp	dbp	pre-HR	tri	sca	sup	abd	thi	cal	∑SKF-2	∑SKF-6
c205	33	162.0	72.6	130	78	90	36.00	26.50	26.00	36.50	41.50	30.00	62.50	196.50
	33	162.0	73.0	122	80	90	36.50	29.50	30.50	39.50	43.50	28.50	70.00	208.00
	33	162.0	73.0	120	65	80	37.00	28.50	28.00	35.50	47.00	27.50	63.50	203.50
	33	162.0	73.6	104	70	76	38.50	31.00	31.00	37.50	49.00	26.00	68.50	213.00
	33	162.0	73.4	110	68	75	37.00	29.00	29.00	37.50	50.50	27.50	66.50	210.50
c206	27	161.0	57.8	110	70	75	25.50	18.00	14.00	32.50	34.00	24.50	46.50	148.50
	27	161.0	57.8	100	70	70	26.50	19.50	14.00	33.50	35.50	28.00	47.50	157.00
	27	161.0	58.0	100	68	65	27.50	20.00	13.50	33.50	36.50	25.00	47.00	156.00
	27	161.0	57.4	100	70	60	27.00	20.50	13.50	33.50	34.00	25.50	47.00	154.00
	27	161.0	57.6	100	70	60	30.50	21.00	14.50	33.50	37.50	25.50	48.00	162.50

Appendix B.1. Height, Weight, Blood Pressure, Pre-exercise Heart Rate, and Skinfold Measures

Appendix B.

2. Flexibility and Strength Measures obtained from 38 Subjects.

(1) Flexibility measurements of the hamstring muscle group, gastrocnemius muscles, soleus muscles, and shoulders.

(2) Strength measurements for the upper body (estimated 1 RM or maximum number of repetitions for the bench press), lower body (estimated 1 RM for the leg press or maximum number of repetitions for the leg extension machine), and abdominals (number of crunches in one minute).

<u>Abbreviations:</u>

R-ham:	right hamstring muscle group
L-ham:	left hamstring muscle group
R+L-H:	right and left hamstring muscle groups measured together
R-sol:	right soleus muscle
L-sol:	left soleus muscle
R-gast:	right gastrocnemius muscle
L-gast:	left gastrocnemius muscle
R-sh:	right shoulder
L-sh:	left shoulder
abd:	abdominals (number of crunches in one minute)
Ben Pr:	weight lifted in kg on the bench press machine (1994 group only)
reps:	number of repetitions completed for either Ben Pr or Leg Ext.
Leg Ext:	weight lifted in kg on the leg extension machine (1994 group only)
1RMBP:	estimated 1RM for the Bench Press (1993 group only)
1RMLP:	estimated 1RM for the leg press (1993 group only)

code	R-ham	L-ham	R+L-H	R-sol	L-sol	R-gast	L-gast	R-sh	L-sh	abd	Ben Pr	reps	Leg Ext	reps	1RM BP	1RM LP
s33	14.0	10.0	7.0	30.0	32.0	32.0	34.0	0.0	2.0	43	22.7	25	8.2	19		
	13.0	7.5	6.5	31.0	32.0	32.5	33.0	-2.0	2.0	39	22.7	18	8.2	24		
	16.0	7.0	7.0	29.0	32.0	32.5	33.5	2.0	4.0	35	22.7	35	8.2	32		
	18.0	5.5	7.5	29.0	32.0	32.0	33.0	1.0	2.0	43	22.7	47	8.2	42		
	14.5	12.0	11.0	29.0	32.0	31.0	33.0	1.0	4.0	40	22.7	43	8.2	46		
s34	10.5	8.0	13.0	29.0	29.0	32.0	33.0	5.0	6.0	30	22.7	13	8.2	23		
	12.0	12.5	10.0	29.0	28.0	33.0	32.0	4.0	6.0	29	22.7	12	8.2	30		
	19.0	17.0	19.0	27.0	25.0	32.0	31.0	6.0	9.0	39	22.7	14	8.2	34		
	16.0	17.0	20.0	26.5	26.5	32.0	31.0	6.0	8.0	43	22.7	20	8.2	32		
	20.0	19.0	21.0	27.0	27.0	31.0	31.0	8.0	11.5	42	22.7	23	8.2	37		
s35	38.0	39.0	38.5	28.0	28.0	32.0	31.0	1.0	9.0	28	22.7	17	8.2	28		
	40.0	39.5	38.0	27.0	29.0	31.0	31.0	2.0	9.0	34	22.7	20	14.4	15		
	39.0	40.0	39.0	26.0	28.5	30.5	32.0	2.5	8.0	36	22.7	29	14.4	21		
	38.0	39.0	38.0	28.0	29.0	29.0	31.0	3.0	7.0	37	22.7	35	14.4	20		
	41.0	41.0	40.5	27.0	27.0	32.0	30.5	3.0	9.0	48	22.7	31	14.4	22		
s36	37.5	38.0	40.0	29.0	30.0	33.0	35.0	4.0	4.0	29	22.7	•	•	•		
	40.0	39.0	39.0	29.5	30.0	33.0	34.0	7.0	6.0	29	22.7	4	14.4	32		
	40.0	42.0	38.0	28.5	29.5	34.0	35.0	6.0	4.0	27	22.7	12	14.4	31		
	44.0	43.0	43.0	27.0	29.5	34.0	33.0	7.0	5.0	32	22.7	18	14.4	34		
	45.0	44.0	42.0	25.0	28.0	33.0	33.0	6.0	4.0	38	22.7	19	14.4	38		
S37	37.0	35.0	34.0	28.0	28.0	33.0	33.0	0.0	7.0	28	22.7	8	8.2	20		
	37.0	36.0	34.0	28.0	28.0	30.0	31.0	0.0	4.0	36	22.7	9	8.2	15		
	39.0	38.0	38.0	28.0	27.0	33.5	34.0	3.0	7.0	32	22.7	10	8.2	28		
	41.0	39.0	38.5	28.0	28.0	33.0	32.0	2.0	5.0	33	22.7	15	8.2	22		
	40.0	38.5	38.0	28.0	29.0	31.5	34.0	2.0	4.0	34	22.7	17	8.2	32		
s40	9.0	10.5	8.0	37.0	38.0	37.5	39.0	9.0	14.0	39	18.2	16	•	•		
	11.0	12.0	11.0	37.0	37.0	37.5	38.0	6.0	11.0	40	18.2	19	14.4	27		
	17.0	23.0	19.0	36.5	37.5	39.0	38.5	9.0	14.0	52	18.2	37	14.4	30		
	19.5	19.0	15.0	36.0	37.5	39.0	39.0	9.0	12.0	46	18.2	30	•	•		
	20.5	20.0	18.0	36.5	38.0	39.0	39.0	8.0	12.0	50	18.2	34	14.4	30		

	R-ham	L-ham	R+L-H	R-sol	L-sol	R-gast	L-gast	R-sh	L-sh	abd	Ben Pr	reps	Leg Ext	reps	1RM BP	1RM LP
s41	6.0	6.0	3.0	32.0	34.0	35.0	36.5	-9.0	0.0	41	22.7	5	14.4	13		
	7.5	9.5	6.0	33.5	34.0	35.5	36.0	-10.0	0.0	51	22.7	6	14.4	16		
	20.0	21.0	16.0	30.0	32.5	33.5	35.0	-6.0	4.0	51	22.7	11	14.4	30		
	29.0	27.0	24.0	28.5	31.0	32.0	34.5	-3.0	4.0	72	22.7	19	14.4	40		
	29.0	25.0	24.0	28.0	32.0	32.0	35.0	-8.0	4.0	94	22.7	24	14.4	47		
s42	30.5	30.5	25.5	30.5	30.0	32.0	33.0	0.0	0.0	32	22.7	10	14.4	11		
	31.0	33.5	30.0	29.0	29.0	32.0	32.5	-3.0	-4.0	36	22.7	6	14.4	10		
	33.0	33.0	29.0	28.0	28.0	30.0	32.0	0.0	-1.0	37	22.7	17	14.4	13		
	33.0	32.0	30.0	29.0	29.0	34.0	33.5	1.5	3.0	36	22.7	19	14.4	15		
	30.0	33.5	30.0	28.0	28.0	32.5	34.5	1.0	2.0	42	22.7	20	14.4	15		
s43	22.0	21.5	20.0	30.0	32.0	35.0	35.5	6.5	7.0	36	22.7	11	8.2	17		
	22.0	21.0	20.0	30.5	32.0	35.5	36.0	6.0	5.0	31	22.7	10	8.2	17		
	19.5	18.0	18.5	31.0	32.0	35.0	34.0	6.5	7.5	38	22.7	9	8.2	16		
	21.0	19.0	19.0	30.5	31.5	34.5	35.5	7.0	8.0	44	22.7	11	8.2	14		
	20.0	18.0	20.0	31.0	32.0	34.5	35.0	6.0	7.0	43	22.7	12	8.2	21		
s44	16.0	14.0	11.5	31.0	31.0	33.0	32.5	11.0	8.0	44	18.2	12	8.2	13		
	17.0	14.0	12.0	31.0	30.5	34.0	33.0	10.0	6.0	49	18.2	6	8.2	15		
	20.5	18.0	15.0	30.0	30.5	32.0	32.0	11.0	12.0	64	18.2	17	8.2	20		
	19.0	18.0	14.5	31.0	30.0	32.5	32.0	10.0	8.0	67	18.2	20	8.2	21		
	20.5	16.0	16.0	31.0	30.0	32.5	31.5	10.0	7.0	69	18.2	21	8.2	22		
s46	28.0	28.0	26.0	34.0	31.0	34.5	33.0	0.0	4.0	40	22.7	12	14.4	14		
	30.0	28.5	27.0	33.5	30.5	35.0	33.5	1.0	4.0	34	22.7	13	14.4	10		
	30.0	29.0	26.0	34.0	31.0	34.5	32.0	1.5	3.0	50	22.7	13	14.4	20		
	33.5	31.0	30.5	33.5	30.5	35.0	33.0	2.0	4.0	49	22.7	15	14.4	20		
	30.0	30.0	31.0	33.0	30.0	34.0	33.0	1.0	3.0	55	22.7	18	14.4	23		
s47	25.0	24.5	23.0	23.5	23.0	27.0	26.0	10.5	9.5	31	18.2	10	8.2	21		
	24.5	27.0	23.0	24.0	23.5	26.5	27.0	9.0	6.0	31	12.3	15	8.2	18		
	25.5	26.5	23.0	23.0	23.0	27.0	26.0	11.0	8.0	34	11.8	23	8.2	20		
	31.0	30.0	29.0	23.0	22.0	26.0	26.0	13.0	11.0	40	11.8	30	8.2	21		
	30.0	31.5	31.0	23.0	23.0	27.5	26.5	10.5	10.5	41	12.0	40	8.2	25		

