1993

Bone Density and Muscle Development Problems in Female Lightweight Rowers Trying to Make-Weight

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BONE DENSITY AND MUSCLE DEVELOPMENT PROBLEMS IN FEMALE LIGHTWEIGHT ROWERS TRYING TO MAKE-WEIGHT

BY

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Bachelor of Applied Science (Sports Science)

A Thesis submitted in partial fulfilment of the requirements for the Award of

Bachelor of Applied Science (Sports Science) with Honours

Date of Submission : 18.01.1993

USE OF THESIS

ABSTRACT

BONE DENSITY AND MUSCLE DEVELOPMENT PROBLEMS IN FEMALE LIGHTWEIGHT ROWERS, TRYING TO MAKE-WEIGHT.

The purpose of this study was to determine whether high intensity exercise, combined with restriction of diet, is counter-productive to the normal health and development of the competitor.
The study investigated the effects of high intensity exercise on body composition (fat, muscle and bone); bone density; and physical performance (aerobic capacity, rowing performance, quadricep strength, power and fatiguability) in twelve lightweight female rowers (age range 17 - 25yrs), training for the State and National lightweight championships. Six of the rowers completed the testing, which consisted of test1 (pre-training) and test2 (post-training) after a 12 weeks training regime.

Skinfold measurements were lower and significantly different ($p<0.05$) from pre-training values. Bodyweight results were also significantly lower ($p<0.05$), however, the mean bodyweight was still above the regulation weight of 59kgs. Mean bone mineral density for female lightweight rowers (n=9, mean age 20.5yrs) was significantly greater than

(p<0.05) (independent t-Test) established norms for 19yr olds (n=20). Physical performance data (Max VO_2, Muscular force, power and fatiguability) were not significantly different from pre-training values. However, normalised data for peak torque (right leg) at 120 and 180 deg/secs were significantly different (p<0.05). The dry (land based) performance test was significantly different (p<0.001), which indicated that all individual performance results were improving.

These data do not suggest that Lightweight rowers experience any health or development problems while involved in high intensity training whilst diet restricting. However, it is recommended that further study be continued until the National titles when the regulation weight limit of 59kgs will be achieved.

DECLARATION

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

Signature

Date ....18-1-93....................

ACKNOWLEDGEMENT

I would like to acknowledge the following persons:

Colin James, Research Supervisor, for his support, advice and professional assistance throughout this research project.

Kathy Hendeson, SCGH, for performing the bone scans, her time was greatly appreciated.

Mary, for assisting with the fitness testing.

Finally, the female rowers who participated in this study, without them the study would not have been possible.

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Introduction

Background to the Problem

Rowing is an endurance sport that is considered to be one of the most physiologically demanding of its type (Hagerman, Hagerman & Mickelson, 1979). The rower must cope with extremely high aerobic and anaerobic energy demands and consequently be able to tolerate high lactate levels during the race to perform well. This is thought to be of a result of the unusual 'pacing' pattern that has developed and is unique to rowing. Rowers are required to commence a race at a very high intensity (stroke rate), the pace is then reduced and maintained until the final stage of the race which is a sprint to the end. This pattern also requires the rower to produce high levels of strength and power in order to cope with the demands of the stroke and repeated forces required for propulsion, both in training and competition.

Rowing events for both male and female are conducted over a 2000m flatwater course in International competition. Rowing in the past included a male light and heavyweight and women's category. More recently a women's lightweight rowing category has emerged, many of these women having competed in the unrestricted category previously (De Rose, Crawford, Kerr, Ward & Ross, 1989). The maximum weight for a single rower is 59 kilograms, with an average weight of 57 kilograms for each boat of four rowers. To qualify as lightweight, many competitors must reduce weight substantially (15% of body weight) by combining high intensity exercise and dieting (Hagerman et al., 1979). The Female lightweight rowing category was only recognised as an International competitive sport in 1985 (DeRose et al., 1989). Consequently, there has been little research conducted in the area of lightweight rowers. DeRose et al. (1989) and the Australian Institute of Sport (AIS) have indicated the need for further study in this area, as weight restriction rules may be counter-productive to the performance and normal health of rowers.

Statement of the Problem

Are female lightweight rowers, who are trying to make the regulation weight limit while involved in high intensity training, combined with restriction of diet, predisposed to counter-productive performance and health problems?

Purpose of the Study

This study will look at two physiological aspects that may influence performance and health in female lightweight rowers. They are:

1. Bone growth

Low body fat is associated with menstrual change (Drinkwater, Bruemmer & Chestnut III, 1990), although is not necessarily causal. Menstrual change such as athletic amenorrhoea may alter the level of circulating oestrogen, which is an important factor in bone development, required for the remodelling and resorption of bone (Warren, Brooks-Gunn, Hamilton, Warren & Hamilton, 1986). Athletic amenorrhoea is defined by Snyder, Wenderoth, Johnston and Hui (1986) as less than two menses per year or menses at intervals greater than six months apart. With long term lowered oestrogen levels bone mineral density may be reduced, at an age where bone mass should be increasing. This places the athlete at immediate risk of stress fractures and long term risk of osteoporosis.

2. Muscle development

An increase in muscular force, power and endurance would normally be expected with training. However, to meet weight restrictions, fat and protein mass must be substantially reduced to possibly unhealthy levels. Consequently increased muscle protein is used as an energy substrate, which may be counter-productive to performance and would be expected to result in a decline of muscular force and power and possibly endurance.

Research Questions

To answer the research problem the following questions must be considered:

1. Are strength, power and fatigue resistance affected by training, combined with restriction of diet?
2. Is bone density lower in female lightweight rowers than in the normal population?
3. Is training/competitive performance impaired by decreased muscle mass?

Objectives of the Study

This study will contribute to the limited knowledge that exists in this area and provide athletes and coaches with the information to recognise any problems that may be occurring, when attempting to maximise performance, possibly at the expense of health.

This will be achieved by:

1. investigating any changes in bodyfat with training/dieting.

2. determining whether rowers have lower bone densities than the normal population.

3. studying the relationship between strength, power and fatigue resistance to peak performance.

4. determining whether muscle mass is decreased following training and dieting and,

5. comparing the results of the physiological parameters tested by statistical analysis and to determine whether there is difference between each variable tested.

The study will measure the physiological parameters stated below that may be altered by a training and dieting regime:

1. Anthropometric measurements.
2. Aerobic capacity.
3. 2500m performance test.
4. Muscular
   - force
   - power
   - fatigue resistance
5. Bone density.
6. Training history.
7. Menstrual history.

Statement of the Hypotheses

In the proposed study it is hypothesized that:

1. There will be a decrease in body fat in female lightweight rowers with high intensity training, whilst diet restricting.

2. Female lightweight rowers will have lower bone density levels than the normal range.

3. There will be an increase in strength power and fatigue resistance necessary for peak performance in female lightweight rowers with high intensity training, whilst diet restricting.

4. There will be a decrease in muscle mass in female lightweight rowers with training, whilst diet restricting.

Significance of the Study

This study is important as little research has been conducted in the area of lightweight female rowers. In one study of female lightweight rowers, 16 rowers were shown to possess bone of normal density (Snyder et al., 1986). All subjects weighed less than 59 kilograms, however, it was not established whether the natural bodyweight was around this level. The problem in this study is that a weight loss (up to 15% of bodyweight), a substantial proportion of which will have to be muscle, is required by most subjects to meet the regulation weight limit by combining high intensity training, with restriction of diet. The training schedule is set by the Australian Institute of Sport and diet set by a West Australian Institute of Sport or private dietician (the study includes subjects on normal and vegetarian diets). This will ensure that all subjects involved in this study have similar training regimes and appropriate dietary guidelines.

Chapter 2

Review of Literature

In an attempt to gain advantage in strength, power and leverage, some lightweight rowers are manipulating diet to reduce bodyweight to below normal, so that the regulation weight limit of 59 kilograms is met (DeRose et al., 1989). These athletes are simultaneously involved in high intensity, training schedules. Weight restriction coupled with high intensity training has the potential to alter the balance of physiological parameters (endocrine, metabolic, body composition) necessary for good health and optimal performance (Brownell, Steen & Wilmore, 1987). Until recently,there were no regulations pertaining to weight restrictions in female rowing so the problem of balance between training and diet is a new one.

Early research has evaluated the characteristics of the ideal rower by studying body size and shape, lever lengths, aerobic and anaerobic capacities and body composition (Lean Body Mass). The literature shows conflict regarding the physical characteristics of elite rowers. Anthropometric data collected on elite female and male rowers in a study by Hagerman et al. (1979), found the rowers to be tall, lean, have a low percent body fat and good aerobic and anaerobic capacities. Further study by Secher and Vaage (1983) found that champion international rowers were no taller than less successful rowers studied. Hahn's (1990) study of elite Australian male and female rowers suggested that the ideal rower should be tall, long-limbed, with high aerobic capacity and muscular power. DeRose et al. (1989) further identified two types of physique in a study of 13 elite lightweight rowers. They were ectomesomorphic (linear, low muscularity) and mesomorphic (with muscular upper body, shorter sitting height and lower percentage of body fat). The research is inconclusive with regard to body shape, however, the biomechanic long limbs would appear to be advantageous to performance.

According to Telford, Egerton, Hahn and Pang (1988) a greater sporting performance is achieved with an increased power to bodyweight ratio. Successful elite athletes have a low percentage body fat when involved in weight bearing competitions. Rowing, however, is not a weight-bearing event and without competitive weight restrictions a rower's body weight would not be of such crucial significance. To increase the power to weight ratio, muscle power has to be increased by training and sufficient energy intake, which increases muscle bulk (lean body mass).

Pavlou, Steffee, Lerman and Burrows (1985) found that diet and exercise preserves lean body, increases maximum oxygen uptake, increases strength, increases fat metabolism for energy and show greater reduction in fat stores than dieting alone. Maughan (1984) suggests that there is a relationship between the size of a muscle and its ability to produce force which is measured by its cross-sectional area. To meet a weight restriction total body mass may have to be reduced. Diet restricting aims to lose weight from adipose tissue while preserving lean body mass. Some excess lean body mass may be lost, however, chronic training schedules deplete the body stores to low and possibly unhealthy levels, and in extreme cases, will increase the reliance on metabolism of muscle for energy requirements. This would obviously be counter-productive to any gains in muscle bulk. Most studies on diet restricting have been reported to cause an initial net loss of body protein (Lemon & Mullin, 1980; McMurray, Ben-Ezra, Forsythe & Smith, 1985; Pavlou et al., 1985). Tarnopolsky, MacDougall and Atkinson (1988) found that endurance athletes require greater protein intakes than bodybuilders and sedentary subjects. The increase in protein breakdown during exercise is the likely reason for increased protein intake (Lemon, Nagel, Mullin, & Benevenga, 1982; Evans, Fisher, Hoerr & Young, 1983; Meredith, Zackin Frontera & Evans, 1989). Lean body mass can be estimated by nitrogen balance techniques, but the site of protein breakdown is unknown. 3-Methylhistidine excretion is an index of myofibril breakdown which indicates what is happening in the muscle (Lemon et al., 1982). The aerobic and anaerobic capacity of the muscle is also trained. Droghetti, Jensen and Nilsen (1991) found the contribution of aerobic and anaerobic metabolism of rowing to be 80 percent and 20 percent respectively. An earlier study by Hagerman (1984) showed similar results.

Physiological problems may occur in female athletes as a result of decreased or fluctuating percent body fat with changes in diet and exercise. The problems include in the short term, amenorrhoea, delayed menarche, bone mineral losses, anaemia, endocrine changes and also psychological problems (anorexia and bulimia) (Drinkwater et al., 1990; Prior, 1992). In the long term - osteoporosis (Drinkwater et al., 1990). Menstrual irregularities are common in female athletes and many of the studies have focused on gymnasts, distance runners and ballet dancers (Drinkwater et al., 1984; Marcus et al., 1985; Nelson et al., 1986; Scott & Johnston, 1982; Warren et al., 1986). Frisch and McArthur (1974) hypothesised that 17% body fat was necessary for menarche and 22% for maintenance of menarche. However, this hypothesis has been discredited (Scott & Johnston, 1982), but has indicated that there is a threshold level that is specific to individuals and that other factors such as activity level must be considered.

Bone mass is determined by genetic, environmental and endocrine factors. The role of oestrogen in bone remodelling and resorption is still unclear. It is thought that menstrual cycle disturbance is related to hypothalamic dysfunction resulting from a number of stressors (physical, emotional, nutritional and overtraining stresses). The result is an increase in the hypothalamic neurotransmitter, corticotrophin-releasing hormone (CRH), which inhibits the gonadotrophin-releasing hormone message to the luteinising hormone (LH) and follicle-stimulating hormone (FSH). These two hormones control the normal menstrual cycle and the end result is a reduced level of circulating oestrogens (Barbarino, DeMarinis, Folli, Tofani & Della Casa, 1989) . Reduced levels of oestrogen may result in infertility or subfertility, but generally this is not a problem as athletes in training do not want to conceive. There may however be a long term problem with bone development. Normal bone development increases rapidly during adolescence and studies have confirmed that bone mineral losses begin between the age of twenty and forty (Bailey, Martin, Houston & Howie, 1986). Bone loss is related to the duration of amenorrhoea. Drinkwater et al.

(1990) found menstrual history to be a major factor in determining current bone density. It was found that women who had always had regular menstrual cycles had higher vertebral lumbar densities than those with episodes of amenorrhoea or olgiomenorrhoea. Cann, Martin, Genant and Jaffe (1984) first found that despite weight-bearing activities having a positive effect on bone density, amenorrhoeic athletes still have lower densities than their normal menstruating counterparts. Other studies have also shown this (Drinkwater et al., 1984; Marcus et al., 1985; Nelson et al., 1986). Many of the studies found cortical bone in amenorrhoeic athletes and normal cyclic counterparts were not significantly different. Bone mass may be jeopardized with lowered oestrogen levels caused from long term amenorrhoea (Drinkwater et al., 1990) which may increase the chance of osteoporosis and possibly stress fractures (Warren et al., 1986). Delayed menarche as a result of amenorrhoea may delay bone mineral deposition and therefore result in a lower peak bone mass, another important consideration for preventing osteoporosis in later life.

Changes in menstrual cycles are reversible (Bullen et al., 1985). Prior (1992) found that if stressors such as psychological factors, reproductive immaturity and rapidly increasing or excessive physical activity are removed, the normal menstrual cycle of healthy women, which included marathon runners, did not differ from the normal menstrual cycles of sedentary women. Drinkwater (1986) also found that bone loss was partly reversible.

Hydrostatic weighing in the past has been considered as the 'gold standard' method of body composition assessment. However, this method and many others (anthropometry, total body electrical conductivity, bioelectrical impedance, population specific equations for calculating percent body fat, total body potassium and total body water) are based on a number of assumptions or have limitations to the methods (Roche, 1987). More recently Quantitative digital radiography QDR (dual energy x-ray absorptiometry DEXA) has been used and correlates highly with other non-invasive method (Taaffe, 1992). DEXA has the capacity to measure lean and fat tissue and to perform whole body scans for total and regional bone mineral content. Skinfold measurements are generally the accepted method of measurement used by many coaches and athletes, they provide good information if used by a trained technician. This method of measuring bodyfat is less expensive, requires less expertise and equipment to allow testing throughout training schedules (Telford et al., 1988). However, to avoid the problem of population based equations, skinfold measurements do not predict percent fat.

Chapter 3

Methods

Design of the Study

This research used a quantitative approach to examine the variables tested. The subjects were tested on two separate occasions and a twelve week training and dieting schedule was implemented during the intervening period. Data collection involved five stages. Testing commenced on September 8, 1992 (data collection period one, which involved stage 1, 2, 3 (to establish baseline data) and stage 4 (which compared data to a control group of similar age and bodyweight) when the rowers were in the preparatory phase of the training schedule. Further testing of the physiological variables commenced on December 7, 1992, four days following the State selection trails for lightweight rowing (high intensive training regime). The second testing period included stages 1, 2,3 and 5.

Stage 1 involved all subjects undertaking:

a) anthropometric measurements including height, weight and skinfold measurements (measurement of body fat). Re-tested at 12 weeks.

b) a maximal oxygen uptake test (Max VO_2 test).

This test is an indication of the subjects ability to transport oxygen to the working muscles (aerobic capacity). A 48 hour recovery was allowed after this stage before testing stage 2. Re-tested at 12 weeks.

Stage 2 a 2500m performance test. Performance is indicated by the dry (land based) measure. A 48 hour recovery was allowed after this stage before testing stage 3. Re-tested at 12 weeks.

Stage 3 involved all subjects undertaking a Cybex isokinetic dynamometer test. This test measures muscular strength, power and fatigue resistance of the quadricep muscle. Re-tested at twelve weeks.

Stage 4 involved all subjects undertaking a bone density scan. This test measures the bone mineral density of Lumbar 1 (L1) to Lumbar 4 (L4) of the vertebrae.

Stage 5 subjects also completed a training and menstrual history questionnaire. The questions were designed to determine menstrual status and prior training regimes and intensities.

Sample and Setting to be used

The researcher studied a group of 12 volunteer West Australian elite, State and West Australian

Institute of Sport (WAIS) lightweight female rowers training for the State and National lightweight championships. Six of the subjects completed the series of physiological testing. Six subjects withdrew from the study as a result of educational and employment commitments or for personal reasons. Three of these subject withdrew completely from the lightweight rowing program. All subjects were informed verbally and in writing to the nature of the testing and were required to sign a consent form. Subjects were given a copy of the data and record sheets and a copy of the consent form.

The research was conducted in the Human Movement Laboratory, Edith Cowan University of Western Australia and QEII Medical Centre.

Description of instruments to be used

The techniques used to measures these parameters were:

1. Anthropometric measurements:

- Height was measured by a SECA stadiometer to the nearest millimetre.

- Weight was measured by a SECA Balance Scale to the nearest tenth of a kilogram.

- Blood Pressure was measured by using a normal mercury sphygmomanometer used with a standard sized cuff (12-14cm wide).

- Body composition was measured by two methods:

a/ skinfold callipers, calibrated to 10gm/mm and,

b/ by a QDR2000 Dual-energy X-ray Densitometer (courtesy of QEII Medical Centre).