	R-ham	L-ham	R+L-H	R-sol	L-sol	R-gast	L-gast	R-sh	L-sh	abd	Ben Pr	reps	Leg Ext	reps	1RM BP	1RM LP
s49	36.5	38.0	38.0	27.5	31.0	31.0	34.0	2.0	8.0	27	22.7	10	8.2	17		
	36.0	37.0	40.0	30.0	30.5	33.0	33.0	3.0	8.0	30	22.7	9	8.2	12		
	39.0	39.5	41.0	28.0	30.0	32.0	33.0	3.5	8.0	35	22.7	7	8.2	21		
	42.5	42.0	43.0	29.0	30.0	31.0	34.0	3.5	9.0	43	22.7	13	8.2	22		
	41.5	42.0	42.0	28.0	31.0	32.0	34.0	2.5	6.0	45	22.7	15	8.2	29		
c1	41.5	39.0	39.0	31.0	30.5	36.0	35.5	3.0	5.0	20	22.7	7	8.2	17		
	38.0	38.5	39.0	26.5	30.5	32.5	33.0	4.0	7.0	25	22.7	8	8.2	13		
	38.0	38.5	38.5	29.0	31.0	31.0	33.5	3.0	7.0	25	22.7	7	8.2	21		
	36.5	38.0	38.0	27.5	31.0	31.0	34.0	2.0	8.0	27	22.7	10	8.2	17		
	36.0	37.0	40.0	30.0	30.5	33.0	33.0	3.0	8.0	30	22.7	9	8.2	12		
c2	20.5	•	21.0	31.5	31.5	35.0	35.0	7.0	6.0	30	22.7	7	8.2	19		
	26.5	24.0	24.0	31.0	32.0	35.5	35.0	8.0	7.0	30	22.7	6	8.2	18		
	24.0	24.0	23.0	31.0	32.0	35.0	36.0	7.0	6.0	29	22.7	8	8.2	17		
	22.0	21.5	20.0	30.0	32.0	35.0	35.5	6.5	7.0	36	22.7	11	8.2	17		
	22.0	21.0	20.0	30.5	32.0	35.5	36.0	6.0	5.0	31	22.7	10	8.2	17		
c3	30.0	33.0	32.0	35.5	35.5	38.0	37.5	•	•	42	22.7	4	14.4	29		
	35.0	36.0	34.5	36.0	36.0	38.0	37.0	4.0	2.0	30	22.7	5	14.4	36		
	34.0	38.0	34.0	35.0	35.0	37.0	37.0	4.0	0.0	32	22.7	4	14.4	29		
	35.0	36.0	33.0	35.0	35.5	36.5	37.5	5.0	2.0	41	22.7	9	14.4	36		
	35.0	35.0	35.0	35.0	36.0	37.0	37.0	5.0	1.0	48	22.7	9	14.4	29		
c4	18.0	11.0	10.0	30.0	30.0	32.0	32.5	7.0	2.0	30	18.2	10	8.2	12		
	18.5	15.0	14.0	31.0	31.0	33.0	32.0	7.0	5.0	37	18.2	9	8.2	15		
	16.0	10.0	10.5	31.0	31.0	33.0	32.0	11.0	7.0	37	18.2	8	8.2	14		
	16.0	14.0	11.5	31.0	31.0	33.0	32.5	11.0	8.0	44	18.2	12	8.2	13		
	17.0	14.0	12.0	31.0	30.5	34.0	33.0	10.0	6.0	49	18.2	6	8.2	15		
c5	36.0	35.0	35.0	24.0	25.5	29.0	29.0	3.0	9.0	39	22.7	16	14.4	18		
	35.0	35.0	34.0	24.0	24.5	29.0	29.0	0.0	7.0	34	22.7	18	14.4	20		
	33.0	33.0	35.0	24.0	24.5	28.0	29.0	4.0	8.0	36	22.7	20	14.4	21		
	34.0	34.0	34.0	24.5	24.5	30.0	29.0	3.5	7.0	37	22.7	15	14.4	21		
	34.0	35.0	32.5	25.0	25.0	28.0	28.0	4.0	6.0	41	22.7	20	14.4	21		

	R-ham	L-ham	R+L-H	R-sol	L-sol	R-gast	L-gast	R-sh	L-sh	abd	Ben Pr	reps	Leg Ext	reps	1RM BP	1RM LP
c6	36.0	37.0	37.0	37.0	37.0	39.0	39.0	0.0	9.0	21	18.2	5	8.2	16		
	37.0	37.0	37.0	37.0	37.0	40.0	40.0	0.0	9.5	28	18.2	6	8.2	13		
	37.0	38.0	37.0	36.0	36.5	38.5	39.0	0.0	6.0	28	18.2	7	8.2	20		
	37.0	37.0	37.0	36.0	37.0	37.0	38.5	1.5	8.0	23	18.2	5	8.2	15		
	37.0	37.5	37.0	36.0	37.0	37.0	38.5	1.0	7.5	30	18.2	6	8.2	17		
c7	41.0	40.0	41.0	35.0	36.0	39.0	40.0	7.0	9.0	42	18.2	15	8.2	24		
	41.0	40.0	41.0	35.0	35.5	38.0	38.0	7.0	11.0	39	18.2	12	8.2	27		
	41.0	40.0	41.0	36.0	36.5	38.0	40.0	7.5	11.0	45	18.2	17	8.2	28		
	42.0	42.0	41.0	34.0	36.0	38.0	39.5	10.0	14.0	45	18.2	19	8.2	26		
	42.0	40.0	41.0	35.0	37.0	37.5	39.0	7.0	12.5	50	18.2	17	8.2	21		
C8	24.0	17.0	16.5	35.0	33.0	37.0	37.5	-1.0	0.0	19	22.7	7	8.2	22		
	20.0	17.5	17.5	35.0	34.0	37.5	36.0	-5.0	-3.0	27	22.7	12	8.2	30		
	19.5	19.5	17.5	34.5	34.0	36.0	35.0	-2.0	0.0	29	22.7	10	8.2	27		
	20.0	21.5	18.0	35.5	33.0	37.0	34.5	1.0	-2.0	30	22.7	11	8.2	35		
	20.5	18.5	21.5	36.0	34.0	38.0	37.0	0.0	1.0	28	22.7	13	8.2	30		
c9	31.0	33.0	32.0	32.0	32.0	33.0	34.0	8.0	-6.0	25	18.2	18	14.4	30		
	32.0	31.0	32.0	33.0	32.5	34.0	34.0	7.0	0.0	26	18.2	20	14.4	25		
	31.0	31.0	30.0	33.5	32.0	35.0	34.0	7.0	-3.0	27	18.2	17	14.4	31		
	*	35.0	32.0	33.0	32.0	34.0	34.0	8.0	-3.0	29	18.2	17	14.4	30		
	35.0	34.0	31.0	32.0	32.0	33.5	33.5	8.5	0.0	32	18.2	18	14.4	30		
c10	42.0	43.0	42.0	28.5	29.0	30.0	30.0	13.5	14.0	34	18.2	8	8.2	17		
	40.0	40.0	40.0	29.0	30.0	30.0	30.0	11.0	13.0	48	18.2	8	8.2	17		
	40.0	40.0	41.0	29.0	28.0	31.0	31.0	14.5	14.0	49	18.2	13	8.2	18		
	35.0	37.0	36.0	29.0	27.5	30.0	32.5	13.0	12.0	45	18.2	5	8.2	20		
	40.0	39.0	39.0	29.5	27.5	30.0	29.0	12.5	14.0	46	18.2	11	8.2	20		
C11	26.0	*	*	32.5	37.0	35.0	39.0	3.0	6.0	14	18.2	5	8.2	10		
	22.0	12.0	16.0	33.0	38.0	36.0	38.0	2.0	5.0	14	18.2	8	8.2	12		
	22.0	13.0	13.0	33.0	36.0	35.5	38.0	1.5	6.0	17	18.2	11	8.2	11		
	20.0	15.0	14.5	34.0	37.0	34.5	38.5	1.0	2.5	17	18.2	9	8.2	13		
	22.0	12.0	13.0	33.5	36.0	36.0	38.5	4.0	6.0	14	18.2	8	8.2	15		

Appendix B.2. Flexibility and Strength Measures

	R-ham	L-ham	R+L-H	R-sol	L-sol	R-gast	L-gast	R-sh	L-sh	abd	Ben Pr	reps	Leg Ext	reps	1RM BP	1RM LP
c12	18.0	15.0	15.0	32.0	31.0	33.0	32.0	-2.0	5.5	23	•	•	8.2	15		
	16.0	14.5	11.0	32.0	31.0	32.5	32.0	2.5	2.5	36	22.7	8	8.2	12		
	15.0	13.0	9.0	30.5	31.0	30.0	31.5	0.0	4.0	44	22.7	9	8.2	10		
	18.0	10.5	13.0	30.0	30.0	30.5	31.0	2.0	4.0	50	22.7	9	8.2	12		
	17.0	15.0	10.5	29.5	30.0	31.0	30.0	4.0	5.0	44	22.7	10	8.2	14		
c13	20.0	21.0	18.0	28.5	29.5	29.0	31.0	-3.0	1.0	15	22.7	5	8.2	21		
	20.0	22.0	19.5	28.0	29.0	28.5	31.5	-4.0	2.5	24	22.7	4	8.2	26		
	21.0	21.5	20.0	28.0	29.5	29.0	31.0	0.0	4.5	24	22.7	5	8.2	30		
	21.5	23.0	21.0	27.0	28.0	28.5	31.0	-2.0	2.0	26	22.7	6	8.2	30		
	22.0	25.5	22.0	27.5	30.0	30.5	30.5	-3.0	2.0	28	22.7	6	8.2	35		
s211	23.0	20.0	20.0	31.5	34.0	35.5	35.5	-12.5	-0.5	20					26	69.1
	22.0	18.0	19.0	31.5	33.0	34.0	35.0	-9.0	0.0	28					27	75.7
	25.0	23.0	24.0	32.0	33.0	35.0	35.0	-10.0	-2.5	32					33	77.2
	24.0	24.0	24.0	31.5	33.5	34.0	35.5	-9.0	0.0	40					41	81.5
	24.0	25.0	25.0	32.0	33.0	34.0	36.0	-7.0	2.0	35					43	83.5
s212	12.0	15.5	15.0	29.0	30.5	29.0	29.0	2.5	9.0	19					24	75.7
	10.0	12.5	12.5	28.5	29.5	29.0	29.0	3.0	8.5	13					•	•
	11.0	14.0	11.5	28.0	30.5	28.5	32.0	6.0	9.0	23					28	82.4
	16.0	19.0	18.0	27.0	32.0	28.5	31.5	6.0	9.0	32					32	89.2
	17.0	19.0	18.0	27.0	29.0	28.5	33.0	6.5	8.0	36					33	95.9
s213	34.0	35.0	36.0	36.5	38.0	36.5	38.0	6.0	5.5	27					28	75.7
	36.5	36.5	37.5	37.0	38.0	37.5	38.0	7.0	6.5	20					28	75.7
	40.0	40.0	39.0	36.0	38.0	36.5	37.5	8.0	8.0	41					28	89.0
	40.5	40.0	40.5	37.0	38.0	37.0	38.0	8.0	8.0	53					37	102.8
	40.5	40.0	40.5	37.0	38.0	36.0	37.0	7.0	8.0	46					37	102.8
s214	•	•	18.0	28.0	29.0	25.0	31.0	5.0	4.0	21					18	62.2
	18.0	18.0	18.0	26.0	29.5	25.0	27.0	4.0	4.0	19					18	62.2
	24.0	23.0	23.0	24.5	28.0	24.0	30.5	5.0	4.0	23					18	68.9
	27.0	25.5	24.0	22.0	24.0	22.0	27.0	4.0	5.0	27					34	75.3
	28.0	26.0	27.5	23.5	28.5	24.0	28.0	5.5	5.0	34					37	70.9

	R-ham	L-ham	R+L-H	R-sol	L-sol	R-gast	L-gast	R-sh	L-sh	abd	Ben Pr	reps	Leg Ext	reps	1RM BP	1RM LP
s215	19.0	21.0	21.0	35.0	36.0	34.0	36.5	-3.0	-10.0	14					28	79.5
	22.0	24.0	21.0	35.0	38.0	33.5	35.0	-5.5	-9.0	19					•	•
	23.0	23.5	23.0	35.5	36.0	34.0	36.0	-9.0	-6.0	23					32	81.5
	24.0	21.5	22.0	34.0	37.0	33.5	37.0	-11.0	-3.0	24					37	95.9
	•	•	•	•	•	•	•	•	•	•					•	•
s216	25.0	17.0	18.0	31.0	33.0	33.0	34.0	2.0	2.0	33					28	89.2
	24.0	18.0	19.0	31.5	32.0	32.0	34.0	2.0	2.0	37					32	92.6
	31.0	25.0	23.0	30.5	33.0	31.0	34.0	2.0	3.5	45					37	95.9
	31.0	24.0	21.5	31.0	33.0	32.0	33.0	2.0	0.0	49					44	•
	31.0	24.0	24.0	31.0	33.0	31.0	33.0	2.0	2.0	49					46	•
c201	28.0	23.0	23.0	37.0	38.0	37.0	38.0	5.0	5.0	40					37	89.2
	25.0	21.0	25.0	37.5	38.5	37.0	38.5	7.0	7.0	29					32	83.5
	21.0	25.0	24.0	37.0	38.5	37.5	38.0	8.0	8.0	33					•	89.2
	20.5	24.0	23.0	37.5	38.5	37.0	38.0	8.5	8.0	32					31	83.5
	22.0	19.0	22.0	38.0	39.0	38.0	38.0	7.0	9.0	31					31	76.7
c202	19.0	15.0	15.5	30.0	34.0	33.0	36.0	0.0	2.5	13					26	75.7
	16.0	21.0	21.0	32.0	34.0	33.0	36.0	2.0	3.0	13					26	75.7
	19.5	18.5	21.5	32.0	35.0	32.0	35.0	3.0	3.0	18					•	75.7
	16.0	18.0	24.0	30.0	34.0	32.5	35.0	1.0	6.0	18					28	75.7
	16.5	21.0	25.0	29.0	34.0	32.5	35.0	2.0	6.0	19					26	75.7
c203	32.5	36.0	35.0	31.5	34.0	32.0	36.0	10.0	13.0	16					28	75.6
	36.0	42.0	39.0	32.0	34.0	32.0	35.5	9.5	12.0	20					28	75.6
	35.0	36.0	34.5	33.0	34.0	32.0	35.0	9.0	12.5	28					•	75.6
	36.0	35.5	34.0	32.0	35.0	31.0	34.0	10.0	12.0	34					28	79.2
	36.0	40.0	37.0	32.0	30.0	32.0	33.0	10.0	11.0	36					28	75.3
c204	24.0	19.0	20.0	30.0	33.0	32.0	34.0	0.0	0.0	32					28	89.2
	23.0	18.5	18.0	30.0	32.0	30.5	32.5	2.0	2.0	33					28	89.2
	26.0	18.0	18.0	31.0	33.0	31.5	34.0	2.5	0.0	29					28	89.2
	25.0	17.0	18.0	31.0	33.0	33.0	34.0	2.0	2.0	33					28	89.2
	24.0	18.0	19.0	31.5	32.0	32.0	34.0	2.0	2.0	37					32	92.6

Appendix B.2. Flexibility and Strength Measures

	R-ham	L-ham	R+L-H	R-sol	L-sol	R-gast	L-gast	R-sh	L-sh	abd	Ben Pr	reps	Leg Ext	reps	1RM BP	1RM LP
c205	20.0	13.5	14.0	34.0	37.0	35.0	36.0	-4.5	7.5	16					37	48.6
	19.0	13.0	14.5	35.0	35.5	35.5	37.0	-3.0	7.0	29					34	•
	19.0	13.0	16.0	34.0	35.0	35.0	36.0	-6.0	7.5	27					37	58.2
	18.0	15.5	17.5	34.0	34.5	34.5	35.0	-4.0	7.0	28					40	68.9
	19.0	14.5	16.5	34.0	34.5	34.0	34.0	-5.0	6.0	30					39	68.9
c206	16.0	16.0	23.0	28.0	35.0	27.0	35.0	10.5	11.0	14					24	63.0
	15.0	15.0	21.0	26.0	31.0	27.5	31.0	6.0	6.0	16					•	61.4
	14.0	13.5	20.0	25.0	32.0	25.0	31.0	9.0	9.0	19					25	67.5
	16.5	16.0	25.0	25.0	27.5	24.5	30.0	10.0	11.0	19					25	72.7
	22.5	20.0	25.5	26.0	27.0	25.5	30.5	7.0	8.0	19					26	75.7

Appendix B.

3. Heart Rate, Perceived Exertion, and Oxygen Uptake Data obtained from 38 Subjects During Cycle Ergometer Tests.

<u>Abbreviations:</u>

max-HR: maximum heart rate calculated from 220-age

Pre-HR: pre-exercise heart rate

load 1: external work load for the first work load (watts)

1HR: heart rate at the completion of the first work load

1PE: rating of perceived exertion at the completion of the first work load

1VO2: oxygen uptake (L/min) for the third minute of the first work load

load 2: external work load for the second work load (watts)

2HR: heart rate at the completion of the second work load

2PE: rating of perceived exertion at the completion of the second work load

2VO2: oxygen uptake (L/min) for the third minute of the second work load

load 3: external work load for the third work load (watts)

3HR: heart rate at the completion of the third work load

3PE: rating of perceived exertion at the completion of the third work load

3VO2: oxygen uptake (L/min) for the third minute of the third work load

mvL-o: estimated maximum oxygen uptake (L/min) based on oxygen uptake

mvL-w: estimated maximum oxygen uptake (L/min) based on external work load (watts)

mvml-o: estimated maximum oxygen uptake (ml/kg/min) based on oxygen uptake

mvml-w: estimated maximum oxygen uptake (ml/kg/min) based on external work load (watts)

HR-1 heart rate 1 minute after completion of the third work load

HR-2 heart rate 2 minutes after completion of the third work load

HR-3 heart rate 3 minutes after completion of the third work load

	max-HR	pre-HR	load1	1HR	1PE	1vo2	load2	2HR	2PE	2vo2	load3	3HR	3PE	3vo2
s33	192	70	45	103	9	0.84	75	121	11	1.09	105	147	13	1.44
	192	80	45	112	10	0.81	75	130	12	0.98	105	156	14	1.51
	192	68	45	104	9	0.94	75	120	11	1.17	105	143	14	1.53
	192	67	45	105	8	0.92	75	121	11	1.26	105	144	14	1.60
	192	75	45	106	9	0.95	75	123	11	1.24	105	145	14	1.57
s34	190	90	45	114	10	0.80	75	133	12	0.96	105	156	•	1.27
	190	85	45	116	11	0.72	75	133	12	0.91	105	154	•	1.27
	190	85	45	109	10	0.87	75	129	13	1.09	105	149	15	1.31
	190	85	45	112	9	0.82	75	125	11	1.20	105	149	13	1.40
	190	90	45	117	9	0.84	75	133	11	1.13	105	152	13	1.35
s35	183	90	45	106	11	0.86	75	123	12	1.11	105	152	15	1.43
	183	84	45	114	9	•	75	122	11	•	105	148	13	•
	183	95	45	115	7	•	75	126	12	•	105	148	15	•
	183	77	45	105	6	0.93	75	120	9	1.12	105	143	13	1.56
	183	80	45	106	6	0.85	75	120	10	1.19	105	141	12	1.57
s36	189	80	45	91	7	0.92	75	102	9	1.02	105	131	11	1.42
	189	70	45	82	8	•	75	101	10	1.08	105	121	12	1.40
	189	80	45	87	7	0.82	75	100	9	1.03	105	114	12	1.41
	189	58	45	87	7	0.82	75	100	9	1.16	105	118	11	1.54
	189	55	45	88	6	0.84	75	98	8	1.07	105	117	11	1.53
S37	178	70	45	94	10	0.88	75	108	13	0.92	105	137	15	1.38
	178	70	45	96	10	0.91	75	107	14	1.06	105	135	17	1.33
	178	63	45	90	9	0.91	75	106	11	1.18	105	128	15	1.45
	178	62	45	92	9	0.89	75	108	13	1.22	105	136	15	1.65
	178	71	45	96	9	0.87	75	113	12	1.18	105	140	16	1.49
s40	200	83	45	119	12	0.87	75	137	13	1.06	105	166	15	1.35
	200	83	45	111	9	0.75	75	131	10	0.99	105	171	17	1.38
	200	79	45	119	7	0.80	75	131	12	0.95	105	162	15	1.44
	200	75	45	118	7	0.81	75	137	12	0.97	105	161	14	1.38
	200	66	45	105	6	0.79	75	123	10	1.11	105	157	13	1.39

	max-HR	pre-HR	load1	1HR	1PE	1vo2	load2	2HR	2PE	2vo2	load3	3HR	3PE	3vo2
s41	194	83	45	100	11	0.83	75	124	13	1.15	105	157	15	1.44
	194	85	45	113	11	0.89	75	134	12	1.13	105	158	13	1.42
	194	75	45	97	9	0.75	75	122	11	•	105	149	13	1.46
	194	76	45	98	8	0.90	75	117	11	1.30	105	140	13	1.59
	194	76	45	105	9	0.94	75	122	11	1.31	105	146	13	1.73
s42	194	85	45	113	12	•	75	141	13	•	90	147	14	1.40
	194	90	45	102	11	0.97	75	122	12	1.19	90	138	14	1.41
	194	78	45	101	12	0.92	75	118	13	1.18	90	135	15	1.37
	194	58	45	98	11	0.89	75	112	12	1.16	90	121	13	1.38
	194	64	45	99	11	0.96	75	112	12	1.23	90	128	13	1.45
s43	187	80	45	109	11	0.97	75	128	13	1.20	105	158	14	1.43
	187	73	45	98	10	0.73	75	119	12	1.07	105	148	14	1.48
	187	68	45	107	9	0.87	75	123	10	1.13	105	153	13	1.53
	187	58	45	100	9	0.84	75	117	11	1.03	105	150	13	1.40
	187	64	45	105	9	0.77	75	122	11	1.04	105	147	13	1.34
s44	188	73	45	117	8	0.76	75	143	15	0.99	105	•	•	•
	188	70	45	113	8	0.70	75	140	14	1.00	105	•	•	•
	188	70	45	118	8	0.78	75	131	13	1.07	105	•	•	•
	188	78	45	127	7	0.83	75	150	12	0.99	105	•	•	•
	188	70	45	121	7	0.77	75	140	11	0.96	105	•	•	•
s46	188	93	45	110	8	•	75	126	12	1.29	105	140	15	1.57
	188	78	45	106	7	0.99	75	118	10	1.23	105	138	12	1.58
	188	74	45	102	7	0.91	75	118	10	1.19	105	137	12	1.54
	188	68	45	103	8	1.14	75	116	8	1.35	105	136	12	1.85
	188	74	45	105	7	1.09	75	118	8	1.48	105	133	11	1.79
s47	188	92	0	•	•	•	30	•	•	•	45	162	11	0.75
	188	72	0	105	8	0.35	30	132	12	0.58	45	163	13	0.84
	188	70	0	110	7	0.42	30	138	10	0.59	45	155	12	0.83
	188	72	0	97	7	0.26	30	135	9	0.55	45	155	11	0.68
	188	73	0	92	7	0.22	30	125	9	0.57	45	154	11	0.77

Appendix B.3. Results from Cycle Ergometer Tests

	max-HR	pre-HR	load1	1HR	1PE	1vo2	load2	2HR	2PE	2vo2	load3	3HR	3PE	3vo2
s49	193	80	45	113	10	0.84	75	138	11	1.28	105	162	14	1.59
	193	70	45	110	8	0.86	75	129	11	1.21	105	154	13	1.42
	193	67	45	114	9	•	75	130	12	•	105	152	14	•
	193	66	45	101	10	0.97	75	123	11	1.30	105	148	13	1.72
	193	64	45	109	9	1.06	75	122	10	1.25	105	144	12	1.68
c1	193	60	45	114	•	•	•	•	•	•	105	163	12	•
	193	80	45	107	10	0.75	75	129	12	1.01	105	159	14	1.35
	193	80	45	108	9	0.65	75	127	11	0.86	105	153	13	•
	193	80	45	113	10	0.84	75	138	11	1.28	105	162	14	1.59
	193	70	45	110	8	0.86	75	129	11	1.21	105	154	13	1.42
c2	187	80	45	104	10	•	•	•	•	•	105	166	14	•
	187	100	45	119	11	•	•	•	•	•	105	174	14	•
	187	85	45	113	10	•	75	127	11	0.88	105	159	14	1.38
	187	80	45	109	11	0.97	75	128	13	1.20	105	158	14	1.43
	187	73	45	98	10	0.73	75	119	12	1.07	105	148	14	1.48
c3	199	80	45	112	7	0.74	75	131	12	0.92	105	159	17	1.27
	199	85	45	112	7	0.86	75	126	12	1.01	105	156	16	1.34
	199	86	45	113	6	0.81	75	132	13	1.19	105	159	17	1.54
	199	102	45	117	7	0.84	75	137	12	1.11	105	163	18	1.40
	199	85	45	112	6	0.88	75	139	13	0.99	105	164	17	1.52
c4	183	82	45	130	12	0.71	75	155	16	0.88	90	175	19	1.19
	183	80	45	130	11	0.66	75	158	15	0.88	90	•	•	•
	183	75	45	118	12	0.63	75	138	16	0.82	90	•	•	•
	183	73	45	117	8	0.76	75	143	15	0.99	90	•	•	•
	183	70	45	113	8	0.70	75	140	14	1.00	90	•	•	•
c5	188	85	45	97	9	0.65	75	112	12	0.93	105	130	14	1.35
	188	68	45	98	9	0.82	75	108	12	1.02	105	125	14	1.40
	188	72	45	90	9	0.81	75	107	12	1.13	105	122	14	1.42
	188	75	45	98	10	0.85	75	109	12	1.08	105	124	14	1.46
	188	78	45	98	9	0.78	75	111	12	1.02	105	127	14	1.33