2. Aerobic metabolism was measured by a VO_2 Max test (maximal oxygen consumption), on a Concept II ergometer (which simulates the rowing action) and a Morgan Gas Analyser. The Concept II ergometer is an air braked ergometer consisting of a 'oar' connected by a chain to a flywheel incorporating eight vanes (which create resistance). The subject is connected to a Morgan Analyser. The volume of inspired air is measured and mixed expired air drawn through the calcium chloride and into the analysers which are calibrated against known gas standards before and after each test. Electrocardiographs (ECG) are recorded during the test. Outputs from the ventilation meter, gas analysis and ECG are monitored by a computer to give 30 second readouts of ventilation, heart rate and other respiratory parameters.

3. Performance was monitored by the 2500m ergometer test, conducted on the Concept II ergometer.

4. Force-velocity characteristics of muscle were measured using the Cybex 6000 Isokinetic Dynamometer.

5. Bone density was measured by the QDR 1000

Dual-energy X-ray Densitometer (courtesy of QEII Medical Centre).

Data Collection Procedures

A smaller version of the proposed study was conducted prior to data collection to determine any problems associated with methodology. This was conducted using the proposed study, similar subjects, setting and data collection methods.

Prior to testing all subjects had blood pressure recorded. Two consecutive blood pressure readings were taken of the right arm while subject seated. The data were collected in five stages. All testing was conducted under similar conditions. The time of testing was kept as close as possible and the laboratory temperature, barometric pressure and relative humidity were recorded.

Stage 1

1. Anthropometry data was collected using the methods according to Draper, Minikin and Telford (1991). Height was measured to the nearest millimetre. Subjects were weighed in light clothing and weight measured to the nearest tenth of a kilogram.

2. Body composition:

a/ skinfold measures of each site were taken using anatomical locations and procedures described by

Telford, Tumulty and Damm (1984). The sites included - tricep, bicep, subscapular, axilla, suprailiac, abdominal, thigh and medial calf. Each location was marked on the preferred side of the body, the skin was lifted by the thumb and index finger and the measurement taken 1cm from the site. The skinfold included two layers of skin and the underlying adipose tissue, but not the muscle. The calliper spring was released and the dial allowed to steady before the measurement was recorded to the nearest 0.01mm and measurements repeated until two measures were within 0.02mm.

b/ Percent bodyfat was also measured during the bone scan by the QDR2000 Dual-energy X-ray Densitometer. The QDR has the capacity to measure bodyfat, lean mass and bone density.

3. The Max VO_2 was measured during an intermittent test on a Concept II rowing ergometer and oxygen consumption measured using a Morgan Gas Analyser. The machine was calibrated for each subject. Heart rate was continuously monitored using direct electrocardiography. The protocol used was a four minute warmup followed by three minutes work rates at an initial speed of 2 minutes and 14 seconds per 500 metres (2:14/500m) and decremented to 2:07, 2:00, 1:55, 1:50 or until the subject could no longer continue or could not increase VO_2. Each workload was followed by a 1 minute recovery period. Oxygen uptake and other respiratory parameters were measured throughout the test. This protocol is used by WAIS and AIS.

Stage 2

1. Subjects were required to complete 2500m using the dry (land based) measure. Subjects rowed on a Concept II rowing ergometer and the time to complete the distance was recorded.

Stage 3

1. Cybex Test - muscular force and power were measured over the functional and competitive ranges of right and left quadricep muscles. Rotational axis of dynamometer was positioned so that it lined up with the lateral epicondyle of the knee during contraction. Subjects were stabilized by a seat belt across the chest in order to isolate movement of leg extensors. The forces were measured at angular velocities of 90°, 120°, 180°, and 240° per second. Four trials were allowed followed by six contractions at each speed. These contractions were followed by a two minute rest period and a 60 second rest period between each set. Peak Torque was measured (newton meters) as the greatest torque developed during the six contractions. Average power was measured in watts and is equal to the total work done divided by the contraction time. Muscular fatigue was measured by monitoring the force

loss with repeated knee extensions at 90° per second. The contraction was repeated 60 times (approximately 2 minutes).

Stage 4

1. Bone density measurement procedures - the subject was required to lie on a platform in a supine position. A weak X-ray beam scanned the whole body (approximately 20 minutes). The radiation dose was in the order of .0023microsieverts. This is less than 2% of the maximum allowed dose to volunteers set by National Health and Medical Research Council guidelines. Total bone mineral density (the regions included head, left and right arm, ribs, thoracic and lumbar spine, pelvis and the left and right leg) was recorded in gms/cm^2.

Stage 5

1. A complete training and menstrual history questionnaire (Appendix B) was recorded by all subjects.

Data Analysis

The data were collected over the two testing periods, test1 (pre-training) and test2 (post-training). The results were analysed using Sigma plot software, Jandel Corporation (paired or independent t-Test) and the level of significance was set at the 0.05 level for the significance testing. The stages were analysed as follows:

1. Stage 1, 2 and 3 (anthropometric, aerobic capacity, 2500m performance test, muscular force, power and fatigue measurements) were analysed using a paired t-Test.

2. Stage 3 (bone density) was analysed using an independent t-Test. The results were compared to normal ranges obtained from a data bank courtesy of QEII Medical Centre.

The results from the data collection are displayed in both tabular and graphic form. All test results, including subjects tested in test1, can be found in the appendices.

<u>Assumptions and limitations to study</u>

<u>Assumptions</u>:

1. Subjects refrained from vigorous activity, eating, and drinking prior to testing, which was requested.

2. It was assumed that the subjects responded to the best of their ability throughout the testing stages.

Limitations:

1. The study is limited to a small population.

2. Adequate training time for differences in bone mineral density was not available. Follow-up testing is necessary. Also, the normal data (control group) used is not exactly matched for age to the subjects in this study.

3. Comparisons between a training and a training and dieting group is impossible with these subjects.

Chapter 4

Results

Anthropometric and Maximal Oxygen Uptake Results

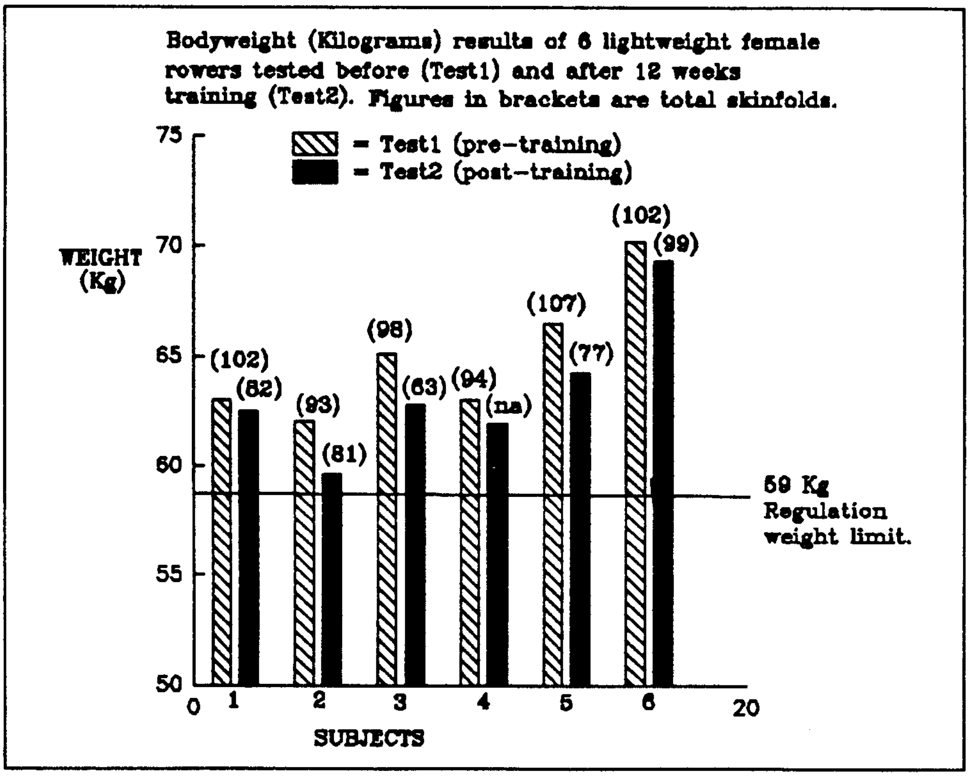
Six female lightweight rowers completed test1 (pre-training) and test2 (post-training) after 12 weeks of training. Means and standard error for Lightweight female rowers are presented in Table 1 for age, height, bodyweight, total skinfolds and maximal oxygen uptake (Max VO_2) with a paired t-Test calculated for bodyweight, total skinfold and Max VO_2. The average bodyweight was found to be higher than the regulation weight of 59kgs (Figure 1). However, the post-training mean for bodyweight was significantly lower ($p<0.05$) than the pre-training value. The mean for eight skinfold sites was significantly different ($p<0.05$) in the post-training test. There appears to be a trend of a decrease for total skinfolds for all subjects. To identify whether aerobic performance had changed between the two testing sessions, Max VO_2 was assessed but the results showed no significant difference. There was, however, a trend for a slight increase in aerobic capacity for three subjects and a decrease in aerobic capacity for two subjects tested. The decrease is thought to be more likely related to general fatigue at the time of testing.

Table 1
Physical Characteristics of Female Lightweight Rowers. n = 6

Age (yr)	Height (cm)	Weight (kg)		Skinfold (mm)		$MaxVO_2$ (L.min)	
		Pre	Post	Pre	Post	Pre	Post
22	174.5	63.0	62.5	101.5	81.5	3.5	3.6
17	171.3	62.0	59.6	93.0	81.0	3.6	3.8
25	166.5	65.1	62.8	98.0	63.0	3.9	3.6
21	177.1	63.0	61.9	94.5	[a]	4.2	[a]
24	177.5	66.5	64.2	107.0	77.0	3.8	3.7
18	170.5	70.2	69.3	102.5	99.0	3.8	4.0
21.2 +/-1.3	172.9 +/-1.7	65.0 +/-1.2	63.4 +/-1.3 *	99.4 +/-2.2	80.3 +/-5.8 **	3.8 +/-0.1	3.7 +/-0.1

[a] = subject unavailable for testing.
Group values expressed as mean +/-SE.
* = significant at <0.05 level.
** = significant at <0.05 level.

Figure 1


Bodyweight (Kilograms) results of 6 lightweight female rowers tested before (Test1) and after 12 weeks training (Test2). Figures in brackets are total skinfolds.
= Test1 (pre-training)
= Test2 (post-training)
WEIGHT (Kg)
75
70
65
60
55
50
(102)
(82)
(93)
(81)
(98)
(63)
(94)
(na)
(107)
(77)
(102)
(99)
59 Kg Regulation weight limit.
0
1
2
3
4
5
6
20
SUBJECTS

Training and Menstrual History

The subjects recorded a training and menstrual history. The training history indicated that the subjects were involved in high intensity training, which included: rowing training 2 hours, 5 - 6 times/week; weight training 1 1/2 - 2 hours, 2 - 3 times/week; ergometer training; and other aerobic exercise such as running and cycling 2 - 3 times/week. The subjects commenced rowing between the ages of 14 - 17 years of age (a range of 4 - 9 years rowing experience). Most subjects take 4 - 6 weeks off rowing after the Nationals but tend to remain physically active. Prior to rowing all subjects had been physically active (school basketball, softball, swimming etc).

The menstrual history showed that all subjects had normal menstrual cycles. Only one subject had experienced any irregular menstrual cycle, this involved a one year period of amenorrhoea, which coincided with a substantial weight loss with normal menses returning with a controlled diet. This subject also has a family history of osteoporosis (grandmother), however, as with all subjects tested, bone mineral density was within normal range for USA normals.

Vertebral Bone Mineral Density

The present study has not shown bone mineral density to be lower than a control group, established norms from 19 year olds (n=20). Bone mineral density, means and standard error for both groups are presented in table 2. An independent t-Test was calculated and BMD was found to be significantly higher in rowers ($p<0.05$). Percent bodyfat is also included in the BMD results. Percent fat was correlated against total skinfolds and pre-training bodyweight, but proved non-significant.

Table 2
QDR Bone Scan Results for Female Lightweight Rowers (n=9) compared to Control Group (n=20).

SUBJECT	BMD *CG	SUBJECT	BMD *R	%FAT	Weight (kg)	Skinfold (mm)
1	0.998	1	1.587	23.4	63.0	101.5
2	1.068	2	1.416	18.1	62.0	93.0
3	0.975	3	1.305	15.4	65.1	98.5
4	0.896	4	1.367	19.9	63.0	94.5
5	1.119	•5	--	--	--	--
6	1.027	6	1.601	24.6	70.2	102.5
7	1.119	7	1.355	26.8	66.8	132.0
8	0.932	•8	--	--	--	--
9	0.858	9	1.296	21.5	67.6	127.0
10	1.137	10	1.261	21.8	65.6	136.5
11	0.945	11	1.214	14.7	58.0	85.0
12	1.174	•12	--	--	--	--
13	1.095					
14	1.020		1.400 +/-0.0 *	20.7 +/-1.4	64.5 +/-1.2	107.8 +/-6.3
15	1.051					
16	0.906					
17	0.902					
18	0.879					
19	1.012					
20	1.043					
	1.000 +/-0.0 *					

Group values expressed as mean +/-SE.
*R = Female lightweight rowers.
*CG = Control group.
• = subject unavailable for testing.
* = Significant at <0.05 level.

Peak Torque

Mean peak torque (n=4) for right leg at 90 to 240 degrees is not significantly different. There is a trend for an increase in peak torque at 120, 180 and 240 degrees. Mean value at 90 degrees shows a large range in results and a lower post-training result (Figure 2a). Mean peak torque for the left leg at 90 to 240 degrees were not significantly different. There is a trend for an increase in peak torque at all angles, but at 180 degrees there is less range in values (Figure 2b). Mean, standard error and range for peak torque are presented in Table 3.

Normalised results of peak torque values are presented in Table 4. Normalised values are calculated by dividing individual peak torque values by the highest sample value, for both the right and left leg at each velocity. The mean results of the right leg were significantly different ($p<0.05$) at 120 and 180 degrees/second, the functional velocity in rowing (Figure 3a). Normalised values for the left leg were not different and there did not appear to be an increasing trend for post-training results (Figure 3b). Peak torque results can be found in Appendix C.

Table 3
Mean, Standard Error and Range of Peak Torque Values, Pre-training (test1) and Post-training (test2) for Right and Left Leg Extensors of Female Lightweight Rowers. (n=4)

	deg/sec			
	90	120	180	240
TEST1 R				
Mean	142.0	123.0	106.0	93.5
SE	+/-10.0	+/-9.9	+/-8.2	+/-6.0
Range	166.0-118.0	149.0-103.0	129.0-90.0	107.0-80.0
TEST2 R				
Mean	133.0	126.0	111.5	100.5
SE	+/-14.2	+/-11.0	+/-9.3	+/-7.1
Range	168.0-99.0	153.0-99.0	134.0-90.0	117.0-84.0
TEST1 L				
Mean	133.8	127.0	110.8	94.5
SE	+/-10.2	+/-9.0	+/-6.5	+/-13.0
Range	163.0-118.0	151.0-110.0	129.0-101.0	118.0-59.0
TEST2 L				
Mean	141.5	139.0	115.8	96.0
SE	+/-6.9	+/-4.1	+/-4.6	+/-12.9
Range	162.0-132.0	151.0-133.0	125.0-106.0	115.0-58.0

Table 4
Normalised Data of Peak Torque Values at Angular Velocities of 90 to 240 Deg/sec for Right and Left Leg Extensors of Female Lightweight Rowers. n = 4

Deg/sec	Pre-training R	Pre-training L	Post-training R	Post-training L
90°	1.0	1.0	1.0	1.0
	1.0	0.9	1.0	1.0
	1.0	1.0	1.0	1.0
	1.0	1.0	1.0	1.0
	1.0	1.0	1.0	1.0
	+/-0.0	+/-0.0	+/-0.0	+/-0.0
120°	0.9	0.9	0.9	0.9
	0.9	0.8	1.0	1.0
	0.8	1.0	0.9	1.0
	0.8	1.0	1.0	1.0
	0.9	0.9	1.0	1.0
	+/-0.0	+/-0.0	+/-0.0	+/-0.0
180°	0.8	0.8	0.8	0.8
	0.7	0.8	0.8	0.8
	0.8	0.9	0.9	0.9
	0.8	0.9	0.9	0.8
	0.7	0.8	0.8	0.8
	+/-0.0.	+/-0.0	+/-0.0	+/-0.0
240°	0.6	0.7	0.6	0.7
	0.6	0.5	0.7	0.5
	0.7	0.9	0.9	0.8
	0.7	0.8	0.9	0.8
	0.7	0.7	0.8	0.7
	+/-0.0	+/-0.0	+/-0.0	+/-0.0

Figure 2.a

Peak torque at angular velocities of 90 to 240 degs/sec in the right legs of female rowers. (means +/-se, n=4)

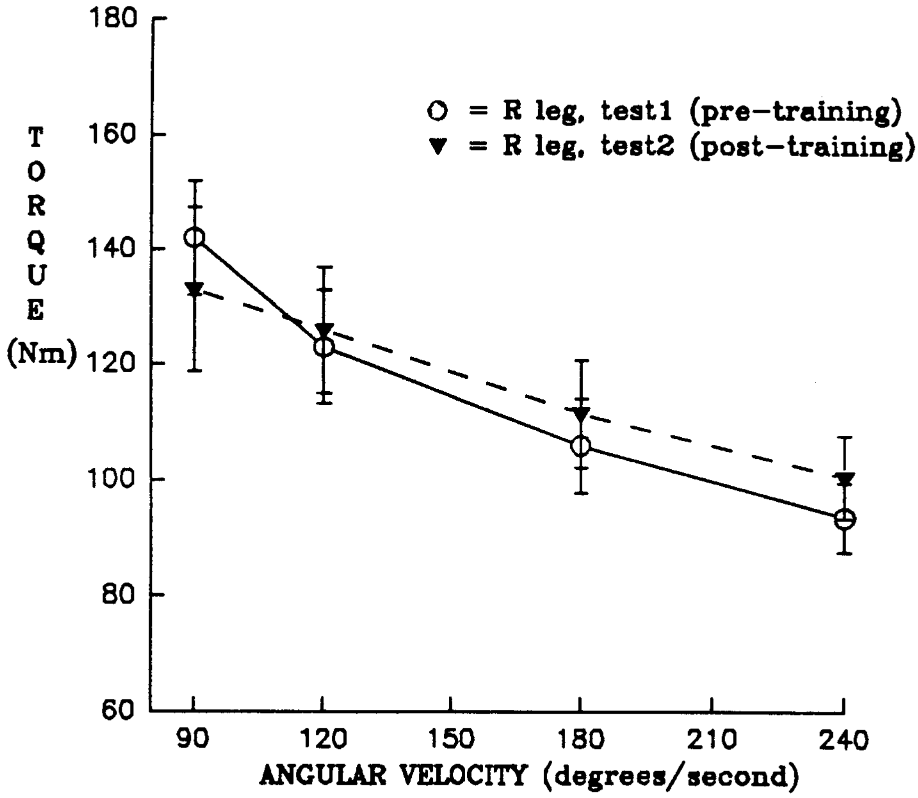


Figure 2.b

Peak torque at angular velocities of 90 to 240 degs/sec in the left legs of female rowers. (means +/-se, n=4)