Appendix B.3. Results from Cycle Ergometer Tests

	max-HR	pre-HR	load1	1HR	1PE	1vo2	load2	2HR	2PE	2vo2	load3	3HR	3PE	3vo2
c6	171	70	45	100	10	0.87	75	121	12	1.04	90	141	13	1.15
	171	65	45	92	9	•	75	116	10	•	90	134	12	•
	171	75	45	84	9	0.81	75	106	11	1.02	90	125	13	1.18
	171	78	45	95	9	0.91	75	116	11	1.03	90	131	13	1.47
	171	68	45	84	9	0.72	75	108	11	•	90	125	13	1.27
c7	177	90	45	125	11	•	75	150	11	0.94	90	170	13	•
	177	90	45	123	9	0.60	75	157	10	1.01	90	168	13	1.15
	177	85	45	118	7	0.66	75	148	11	0.98	90	168	13	1.21
	177	73	45	112	7	0.81	75	151	11	1.12	90	170	13	1.25
	177	93	45	125	7	0.81	75	157	9	1.17	90	176	12	1.31
C8	177	78	45	115	11	•	75	131	15	•	90	150	18	•
	177	73	45	106	11	1.04	75	121	15	1.22	90	140	18	1.39
	177	74	45	104	11	0.73	75	124	17	1.11	90	142	16	1.31
	177	64	45	99	10	0.93	75	115	13	1.15	90	133	17	1.39
	177	77	45	97	9	0.90	75	115	15	1.20	90	134	17	1.40
c9	182	76	45	110	10	0.90	75	136	11	1.19	90	152	12	1.40
	182	72	45	106	11	0.96	75	120	11	0.99	90	141	12	1.30
	182	70	45	96	10	0.76	75	113	11	1.08	90	130	12	1.29
	182	69	45	105	10	0.92	75	116	11	1.04	90	137	12	1.43
	182	66	45	97	10	0.90	75	116	11	1.08	90	134	12	1.34
c10	194	82	45	128	11	0.81	75	153	14	1.11	90	183	16	1.29
	194	75	45	122	9	0.78	75	149	13	0.99	90	177	17	1.23
	194	67	45	117	10	1.05	75	153	13	1.33	90	183	16	1.60
	194	75	45	118	11	0.76	75	150	14	•	90	172	18	1.30
	194	70	45	111	11	0.85	75	144	13	1.07	90	173	15	1.33
C11	188	93	45	122	6	1.25	75	143	9	1.54	90	164	15	1.94
	188	101	45	126	6	1.16	75	147	9	1.45	90	162	15	1.83
	188	86	45	114	6	0.93	75	141	7	1.11	90	166	12	1.55
	188	93	45	126	6	0.80	75	139	7	1.14	90	164	9	1.46
	188	94	45	122	6	0.79	75	147	6	1.14	90	•	•	•

Appendix B.3. Results from Cycle Ergometer Tests

	max-HR	pre-HR	load1	1HR	1PE	1vo2	load2	2HR	2PE	2vo2	load3	3HR	3PE	3vo2
c12	192	74	45	102	7	•	75	116	11	•	105	135	15	•
	192	66	45	92	7	0.73	75	114	11	1.10	105	141	15	1.46
	192	72	45	102	6	0.83	75	116	8	1.12	105	136	13	1.56
	192	75	45	107	6	0.75	75	124	9	1.15	105	151	14	1.60
	192	75	45	105	6	0.82	75	126	9	1.19	105	144	13	1.55
c13	181	92	45	120	11	0.85	75	141	13	1.10	90	162	15	1.40
	181	90	45	115	11	•	75	143	13	1.04	90	170	16	1.31
	181	94	45	121	11	0.88	75	139	13	1.06	90	162	15	1.29
	181	87	45	117	11	0.92	75	143	13	1.23	90	163	16	1.48
	181	86	45	113	11	0.98	75	140	13	1.25	90	158	15	1.41
s211	176	65	45	98	7	•	75	110	11	1.11	105	133	13	1.45
	176	60	45	106	9	0.89	75	120	11	0.96	105	137	13	1.29
	176	70	45	94	7	0.91	75	110	10	1.08	105	136	13	1.45
	176	52	45	95	7	0.87	75	106	10	1.06	105	128	13	1.62
	176	60	45	90	7	0.88	75	105	10	1.05	105	129	13	1.47
s212	188	95	45	131	11	0.81	75	147	12	1.07	105	165	15	1.32
	188	92	45	122	11	0.73	75	144	13	1.07	105	156	15	1.30
	188	83	45	111	11	0.84	75	131	12	1.10	105	147	13	1.47
	188	76	45	103	11	0.84	75	124	12	1.15	105	144	15	1.55
	188	80	45	101	11	0.78	75	116	12	1.12	105	142	14	1.47
s213	194	90	45	110	6	0.83	90	132	10	1.28	120	151	14	1.75
	194	78	45	100	7	0.78	90	120	10	1.26	120	140	14	•
	194	75	45	105	6	0.67	90	127	9	1.23	120	148	13	1.69
	194	80	45	101	6	0.74	90	119	9	1.12	120	142	12	1.66
	194	92	45	103	6	0.77	90	124	10	1.29	120	146	13	1.71
s214	198	90	45	111	9	0.81	90	145	13	1.27	120	169	17	1.67
	198	100	45	125	9	0.79	90	158	13	1.28	120	180	19	1.78
	198	88	45	124	9	0.86	90	152	13	•	120	176	17	1.84
	198	80	45	114	9	0.78	90	147	12	1.24	120	167	17	1.66
	198	78	45	114	8	0.87	90	150	12	1.35	120	171	17	1.71

Appendix B.3. Results from Cycle Ergometer Tests

	max-HR	pre-HR	load1	1HR	1PE	1vo2	load2	2HR	2PE	2vo2	load3	3HR	3PE	3vo2
s215	195	107	45	113	7	0.87	90	137	13	1.31	120	162	15	1.77
	195	83	45	103	7	0.89	90	129	13	1.43	120	145	17	1.83
	195	72	45	100	7	•	90	113	11	1.34	120	134	16	1.70
	195	82	45	102	6	0.92	90	117	11	1.37	120	133	15	1.83
	•	•	•	•	•	•	90	•	•	•	120	•	•	•
s216	199	82	45	109	9	1.02	90	142	13	1.34	120	166	18	1.76
	199	76	45	104	9	0.96	90	141	14	1.41	120	170	18	1.74
	199	73	45	104	9	0.92	90	135	13	1.42	120	164	17	1.86
	199	70	45	98	10	0.90	90	127	12	1.36	120	161	15	1.55
	199	70	45	106	9	0.88	90	131	12	1.23	120	157	16	1.62
c201	192	100	45	132	10	0.91	75	161	12	1.02	105	170	15	1.50
	192		45	115	11	0.87	75	136	13	0.99	105	158	15	1.42
	192	85	45	110	11	0.82	75	131	12	1.10	105	162	15	1.52
	192	85	45	113	10	•	75	137	12	1.14	105	160	15	1.56
	192	73	45	107	10	0.85	90	144	13	1.26	105	162	15	1.50
c202	192	85	45	104	11	0.99	75	116	13	1.17	105	136	14	1.59
	192	•	45	99	9	0.94	75	115	11	1.27	105	135	13	1.63
	192	80	45	108	11	1.01	75	123	12	1.12	105	152	13	1.75
	192	78	45	100	11	0.90	75	110	12	•	105	131	14	1.48
	192	82	45	105	11	1.09	75	113	12	1.26	105	133	14	1.68
c203	195	71	45	95	11	0.79	90	125	12	1.19	120	145	14	1.68
	195	90	45	111	11	0.77	90	131	13	1.26	120	153	15	1.66
	195	70	45	95	10	0.74	90	113	12	1.20	120	138	14	1.72
	195	85	45	105	11	0.84	90	126	13	1.20	120	149	15	1.87
	195	85	45	103	11	0.79	90	125	13	1.33	120	150	15	1.75
c204	199	76	45	105	7	0.89	90	143	12	1.31	120	172	16	1.81
	199	75	45	109	8	0.89	90	140	12	1.31	120	165	17	1.74
	199	70	45	104	8	0.96	90	141	13	1.33	120	167	17	1.81
	199	82	45	109	9	1.02	90	142	13	1.34	120	166	18	1.76
	199	76	45	104	9	0.96	90	141	14	1.41	120	170	18	1.74

	max-HR	pre-HR	load1	1HR	1PE	1vo2	load2	2HR	2PE	2vo2	load3	3HR	3PE	3vo2
c205	187	90	45	111	10	0.95	90	139	13	1.36	105	153	15	1.68
	187	90	45	107	8	•	90	137	13	•	105	152	15	•
	187	80	45	100	8	0.85	90	136	12	1.34	105	159	15	1.85
	187	76	45	107	9	0.96	90	132	14	1.43	105	150	17	1.75
	187	75	45	108	9	0.85	90	134	14	1.17	105	155	18	1.56
c206	193	75	45	100	11	0.84	90	144	14	1.19	105	165	14	1.44
	193	70	45	106	10	0.83	90	150	12	1.23	105	170	14	1.46
	193	65	45	107	10	0.87	90	148	12	1.22	105	170	13	1.48
	193	60	45	100	9	0.75	90	148	11	1.24	105	169	13	1.52
	193	60	45	104	8	0.80	90	152	11	1.31	105	173	12	1.50

code	mvL-o	mvL-w	mvml-o	mvml-w	HR-1	HR-2	HR-3
s33	2.45	2.60	33.38	35.42	110	98	78
	2.30	2.40	31.68	33.06	114	99	92
	2.64	2.79	36.67	38.75	103	97	85
	2.79	2.69	38.64	37.26	105	107	92
	2.79	2.69	38.75	37.36	100	91	94
s34	2.35	2.50	37.90	40.32	103	105	92
	2.50	2.60	40.32	41.94	111	101	95
	2.30	2.70	36.86	43.27	89	87	93
	2.70	2.70	43.69	43.69	91	96	95
	2.32	2.63	37.79	42.83	105	105	106
s35	2.01	2.20	25.77	28.21	117	107	99
	•	2.30	•	29.41	•	•	•
	•	2.30	•	28.82	122	142	107
	2.52	2.43	31.98	30.84	113	105	83
	2.56	2.52	32.41	31.90	108	103	97
s36	2.95	3.18	39.44	42.51	85	80	85
	3.30	3.80	44.12	50.80	77	75	67
	4.43	4.52	59.07	60.27	•	•	•
	4.06	4.06	53.28	53.28	83	80	80
	4.15	4.24	54.32	55.50	89	80	78
S37	2.27	2.55	30.59	34.37	96	87	87
	2.60	2.60	34.76	34.76	98	93	83
	2.84	2.96	38.17	39.78	•	•	•
	2.75	2.60	36.86	34.85	105	97	87
	2.35	2.43	31.50	32.57	110	108	82
s40	1.94	2.26	30.79	35.87	139	130	101
	1.94	2.15	30.89	34.24	145	122	107
	2.21	2.36	35.53	37.94	142	126	95
	2.15	2.21	33.91	34.86	133	121	109
	2.31	2.52	36.55	39.87	135	117	86

Appendix B.3. Results from Cycle Ergometer Tests

	mvL-o	mvL-w	mvml-o	mvml-w	HR-1	HR-2	HR-3
s41	2.22	2.37	31.81	33.95	120	115	101
	2.17	2.37	30.74	33.57	129	118	103
	2.52	2.62	36.00	37.43	112	102	96
	3.06	2.92	42.74	40.78	112	116	72
	3.06	2.71	42.86	37.96	112	107	102
s42	2.47	2.47	32.59	32.59	123	107	103
	2.76	2.66	35.66	34.37	108	102	94
	2.86	2.81	36.48	35.84	110	99	100
	3.75	3.60	48.08	46.15	103	95	75
	3.41	3.16	43.72	40.51	98	90	82
s43	1.97	2.10	32.72	34.88	122	115	106
	2.33	2.42	38.96	40.47	121	95	92
	2.50	2.28	41.95	38.26	119	103	87
	2.15	2.37	36.69	40.44	102	103	74
	2.10	2.46	•	•	108	99	85
s44	1.68	2.09	31.34	38.99	106	•	•
	1.77	2.18	33.27	40.98	105	96	82
	2.18	2.45	41.29	46.40	108	106	83
	1.54	1.95	28.95	36.65	134	116	101
	1.73	2.14	32.77	40.53	119	110	113
s46	2.77	2.73	33.78	33.29	124	118	113
	2.86	2.86	34.38	34.38	122	116	90
	2.86	2.86	34.46	34.46	114	104	91
	3.45	2.91	41.87	35.32	120	104	90
	3.50	3.09	42.79	37.78	119	105	84
s47	•	1.09	•	28.53	150	140	120
	•	1.09	•	28.39	143	127	106
	•	1.23	•	31.54	124	118	106
	•	1.23	•	32.37	132	117	88
	•	1.23	•	32.03	121	104	75

	mvL-o	mvL-w	mvml-o	mvml-w	HR-1	HR-2	HR-3
s49	2.29	2.20	32.25	30.99	130	121	113
	2.39	2.40	33.57	33.71	122	117	104
	•	2.48	•	33.97	130	114	95
	2.90	2.60	39.84	35.71	•	•	91
	3.02	2.73	41.48	37.50	119	103	85
c1	•	2.19	•	31.38	137	126	122
	2.00	2.29	28.41	32.53	129	120	101
	•	2.48	•	35.23	115	105	90
	2.29	2.20	32.25	30.99	130	121	113
	2.39	2.40	33.57	33.71	122	117	104
c2	•	1.90	•	32.09	143	128	123
	•	1.80	•	30.10	159	143	124
	1.90	2.10	31.67	35.00	114	104	102
	1.97	2.10	32.72	34.88	122	115	106
	2.33	2.42	38.96	40.47	121	95	92
c3	1.95	2.40	26.28	32.35	126	114	117
	2.20	2.50	29.49	33.51	114	108	102
	2.50	2.50	33.60	33.60	117	102	102
	2.18	2.29	29.30	30.78	122	118	115
	2.18	2.29	29.22	30.70	129	115	102
c4	1.30	1.70	25.29	33.07	144	132	114
	1.20	1.68	23.35	32.68	117	108	102
	2.09	2.30	40.66	44.75	105	98	92
	1.68	2.09	31.34	38.99	106	•	•
	1.77	2.18	33.27	40.98	105	96	82
c5	2.80	3.20	42.42	48.48	103	90	78
	3.09	3.50	46.54	52.71	88	85	80
	3.27	3.70	50.00	56.57	94	88	80
	3.41	3.54	50.29	52.21	97	95	84
	3.18	3.32	47.32	49.40	110	104	90

Appendix B.3. Results from Cycle Ergometer Tests

	mvL-o	mvL-w	mvml-o	mvml-w	HR-1	HR-2	HR-3
c6	1.70	1.96	25.30	29.17	102	93	81
	•	2.90	•	43.41	95	78	80
	2.80	2.60	41.42	38.46	87	73	78
	2.49	2.34	37.61	35.35	98	78	81
	2.42	2.57	36.56	38.82	89	78	70
c7	1.16	1.48	18.83	24.03	132	114	96
	1.28	1.52	20.78	24.68	141	122	101
	1.32	1.52	21.57	24.84	•	•	•
	1.36	1.48	22.08	24.03	153	127	110
	1.32	1.40	21.36	22.65	148	125	120
C8	•	1.88	•	25.54	127	116	106
	2.16	2.12	29.35	28.80	119	108	107
	2.50	2.08	33.97	28.26	125	118	105
	2.40	2.40	32.17	32.17	113	•	97
	2.40	2.36	32.35	31.81	124	110	106
c9	1.90	1.90	26.32	26.32	127	111	101
	2.12	2.24	30.03	31.73	114	105	94
	2.45	2.66	34.90	37.89	104	93	85
	2.45	2.37	35.10	33.95	113	106	92
	2.41	2.50	34.23	35.51	104	97	80
c10	1.48	1.58	25.52	27.24	159	142	138
	1.48	1.68	25.69	29.17	155	140	131
	1.83	1.58	31.88	27.53	162	148	144
	1.68	1.78	28.87	30.58	156	155	141
	1.73	1.73	29.12	29.12	142	131	111
C11	2.50	1.77	33.42	23.66	139	136	124
	2.41	1.82	32.31	24.40	152	140	134
	1.95	1.77	26.35	23.92	154	144	135
	1.91	1.82	25.33	24.11	151	142	137
	•	•	•	•	•	•	•

	mvL-o	mvL-w	mvml-o	mvml-w	HR-1	HR-2	HR-3
c12	•	3.07	•	51.34	85	78	69
	2.55	2.69	43.22	45.59	105	90	75
	3.07	3.07	50.49	50.49	98	83	84
	2.50	2.50	41.25	41.25	98	96	95
	2.69	2.69	44.54	44.54	99	92	77
c13	1.71	1.67	32.14	31.39	143	129	133
	1.46	1.55	27.04	28.70	147	135	133
	1.59	1.67	29.30	30.85	130	124	120
	1.80	1.67	33.30	30.96	141	134	126
	1.84	1.76	33.82	32.35	143	129	118
s211	2.50	2.60	34.25	35.62			
	2.10	2.50	28.93	34.44			
	2.40	2.50	33.15	34.53			
	3.00	2.80	41.67	38.89			
	2.70	2.80	37.71	39.11			
s212	1.70	2.00	25.53	30.03			
	1.90	2.20	28.44	32.93			
	2.40	2.50	35.61	37.09			
	2.50	2.50	37.43	37.43			
	2.50	2.60	37.31	38.81			
s213	2.9	2.8	51.1	49.5			
	•	3.3	•	57.4			
	2.9	3.0	50.2	51.2			
	3.1	3.2	53.8	55.7			
	3.1	3.1	54.2	53.5			
s214	2.4	2.4	40.0	40.3			
	2.3	2.2	38.5	36.2			
	2.4	2.3	39.5	37.3			
	2.4	2.5	39.5	40.7			
	2.4	2.4	39.2	38.7			

Appendix B.3. Results from Cycle Ergometer Tests

	mvL-o	mvL-w	mvml-o	mvml-w	HR-1	HR-2	HR-3
s215	2.7	2.6	34.5	33.2			
	3.3	3.1	43.1	40.5			
	3.6	3.7	47.0	47.7			
	4.0	3.7	51.2	47.9			
	2.6	2.5	35.6	34.2			
s216	2.4	2.4	33.3	32.6			
	2.8	2.6	37.3	35.2			
	2.4	2.7	32.2	35.6			
	2.7	2.8	35.9	38.0			
	2.0	2.0	33.5	34.3			
c201	2.1	2.3	35.8	39.1			
	2.2	2.2	36.8	36.8			
	2.3	2.3	38.4	38.4			
	2.2	2.1	36.9	36.1			
	3.1	3.1	43.6	42.9			
c202	3.3	3.1	46.3	44.2			
	2.8	2.5	38.5	34.5			
	3.2	3.3	41.7	43.6			
	3.5	3.2	45.2	42.0			
	3.0	3.1	43.2	44.7			
c203	2.7	2.8	38.7	40.1			
	3.5	3.4	49.9	48.4			
	3.2	2.9	46.1	41.8			
	3.0	2.9	42.4	41.7			
	2.5	2.3	33.9	31.8			
c204	2.6	2.5	35.2	34.5			
	2.7	2.5	35.7	33.6			
	2.6	2.5	35.6	34.2			
	2.4	2.4	33.3	33.3			
	•	2.3	•	31.3			

	mvL-o	mvL-w	mvml-o	mvml-w	HR-1	HR-2	HR-3
c205	2.5	2.2	33.9	30.9			
	•	2.3	•	31.3			
	2.5	2.1	34.4	28.8			
	2.6	2.4	35.9	32.3			
	2.2	2.2	30.5	29.9			
c206	2.0	2.1	34.5	37.1			
	1.9	2.0	32.9	35.4			
	1.9	2.0	33.6	35.3			
	2.0	2.0	35.6	35.6			
	1.9	2.0	33.0	34.7			

Appendix B.

4. Results of the Questionnaires Completed by the 1994 Group prior to and after the Six Week Supercircuit Programme.

Questionnaire 1: 'Perceived Level of Fitness'. This questionnaire was completed prior to and after the six week supercircuit programme.

Abbreviations:

Start: Results of the questionnaire completed prior to the supercircuit programme.

Finish: Results of the questionnaire completed after the supercircuit programme.

Δ: Difference between 'start' and 'finish'.

Questionnaire 2: 'Perceived Changes in Fitness' This questionnaire was completed after the six week supercircuit programme.

	Perceived level of fitness prior to and after training														
	Body Fat			Muscle Tone			Stamina			Strength arms			Strength legs		
code	Start	Finish	Δ	Start	Finish	Δ	Start	Finish	Δ	Start	Finish	Δ	Start	Finish	Δ
s33	4	4	0	2	4	2	2	4	2	3	4	1	2	3	1
s34	4	3	-1	1	3	2	2	3	1	1	2	1	1	3	1
s35	4	2	-2	3	4	1	3	4	1	4	4	0	4	3	-1
s36	3	3	0	2	3	1	1	2	1	1	3	2	1	3	2
s37	3	3	0	3	4	1	3	4	1	3	4	1	4	4	0
s40	2	3	1	1	3	2	2	3	1	2	4	2	3	4	1
s41	4	4	0	2	3	1	2	3	1	2	2	0	3	3	0
s42	2	4	2	2	2	0	2	3	1	3	3	0	3	3	0
s43	3	3	0	2	4	2	2	3	1	2	3	1	3	3	0
s44	3	3	0	2	3	1	3	3	0	2	3	1	2	4	2
s46	5	4	-1	2	3	1	3	3	0	2	3	1	3	3	0
s47	3	3	0	3	3	0	2	4	2	2	4	2	3	2	-1
s49	4	4	0	2	3	1	2	3	1	2	3	1	2	2	0
c1	4	4	0	3	2	-1	2	2	0	2	2	0	3	2	-1
c2	3	3	0	3	2	-1	2	2	0	1	2	1	3	3	0
c3	5	5	0	3	3	0	2	1	-1	3	3	0	4	5	1
c4	3	3	0	2	2	0	3	3	0	2	2	0	2	2	0
c5	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
c6	2	2	0	2	2	0	3	3	0	2	2	0	2	2	0
c7	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
c8	4	4	0	2	2	0	1	1	0	3	2	-1	2	2	0
c9	2	2	0	2	2	0	3	3	0	2	2	0	4	4	0
c10	5	4	-1	3	2	-1	2	2	0	2	2	0	3	3	0
c11	3	3	0	2	2	0	2	2	0	3	2	-1	3	3	0
c12	2	3	1	3	2	1	3	3	0	2	2	0	3	3	0
c13	4	2	-2	2	2	0	2	2	0	3	2	0	2	2	0

Appendix B.4. Results from the Questionnaires.

Perceived level of fitness prior to and after training						
	Flexibility arms			Flexibility legs		
code	Start	Finish	Δ	Start	Finish	Δ
s33	3	4	1	1	2	1
s34	1	4	3	1	3	2
s35	4	5	1	4	5	1
s36	3	3	0	3	3	0
s37	4	3	-1	4	4	0
s40	3	4	1	3	4	1
s41	2	2	0	2	2	0
s42	3	3	0	3	3	0
s43	2	4	2	1	1	0
s44	3	3	0	1	2	1
s46	3	2	-1	3	3	0
s47	3	4	1	3	3	0
s49	3	4	1	3	4	1
c1	3	3	0	3	3	0
c2	4	2	-2	1	1	0
c3	1	2	1	1	1	0
c4	2	3	1	3	1	-2
c5	•	•	•	•	•	•
c6	3	3	0	3	3	0
c5	•	•	•	•	•	•
c8	3	2	-1	3	1	-2
c9	3	2	-1	3	2	-1
c10	4	4	0	3	4	1
c11	3	2	0	2	2	0
c12	1	1	0	3	1	-1
c13	3	2	-1	2	2	0

	Perceived Change in Fitness in Six Weeks							
	Body			Strength	Strength	Flexibility		Physical
code	Shape	Toning	Stamina	legs	arms	shoulders	legs	feeling
s33	2	3	4	4	4	1	1	4
s34	1	2	3	2	4	1	3	2
s35	2	4	4	4	4	2	2	4
s36	2	2	2	3	3	2	2	3
s37	4	4	4	4	4	3	4	5
s40	2	3	3	3	4	3	4	4
s41	2	3	3	4	2	3	3	3
s42	2	2	2	3	3	3	3	1
s43	1	3	2	2	3	1	1	3
s44	2	4	2	2	4	3	2	3
s46	2	3	3	4	4	3	3	4
s47	2	2	3	2	4	2	2	2
s49	2	2	1	2	3	3	1	3
c1	1	1	1	1	1	1	1	1
c2	1	1	1	1	1	1	1	1
c3	-3	-3	-3	-3	-3	-3	-3	-3
c4	1	1	1	1	1	1	1	1
c5	•	•	•	•	•	•	•	•
c6	1	1	1	1	1	1	1	1
c7	•	•	•	•	•	•	•	•
c8	1	1	1	1	1	1	1	1
c9	1	1	1	1	1	1	1	1
c10	1	1	1	1	1	1	1	1
c11	1	1	1	1	1	1	1	1
c12	1	1	1	1	1	1	1	1
c13	1	1	1	1	1	1	1	1

Appendix B.4. Results from the Questionnaires.

Appendix C.

1. Summary tables for ANOVA for the Comparison of Characteristics of the 1993 and 1994 Groups.

A summary of the calculations to determine F for the comparison of characteristics of the 1993 and 1994 groups. The results are taken from the first two tests only, prior to starting supercircuit training.

1.1. Age

Source	df	SS	MS	F
Between subjects	37	211.1		
Between years	1	12.6	12.6	2.28
Between subjects/within groups error	36	198.6	5.5	

For $\infty = 0.05$, F must be greater than 4.1 to be significant.

1.2. Height

Source	df	SS	MS	F
Between subjects	37	10709.0		
Between years	1	50.3	50.3	0.17
Between subjects/within groups error	36	10658.3	296.1	

For $\infty = 0.05$, F must be greater than 4.1 to be significant.

1.3. Body Mass

Source	df	SS	MS	F
Between subjects	37	6270.8		
Between years	1	34.9	34.9	0.20
Between subjects/within groups error	36	6235.9	173.2	

For $\infty = 0.05$, F must be greater than 4.1 to be significant.