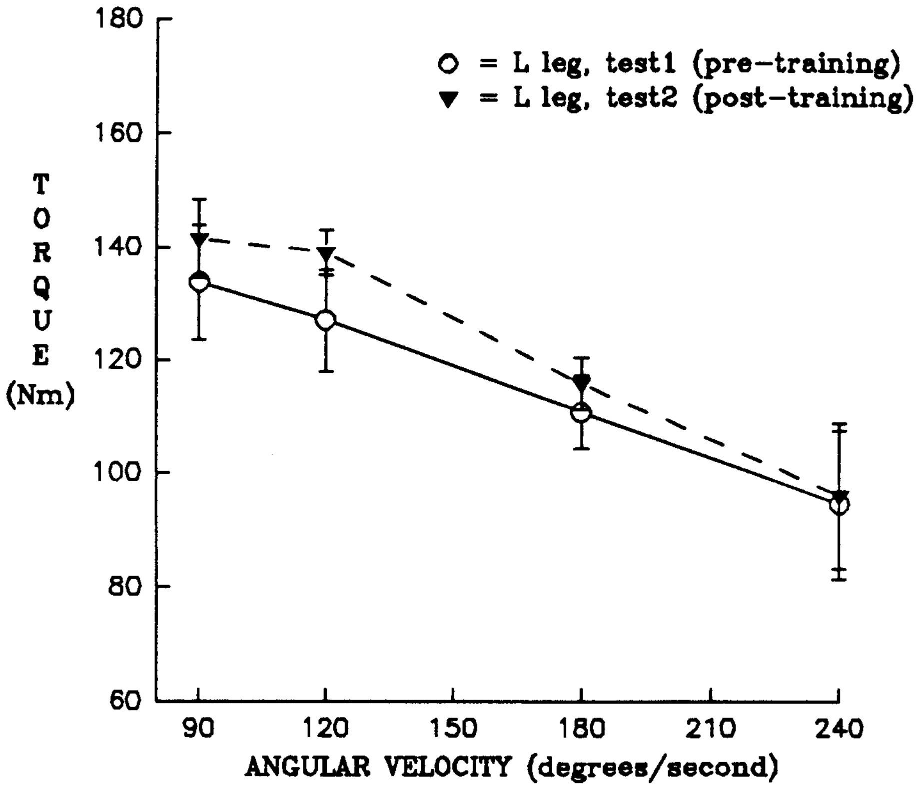


Figure 3.a

Normalised data of peak torque at angular velocities of 90 to 240 degs/sec in the right leg of female rowers. (means +/−se, n=4)

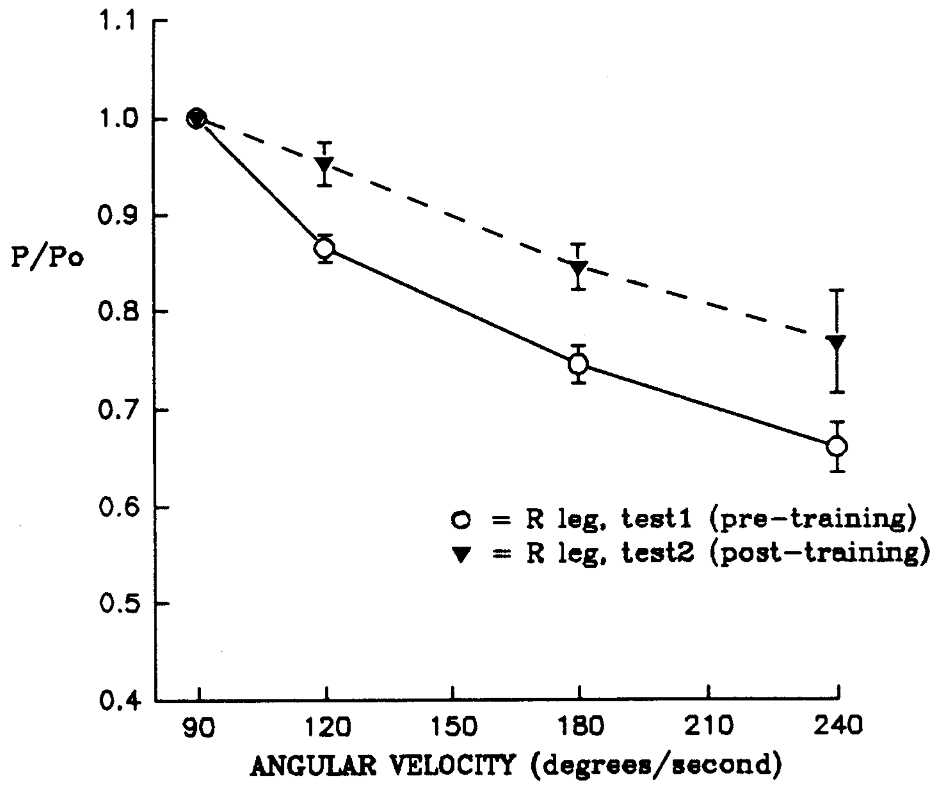
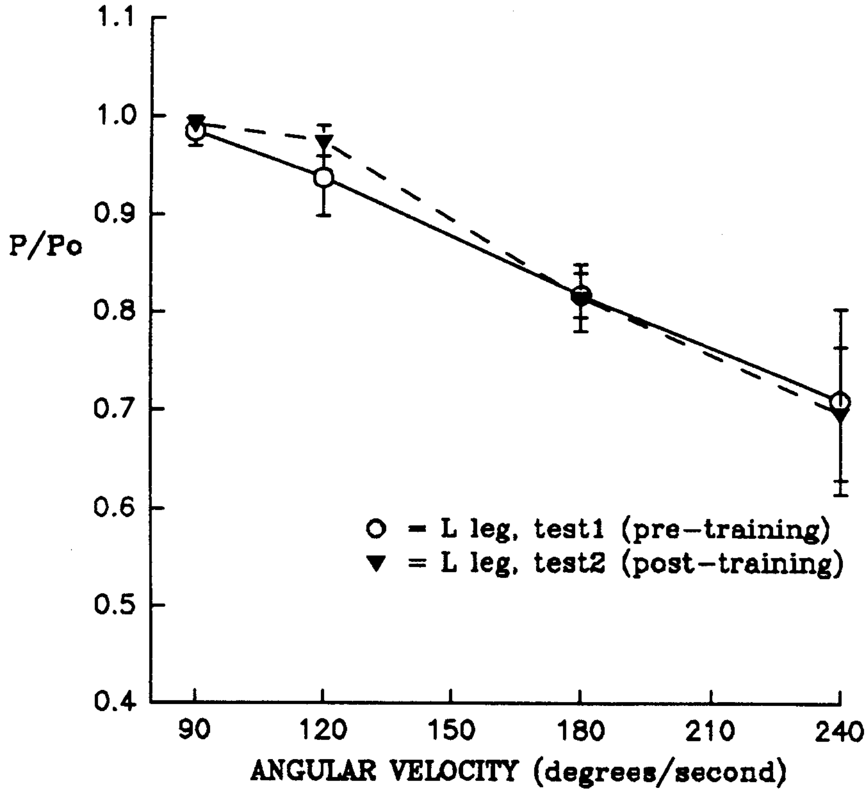


Figure 3.b

Normalised data of peak torque at angular velocities of 90 to 240 degs/sec in the left leg of female rowers. (means +/-se, n=4)



Average Power

Average Power has been calculated for each subject (see appendix E) which uses a functional range (over 6 reps) which is a better indicator of power than using peak power alone. Mean, SE and range values for the sample are presented in Table 5. There is no significance between the mean pre-training and post-training power results for either the right or left leg for the sample tested (Figure 4a. and 4b.). There does appear to be a trend for power to increase at 120 degrees. The value recorded at 120 degrees for subject 1 is not considered to be representative (see appendix E. This result has affected the mean (lowered) for the pre-test and altered the shape of the normal curve. There is also a small trend for an increase in mean average power for both legs (except at 90 degrees in right leg, where value is slightly lower). Subject 3 and 6 data were not included in group data as they were unavailable for post-training testing.

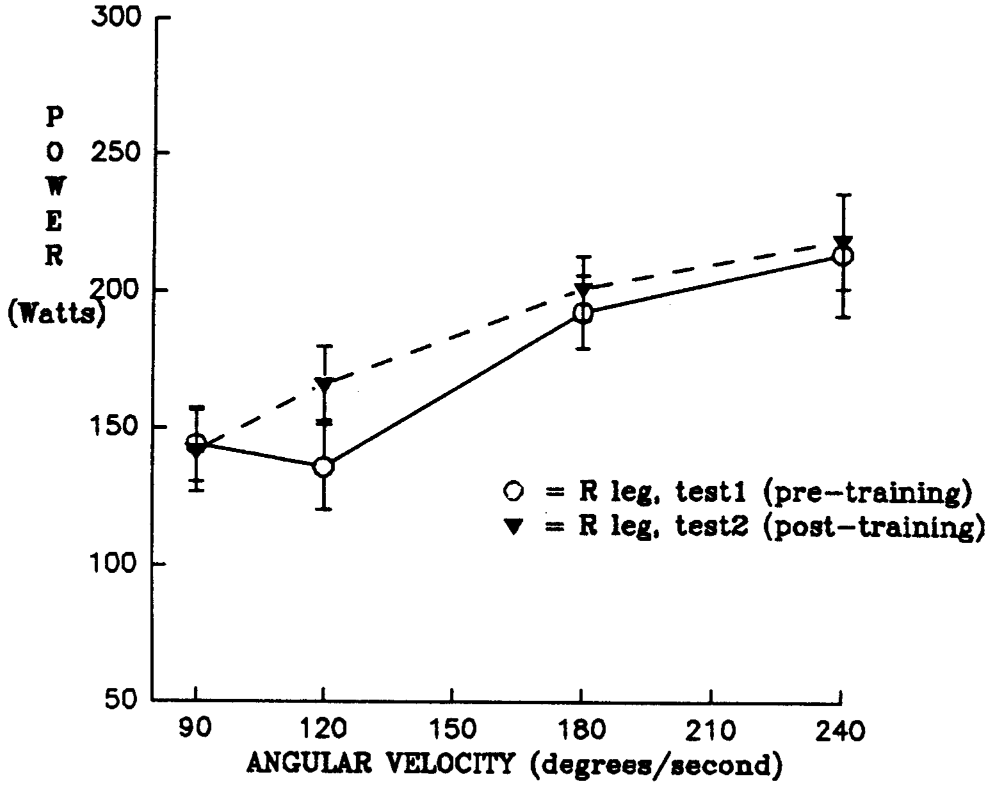
Table 5

Mean, Standard Error and Range of Average Power for Pre-training (test1) and Post-training (test2) for Right and Left Leg Extensors of Female Lightweight Rowers. (n=4)

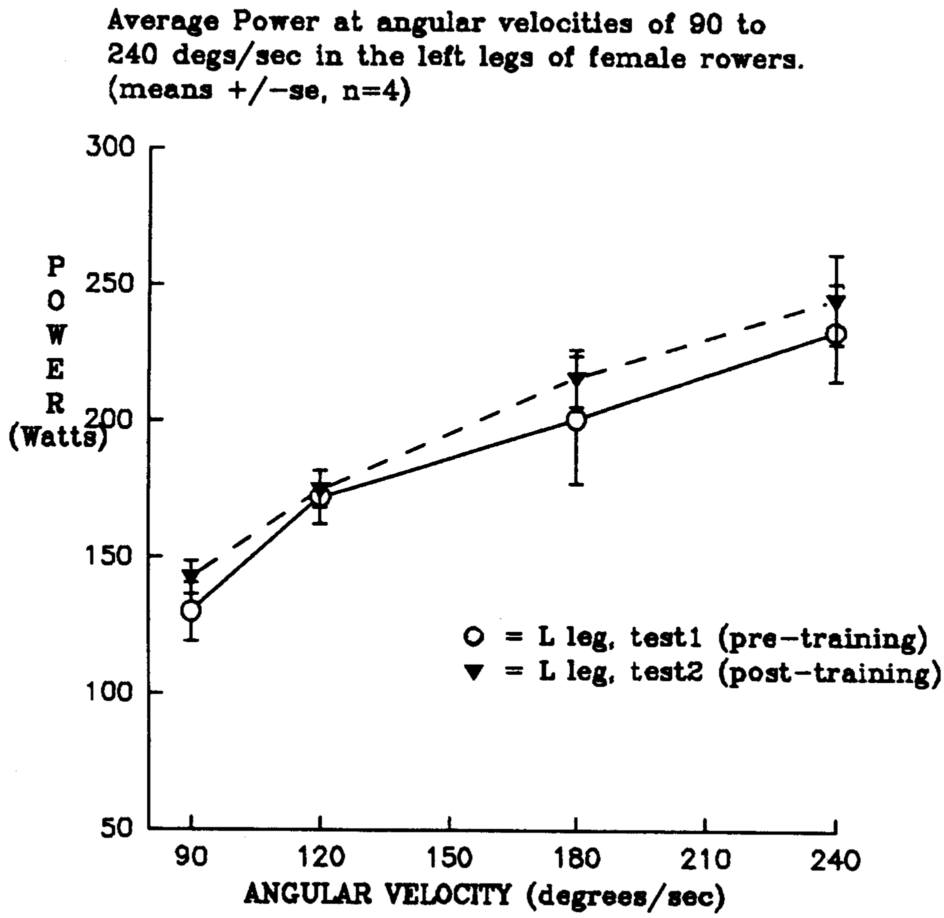
	Deg/sec			
	90	120	180	240
TEST1 R				
Mean	144.0	135.8	192.5	213.8
SE	+/-13.3	+/-15.5	+/-13.2	+/-22.1
Range	170.0-107.0	172.0-98.0	216.0-162.0	269.0-167.0
TEST2 R				
Mean	141.8	166.3	201.3	218.8
SE	+/-14.7	+/-13.5	+/-11.7	+/-17.4
Range	178.0-106.0	191.0-128.0	235.0-182.0	247.0-170.0
TEST1 L				
Mean	130.3	172.3	200.8	233.3
SE	+/-10.7	+/-9.9	+/-23.4	+/-18.0
Range	160.0-114.0	196.0-148.0	268.0-160.0	276.0-200.0
TEST2 L				
Mean	142.8	175.0	216.0	245.3
SE	+/-6.1	+/-6.7	+/-10.4	+/-16.7
Range	160.0-131.0	194.0-164.0	243.0-199.0	276.0-200.0

Figure 4.a

Average power at angular velocities of 90 to 240 degs/sec in the right legs of female rowers. (means +/-se, n=4)



Fiqure 4.b


Average Power at angular velocities of 90 to
240 degs/sec in the left legs of female rowers.
(means +/-se, n=4)
300
250
200
150
100
50
POWER
(Watts)
90
120
150
180
210
240
ANGULAR VELOCITY (degrees/sec)
O = L leg, test1 (pre-training)
▼ = L leg, test2 (post-training)

Fatiguability

Fatiguability was measured at 90 degrees/second over 60 reps. Twenty percent fatigue time and twenty percent fatigue work were calculated for the pre and post training tests. The values, means, standard error and percent difference are presented in table 6. A paired t-Test indicated that the mean of the samples were not different at the 0.05 level for both fatigue time and fatigue work. There was, however, a trend for time to fatigue to increase as well as amount of work done to increase in all subjects except subject 4. Therefore, endurance capacity was still increasing with training, which may depend on initial state of training. Subject 3 and 6 were unavailable for post-training testing therefore results not included.

Table 6
Fatiguability Results of Dominant Leg of Female Lightweight Rowers, tested before (pre-training) and after 12 weeks training (post-training). n = 4

Subject	20% FT (sec)			20% FW (Joule)		
	Pre	Post	%d	Pre	Post	%d
1	13.0	21.0	61.5	1816.0	2865.0	57.7
2	12.0	18.0	50.0	1353.0	2000.0	47.8
4	24.0	24.0	0.0	2570.0	2265.0	-11.9
5	26.0	27.0	3.8	2075.0	2457.0	18.4
	18.8 +/-3.6	22.5 +/-1.9	19.7	1953.5 +/-254.0	2396.8 +/-182.0	22.7

FT = Fatigue Time.
FW = Fatigue Work.
%d = percent difference between Pre and Post training.
Group values expressed as mean +/-SE.

2500m Performance Test

Each subject completed a 2500m dry (land based) performance test on a rowing ergometer. The subjects were tested before (pre-training) and after 12 weeks of training (post-test) and times to complete the distance were recorded in minutes and seconds. The values, means and standard deviations are presented in Table 7. A paired t-Test found the means of the sample to be significantly different ($p<0.001$). The rowers were all able to decrease rowing performance times in the post-training test.

Table 7
2500m Performance Results of Female Lightweight Rowers, tested before (pre-training) and after 12 weeks of training (post-training). n=10

Subject	Test1 Min:sec	Test2 Min:sec
1	10:15	9:54
2	10:32	10:02
3	10:10	9:51
4	10:14	9:51
5	10:17	9:57
6	10:21	10:03
7	10:16	9:51
8	10:11	9:47
9	10:15	9:53
10	10:17	9:49
	10:16.8 +/-6.18	9:61.8 +/-5.33

Group values expressed as mean and SD.
Min:Sec = time in minutes and seconds.

Chapter 5

Conclusion

The purpose of this study was to determine whether high intensity exercise under conditions of restricted dietary intake is counter-productive to the normal health and development of female lightweight rowers. The study looked at two physiological aspects, bone growth and muscle development problems, that may influence performance and health in the competitor. The physiological parameters measured were anthropometry; aerobic capacity; rowing performance; muscular force, power and fatiguability and bone mineral density. Training and menstrual histories were also recorded to establish suitable lifestyle patterns. Twelve subjects commenced testing, however, only six subjects were able to complete the testing requirements. The subjects were tested pre-training (test1) and post-training (test2), after 12 weeks of training. From the data collected it was possible to:

1. investigate any changes in bodyfat with training/dieting.
2. determine whether the rowers have lower vertebral BMD's than the normal population.
3. follow the relationship between strength, power and fatigue resistance to peak performance.
4. determine whether muscle mass is decreased

following training, whilst under diet restriction.