1.4. Sum of Two Skinfolds

Source	df	SS	MS	F
Between subjects	37	17145.1		
Between years	1	1.8	1.8	0.00
Between subjects/within groups error	36	17143.3	476.2	

For ∞ = 0.05, F must be greater than 4.1 to be significant.

1.5. Sum of Six Skinfolds

Source	df	SS	MS	F
Between subjects	37	101757.2		
Between years	1	782.9	782.9	0.028
Between subjects/within groups error	36	100974.3	2804.8	

For ∞ = 0.05, F must be greater than 4.1 to be significant.

1.6. Systolic Blood Pressure

Source	df	SS	MS	F
Between subjects	37	5005.8		
Between years	1	593.7	593.7	4.84
Between subjects/within groups error	36	4412.1	122.6	

For ∞ = 0.05, F must be greater than 4.1 to be significant.

1.7. Diastolic Blood Pressure

Source	df	SS	MS	F
Between subjects	37	2868.4		
Between years	1	542.9	542.9	8.4
Between subjects/within groups error	36	2325.5	64.6	

For ∞ = 0.05, F must be greater than 4.1 to be significant.

1.8. Hamstring Flexibility (right + left leg)

Source	df	SS	MS	F
Between subjects	37	8593.3		
Between years	1	178.1	178.1	0.76
Between subjects/within groups error	36	8415.2	233.8	

For ∞ = 0.05, F must be greater than 4.1 to be significant.

1.9. Flexibility of Right Hamstring

Source	df	SS	MS	F
Between subjects	37	6982.4		
Between years	1	292.2	292.2	1.57
Between subjects/within groups error	36	6690.2	185.8	

For ∞ = 0.05, F must be greater than 4.1 to be significant.

1.10. Flexibility of the Left Hamstring

Source	df	SS	MS	F
Between subjects	37	8331.9		
Between years	1	376.8	376.8	1.71
Between subjects/within groups error	36	7955.1	221.0	

For ∞ = 0.05, F must be greater than 4.1 to be significant.

1.11. Flexibility of the Right Gastrocnemius

Source	df	SS	MS	F
Between subjects	37	818.3		
Between years	1	25.5	25.5	1.16
Between subjects/within groups error	36	792.8	22.0	

For ∞ = 0.05, F must be greater than 4.1 to be significant.

1.12. Flexibility of the Left Gastrocnemius

Source	df	SS	MS	F
Between subjects	37	715.8		
Between Groups	1	5.4	5.4	0.27
Between subjects/within groups error	36	710.4	19.7	

For ∞ = 0.05, F must be greater than 4.1 to be significant.

1.13. Flexibility of the Right Soleus

Source	df	SS	MS	F
Between subjects	37	874.0		
Between years	1	14.4	14.4	0.6
Between subjects/within groups error	36	859.6	23.8	

For ∞ = 0.05, F must be greater than 4.1 to be significant.

1.14. Flexibility of the Left Soleus

Source	df	SS	MS	F
Between subjects	37	920.9		
Between years	1	118.3	118.3	5.3
Between subjects/within groups error	36	802.6	22.9	

For ∞ = 0.05, F must be greater than 4.1 to be significant.

1.15. Flexibility of the Right Shoulder

Source	df	SS	MS	F
Between subjects	37	1996.9		
Between years	1	25.9	25.9	0.47
Between subjects/within groups error	36	1971.0	54.8	

For ∞ = 0.05, F must be greater than 4.1 to be significant.

1.16. Flexibility of the Left Shoulder

Source	df	SS	MS	F
Between subjects	37	1579.3		
Between years	1	24.3	24.3	0.56
Between subjects/within groups error	36	1555.0	43.2	

For ∞ = 0.05, F must be greater than 4.1 to be significant.

1.17. Bench Press (1RM)

Source	df	SS	MS	F
Between subjects	11	4633.4		
Between years	1	193.1	193.1	.43
Between subjects/within groups error	10	4440.3	444.0	

For ∞ = 0.05, F must be greater than 5.0 to be significant.

1.18. Crunches

Source	df	SS	MS	F
Between subjects	37	5920.5		
Between years	1	1499.0	1499.0	12.2
Between subjects/within groups error	36	4421.5	122.8	

For ∞ = 0.05, F must be greater than 4.1 to be significant.

1.19. Pre-exercise Heart Rate

Source	df	SS	MS	F
Between subjects	37	5638.6		
Between years	1	191.7	191.7	1.27
Between subjects/within groups error	36	5446.9	151.3	

For ∞ = 0.05, F must be greater than 4.1 to be significant.

1.20. Estimated VO_2max based on Watts

Source	df	SS	MS	F
Between subjects	37	3359.3		
Between years	1	202.6	202.6	2.31
Between subjects/within groups error	36	3156.7	87.7	

For ∞ = 0.05, F must be greater than 4.1 to be significant.

1.21. Rating of Perceived Exertion

Source	df	SS	MS	F
Between subjects	35	211.2		
Between years	1	12.6	12.6	2.28
Between subjects/within groups error	34	198.6	5.5	

For ∞ = 0.05, F must be greater than 4.2 to be significant.

Appendix C.

2. Summary tables for ANOVA for the Comparison of Characteristics of the Supercircuit and Control Groups.

A summary of the calculations to determine F for the comparison of characteristics of the Supercircuit and Control groups. The results are taken from the first two tests only, prior to starting supercircuit training.

2.1. Age

Source	df	SS	MS	F
Between subjects	37	9515.4		
Between Groups	1	290.7	290.7	1.13
Between subjects/within groups error	36	9224.7	256.2	

For $\infty = 0.05$, F must be greater than 4.1 to be significant.

2.2. Height

Source	df	SS	MS	F
Between subjects	37	10709.0		
Between Groups	1	20.6	20.6	.07
Between subjects/within groups error	36	10688.3	296.9	

For $\infty = 0.05$, F must be greater than 4.1 to be significant.

2.3. Body Mass

Source	df	SS	MS	F
Between subjects	37	6270.8		
Between Groups	1	82.1	82.2	.48
Between subjects/within groups error	36	6188.7	171.9	

For $\infty = 0.05$, F must be greater than 4.1 to be significant.

2.4. Sum of Two Skinfolds

Source	df	SS	MS	F
Between subjects	37	17145.1		
Between Groups	1	231.9	231.9	.49
Between subjects/within groups error	36	16913.2	469.8	

For $\infty = 0.05$, F must be greater than 4.1 to be significant.

2.5. Sum of Six Skinfolds

Source	df	SS	MS	F
Between subjects	37	101757.2		
Between Groups	1	96.8	96.8	.03
Between subjects/within groups error	36	101660.4	2823.9	

For $\infty = 0.05$, F must be greater than 4.1 to be significant.

2.6. Systolic Blood Pressure

Source	df	SS	MS	F
Between subjects	37	5005.8		
Between Groups	1	25.5	25.5	.18
Between subjects/within groups error	36	4980.3	138.3	

For $\infty = 0.05$, F must be greater than 4.1 to be significant.

2.7. Diastolic Blood Pressure

Source	df	SS	MS	F
Between subjects	37	2868.4		
Between Groups	1	7.6	7.6	.096
Between subjects/within groups error	36	2860.8	79.46	

For ∞ = 0.05, F must be greater than 4.1 to be significant.

2.8. Hamstring Flexibility (right + left leg)

Source	df	SS	MS	F
Between subjects	37	8593.3		
Between Groups	1	308.4	308.4	1.34
Between subjects/within groups error	36	8284.9	230.13	

For ∞ = 0.05, F must be greater than 4.1 to be significant.

2.9. Flexibility of Right Hamstring

Source	df	SS	MS	F
Between subjects	37	6982.4		
Between Groups	1	248.4	2948.4	1.33
Between subjects/within groups error	36	6734.0	187.1	

For ∞ = 0.05, F must be greater than 4.1 to be significant.

2.10. Flexibility of the Left Hamstring

Source	df	SS	MS	F
Between subjects	37	8331.9		
Between Groups	1	161.6	161.6	.71
Between subjects/within groups error	36	8170.3	227.0	

For ∞ = 0.05, F must be greater than 4.1 to be significant.

2.11. Flexibility of the Right Gastrocnemius

Source	df	SS	MS	F
Between subjects	37	818.3		
Between Groups	1	22.7	22.7	1.03
Between subjects/within groups error	36	795.6	22.1	

For ∞ = 0.05, F must be greater than 4.1 to be significant.

2.12. Flexibility of the Left Gastrocnemius

Source	df	SS	MS	F
Between subjects	37	715.8		
Between Groups	1	40.5	40.5	2.16
Between subjects/within groups error	36	675.3	18.8	

For ∞ = 0.05, F must be greater than 4.1 to be significant.

2.13. Flexibility of the Right Soleus

Source	df	SS	MS	F
Between subjects	37	874		
Between Groups	1	24.3	24.3	1.03
Between subjects/within groups error	36	849.7	23.6	

For ∞ = 0.05, F must be greater than 4.1 to be significant.

2.14. Flexibility of the Left Soleus

Source	df	SS	MS	F
Between subjects	37	920.9		
Between Groups	1	52.2	52.2	2.16
Between subjects/within groups error	36	868.7	24.1	

For ∞ = 0.05, F must be greater than 4.1 to be significant.

2.15. Flexibility of the Right Shoulder

Source	df	SS	MS	F
Between subjects	37	1996.9		
Between Groups	1	50.9	50.9	.94
Between subjects/within groups error	36	1946.0	54.1	

For ∞ = 0.05, F must be greater than 4.1 to be significant.

2.16. Flexibility of the Left Shoulder

Source	df	SS	MS	F
Between subjects	37	1579.3		
Between Groups	1	28.7	28.7	.67
Between subjects/within groups error	36	1550.6	43.1	

For ∞ = 0.05, F must be greater than 4.1 to be significant.

2.17. Bench Press (1RM)

Source	df	SS	MS	F
Between subjects	11	4633.4		
Between Groups	1	193.1	193.1	.43
Between subjects/within groups error	10	4440.3	444.0	

For ∞ = 0.05, F must be greater than 5.0 to be significant.

2.18. Bench Press (reps)

Source	df	SS	MS	F
Between subjects	25	1156.9		
Between Groups	1	84.5	84.5	1.89
Between subjects/within groups error	24	1072.4	44.7	

For ∞ = 0.05, F must be greater than 4.3 to be significant.

2.19. Leg Press (1RM)

Source	df	SS	MS	F
Between subjects	11	4721.8		
Between Groups	1	419.7	419.7	0.98
Between subjects/within groups error	10	4302.1	430.2	

For ∞ = 0.05, F must be greater than 5.0 to be significant.

2.20. Leg Extension (reps)

Source	df	SS	MS	F
Between subjects	25	1819		
Between Groups	1	30.4	30.4	0.40
Between subjects/within groups error	10	1788.6	74.5	

For ∞ = 0.05, F must be greater than 4.3 to be significant.

2.21. Crunches

Source	df	SS	MS	F
Between subjects	37	5920.5		
Between Groups	1	353.9	353.9	2.29
Between subjects/within groups error	36	5566.6	154.6	

For ∞ = 0.05, F must be greater than 4.1 to be significant.

2.22. Pre-exercise Heart Rate

Source	df	SS	MS	F
Between subjects	37	5638.6		
Between Groups	1	8.9	8.9	.06
Between subjects/within groups error	36	5629.7	156.4	

For ∞ = 0.05, F must be greater than 4.1 to be significant.

2.23. Estimated VO_2max based on Oxygen Consumption

Source	df	SS	MS	F
Between subjects	35	2470.1		
Between Groups	1	75.4	75.4	1.07
Between subjects/within groups error	34	2394.7	70.4	

For ∞ = 0.05, F must be greater than 4.2 to be significant.

2.24. Estimated VO_2max based on Watts

Source	df	SS	MS	F
Between subjects	37	3359.3		
Between Groups	1	76.8	76.8	0.84
Between subjects/within groups error	36	3282.5	91.2	

For ∞ = 0.05, F must be greater than 4.1 to be significant.

2.25. Rating of Perceived Exertion

Source	df	SS	MS	F
Between subjects	35	211.2		
Between Groups	1	1.5	1.5	0.24
Between subjects/within groups error	34	209.7	6.2	

For ∞ = 0.05, F must be greater than 4.2 to be significant.

Appendix D. Tables of Results.

Table 1. Pre-, mid-, and post-six week Body Composition Characteristics.