The following statement of hypotheses were tested:

Hypothesis 1. There will be a decrease in bodyfat in female lightweight rowers with training, combined with diet restricting.

Results: The first hypothesis was tested using a paired t-Test, and was accepted, $p<0.05$.

Conclusions: There was a significant decrease in bodyfat ($P < 0.05$) in female lightweight rowers. Both total skinfolds and bodyweight were significantly decreased. However, the average bodyweight at the post-training Test 2 stage was still higher than the regulation mean team weight of 57 Kg. Regulation weight is measured 2 hours before the National competition which is held in April. Therefore high intensity training, combined with an even more calorie reduced diet is necessary for these athletes to attain a desired weight level. The next 3 months would therefore appear to be a more suitable time to study the effects of training on the rowers muscle function, when the effects of muscle degradation may be more pronounced. The periodised training schedule peaks for both strength, power and endurance at the end of

February, thus maximal physiological stresses will necessarily combine with the greatest dietary restriction.

Hypothesis 2. Female lightweight rowers will have lower bone density levels than the normal range.

Conclusion: The converse of the above hypothesis was found with Lumbar BMD of female lightweight rowers being significantly higher ($P < 0.05$) than lumbar density derived from a West Australian control group matched for age. The results therefore support the findings of Snyder et al. (1986) who found that bone mineral density of female lightweight rowers was not lower than normal counterparts. The difference between Snyder's work and our own which show's increased BMD may be due to different comparitive databases for norms. Snyder's subjects were based in the USA and when our rowers are compared to a USA database they fit within normal values. In Australia there is no local database for normal values over the age range of our rowers as yet, but it does appear that there is a positive effect on BMD as a result of the stress placed on the bone through the action of rowing (Snyder et al. 1986). Drinkwater et al. (1990) found that athletes with menstrual irregularities had decreased vertebral lumbar bone density. As none of the subjects in this study had irregular menstrual cycles it was difficult to determine whether the results would be the same. At the present stage of training there appears to be no negative affect on bone from lowered body fat in these rowers. However, as low body fat is associated with menstrual irregularity, this may become more of a problem when the rowers approach the final regulation weight limit of 59kgs. So far, the exercise and dietary regimes of the rowers have been beneficial but few of these athletes have training history's long enough to see the negative, long-term effects that lowered body weight may have on BMD.

Hypothesis 3. There will be an increase in aerobic power, strength, power and fatigue resistance, necessary for peak performance in female lightweight rowers with training, combined with dietary restriction.

Conclusion: Max VO_2 results showed no significant difference, however in three of the five subjects tested there was a tendency to increase. The surprising finding of a decreased Max VO_2 in two subjects may have been caused by overtraining, since at the stage of the second test, despite pre-test resting some residual fatigue may well have been present. This is always a hazard when dealing with elite athletes who undergo extremely high levels of exercise at a level prescribed by a National coach and which may be counter-productive for certain individuals.

Mean peak torque for right (dominant) and left (non-dominant) legs were not significantly different pre and post training. This is a surprising result as 12 weeks of intensive training should produce significant increases. There is however a trend to increase peak torque at the upper end of the functional range (240 degrees/second). This is approximately the velocity of contraction undergone by the quadriceps at racing speed, so it is possible that a velocity specific training effect may be occuring.

The power produced during the whole of a rowing stroke is perhaps a more relevent index of the effects of training, being an indicator of the more sustained dynamic contraction. Again no significant increases were found pre and post training but there was a trend showing a slight increase in average power.

The resistance to fatigue, as determined by 60 maximal dynamic contractions of the quadriceps showed no statistically significant changes. However there was a very definite tendency to increase both the time taken to lose 20% of force and the work done during that time. Both of these are reasonable measures of fatigue but the means of contraction may not have been suitable. Had a more functional test contraction protocol been used, such as a leg-press which is more closely related to the movement carried out by the rowers, then perhaps a more significant result may have been shown.

Performance as indicated by the dry (land based) measure of the 2500 metre ergometer test has shown a significant increase ($P < 0.001$). Although at a fine level of discrimination (10 seconds improvement) such a test may not distinguish between individual actual rowing performances (personal communication A.Schreiner, WAIS) it is a very useful method of showing increases in an individuals performance.

Hypothesis 4. There will be a decrease in muscle mass in female lightweight rowers with training, combined with diet restricting.

Conclusion: The large decrease in the sum of skinfold measurements together with relatively small weight loss indicates that there is a loss of adipose tissue together with an increase in the relative amount of lean tissue in these athletes. It is tempting to assume that at this stage there is very little loss of muscle tissue. However a more precise study on muscle protein turnover would be required to substantiate this.

In summary, the study clearly indicates that high intensity exercise, combined with diet restriction has resulted in (1) decreased body fat; (2) BMD of vertebrae measured to be within normal ranges; (3) preservation of muscle tissue; (4) a trend to increase strength, power and fatigue resistance; (5) and an increase in (dry) rowing performance.

However, the validity of these results is limited to the small numbers tested. Also it is difficult to determine whether these results would be the same if the weight limit had been achieved by the rowers at this stage and the high intensity training regime had continued under these conditions. It is unlikely that at the stage of the second test these rowers were under sufficient nutritional depletion to cause any health problems.

Recommendations:

It is recommended that further study:

1. Is required to determine conclusively whether long term high intensity exercise, combined with diet restricting alters the protein turnover in rowers. Future studies should include regular testing

throughout a training regime, to determine whether a certain amount of lean tissue can be lost and what preventative measures (increased dietary protein, reduced training) are necessary to maintain performance.

2. Measure the lightweight rowers up until the National titles when the regulation weight limit is enforced. To determine whether lowered bodyweight as a result of high intensity exercise, combined with diet restricting is counter-productive to performance and normal health of the rower.

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APPENDIX A

FORM OF DISCLOSURE AND INFORMED CONSENT

BONE GROWTH AND MUSCLE DEVELOPMENT PROBLEMS IN FEMALE LIGHTWEIGHT ROWERS, TRYING TO MAKE WEIGHT STUDY.

AIM OF STUDY: The effect of high intensity training and diet restricting on bone growth and muscle development is unknown in oarswomen trying to make weight. Lowered body fat has been associated, although not causal, to disrupted or irregular menstrual cycles. Amenorrhoea results in lowered oestrogen levels which is an important factor in bone development. Athletes on a dieting regimes may reduce calcium intake which is an important factor for bone development. Athletes with long term lowered oestrogen levels and calcium intake may delay or reduce bone mass and risk developing stress fractures and osteoporosis. It would normally be expected with training to increase strength, power and endurance, however to meet weight restrictions fat and protein mass (muscle bulk) may be substantially reduced.

The aim of the study will be to measure the following parameters, that may be altered by a training and dieting regime and decrease the performance and health of athletes trying to make weight:
1. Anthropometric measurements
2. Aerobic Capacity
3. Muscular force, power and endurance
4. Bone density
5. Oestrogen, nitrogen compounds and calcium levels
6. Nitrogen balance

TIME LINE: During the study the participants will be required to participate in three testing sessions over a period of twelve weeks. Each testing session will require visits to Edith Cowan University or QEII Hospital, of approximately three to four hours.

PROCEDURES:
1. Anthropometric Measurements: this includes measurements of height, weight and body composition. Body will be measured using skinfold callipers using the standard 8 site skinfold thickness and by Dual-energy X-ray Densitometer (DEXA).
2. Maximal Aerobic Power (Max VO2) will be measured during an intermittent test on rowing ergometer and oxygen consumption measured using a gas analyser. Heart rate is continuously monitored by electrocardiography (ECG).
3. Force-velocity characteristics of muscle will be measured on a Cybex Isokinetic Dynamometer. This test

measures similar efforts of force produced during knee extension in rowing.
4. Bone density will be measured by Dual-energy X-ray Densitometer courtesy of QEII Hospital. The subject lies (supine) on a platform and a weak X-ray beam scans the whole body, lumbar spine and left hip. The radiation dose is less than 2% of the allowed dose to volunteers set by the National Health and Medical Research Council guidelines. The results will be compared to the normal population.
5. Blood test - a venous blood sample will be analysed for oestrogen, nitrogen compounds and calcium levels as per hospital procedures. As with all blood sampling there is minimal risk of infection.
6. Participants will be required to record a four day diet, 24 hour urine samples will be collected and analysed for negative nitrogen balance.

BENEFITS FOR THE PARTICIPANT AND SOCIETY: This study will contribute to the limited knowledge that exists in the area of bone growth and muscle development in young athletes trying to make weight restrictions. The study will benefit the participant by providing, free of charge, extensive physiological testing beneficial for monitoring training/performance and normal health.

Participation in this study is voluntary and you may withdraw from the study at anytime. You will be asked to provide a menstrual history, a four day diet record and a training log book. This information and the results of the tests are confidential and will only be used for the purpose of this study. All information will be kept under lock and key and access restricted to the principal investigators. All names will be removed prior to data analysis.

Any questions concerning the project entitled "Bone Growth and Muscle Development Problems in Female Light Weight Rowers, Trying to Make Weight", can be directed to Carmel Shipway on 447 2657 or Colin James of the Human Movements Department, Edith Cowan University on 383 8046.

I (the participant) have read the information above and any questions I have asked have been answered to my satisfaction. I agree to participate in this activity realising that I may withdraw at any time.

I agree that the research data gathered for this study may be published provided I am not identifiable.

I understand and agree that Edith Cowan University and Human Movement Department and others involved will not be held responsible for any injury or permanent damage

sustained.

....
..
Participant or authorised representative date

....
..
Investigator date

APPENDIX B

EDITH COWAN UNIVERSITY

TRAINING AND MENSTRUAL HISTORY QUESTIONNAIRE

The questions in this questionnaire are designed to assist us in our research into Bone Growth and Muscle Development Problems in Lightweight Rowers Trying to Make-Weight. All personal details will be treated in the strictest confidence, with access to information being restricted to the principal investigators. When answering a yes/no question, please circle the correct answer. Attempt to answer all questions in both Part A (Training History) and Part B (Menstrual History) as accurately as possible. Thankyou for participating in this questionnaire.

DATE ____________________

NAME ______________________________ (Surname)

______________________________ (Other names)

DATE OF BIRTH ____________________

PART A TRAINING HISTORY

1. Are you currently training (rowing)? Yes/No
   If no, please state:
   Reason (injured, illness etc): ___________

____

____

____

2. How old were you when you started rowing? _____

3. Before commencing rowing did you participate in any other physical activities?
Yes/No

If so, please state
- a) Activity: ________________
  Duration (Months or years): ________
  Frequency (times per week): ________
- b) Activity: ________________
  Duration: ________________
  Frequency: ________________
- c) Activity: ________________
  Duration: ________________
  Frequency: ________________

4. List rowing levels achieved (Club, State etc).

YEAR	AGE	LEVEL

What do you consider to be your personal best performance?

____

What was your best performance last season?

____

5. Have there been any periods of absence from rowing since commencing? Yes/No
   If so, please state:
   - a) Length of time absent: ____________
     Reason: ________________

While absent from rowing, did you remain physically active? Yes/No
If yes, please state:
   Activity: ________________
   Duration (months or Years): ________
   Frequency (times per week: ________

   - b) Length of time absent: ____________
     Reason: ________________

While absent from rowing, did you remain physically active? Yes/No

If yes, please state:

Activity: ______________________

Duration: ______________________

Frequency: ______________________

6. Apart from rowing training, please list any other physical activities that you currently participate in.

a) Activity: ______________________

Duration (Months or Years): ________

Frequency (Times per week): ________

b) Activity: ______________________

Duration: ______________________

Frequency: ______________________

7. Please outline your rowing training program for the preceding week.

a) On water:

Duration of training (Hours): ___

Frequency (Times per week): ______

b) Ergometer:

Duration of training: ____________

Frequency: ______________________

c) Weight Training:

Reps: ______________________

Sets: ______________________

Load: ______________________

Duration of training: ____________

Frequency: ______________________

d) Other aerobic or specific training:

Type: ______________________

Duration of training: ____________

Frequency: ______________________

Is your answer to this question typical of training in the past month?

More active/Same/Less

8. What time of the year do you participate in rowing?

____

9. Do you participate in any physical activity during the off-season? Yes/No

If yes, please state:

a) Activity: ______________________

Duration (Months): ________________

Frequency (Times per week): ______

b) Activity: ______________________

Duration: ______________________

Frequency: ______________________

9. Self rating of fitness.

How fit do you consider yourself to be compared to other people your age?

Fitter than most/about average fitness/
Not as fit

10. Is your health usually
Very good/Good/Average/Poor?

11. Have you ever taken steroid tablets regularly?
Yes/No

PART B MENSTRUAL HISTORY

1. Has anyone in your immediate family (eg grandparents, parents, siblings) had osteoporosis? Yes/No
   If yes, please state relation: ______________

2. Have you had a hysterectomy? Yes/No

3. Have you had either ovary removed? Yes/No

4. Do you menstruate regularly? Yes/No
   If yes, please state:
   Age at onset: _______________
   Approx. length of cycle: _____ weeks.

5. Have your periods always been regular? Yes/No

6. Have you ever been medically treated for amenorrhoea or irregular periods? Yes/No
   If yes, please state:
   Medication: __________________________
   Period of treatment: ________________

7. Have you ever had any children? Yes/No
   If so, please state:
   Length of pregnancy: _________________
   Present age of child: _________________

8. Have you ever taken oestrogen or oral contraceptives? Yes/No
   If yes, please state:
   a) Duration of use: (Months or Years) _______
      Brand name (if known): ________________
   b) Duration of use: (Months or Years) _______
      Brand name (if known): ________________

9. Have you ever taken calcium tablets Yes/No
   If yes, please state:
   Reason for use: ______________________
   Duration of use: _____________________
   Frequency of use: ____________________
   Brand name: __________________________
   Dose per day: ________________________

APPENDIX C

PRE AND POST TRAINING TEST RESULTS

SUBJECT	AGE	HEIGHT	WEIGHT PRE	WEIGHT POST
1	22.0	174.5	63.0	62.5
2	17.0	171.3	62.0	59.6
3	25.0	166.5	65.1	62.8
4	21.0	177.1	63.0	61.9
5	24.0	177.5	66.5	64.2
6	18.0	170.5	70.2	69.3
7	18.0	177.4	66.8	
8	21.0	175.5	63.3	
9	21.0	171.1	67.6	
10	18.0	165.5	65.2	
11	20.0	177.0	58.0	
12	18.0	171.5	62.3	
Mean	20.5	173.1	64.6	63.4
Std Dev	2.6	4.4	3.3	3.3
Std Err	0.8	1.3	1.0	1.3
95% Conf	1.7	2.9	2.2	3.4
99% Conf	2.5	4.2	3.1	5.4
Size	11.0	11.0	11.0	6.0
Sum	225.0	1903.9	710.7	380.3
Max	25.0	177.5	70.2	69.3
Min	17.0	165.5	58.0	59.6
Missing	0.0	0.0	0.0	0.0

MAXIMAL OXYGEN UPTAKE

SUBJECT	MAX VO2	MAX VO2
1	3.5	3.6
2	3.6	3.8
3	3.9	3.6
4	4.2	--
5	3.8	3.7
6	3.8	4.0
7	3.5	--
8	--	--
9	3.8	--
10	3.5	--
11	—	3.3
12	3.5	—

QDR BONE SCAN AND PERCENT FAT

SUBJECT	BMD *R	%FAT
1	1.587	23.4
2	1.416	18.1
3	1.305	15.4
4	1.367	19.9
5	--	—
6	1.601	24.6
7	1.355	26.8
8	--	16.3
9	1.296	21.5
10	1.261	21.8
11	1.214	14.7
12		

*R = Lightweight Rowers

SUBJECT	BMD *N
1	0.998
2	1.068
3	0.975
4	0.896
5	1.119
6	1.027
7	1.119
8	0.932
9	0.858
10	1.137
11	0.945
12	1.174
13	1.095
14	1.020
15	1.051
16	0.906
17	0.902
18	0.879
19	1.012
20	1.043

*N = Normal 19yr olds
SCGH Data Bank

SKINFOLDS

PRE-TRAINING

SUBJECT	TRICEP	BICEP	SUB/SCAP	AXILLA	SUPRAI	ABDOM	THIGH	M/CALF	TOTAL
1	14.0	6.5	9.0	6.5	8.5	11.0	30.0	16.0	101.5
2	13.0	5.0	8.0	8.5	12.0	14.0	18.5	14.0	93.0
3	12.0	5.0	7.0	6.0	6.0	6.5	41.0	15.0	98.5
4	16.0	4.0	7.5	6.0	7.0	7.0	27.5	19.5	94.5
5	14.0	5.5	13.0	8.0	9.0	14.0	26.0	17.5	107.0
6	17.0	7.0	10.0	7.0	7.0	10.0	26.0	18.5	102.5
7	21.0	9.5	15.0	16.0	9.0	17.0	29.0	15.5	132.0
8	17.0	4.0	13.0	9.0	8.0	11.0	29.0	17.0	108.0
9	15.0	5.0	13.0	11.0	18.0	19.0	31.0	15.0	127.0
10	18.0	8.0	18.5	12.0	16.0	19.0	27.0	18.0	136.5
11	--	--	--	--	--	--	--	--	--
12	3.0	7.5	8.0	5.0	7.0	7.5	26.0	19.0	85.0

POST-TRAINING

SUBJECT	TRICEP	BICEP	SUB/SCAP	AXILLA	SUPRAI	ABDOM	THIGH	M/CALF	TOTAL
1	12.0	5.0	7.0	6.5	7.5	8.5	20.0	15.0	81.5
2	11.0	4.5	8.0	8.0	8.0	12.5	18.0	11.0	81.0
3	8.0	3.0	6.0	4.0	4.0	6.0	21.5	10.5	63.0
4	--	--	--	--	--	--	--	--	--
5	11.0	3.5	10.0	5.5	5.5	9.0	18.0	14.5	77.0
6	15.5	5.5	12.0	8.0	8.0	7.0	26.0	17.0	99.0
7	--	--	--	--	--	--	--	--	--
8	--	--	--	--	--	--	--	--	--
9	--	--	--	--	--	--	--	--	--
10	--	--	--	--	--	--	--	--	--
11	6.5	2.0	5.0	3.0	3.0	5.0	17.5	9.5	51.5
12	--	--	--	--	--	--	--	--	--