Mean (± SD) of body mass, sum of 2 skinfolds, and sum of 6 skinfolds at zero, three, and six weeks.

		weeks		
		zero X±SD	three X±SD	six X±SD
Body mass	supercircuit	67.6±10.5 (n=38)	67.9±10.8 (n=19)	67.8±10.8 (n=36)
	control	65.5±7.5 (n=38)	65.6±7.6 (n=19)	66.1±7.5 (n=38)
SKF-2	supercircuit	54.2±17.4 (n=38)	52.7±15.3 (n=19)	52.9±15.1 (n=37)
	control	50.7±12.7 (n=38)	51.8±12.7 (n=19)	53.4±13.5 (n=38)
SKF-6	supercircuit	160.1±41.4 (n=38)	158.5±36.6 (n=19)	154.6±44.3 (n=38)
	control	157.8±32.6 (n=38)	160.8±33.2 (n=19)	165.4±32.0 (n=38)

'n' is the number of tests completed for each characteristic with each subject being tested twice at 0 weeks, once at 3 weeks, and twice at 6 weeks. SKF-2 is the sum of the suprailiac and abdominal skinfolds, and SKF-6 is the sum of the triceps, subscapular, suprailiac, abdominal, thigh, and calf skinfolds.

Appendix D.
Table 2. Pre-, mid-, and post-six week, Pre-exercise Blood Pressure and Heart Rate.

Blood pressure and heart rate were recorded prior to commencing the cycle ergometer test.

		weeks		
		zero X±SD	three X±SD	six X±SD
Systolic Blood Pressure (mm/Hg)	supercircuit	112.6±8.4 (n=38)	112.1±10.0 (n=19)	107.7±12.0 (n=38)
	control	111.5±10.6 (n=38)	109.3±8.6 (n=19)	107.8±8.1 (n=38)
Diastolic Blood Pressure (mm/Hg)	supercircuit	73.5±7.4 (n=38)	70.8±9.4 (n=19)	69.6±7.3 (n=38)
	control	74.1±6.7 (n=38)	70.9±5.9 (n=19)	71.1±5.9 (n=38)
Pre-exercise Heart Rate	supercircuit	81.5±10.1 (n=38)	75.4±8.1 (n=19)	71.4±9.5 (n=38)
	control	80.8±10.3 (n=38)	77.4±7.9 (n=19)	77.5±9.3 (n=38)

'n' is the number of tests completed for each characteristic with each subject being tested twice at 0 weeks, once at 3 weeks, and twice at 6 weeks.

Appendix D.

Table 3. ` Pre-, mid-, and post-six week Flexibility Characteristics.

		weeks		
		zero X±SD	three X±SD	six X±SD
Hamstrings Legs Together	supercircuit	22.1±11.2 (n=38)	24.8±0.1 (n=19)	27.1±9.9 (n=37)
	control	26.1±10.2 (n=37)	25.4±10.5 (n=19)	26.1±9.6 (n=38
Right Hamstring	supercircuit	23.6±10.5 (n=37)	26.9±9.3 (n=19)	28.9±9.2 (n=37)
	control	27.3±8.7 (n=38)	26.6±9.0 (n=19)	26.7±8.8 (n=37)
Left Hamstring	supercircuit	23.1±10.9 (n=37)	26.3±10.0 (n=19)	27.6±9.9 (n=37)
	control	26.1±10.7 (n=36)	25.4±10.8 (n=19)	26.0±10.1 (n=38)
Right Gastrocnemius	supercircuit	32.6±3.1 (n=38)	32.3±3.4 (n=19)	32.1±3.5 (n=37)
	control	33.7±3.5 (n=38)	33.2±3.7 (n=19)	33.2±3.5 (n=38)

Appendix D, Table 3 continued.

Left Gastrocnemius	supercircuit	33.4±3.1 (n=38)	33.3±2.8 (n=19)	33.1±3.1 (n=37)
	control	34.8±3.1 (n=38)	34.5±3.1 (n=19)	34.2±3.1 (n=38)
Right Soleus	supercircuit	30.6±3.3 (n=38)	29.8±3.7 (n=19)	29.3±3.8 (n=37)
	control	31.8±3.5 (n=38)	31.7±3.6 (n=19)	31.5±3.6 (n=38)
Left Soleus	supercircuit	31.4±3.6 (n=38)	30.7±3.9 (n=19)	30.6±3.9 (n=37)
	control	33.0±3.3 (n=38)	32.9±3.3 (n=19)	32.4±3.7 (n=38)
Right Shoulder	supercircuit	2.0±5.7 (n=38)	3.1±6.0 (n=19)	3.4±5.5 (n=37)
	control	3.6±4.8 (n=38)	4.3±5.0 (n=19)	4.6±4.6 (n=38)
Left Shoulder	supercircuit	4.3±4.9 (n=38)	5.4±4.9 (n=19)	5.8±3.5 (n=37)
	control	5.5±4.5 (n=37)	5.8±4.4 (n=19)	6.1±4.2 (n=38)

'n' is the number of tests completed for each characteristic with each subject being tested twice at 0 weeks, once at 3 weeks, and twice at 6 weeks.

Appendix D.

Table 4. Pre-, mid-, and post-six week Strength Characteristics.

		weeks		
		zero X±SD	three X±SD	six X±SD
Bench Press estimated 1RM (kg)	supercircuit	25.5±4.4 (n=10)	29.2±6.3 (n=6)	38.3±4.7 (n=11)
	control	29.6±4.6 (n=11)	29.7±6.4 (n=3)	29.9±4.8 (n=12)
Bench Press (repetitions)	supercircuit	11.8±5.2 (n=25)	18.0±10.0 (n=13)	23.4±9.8 (n=26)
	control	9.2±4.7 (n=25)	10.5±4.9 (n=13)	10.8±9.8 (n=26)
Leg Press estimated 1RM (kg)	supercircuit	75.8±9.9 (n=10)	82.5±9.3 (n=6)	88.6±11.6 (n=9)
	control	75.2±13.1 (n=11)	75.9±12.1 (n=6)	77.8±7.3 (n=12)
Leg Extension (repetitions)	supercircuit	18.2±6.2 (n=24)	24.3±6.8 (n=13)	27.6±9.8 (n=25)
	control	19.8±6.8 (n=26)	21.3±7.2 (n=13)	21.6±7.8 (n=26)

Appendix D, Table 4 continued.

		weeks		
		zero X±SD	three X±SD	six X±SD
Crunches (repetitions)	supercircuits	31.2±9.0 (n=38)	37.7±10.9 (n=19)	44.6±13.3 (n=37)
	control	26.9±9.5 (n=38)	30.3±8.8 (n=19)	33.1±9.9 (n=38)

'n' is the number of tests completed for each characteristic with each subject being tested twice at 0 weeks, once at 3 weeks, and twice at 6 weeks.

Appendix D.
Table 5. Pre-, mid-, and post-six week Heart Rates at the Third Workload on the Cycle Ergometer

		weeks		
		zero X±SD	three X±SD	six X±SD
Heart Rate (bpm)	supercircuit	151.4±13.2 (n=38)	145.3±14.3 (n=19)	143.6±12.6 (n=37)
	control	156.0±14.7 (n=38)	152.2±16.9 (n=19)	151.8± 15.6 (n=37)

'n' is the number of tests completed for each characteristic with each subject being tested twice at 0 weeks, once at 3 weeks, and twice at 6 weeks.

Appendix D.
Table 6. Pre-, mid-, and post-six week Oxygen Uptake at the Third Workload.

		weeks		
		zero X±SD	three X±SD	six X±SD
Oxygen Uptake (L/min)	supercircuit	1.45±.23 (n=34)	1.49±.24 (n=16)	1.52±.24 (n=35)
	control	1.46±.21 (n=29)	1.50±.21 (n=21)	1.49±.15 (n=35)

'n' is the number of tests completed for each characteristic with each subject being tested twice at 0 weeks, once at 3 weeks, and twice at 6 weeks.

Appendix D.
Table 7. Pre-, mid-, and post-six week Estimated Maximum Oxygen Uptake.

		weeks		
		zero X±SD	three X±SD	six X±SD
Estimated Maximum Oxygen Uptake* (ml/kg/min)	supercircuit	34.5± 5.2 (n=34)	40.0± 6.8 (n=16)	40.3± 6.9 (n=34)
	control	32.4 ± 7.4 (n=31)	36.4 ± 7.9 (n=18)	35.2 ± 6.6 (n=37)
Estimated Maximum Oxygen Uptake** (ml/kg/min)	supercircuit	36.2 ± 6.1 (n=38)	39.5 ± 7.5 (n=19)	39.8 ± 6.5 (n=36)
	control	34.2 ± 7.6 (n=38)	36.0 ± 8.7 (n=19)	36.2 ± 6.1 (n=38)

'n' is the number of tests completed for each characteristic with each subject being tested twice at 0 weeks, once at 3 weeks, and twice at 6 weeks.
* calculated from oxygen uptake.
** calculated from external workload (watts).

Appendix D.
Table 8. Pre-, mid-, and post-six week Rating of Perceived Exertion at the Third Workload on the Cycle Ergometer

At the end of the third work load on the cycle ergometer, subjects were asking to give a rating of perceived exertion.

		weeks		
		zero X±SD	three X±SD	six X±SD
Rating of Perceived Exertion	supercircuit	14.6±2.0 (n=34)	14.1±1.6 (n=20)	13.3±1.6 (n=35)
	control	14.8±1.7 (n=37)	14.2±1.6 (n=20)	14.6±2.2 (n=35)

'n' is the number of tests completed for each characteristic with each subject being tested twice at 0 weeks, once at 3 weeks, and twice at 6 weeks.

Appendix D.
Table 9. Pre-, mid-, and post-six week Rate of Decline in Heart Rate after the Completion after the Completion of the Third Workload on the Cycle Ergometer.

Heart rate was recorded one minute, two minutes and three minutes after the completion of the third work load on the cycle ergometer.

		weeks		
		zero X±SD	three X±SD	six X±SD
Heart Rate One Minute	supercircuit	116.8±17.8 (n=25)	115.7±14.1 (n=15)	111.0±13.9 (n=25)
	control	127.0±21.5 (n=26)	117.1±22.8 (n=14)	121.4± 19.9 (n=25)
Heart Rate Two Minutes	supercircuit	107.7±15.9 (n=24)	108.9±15.3 (n=11)	103.2±10.6 (n=25)
	control	115.0±20.1 (n=26)	106.6±23.1 (n=14)	112.0± 19.7 (n=23)
Heart Rate Three Minutes	supercircuit	96.4±12.4 (n=24)	94.4±7.8 (n=11)	88.7±11.0 (n=26)
	control	106.4±20.7 (n=26)	101.4±21.5 (n=12)	102.0± 18.8 (n=24)

'n' is the number of tests completed for each characteristic with each subject being tested twice at 0 weeks, once at 3 weeks, and twice at 6 weeks.

Appendix E.
Table 1. Multiple Regression Equations for Changes in Body Composition with Time

	Multiple Regression Equation	Supercircuits C = 1	Control C = 0
Body Mass	y = 65.5 + 1.9C - .02T + 0.5CT - .2Tsq - 0.4CTsq (p=.3) (p=1) (p=.9) (p=.9) (p=.9)		
	y = 65.8	y = 65.8	y = 65.8
SKF-2	y = 50.6 + 3.4C + .9T - 0.6CT +.3Tsq +.6CTsq (p=.3) (p=.9) (p=.8) (p=.9) (p=.9)		
	y = 52.0	y = 52.0	y = 52.0
SKF-6	y = 157.8 - 3.9C + 2.1T - 2.7CT +.8Tsq - 1.9CTsq (p=.8) (p=.9) (p=.9) (p=.9) (p=.9)		
	y = 161.4	y = 161.4	y = 161.4

The variables used in each equation are T (time, where T = 0, 1, or 2, for 0, 3, or 6 weeks), C (training status, in which supercircuits = 1 and controls = 0), CxT (the linear interaction of training with time), Tsq (time squared), and CxTsq (the quadratic interaction of training with time). Two equations are shown for each measurement. The first equation for each measurement shows all the variables and interactions ie C, T, CT, Tsq, and CTsq. The least significant variables/interactions were then removed step by step until all variables which were not significant (p>.05) had been removed (second equation). The multiple regression equations for body mass, sum of two skinfolds, and sum of six skinfolds had no significant variables or interactions.