CYBEX TEST : SUBJECT 1

SIDE(S) TESTED / DATE	R	07/09/1992			R	[illegible]/12/199[illegible]			PROGRESS			
BW (kgs) / MAX GET (Nm)	62	2			[illegible]	0						
REPS	6	6	6	6	5	6	6	6				
SPEED(S) (deg/sec)	90	120	180	240	[illegible]	[illegible]	[illegible]	240	90	120	180	240
PEAK TORQUE (Nm)	166	149	129	107	166	[illegible]	134	106	1%	2%	3%	0%
PEAK TORQUE % BW	267%	240%	208%	172%	[illegible]	[illegible]	219%	173%				
ANGLE OF PEAK TORQUE	46	54	57	47	50	49	[illegible]	45				
TORQUE à 40 deg	163	148	125	105	166	145	128	105	1%	-2%	2%	0%
TORQUE à 60 deg	151	140	125	98	156	110	126	102	3%	0%	0%	4%
ACCEL TIME (sec)	0.01	0.03	0.04	0.05	0.02	[illegible]	0.04	0.04				
TOTAL WORK (BWR) (J)	193	172	144	114	195	170	145	115	1%	-1%	0%	0%
TOTAL WORK (BWR) % BW	311%	277%	232%	183%	319%	[illegible]	237%	188%				
AVG POWER (BWR) (watts)	170	98	216	269	178	191	235	247	4%	94%	8%	-8%
AVG POWER (BWR) % BW	274%	158%	348%	433%	291%	313%	385%	404%				
TAE (J)	17.1	21.6	33.6	46.2	17.4	21.5	34.3	43.5	2%	0%	2%	-6%
ASD (Nm)	4	3	4	3	3	3	2	3				
SET TOTAL WORK (J)	1105	968	822	646	1123	974	844	651	1%	0%	3%	0%

SIDE(S) TESTED / DATE	L	07/09/1992			L	[illegible]/12/1992			PROGRESS			
BW (kgs) / MAX GET (Nm)	62	0			61	0						
REPS	6	6	6	6	6	6	6	6				
SPEED(S) (deg/sec)	90	120	180	240	90	120	180	240	90	120	180	240
PEAK TORQUE (Nm)	163	151	129	118	162	151	122	105	0%	0%	-5%	-11%
PEAK TORQUE % BW	262%	243%	208%	190%	265%	[illegible]	200%	172%				
ANGLE OF PEAK TORQUE	49	51	46	60	57	56	58	69				
TORQUE à 40 deg	160	147	128	96	141	147	113	92	-11%	-6%	-11%	-4%
TORQUE à 60 deg	148	137	121	118	160	144	121	101	8%	5%	0%	-14%
ACCEL TIME (sec)	0.02	0.03	0.04	0.05	0.02	[illegible]	0.04	0.04				
TOTAL WORK (BWR) (J)	175	164	134	110	176	[illegible]	138	110	0%	3%	2%	0%
TOTAL WORK (BWR) % BW	282%	264%	216%	177%	288%	[illegible]	226%	180%				
AVG POWER (BWR) (watts)	160	196	268	276	160	194	222	264	0%	-1%	-17%	-4%
AVG POWER (BWR) % BW	258%	316%	432%	445%	262%	[illegible]	363%	432%				
TAE (J)	17.6	24.6	35.7	47.2	17.5	[illegible]	34.0	41.5	-1%	-4%	-5%	-12%
ASD (Nm)	3	4	4	3	4	4	3	4				
SET TOTAL WORK (J)	1014	914	764	627	1004	[illegible]	783	623	0%	2%	2%	0%

SUBJECT 1 (Cont)

SIDE(S) TESTED / DATE :	R 07/09/1992		R 07/13/1992		PROGRESS
BW (kgs) / MAX GET (Nm)	62	2	62	2	
REPS	60		60		
	CONCENTRIC EXTENSORS				
SPEED(S) (deg/sec)	90		90		90
PEAK TORQUE (Nm)	159		160		0%
PEAK TORQUE % BW	256%		258%		
ANGLE OF PEAK TORQUE	45		51		
TORQUE à deg					
TORQUE à deg					
ACCEL TIME (sec)	0.02		0.02		
TOTAL WORK (BWR) (J)	175		182		4%
TOTAL WORK (BWR) % BW	282%		293%		
AVG POWER (BWR) (watts)	171		160		-6%
AVG POWER (BWR) % BW	275%		258%		
TAE (J)	16.9		17.1		1%
ASD (Nm)	6		6		
SET TOTAL WORK (J)	6813		8439		23%
ENDURANCE RATIO	73%		85%		
20% FATIGUE WORK (J)	1816		2865		57%
20% FATIGUE TIME (sec)	13		21		61%
20% FATIGUE REPS	12		18		50%
WORK RECOVERY RATIO					

CYBEX TEST : SUBJECT 2

SIDE(S) TESTED / DATE :	R	07/09/1992			R	12/1992			PROGRESS			
BW (kgs) / MAX GET (Nm)	61	0			61	0						
REPS	6	6	6	6	6	6	6	6				
	CONCENTRIC EXTENSORS											
SPEED(S) (deg/sec)	90	120	180	240	90	120	180	240	90	120	180	240
PEAK TORQUE (Nm)	147	126	102	88	129	126	105	95	-12%	0%	2%	7%
PEAK TORQUE % BW	240%	206%	167%	144%	[illegible]	[illegible]	172%	155%				
ANGLE OF PEAK TORQUE	41	41	42	56	46	48	47	64				
TORQUE à 40 deg	147	126	101	82	[illegible]	121	99	84	-14%	-3%	-1%	2%
TORQUE à 60 deg	124	106	87	88	117	124	90	91	-5%	[illegible]	3%	5%
ACCEL TIME (sec)	0.04	0.03	0.04	0.05	[illegible]	0.04	0.05	0.05				
TOTAL WORK (BWR) (J)	148	133	105	91	149	143	111	[illegible]	0%	7%	4%	1%
TOTAL WORK (BWR) % BW	242%	218%	173%	149%	244%	[illegible]	181%	150%				
AVG POWER (BWR) (watts)	146	145	179	227	[illegible]	175	197	218	-2%	20%	10%	-3%
AVG POWER (BWR) % BW	239%	237%	293%	372%	[illegible]	[illegible]	[illegible]	357%				
TAE (J)	17.4	20.9	27.8	37.5	[illegible]	[illegible]	30.6	36.8	-6%	11%	10%	-2%
ASD (Nm)	6	6	2	3	2	3	2	2				
SET TOTAL WORK (J)	852	751	608	514	[illegible]	[illegible]	644	539	-1%	6%	5%	4%

SIDE(S) TESTED / DATE	L	07/09/1992			LT	12/1992			PROGRESS			
BW (kgs) / MAX GET (Nm)	61	0			61	2						
REPS	6	6	6	6	6	6	6	6				
	CONCENTRIC EXTENSORS											
SPEED(S) (deg/sec)	90	120	180	240	90	120	180	240	90	120	180	240
PEAK TORQUE (Nm)	132	110	102	96	134	133	110	103	1%	20%	7%	7%
PEAK TORQUE % BW	216%	180%	167%	157%	[illegible]	[illegible]	180%	168%				
ANGLE OF PEAK TORQUE	46	52	62	59	42	43	41	56				
TORQUE à 40 deg	132	110	99	73	134	142	110	84	1%	20%	11%	15%
TORQUE à 60 deg	117	95	102	95	124	117	106	103	5%	23%	3%	8%
ACCEL TIME (sec)	0.02	0.02	0.03	0.04	[illegible]	[illegible]	[illegible]	0.06				
TOTAL WORK (BWR) (J)	137	121	99	84	[illegible]	[illegible]	110	94	5%	16%	11%	11%
TOTAL WORK (BWR) % BW	224%	198%	162%	137%	[illegible]	[illegible]	180%	154%				
AVG POWER (BWR) (watts)	115	170	160	207	[illegible]	[illegible]	199	241	21%	2%	24%	16%
AVG POWER (BWR) % BW	188%	278%	262%	339%	[illegible]	[illegible]	326%	395%				
TAE (J)	17.2	21.9	31.1	40.0	[illegible]	[illegible]	31.6	40.7	0%	7%	2%	2%
ASD (Nm)	10	3	2	[illegible]	4	[illegible]	[illegible]	[illegible]				
SET TOTAL WORK (J)	765	669	572	495	[illegible]	[illegible]	640	548	6%	17%	11%	10%

SUBJECT 2 (cont)

SIDE(S) TESTED / DATE	R	07/09/1992	[illegible]	07/12/1992	PROGRESS
BW (lbs) / MAX GET (Nm)	61	3	[illegible]	3	
REPS	60		[illegible]		
	CONCENTRIC EXTENSORS				
SPEED(S) (deg/sec)	90		[illegible]		90
PEAK TORQUE (Nm)	135		[illegible]		0%
PEAK TORQUE % BW	226%		[illegible]		
ANGLE OF PEAK TORQUE	38		[illegible]		
TORQUE @ deg					
TORQUE @ deg					
ACCEL TIME (sec)	0.02		[illegible]		
TOTAL WORK (BWR) (J)	141		[illegible]		5%
TOTAL WORK (BWR) % BW	231%		[illegible]		
AVG POWER (BWR) (watts)	144		[illegible]		2%
AVG POWER (BWR) % BW	236%		[illegible]		
TAE (J)	15.5		[illegible]		3%
ASD (Nm)	4		[illegible]		
SET TOTAL WORK (J)	5045		[illegible]		19%
ENDURANCE RATIO	65%		[illegible]		
20% FATIGUE WORK (J)	1353		[illegible]		47%
20% FATIGUE TIME (sec)	12		[illegible]		50%
20% FATIGUE REPS	11		[illegible]		36%

CYBEX TEST : SUBJECT 3

SIDE(S) TESTED / DATE :	R 07/09/1992				L 07/09/1992			
BW (kgs) / MAX GET (Nm) :	65	10			65	2		
REPS	6	6	6	6	6	6	6	6
SPEED(S) (deg/sec)	90	120	180	240	90	120	180	240
PEAK TORQUE (Nm)	187	167	144	122	178	167	134	124
PEAK TORQUE % BW	287%	256%	221%	187%	273%	256%	206%	190%
ANGLE OF PEAK TORQUE	57	65	54	66	52	46	41	51
TORQUE à 40 deg	171	148	130	113	163	162	134	109
TORQUE à 60 deg	185	163	133	120	149	144	128	106
ACCEL TIME (sec)	0.01	0.01	0.04	0.04	0.01	0.02	0.03	0.03
TOTAL WORK (BWR) (J)	208	189	156	125	141	149	124	102
TOTAL WORK (BWR) % BW	320%	290%	240%	192%	216%	229%	190%	156%
AVG POWER (BWR) (watts)	-199	233	292	308	165	205	283	145
AVG POWER (BWR) % BW	306%	358%	449%	473%	253%	315%	435%	223%
TAE (J)	20.1	26.2	52.2	58.8	32.9	39.8	50.3	54.6
ASD (Nm)	14	6	7	6	7	8	7	3
SET TOTAL WORK (J)	1158	1042	925	707	876	854	705	601

SIDE(S) TESTED / DATE	R	07/09/1992
BW (kgs) / MAX GET (Nm) :	65	0
REPS	60	
SPEED(S) (deg/sec)	90	
PEAK TORQUE (Nm)	147	
PEAK TORQUE % BW	226%	
ANGLE OF PEAK TORQUE	62	
TORQUE à deg		
TORQUE à deg		
ACCEL TIME (sec)	0.06	
TOTAL WORK (BWR) (J)	130	
TOTAL WORK (BWR) % BW	200%	
AVG POWER (BWR) (watts)	124	
AVG POWER (BWR) % BW	190%	
TAE (J)	17.9	
ASD (Nm)	12	
SET TOTAL WORK (J)	5672	
ENDURANCE RATIO	81%	
20% FATIGUE WORK (J)	3309	
20% FATIGUE TIME (sec)	55	
20% FATIGUE REPS	32	

CYBEX TEST : SUBJECT 4

SIDE(S) TESTED / DATE	R 07/09/1992				[illegible] 07/12/1992				PROGRESS			
BW (kgs) / MAX GET (Nm)	63	2			[illegible]	0						
REPS	6	6	6	6	[illegible]	6	6	6				
	CONCENTRIC EXTENSORS											
SPEED(S) (deg/sec)	90	120	180	240	[illegible]	[illegible]	[illegible]	240	90	120	180	240
PEAK TORQUE (Nm)	137	114	103	99	[illegible]	126	117	117	0%	10%	13%	18%
PEAK TORQUE % BW	217%	180%	163%	157%	[illegible]	206%	191%	191%				
ANGLE OF PEAK TORQUE	54	45	54	67	[illegible]	60	66	59				
TORQUE à 40 deg	132	113	96	86	[illegible]	117	102	91	0%	3%	6%	5%
TORQUE à 60 deg	1?6	109	95	91	[illegible]	125	110	115	[illegible]	1?%	15%	26%
ACCEL TIME (sec)	[illegible]	0.01	0.04	0.02	[illegible]	0.08	0.03	0.04				
TOTAL WORK (BWR) (J)	160	138	114	95	[illegible]	137	114	96	-4%	0%	0%	1%
TOTAL WORK (BWR) % BW	25?%	219%	180%	150%	250%	224%	166%	157%				
AVG POWER (BWR) (watts)	153	172	213	192	1??	171	191	240	-8%	0%	-10%	25%
AVG POWER (BWR) % BW	242%	273%	338%	304%	2??%	280%	313%	393%				
TAE (J)	19.0	22.9	33.5	40.5	19.?	25.9	36.4	47.0	4%	13%	9%	16%
ASD (Nm)	4	4	3	22	[illegible]	3	3	3				
SET TOTAL WORK (J)	929	795	663	449	9??	772	646	539	-4%	-2%	-2%	20%

SIDE(S) TESTED / DATE	L 07/09/1992				[illegible] 12 1992				PROGRESS			
BW (kgs) / MAX GET (Nm)	63	0			61	0						
REPS	6	6	6	6	[illegible]	6	[illegible]	6				
	CONCENTRIC EXTENSORS											
SPEED(S) (deg/sec)	90	120	180	240	90	120	180	240	90	120	180	240
PEAK TORQUE (Nm)	122	130	111	109	13?	136	125	115	13%	4%	12%	5%
PEAK TORQUE % BW	1??%	206%	176%	173%	226%	222%	204%	188%				
ANGLE OF PEAK TORQUE	57	66	73	66	[illegible]	65	54	64				
TORQUE à 40 deg	11?	107	91	96	12?	115	111	101	8%	7%	21%	5%
TORQUE à 60 deg	120	124	105	98	1??	130	114	110	14%	4%	8%	12%
ACCEL TIME (sec)	0.06	0.05	0.03	0.05	[illegible]	0.04	0.04	0.04				
TOTAL WORK (BWR) (J)	145	140	115	106	[illegible]	[illegible]	129	107	2%	-1%	12%	0%
TOTAL WORK (BWR) % BW	2??%	222%	18?%	168%	[illegible]	[illegible]	[illegible]	175%				
AVG POWER (BWR) (watts)	15?	175	155	250	14?	[illegible]	[illegible]	276	[illegible]	-6%	31%	10%
AVG POWER (BWR) % BW	[illegible]	277%	253%	396%	[illegible]	[illegible]	342%	452%				
TAE (J)	[illegible]	27.?	33.1	45.5	1?	[illegible]	37.?	46.4	-5%	0%	13%	6%
ASD (Nm)	6	4	2	3		2	[illegible]	6				
SET TOTAL WORK (J)	[illegible]	7??	548	504	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	31%	[illegible]

SUBJECT 4 (cont)

SIDE(S) TESTED / DATE	R 07/09/1992		L [illegible]/1992		[illegible]
BW (kgs) / MAX GET (Nm)	63	[illegible]	[illegible]	[illegible]	
REPS	60		[illegible]		
	CONCENTRIC EXTENSORS				
SPEED(S) (deg/sec)	90		90		90
PEAK TORQUE (Nm)	134		[illegible]		2%
PEAK TORQUE % BW	212%		[illegible]		
ANGLE OF PEAK TORQUE	59		60		
TORQUE @ deg					
TORQUE @ deg					
ACCEL TIME (sec)	0.03		0.02		
TOTAL WORK (BWR) (J)	164		162		-1%
TOTAL WORK (BWR) % BW	260%		[illegible]		
AVG POWER (BWR) (watts)	154		[illegible]		1%
AVG POWER (BWR) % BW	244%		[illegible]		
TAE (J)	19.2		[illegible]		7%
ASD (Nm)	4		3		
SET TOTAL WORK (J)	7164		[illegible]		1%
ENDURANCE RATIO	82%		[illegible]		
20% FATIGUE WORK (J)	[illegible]		[illegible]		-11%
20% FATIGUE TIME (sec)	24		[illegible]		0%
20% FATIGUE REPS	18		[illegible]		-11%

CYBEX TEST : SUBJECT 5

SIDE(S) TESTED / DATE :	[illegible]	29/09/1992				07/12/1992			PROGRESS			
BW (kgs) / MAX GET (Nm) :	66	0				0						
REPS	6	6	6	6		6	6	6				
	CONCENTRIC EXTENSORS											
SPEED(S) (deg/sec)	90	120	180	240	[illegible]	120	180	240	90	120	180	240
PEAK TORQUE (Nm)	118	103	90	80	[illegible]	94	90	84	-16%	-3%	0%	5%
PEAK TORQUE % BW	178%	156%	136%	121%	[illegible]	157%	142%	133%				
ANGLE OF PEAK TORQUE	70	53	42	56		[illegible]	72	63				
TORQUE à 40 deg	110	102	88	65		[illegible]	[illegible]	65	[illegible]	-24%	-10%	0%
TORQUE à 60 deg	106	54	84	73		[illegible]	[illegible]	62	7%	17%	-4%	12%
ACCEL TIME (sec)	[illegible]	[illegible]	0.06	0.06	[illegible]	0.02	[illegible]	[illegible]				
TOTAL WORK (BWR) (J)	[illegible]	[illegible]	86	71		102	[illegible]	71	[illegible]	4%	10%	0%
TOTAL WORK (BWR) % BW	[illegible]	162%	130%	107%	[illegible]	161%	150%	112%				
AVG POWER (BWR) (watts)	[illegible]	128	162	167	[illegible]	128	182	170	0%	0%	12%	1%
AVG POWER (BWR) % BW	[illegible]	193%	245%	253%	[illegible]	203%	[illegible]	264%				
TAE (J)	13.8	17.5	25.4	33.4	[illegible]	19.8	29.1	33.2	20%	13%	15%	-1%
ASD (Nm)	3	2	2	2		6	3	3				
SET TOTAL WORK (J)	642	619	495	397	[illegible]	566	541	[illegible]	2%	-8%	9%	-13%

SIDE(S) TESTED / DATE :	L	29/09/1992				07/12/1992			PROGRESS			
BW (kgs) / MAX GET (Nm) :	66	0			[illegible]	0						
REPS	6	6	6	6		6	6	6				
	CONCENTRIC EXTENSORS											
SPEED(S) (deg/sec)	90	120	180	240	[illegible]	120	180	240	90	120	180	240
PEAK TORQUE (Nm)	118	117	101	92	[illegible]	136	106	106	11%	16%	4%	15%
PEAK TORQUE % BW	178%	177%	153%	139%	[illegible]	215%	168%	168%				
ANGLE OF PEAK TORQUE	49	52	54	51	[illegible]	39	32	43				
TORQUE à 40 deg	115	109	99	72	[illegible]	134	92	105	14%	22%	-7%	45%
TORQUE à 60 deg	109	99	98	68	[illegible]	60	37	26	-22%	-39%	-62%	-61%
ACCEL TIME (sec)	0.02	0.04	0.04	0.06	[illegible]	0.04	0.03	[illegible]				
TOTAL WORK (BWR) (J)	109	111	94	77	[illegible]	118	92	[illegible]	4%	6%	-2%	6%
TOTAL WORK (BWR) % BW	165%	168%	142%	116%	[illegible]	[illegible]	146%	[illegible]				
AVG POWER (BWR) (watts)	114	148	190	200	[illegible]	167	200	200	14%	[illegible]	5%	0%
AVG POWER (BWR) % BW	172%	224%	287%	303%	[illegible]	265%	317%	[illegible]				
TAE (J)	17.4	23.3	33.0	39.7	[illegible]	[illegible]	33.0	[illegible]	5%	[illegible]	0%	8%
ASD (Nm)	3	2	3	3		6	6	4				
SET TOTAL WORK (J)	631	642	536	435	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-2%	[illegible]

SUBJECT 5 (cont)

SIDE(S) TESTED / DATE	R	29/09/1992	R	[illegible]12/1992	PROGRESS
BW (kgs) / MAX SET (Nm)	66	0	68	3	
REPS	60		60		
	CONCENTRIC EXTENSORS				
SPEED(S) (deg/sec)	90		90		90
PEAK TORQUE (Nm)	99		101		2%
PEAK TORQUE % BW	150%		160%		
ANGLE OF PEAK TORQUE	68		50		
TORQUE à deg					
TORQUE à deg					
ACCEL TIME (sec)	0.02		0.01		
TOTAL WORK (BWR) (J)	109		101		-7%
TOTAL WORK (BWR) % BW	165%		160%		
AVG POWER (BWR) (watts)	104		108		4%
AVG POWER (BWR) % BW	157%		173%		
TAE (J)	13.5		16.8		24%
ASD (Nm)	3		6		
SET TOTAL WORK (J)	4672		[illegible]		-9%
ENDURANCE RATIO	68%		68%		
20% FATIGUE WORK (J)	2075		2457		18%
20% FATIGUE TIME (sec)	26		[illegible]		3%
20% FATIGUE REPS	21		27		28%

CYBEX TEST : SUBJECT 6

SIDE(S) TESTED / DATE	L	24/09/1992			R	24/09/1992		
BW (kgs) / MAX GET (Nm) :	71	14			71	11		
REPS	6	6	6	6	6	6	6	6
SPEED(S) (deg/sec)	90	120	180	240	90	120	180	240
PEAK TORQUE (Nm)	144	134	114	111	138	122	114	101
PEAK TORQUE % BW	202%	188%	160%	156%	194%	171%	160%	142%
ANGLE OF PEAK TORQUE	53	48	52	49	55	46	53	46
TORQUE à 40 deg	115	124	92	94	106	117	99	94
TORQUE à 60 deg	130	128	73	65	128	115	92	46
ACCEL TIME (sec)	0.02	0.02	0.08	0.04	0.01	0.02	0.00	0.04
TOTAL WORK (BWR) (J)	120	114	87	83	117	107	98	71
TOTAL WORK (BWR) % BW	169%	160%	122%	116%	164%	150%	138%	100%
AVG POWER (BWR) (watts)	106	161	137	247	108	129	180	206
AVG POWER (BWR) % BW	149%	226%	192%	347%	152%	181%	253%	290%
TAE (J)	19.8	25.5	33.6	44.5	17.1	23.4	31.6	39.2
ASD (Nm)	3	2	3	4	6	4	26	2
SET TOTAL WORK (J)	685	655	501	438	536	608	469	346

SIDE(S) TESTED / DATE :	L	24/09/1992
BW (kgs) / MAX GET (Nm) :	71	11
REPS	60	
SPEED(S) (deg/sec)	90	
PEAK TORQUE (Nm)	155	
PEAK TORQUE % BW	218%	
ANGLE OF PEAK TORQUE	54	
TORQUE à deg		
TORQUE à deg		
ACCEL TIME (sec)	0.02	
TOTAL WORK (BWR) (J)	137	
TOTAL WORK (BWR) % BW	192%	
AVG POWER (BWR) (watts)	145	
AVG POWER (BWR) % BW	204%	
TAE (J)	20.0	
ASD (Nm)	11	
SET TOTAL WORK (J)	5626	
ENDURANCE RATIO	69%	
20% FATIGUE WORK (J)	2684	
20% FATIGUE TIME (sec)	23	
20% FATIGUE [illegible]	[illegible]	

CYBEX TEST : SUBJECT 7

SIDE(S) TESTED / DATE :	R	07/09/1992			L	07/09/1992		
BW (kgs) / MAX GET (Nm) :	66	6			66	2		
REPS	6	6	6	6	6	6	6	6
	CONCENTRIC	EXTENSORS						
SPEED(S) (deg/sec)	90	120	180	240	90	120	180	240
PEAK TORQUE (Nm)	137	126	109	105	143	126	118	106
PEAK TORQUE % BW	207%	190%	165%	159%	216%	190%	178%	160%
ANGLE OF PEAK TORQUE	29	29	33	51	44	50	56	53
TORQUE à 40 deg	133	121	103	92	138	121	101	94
TORQUE à 60 deg	103	101	99	75	128	115	105	96
ACCEL TIME (sec)	0.02	0.02	0.03	0.05	0.01	0.02	0.02	0.04
TOTAL WORK (BWR) (J)	147	132	110	96	136	133	110	94
TOTAL WORK (BWR) % BW	222%	200%	166%	145%	206%	201%	166%	142%
AVG POWER (BWR) (watts)	147	176	215	241	148	172	207	250
AVG POWER (BWR) % BW	222%	266%	325%	365%	224%	260%	313%	378%
TAE (J)	14.8	20.5	31.6	41.5	17.2	25.2	33.8	41.1
ASD (Nm)	6	6	8	6	10	12	10	8
SET TOTAL WORK (J)	814	766	614	545	789	709	609	525

SIDE(S) TESTED / DATE :	R	07/09/1992
BW (kgs) / MAX GET (Nm) :	66	2
REPS	60	
SPEED(S) (deg/sec)	90	
PEAK TORQUE (Nm)	122	
PEAK TORQUE % BW	184%	
ANGLE OF PEAK TORQUE	50	
TORQUE à deg		
TORQUE à deg		
ACCEL TIME (sec)	0.02	
TOTAL WORK (BWR) (J)	134	
TOTAL WORK (BWR) % BW	203%	
AVG POWER (BWR) (watts)	125	
AVG POWER (BWR) % BW	189%	
TAE (J)	14.4	
ASD (Nm)	6	
SET TOTAL WORK (J)	5506	
ENDURANCE RATIO	70%	
20% FATIGUE WORK (J)	2408	
20% FATIGUE TIME (sec)	24	

CYBEX TEST : SUBJECT 8

SIDE(S) TESTED / DATE :	R	07/09/1992			L	07/09/1992		
BW (kgs) / MAX GET (Nm) :	65	11			65	0		
REPS	6	6	6	6	6	6	6	6
	CONCENTRIC EXTENSORS							
SPEED(S) (deg/sec)	90	120	180	240	90	120	180	240
PEAK TORQUE (Nm)	148	144	120	110	132	133	109	102
PEAK TORQUE % BW	227%	221%	184%	169%	203%	204%	167%	156%
ANGLE OF PEAK TORQUE	51	44	52	51	53	56	45	53
TORQUE à 40 deg	145	143	118	95	115	117	101	83
TORQUE à 60 deg	138	121	110	91	129	122	105	98
ACCEL TIME (sec)	0.01	0.02	0.03	0.04	0.02	0.03	0.03	0.05
TOTAL WORK (BWR) (J)	156	136	120	96	134	121	99	88
TOTAL WORK (BWR) % BW	240%	209%	184%	147%	206%	186%	152%	135%
AVG POWER (BWR) (watts)	138	183	200	248	133	130	147	162
AVG POWER (BWR) % BW	212%	281%	307%	381%	204%	200%	226%	249%
TAE (J)	19.2	24.6	34.8	46.2	19.3	23.6	33.4	40.7
ASD (Nm)	6	6	6	3	3	10	3	6
SET TOTAL WORK (J)	873	795	675	571	781	551	543	479

SIDE(S) TESTED / DATE :	R	07/09/1992
BW (kgs) / MAX GET (Nm) :	65	12
REPS	60	
SPEED(S) (deg/sec)	90	
PEAK TORQUE (Nm)	138	
PEAK TORQUE % BW	212%	
ANGLE OF PEAK TORQUE	59	
TORQUE à deg		
TORQUE à deg		
ACCEL TIME (sec)	0.01	
TOTAL WORK (BWR) (J)	149	
TOTAL WORK (BWR) % BW	229%	
AVG POWER (BWR) (watts)	153	
AVG POWER (BWR) % BW	235%	
TAE (J)	17.4	
ASD (Nm)	6	
SET TOTAL WORK (J)	6834	
ENDURANCE RATIO	79%	
20% FATIGUE WORK (J)	2411	
20% FATIGUE TIME (sec)	19	

CYBEX TEST : SUBJECT 9

SIDE(S) TESTED / DATE	R	16/09/1992			L	16/09/1992		
BW (kgs) / MAX GET (Nm)	67	0			67	0		
REPS	6	6	6		6	6	6	
	CONCENTRIC EXTENSORS							
SPEED(S) (deg/sec)	90	120	180	240	90	120	180	240
PEAK TORQUE (Nm)	~147	128	114	102	141	132	115	96
PEAK TORQUE % BW	219%	191%	170%	152%	210%	197%	171%	143%
ANGLE OF PEAK TORQUE	57	51	53	63	55	46	55	46
TORQUE à 40 deg	130	121	102	95	130	129	113	96
TORQUE à 60 deg	144	126	106	102	138	122	111	94
ACCEL TIME (sec)	0.02	0.02	0.03	0.04	0.02	0.02	0.04	0.04
TOTAL WORK (BWR) (J)	— 160	144	124	107	159	155	133	106
TOTAL WORK (BWR) % BW	238%	214%	185%	159%	237%	231%	198%	158%
AVG POWER (BWR) (watts)	~ 125	162	203	213	150	161	248	220
AVG POWER (BWR) % BW	186%	241%	302%	317%	224%	240%	370%	328%
TAE (J)	21.0	23.6	32.2	40.0	17.2	22.9	35.8	39.8
ASD (Nm)	7	4	3	3	7	3	3	3
SET TOTAL WORK (J)	920	827	715	608	849	879	754	614

SIDE(S) TESTED / DATE	R	16/09/1992
BW (kgs) / MAX GET (Nm)	67	2
REPS	60	
SPEED(S) (deg/sec)	90	
PEAK TORQUE (Nm)	128	
PEAK TORQUE % BW	191%	
ANGLE OF PEAK TORQUE	57	
TORQUE à deg		
TORQUE à deg		
ACCEL TIME (sec)	0.01	
TOTAL WORK (BWR) (J)	149	
TOTAL WORK (BWR) % BW	222%	
AVG POWER (BWR) (watts)	136	
AVG POWER (BWR) % BW	202%	
TAE (J)	14.5	
ASD (Nm)	4	
SET TOTAL WORK (J)	5417	
ENDURANCE RATIO	67%	
20% FATIGUE WORK (J)	1551	
20% FATIGUE TIME (sec)	15	
20% FATIGUE REPS	[illegible]	

CYBEX TEST : SUBJECT 10

SIDE(S) TESTED / DATE	L	08/09/1992			R	08/09/1992		
BW (kgs) / MAX GET (Nm)	65	0			65	2		
REPS	6	6	6	6	6	6	6	6
	CONCENTRIC EXTENSORS							
SPEED(S) (deg/sec)	90	120	180	240	90	[illegible]	180	240
PEAK TORQUE (Nm)	132	118	102	90	[illegible]	118	110	91
PEAK TORQUE % BW	203%	181%	156%	138%	[illegible]	181%	164%	140%
ANGLE OF PEAK TORQUE	60	53	52	64	[illegible]	[illegible]	49	45
TORQUE à 25 deg	99	90	77	69	102	44	87	73
TORQUE à 65 deg	124	111	86	88	114	104	[illegible]	87
ACCEL TIME (sec)	0.02	0.04	0.03	0.04	0.04	0.02	0.05	0.04
TOTAL WORK (BWR) (J)	156	143	118	98	152	141	125	103
TOTAL WORK (BWR) % BW	240%	220%	181%	150%	[illegible]	216%	192%	158%
AVG POWER (BWR) (watts)	138	103	184	232	121	158	158	229
AVG POWER (BWR) % BW	212%	158%	283%	356%	[illegible]	243%	244%	352%
TAE (J)	15.8	19.6	26.9	35.5	[illegible]	16.2	26.3	34.9
ASD (Nm)	3	3	2	3	[illegible]	[illegible]	[illegible]	2
SET TOTAL WORK (J)	910	804	681	572	[illegible]	796	[illegible]	597

SIDE(S) TESTED / DATE	L	08/09/1992
BW (kgs) / MAX GET (Nm)	65	0
REPS	60	
SPEED(S) (deg/sec)	90	
PEAK TORQUE (Nm)	128	
PEAK TORQUE % BW	196%	
ANGLE OF PEAK TORQUE	55	
TORQUE à 25 deg	91	
TORQUE à 65 deg	118	
ACCEL TIME (sec)	0.02	
TOTAL WORK (BWR) (J)	155	
TOTAL WORK (BWR) % BW	238%	
AVG POWER (BWR) (watts)	126	
AVG POWER (BWR) % BW	193%	
TAE (J)	14.9	
ASD (Nm)	4	
SET TOTAL WORK (J)	6071	
ENDURANCE RATIO	68%	
20% FATIGUE WORK (J)	[illegible]	
20% FATIGUE TIME (sec)	[illegible]	
[illegible]	[illegible]	

CYBEX TEST : SUBJECT 11

SIDE(S) TESTED / DATE :	R 08/09/1992				L 08/09/1992			
BW (kgs) / MAX GET (Nm) :	58	2			58	0		
REPS	6	6	6	6	6	6	6	6
	CONCENTRIC EXTENSORS							
SPEED(S) (deg/sec)	90	120	180	240	90	120	180	240
PEAK TORQUE (Nm)	134	124	110	95	130	134	113	107
PEAK TORQUE % BW	231%	213%	189%	163%	224%	231%	194%	184%
ANGLE OF PEAK TORQUE	47	48	52	74	27	36	42	53
TORQUE à 60 deg	129	115	98	83	117	107	107	91
TORQUE à 40 deg	132	122	102	92	126	130	113	86
ACCEL TIME (sec)	0.02	0.02	0.04	0.04	0.05	0.05	0.04	0.05
TOTAL WORK (BWR) (J)	179	160	136	114	164	160	134	111
TOTAL WORK (BWR) % BW	308%	275%	234%	196%	282%	275%	231%	191%
AVG POWER (BWR) (watts)	155	187	243	266	149	182	255	263
AVG POWER (BWR) % BW	267%	322%	418%	458%	256%	313%	439%	453%
TAE (J)	17.3	21.8	29.8	36.8	18.9	22.8	32.8	42.4
ASD (Nm)	4	4	3	2	3	3	3	3
SET TOTAL WORK (J)	1017	909	776	651	956	924	770	627

SIDE(S) TESTED / DATE :	R 08/09/1992	
BW (kgs) / MAX GET (Nm)	58	0
REPS	60	
SPEED(S) (deg/sec)	90	
PEAK TORQUE (Nm)	140	
PEAK TORQUE % BW	241%	
ANGLE OF PEAK TORQUE	43	
TORQUE à deg		
TORQUE à deg		
ACCEL TIME (sec)	0.08	
TOTAL WORK (BWR) (J)	[illegible]	
TOTAL WORK (BWR) % BW	306%	
AVG POWER (BWR) (watts)	131	
AVG POWER (BWR) % BW	225%	
TAE (J)	[illegible]	
ASD (Nm)	4	
[illegible]	[illegible]	