Appendix E.
Table 2. Multiple Regression Equations for Changes in Pre-exercise Biood Pressure and Heart Rate with Time

	Multiple Regression Equation	Supercircuits C = 1	Control C = 0
Systolic Bl Pressure	y = 111.5 + 1.2C - 2.5T + 3.8CT +.3Tsq - 2.2CTsq (p=.58) (p=.63) (p=.60) (p=.90) (p=.53)		
	y = 111.4 - 2.2T (p=.007)*	y = 111.4 - 2.2T	y = 111.4 - 2.2T
Diastolic Bl Pressure	y = 74.1 - .6C - 4.9T + 1.5CT +1.7Tsq - CTsq (p=.70) (p=.19) (p=.78) (p=.39) (p=.70)		
	y = 73.5 - 1.7T (p=.003)*	y = 73.5 - 1.7T	y = 73.5 - 1.7T
Pre-exercise Heart Rate	y = 80.8 +.7C -1.7T - 2CT - 1.7Tsq - .7CTsq (p=.75) (p=.31) (p=.78) (p=.47) (p=.84)		
	y = 80.9 - 1.9T - 2.9CT (p=.04)* (p=.005)*	y = 80.9 - 4.8T	y = 80.9 - 1.9T

* p is significant (p<.05).
The variables used in each equation are T (time, where T = 0, 1, or 2, for 0, 3, or 6 weeks), C (training status, in which supercircuits = 1 and controls = 0), CxT (the linear interaction of training with time), Tsq (time squared), and CxTsq (the quadratic interaction of training with time).
Two equations are shown for each measurement. The first equation for each measurement shows all the variables and interactions ie C, T, CT, Tsq, and CTsq. The least significant variables/interactions were then removed step by step until all variables which were not significant (p>.05) had been removed (second equation). T is significant for both systolic and diastolic blood pressure, and both CT and T are significant for pre-exercise heart rate.

Appendix E.
Table 3. Multiple Regression Equations for Changes in Flexibility with Time.

	Multiple Regression Equation	Supercircuits C = 1	Control C = 0
R+L Hamstring	y = 26.1- 4.1C - 1.3T + 4.4CT +.7Tsq - .9CTsq (p=.1) (p=.8) (p=.6) (p=.8) (p=.8)		
	y = 26.0- 3.8C + 2.5CT (p=.04)* (p=.04)*	y = 22.1 + 2.5T	y = 26.0
R Hamstring	y = 27.3 - 3.6C - 1.1T + 4.9CT +.4Tsq - CTsq (p=.1) (p=.8) (p=.5) (p=.9) (p=.8)		
	y = 26.9 - 3.1C + 2.6CT (p=.07) (p=.02)*	y = 23.8+ 2.6T	y = 26.9
L Hamstring	y = 26.1 - 3C - 2.5T - 1.2CT +.6Tsq + .6CTsq (p=.2) (p=.8) (p=.5) (p=.8) (p=.7)		
	y = 25.9	y = 25.9	y = 25.9
R Gastrocnemius	y = 33.7 - C - .8T + .6CT+ .3Tsq - .3CTsq (p=.2) (p=.6) (p=.8) (p=.7) (p=.8)		
	y = 33.4 - 1.1C (p=.04)*	y = 32.3	y = 33.4

Appendix E, Table 3 continued

	Multiple Regression Equation	Supercircuits C = 1	Control C = 0
L Gastrocnemius	y = 34.8- 1.5C - .3T + .3CT +.007Tsq - .07CTsq (p=.04) (p=.9) (p=.9) (p=1) (p=.9)		
	y = 34.5 - 1.3C (p=.005)*	y = 33.2	y = 34.5
R Soleus	y = 31.7 - 1.1C +.07T - 1.1CT -.09Tsq +.3CTsq (p=.2) (p=.9) (p=.7) (p=.9) (p=.8)		
	y = 31.6 - 1.7C (p=.001)*	y = 29.4	y = 31.6
L Soleus	y = 33 - 1.6C +.02T - .4CT - .2Tsq + .4CTsq (p=.048)* (p=1) (p=.8) (p=.9) (p=.8)		
	y = 32.7 - 1.8C (p=.0008)*	y = 30.9	y = 32.7
R Shoulder	y = 3.6 - 1.6C +T + .4CT - .3Tsq - .09CTsq (p=.2) (p=.7) (p=.9) (p=.9) (p=1)		
	y = 4.2	y = 4.2	y = 4.2

Appendix E. Multiple Regression Equations for each Characteristic over Six Weeks.

Appendix E, Table 3 continued.

	Multiple Regression Equation	Supercircuits C = 1	Control C = 0
L Shoulder	y = 5.5 - 1.2C + .3T + 1.2CT + .001Tsq - .4CTsq (p=.2) (p=.9) (p=.7) (p=1) (p=.8)		
	y = 5.8	y = 5.8	y = 5.8

* p is significant (p<.05).
The variables used in each equation are T (time, where T = 0, 1, or 2, for 0, 3, or 6 weeks), C (training status, in which supercircuits = 1 and controls = 0), CxT (the linear interaction of training with time), Tsq (time squared), and CxTsq (the quadratic interaction of training with time). Two equations are shown for each measurement. The first equation for each measurement shows all the variables and interactions ie C, T, CT, Tsq, and CTsq. The least significant variables/interactions were then removed step by step until all variables which were not significant (p>.05) had been removed (second equation). The interaction of training with time (CT) is significant for right hamstring flexibility, and the flexibility of both hamstrings measured together. There was a significant difference between the two groups (C) for both hamstrings measured together, and flexibility of the right gastrocnemius, left gastrocnemius, right soleus, and left soleus.

Appendix E.
Table 4. Multiple Regression Equations for Changes in Strength Characteristics with Time

	Multiple Regression Equation	Supercircuits C = 1	Control C = 0
Bench Press (estimated 1RM, kg)	y = 29.7 - 4.9C + 6.4CT (p=.006)* (p=.0001)*	y = 124.8 + 6.4T	y = 29.7
Bench Press (repetitions)	y = 10.7 + 6.5CT (p = .0001)*	y = 10.7 + 6.5T	y = 10.7
Leg Press (estimated 1RM, kg)	y = 76.3 + 2.1CT (p = .001)*	y = 76.3 + 2.1T	y = 76.3
Leg Extension (repetitions)	y = 20.1 + 3.9CT (p = .0001)*	y = 20.13+ 3.8T	y = 20.1
Crunches	y = 30.4+ 7.1CT (p=.0001)*	y = 30.4+ 7.1T	y = 30.4

* p is significant (p<.05).
The variables used in each equation are T (time, where T = 0, 1, or 2, for 0, 3, or 6 weeks), C (training status, in which supercircuits = 1 and controls = 0), CxT (the linear interaction of training with time), Tsq (time squared), and CxTsq (the quadratic interaction of training with time). The least significant variables/interactions have been removed leaving only the significant variables (p<.05).
CT is significant for all the strength variables. There was also a significant difference between the two groups (C) for the bench press (1RM).

Appendix E.
Table 5. Multiple Regression Equation for Changes in Heart Rate at the third Workload with Time

	Multiple Regression Equation	Supercircuits C = 1	Control C = 0
Heart Rate	y = 156.0 - 4.6C - 5.6T - 2.8CT + 1.7Tsq + .5CTsq (p=.2) (p=.5) (p=.8) (p=.6) (p=.9)		
	y = 156.6 - 6.4C - 3T (p=.0025)* (p=.01)*	y = 150.2 - 3T	y = 156.6 - 3T

* p is significant (p<.05).
The variables used in each equation are T (time, where T = 0, 1, or 2, for 0, 3, or 6 weeks), C (training status, in which supercircuits = 1 and controls = 0), CxT (the linear interaction of training with time), Tsq (time squared), and CxTsq (the quadratic interaction of training with time). Two equations are shown for each measurement. The first equation for each measurement shows all the variables and interactions ie C, T, CT, Tsq, and CTsq. The least significant variables/interactions have been removed leaving only the significant variables (p<.05). There is a significant difference between the two groups (C) and a significant decrease in heart rate over the 6 weeks for both groups (T).

Appendix E.
Table 6. Multiple Regression Equation for Changes in Oxygen Uptake at the Third Workload with Time

	Multiple Regression Equation	Supercircuits C = 1	Control C = 0
Oxygen Uptake (L/min)	y = 1.46 - .02C + .06T - .003CT - .02Tsq + .01CTsq (p=.8) (p=.6) (p=1) (p=.7) (p=.9)		
	y = 1.46	y = 1.46	y = 1.46

The variables used in each equation are T (time, where T = 0, 1, or 2, for 0, 3, or 6 weeks), C (training status, in which supercircuits = 1 and controls = 0), CxT (the linear interaction of training with time), Tsq (time squared), and CxTsq (the quadratic interaction of training with time). Two equations are shown for each measurement. The first equation for each measurement shows all the variables and interactions ie C, T, CT, Tsq, and CTsq. The least significant variables/interactions have been removed leaving only the significant variables ($p<.05$). None of the variables were found to be significant.

Appendix E.
Table 7. Multiple Regression Equation for Changes in Estimated VO_2max with Time

	Multiple Regression Equation	Supercircuit C = 1	Control C = 0
Estimated VO_2max (ml/kg/min) based on oxygen uptake	y = 32.4 + 2.2C + 6.6T + 1.3CT - 2.6Tsq + .09CTsq (p=.2) (p=.08) (p=.8) (p=.1) (p=1)		
	y = 31.6 + 3.7C -7.4T - 2.6Tsq (p=.0004)*(p=.006)*(p=.045)*	y = 35.3 - 7.4T - 2.6Tsq	y = 31.6 - 7.4T - 2.6Tsq
Estimated VO_2max (ml/kg/min) based on watts	y = 34.2 + 2C + 3T + 1.7CT - 1.2Tsq - .3CTsq (p=.2) (p=.4) (p=.8) (p=.5) (p=.9)		
	y = 33.9 + 3.2C + 1.2T (p=.002)* (p=.04)*	y = 37.1 + 1.2T	y = 33.9 + 1.2T

* p is significant ($p<.05$).
The variables used in each equation are T (time, where T = 0, 1, or 2, for 0, 3, or 6 weeks), C (training status, in which supercircuits = 1 and controls = 0), CxT (the linear interaction of training with time), Tsq (time squared), and CxTsq (the quadratic interaction of training with time). Two equations are shown for each measurement. The first equation for each measurement shows all the variables and interactions ie C, T, CT, Tsq, and CTsq. The least significant variables/interactions have been removed leaving only the significant variables ($p<.05$). There is a significant difference between both groups (C) for both measurements, and a significant decrease in estimated VO_2max with time (T, Tsq) for both groups.

Appendix E.
Table 8. Multiple Regression Equation for Changes in Rating of Perceived Exertion with Time

	Multiple Regression Equation	Supercircuits C = 1	Control C = 0
Rating of Perceived Exertion	y = 14.8 - .3C - 1.1T + .9CT + .5Tsq - .7CTsq (p=.5) (p=.3) (p=.5) (p=.3) (p=.3)		
	y = 14.5 - .3CTsq (p=.0006)*	y = 14.5 - .3Tsq	y = 14.5

* p is significant ($p<.05$).
The variables used in each equation are T (time, where T = 0, 1, or 2, for 0, 3, or 6 weeks), C (training status, in which supercircuits = 1 and controls = 0), CxT (the linear interaction of training with time), Tsq (time squared), and CxTsq (the quadratic interaction of training with time). Two equations are shown for each measurement. The first equation for each measurement shows all the variables and interactions ie C, T, CT, Tsq, and CTsq. The least significant variables/interactions have been removed leaving only the significant variables ($p<.05$). CTsq, the interaction of condition with time squared is significant .

Appendix E.
Table 9. Multiple Regression Equations for the Change in the Rate of Decline in Heart Rate after the Completion of the Third Workload on the Cycle Ergometer.
Heart rate was recorded one minute, two minutes and three minutes after the completion of the third workload on the cycle ergometer.

	Multiple Regression Equation	Supercircuits C = 1	Control C = 0
Heart Rate at 1 min	y = 127 - 10.2C - 17T + 17.8CT + 7.1Tsq - 8.9CTsq (p=.05) (p=.2) (p=.3) (p=.2) (p=.3)		
	y = 122.9 - 8.7C (p=.01)*	y = 114.2	y = 122.9
Heart Rate at 2 min	y = 115 - 7.4C - 15.2T + 19.9CT + 6.9Tsq - 10.3CTsq (p=.14) (p=.2) (p=.2) (p=.2) (p=.2)		
	y = 112.2 - 6.2C (p=.05)*	y = 106.0	y = 112.2
Heart Rate at 3 min	y = 106.4 - 10C - 7.8T + 7.6CT + 2.8Tsq - 4.6CTsq (p=.03) (p=.5) (p=.6) (p=.6) (p=.5)		
	y = 103.7 - 11C (p=.0003)*	y = 92.7	y = 103.7

* p is significant ($p<.05$).
The variables used in each equation are T (time, where T = 0, 1, or 2, for 0, 3, or 6 weeks), C (training status, in which supercircuits = 1 and controls = 0), CxT (the linear interaction of training with time), Tsq (time squared), and CxTsq (the quadratic interaction of training with time). Two equations are shown for each measurement. The first equation for each measurement shows all the variables and interactions ie C, T, CT, Tsq, and CTsq. The least significant variables/interactions have been removed leaving only the significant variables ($p<.05$). Only C was found to be significant.