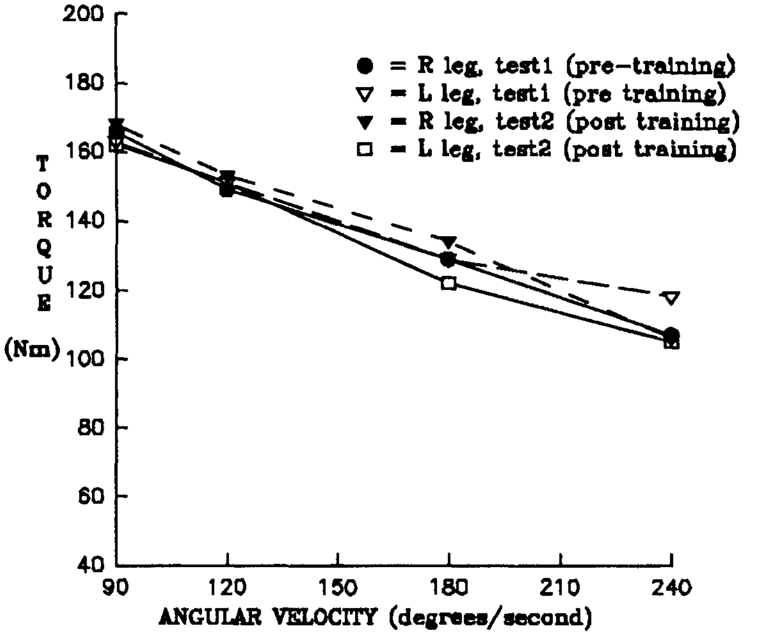
CYBEX TEST : SUBJECT 12

SIDE(S) TESTED / DATE :	RI	20/08/1992			LU	20/08/1992		
BW (kgs) / MAX GET (Nm) :	62	0			62	0		
REPS	6	6	6	6	6	6	6	6
	CONCENTRIC EXTENSORS							
SPEED(S) (deg/sec)	90	120	180	240	90	120	180	240
PEAK TORQUE (Nm)	125	109	91	79	117	113	87	75
PEAK.TORQUE % BW	201%	175%	146%	127%	188%	182%	140%	120%
ANGLE OF PEAK TORQUE	53	44	47	54	65	61	65	69
TORQUE à 25 deg	103	98	80	71	68	68	60	48
TORQUE à 75 deg	84	79	60	41	106	95	72	71
ACCEL TIME (sec)	0.03	0.04	0.04	0.05	0.01	0.02	0.04	0.00
TOTAL WORK (BWR) (J)	148	134	109	88	137	125	106	76
TOTAL WORK (BWR) % BW	238%	216%	175%	141%	220%	201%	170%	122%
AVG POWER (BWR) (watts)	118	146	168	196	116	133	162	151
AVG POWER (BWR) % BW	190%	235%	270%	316%	187%	214%	261%	243%
TAE (J)	12.2	16.4	23.3	32.7	12.7	17.0	24.8	32.8
ASD (Nm)	4	4	3	4	3	4	3	18
SET TOTAL WORK (J)	841	749	625	494	793	713	572	377

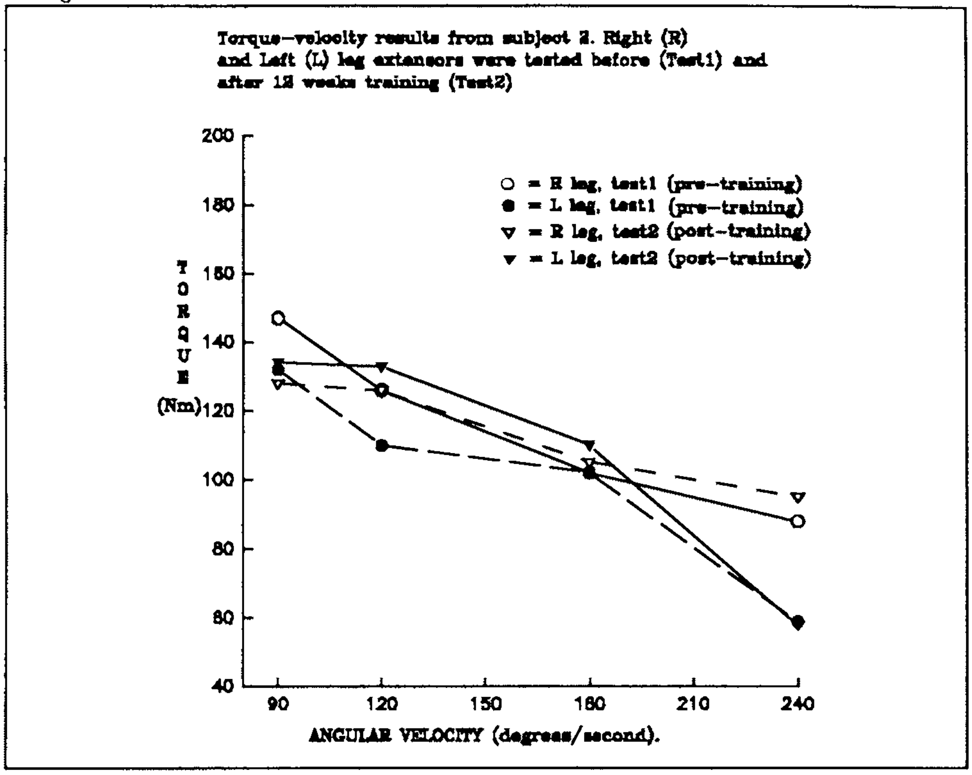
INDIVIDUAL PEAK TORQUE GRAPHS

Subject 1

Torque–velocity results from subject 1. Right (R) and Left (L) leg extensors were tested before (Test1) and after 12 weeks training (Test2).

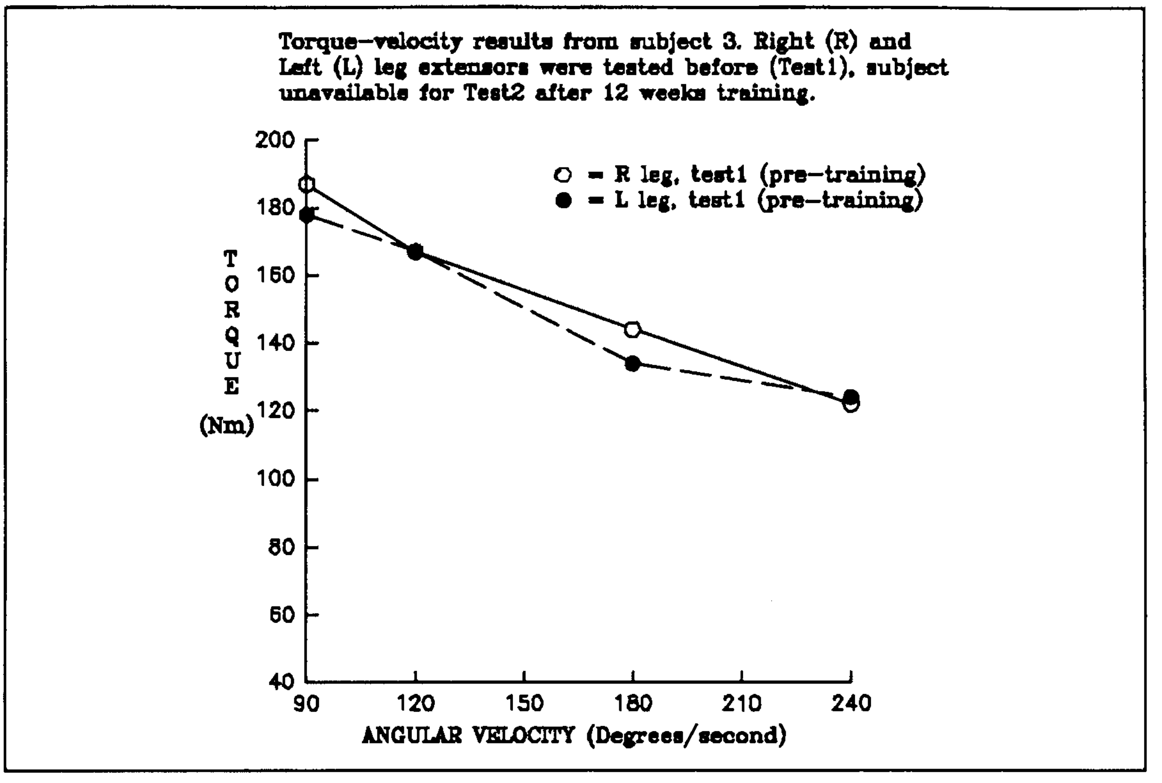


Subject 2

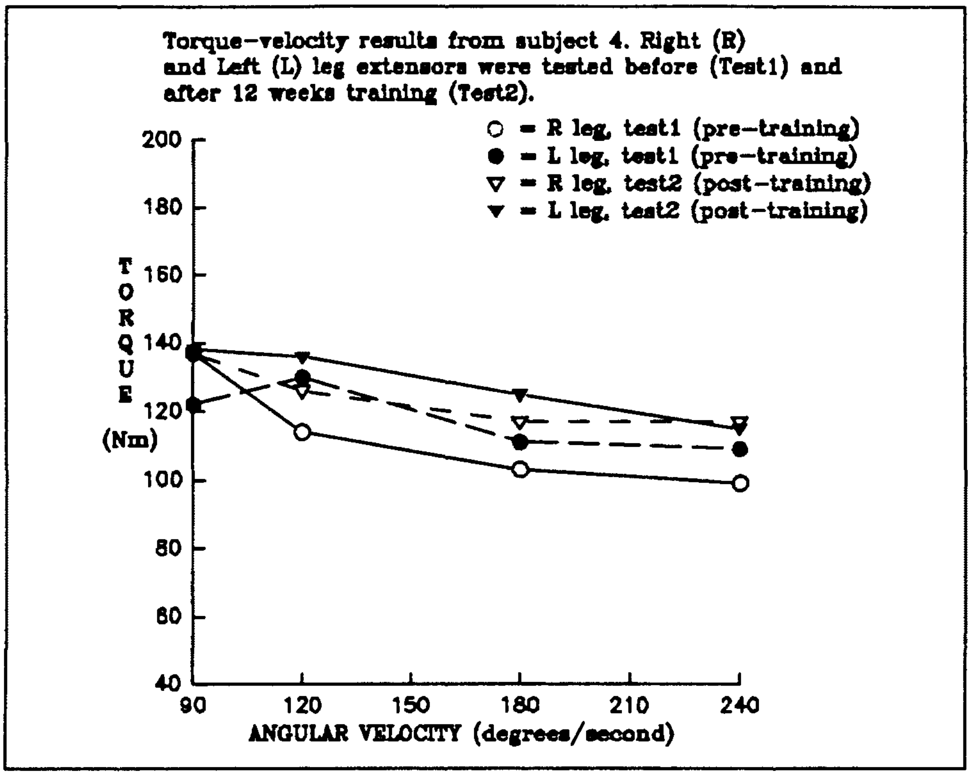


Torque-velocity results from subject 2. Right (R) and Left (L) leg extensors were tested before (Test1) and after 12 weeks training (Test2)
○ = R leg, test1 (pre-training)
● = L leg, test1 (pre-training)
▽ = R leg, test2 (post-training)
▼ = L leg, test2 (post-training)
TORQUE (Nm)
200
180
160
140
120
100
80
60
40
90
120
150
180
210
240
ANGULAR VELOCITY (degrees/second).

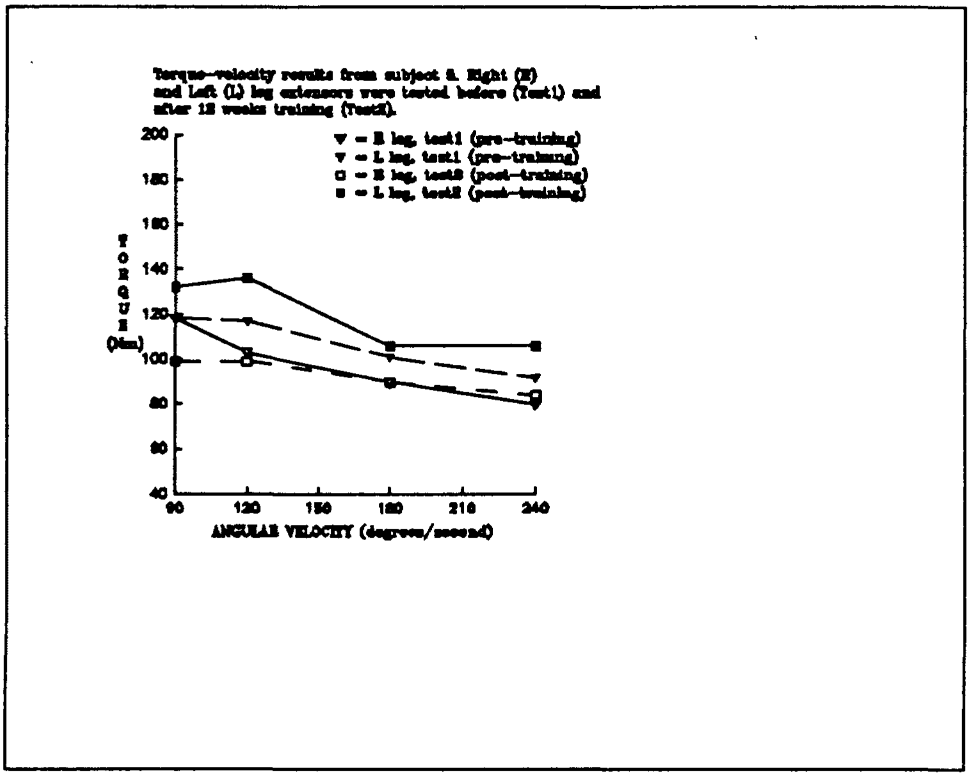
Subject 3


Torque–velocity results from subject 3. Right (R) and Left (L) leg extensors were tested before (Test1), subject unavailable for Test2 after 12 weeks training.
○ = R leg, test1 (pre–training)
● = L leg, test1 (pre–training)
TORQUE (Nm)
200
180
160
140
120
100
80
60
40
90
120
150
180
210
240
ANGULAR VELOCITY (Degrees/second)

Subject 4

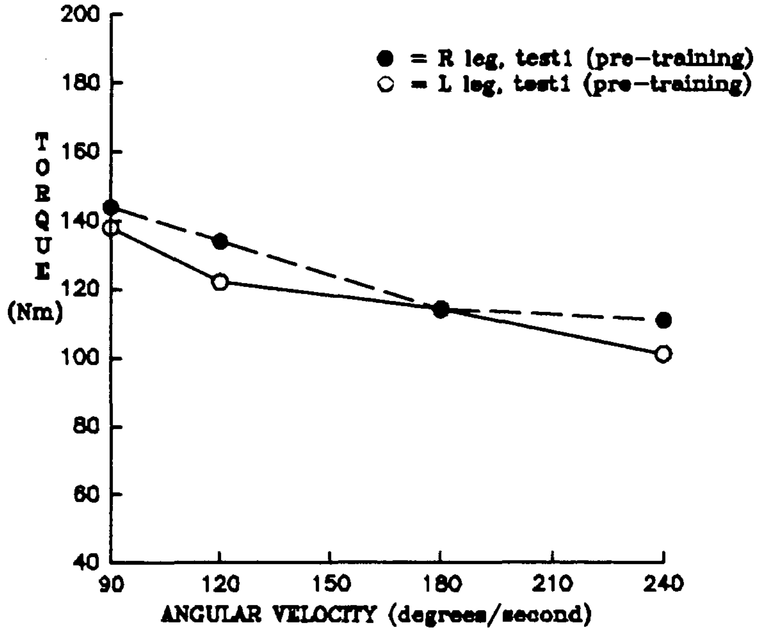

Torque-velocity results from subject 4. Right (R) and Left (L) leg extensors were tested before (Test1) and after 12 weeks training (Test2).
○ = R leg, test1 (pre-training)
● = L leg, test1 (pre-training)
▽ = R leg, test2 (post-training)
▼ = L leg, test2 (post-training)
TORQUE (Nm)
200
180
160
140
120
100
80
60
40
90
120
150
180
210
240
ANGULAR VELOCITY (degrees/second)

Subject 5


200
140
120
100
40
90
120
150
210
240
ANGULAR VELOCITY (degrees/second)

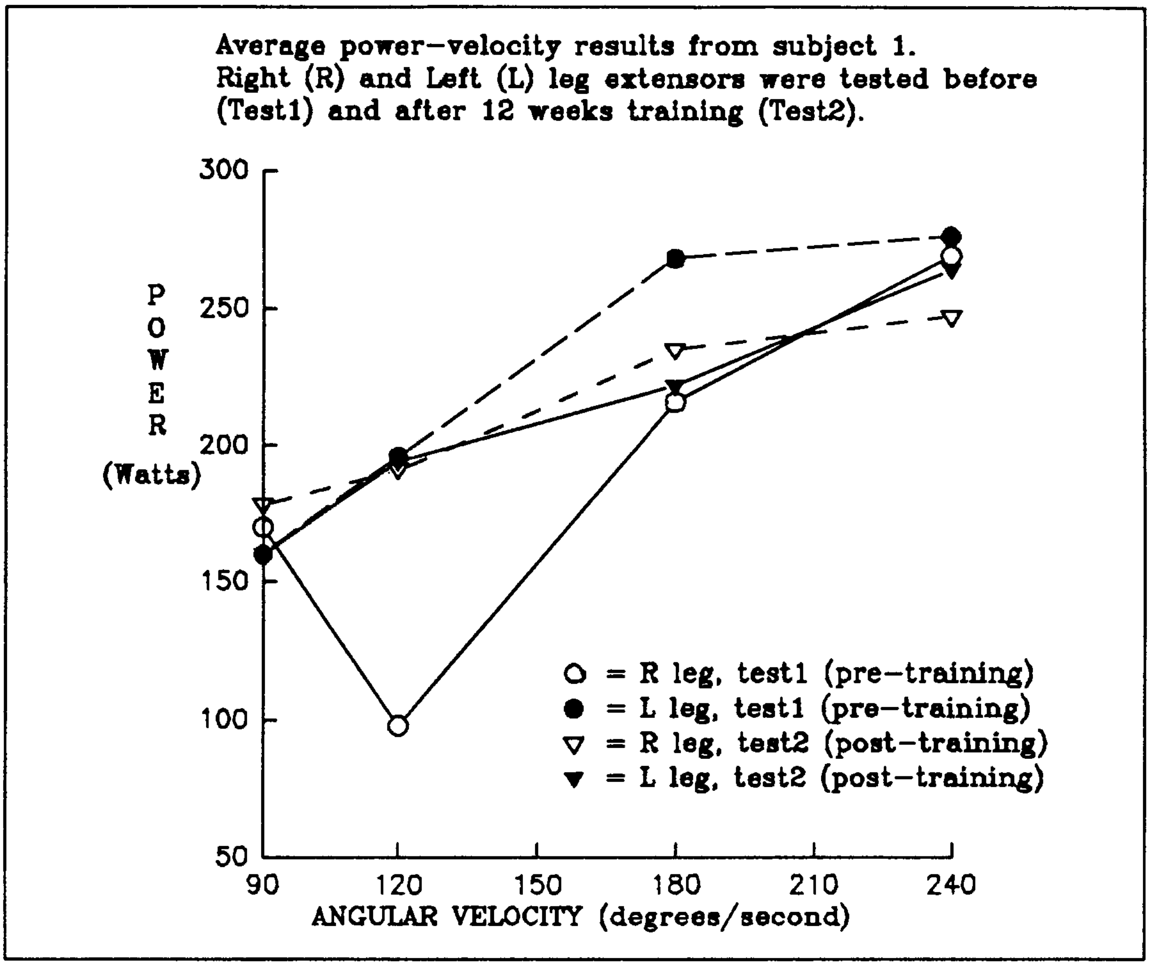
Subject 6

Torque-velocity results from subject 6. Right (R) and Left (L) leg extensors were tested before (Test1), subject unavailable for Test2 after 12 weeks training.

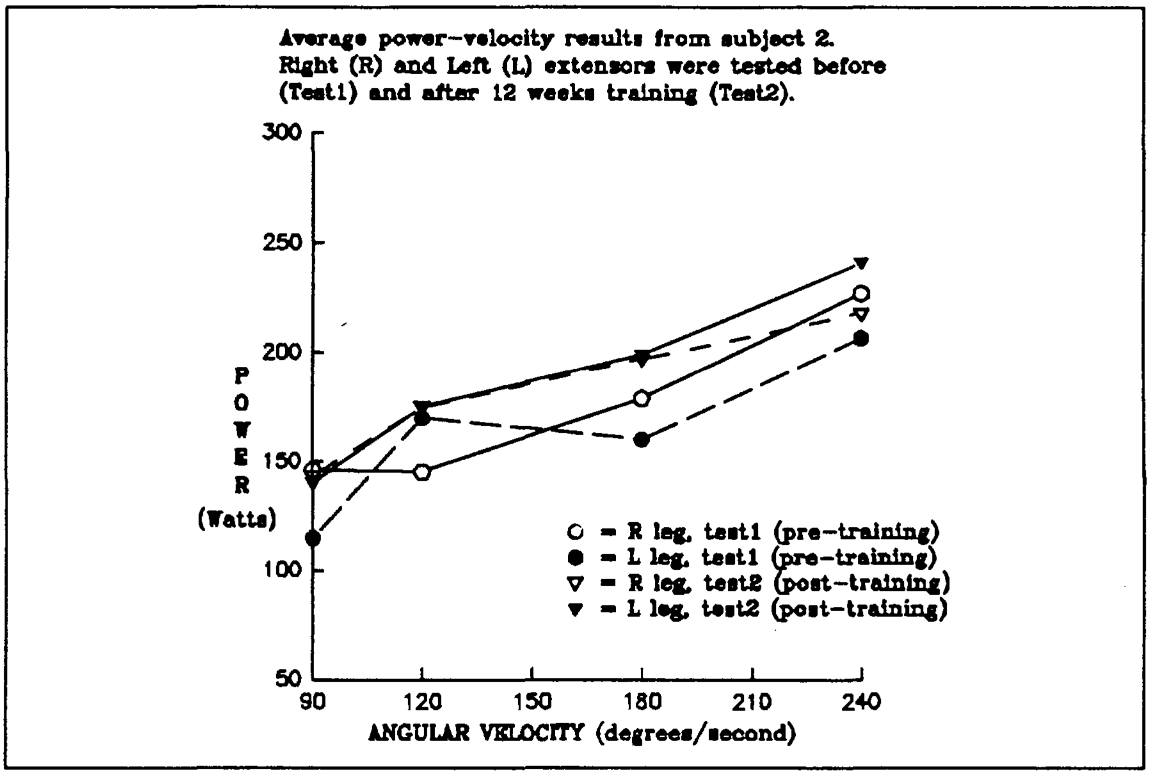


INDIVIDUAL AVERAGE POWER GRAPHS

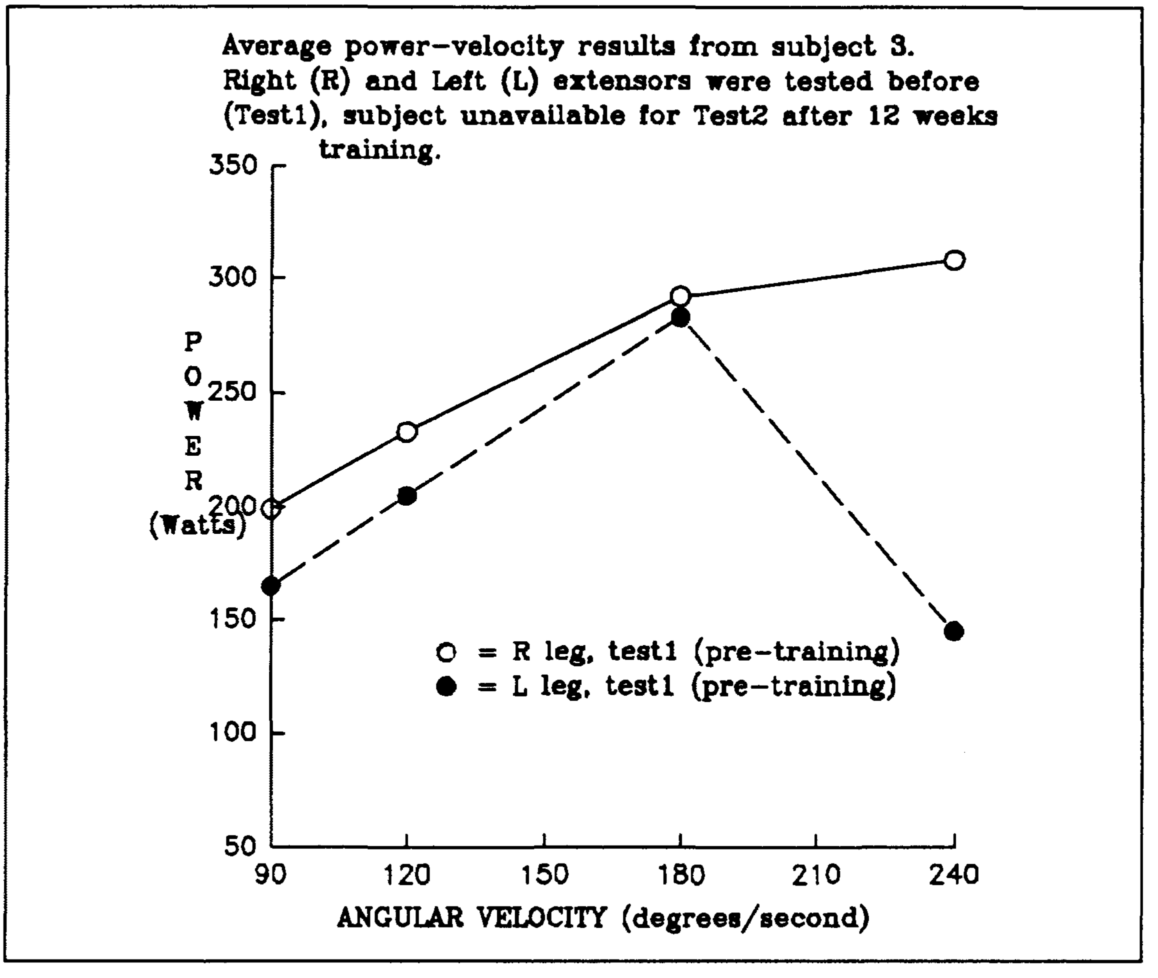
Subject 1



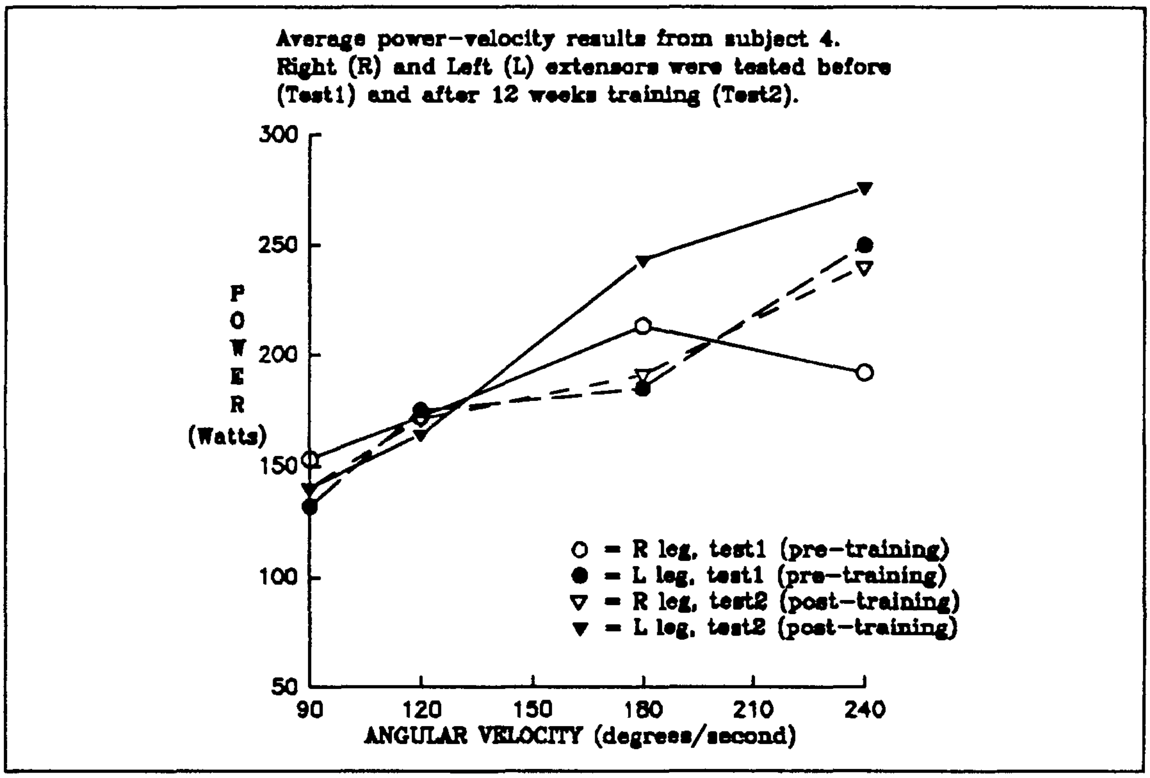
Subject 2


Average power-velocity results from subject 2.
Right (R) and Left (L) extensors were tested before
(Test1) and after 12 weeks training (Test2).
POWER (Watts)
300
250
200
150
100
50
90
120
150
180
210
240
ANGULAR VELOCITY (degrees/second)
○ = R leg, test1 (pre-training)
● = L leg, test1 (pre-training)
▽ = R leg, test2 (post-training)
▼ = L leg, test2 (post-training)

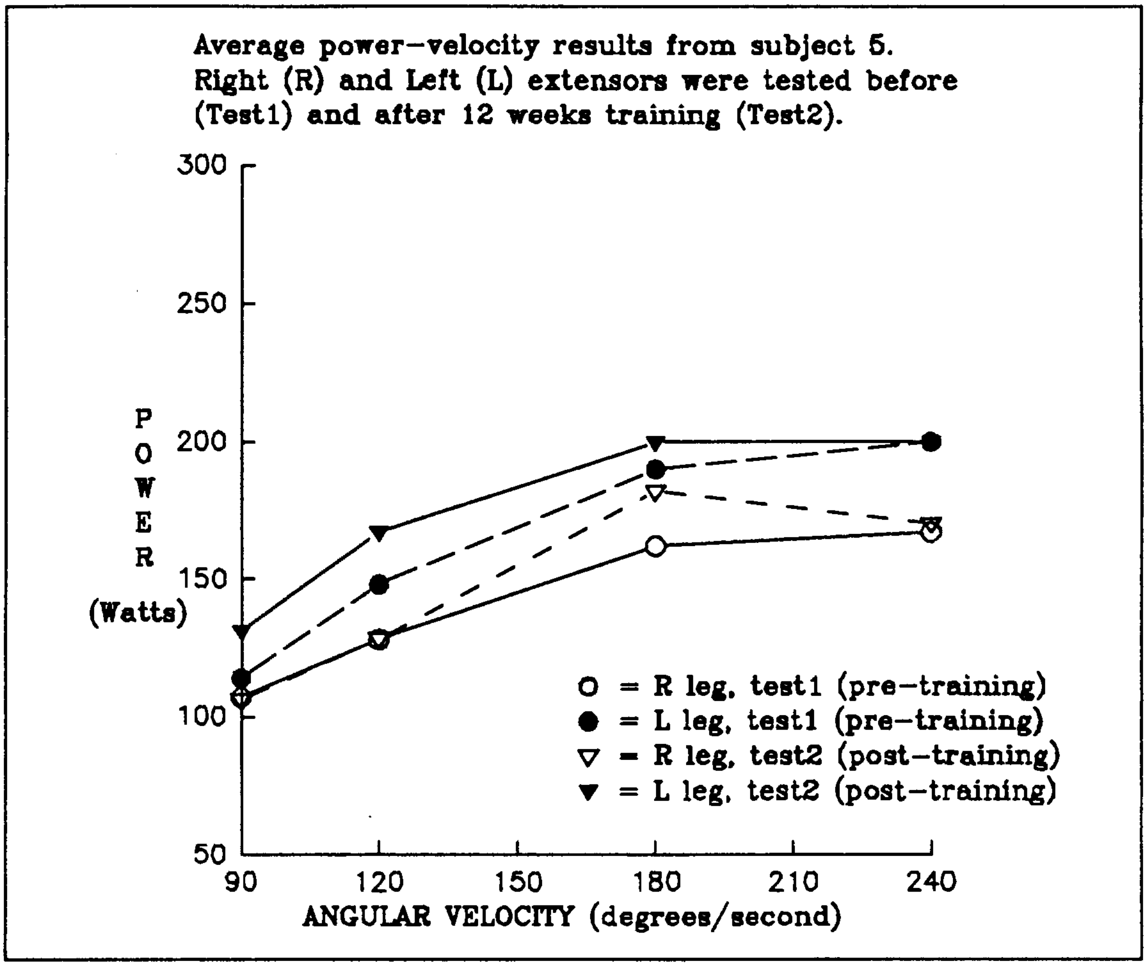
Subject 3


Average power-velocity results from subject 3.
Right (R) and Left (L) extensors were tested before (Test1), subject unavailable for Test2 after 12 weeks training.
350
300
250
200
150
100
50
P
O
W
E
R
(Watts)
90
120
150
180
210
240
ANGULAR VELOCITY (degrees/second)
○ = R leg, test1 (pre-training)
● = L leg, test1 (pre-training)

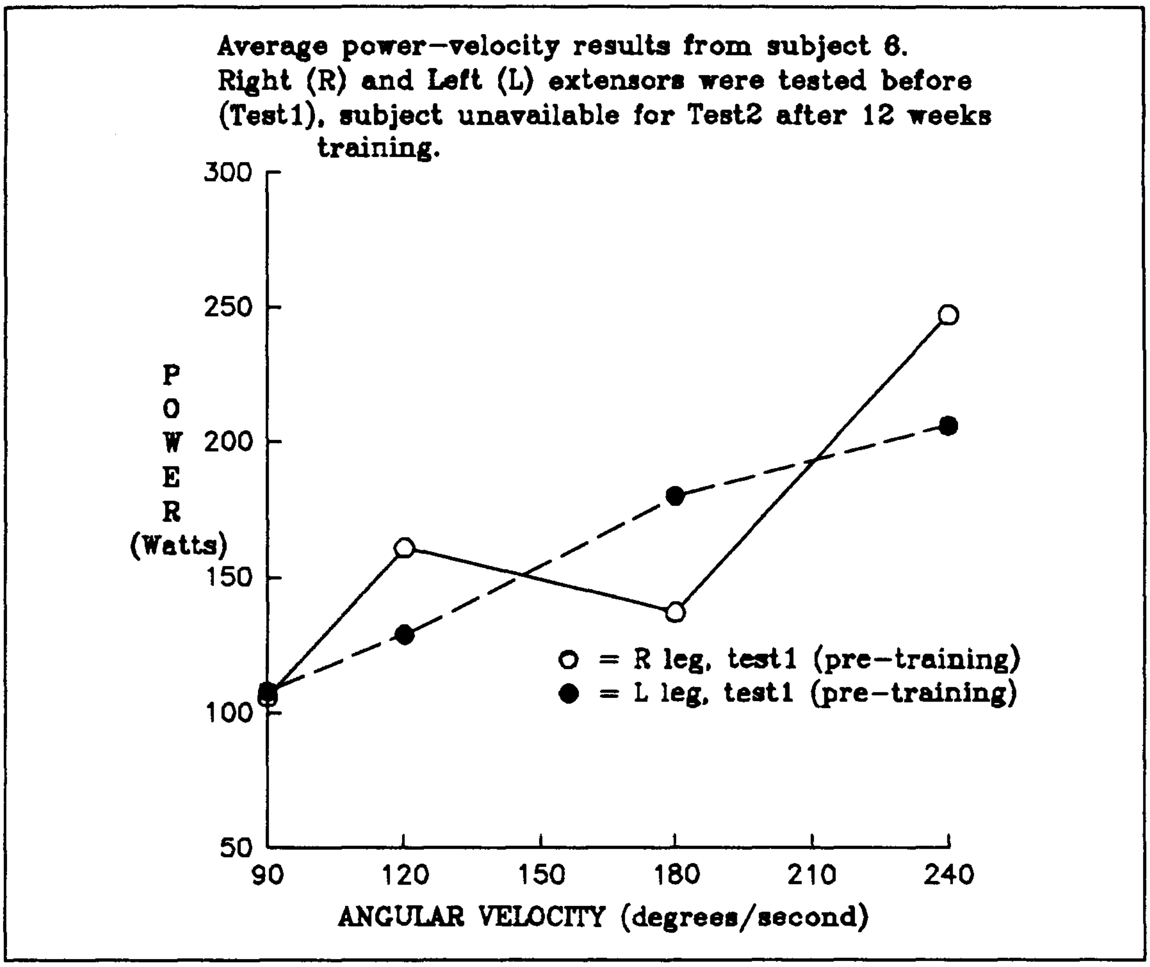
Subject 4


Average power-velocity results from subject 4.
Right (R) and Left (L) extensors were tested before
(Test1) and after 12 weeks training (Test2).
POWER (Watts)
300
250
200
150
100
50
90
120
150
180
210
240
ANGULAR VELOCITY (degrees/second)
○ = R leg, test1 (pre-training)
● = L leg, test1 (pre-training)
▽ = R leg, test2 (post-training)
▼ = L leg, test2 (post-training)

Subject 5


Average power–velocity results from subject 5.
Right (R) and Left (L) extensors were tested before
(Test1) and after 12 weeks training (Test2).
300
250
200
150
100
50
POWER
(Watts)
90
120
150
180
210
240
ANGULAR VELOCITY (degrees/second)
○ = R leg, test1 (pre–training)
● = L leg, test1 (pre–training)
▽ = R leg, test2 (post–training)
▼ = L leg, test2 (post–training)

Subject 6


Average power-velocity results from subject 6.
Right (R) and Left (L) extensors were tested before
(Test1), subject unavailable for Test2 after 12 weeks
training.
300
250
200
150
100
50
P
O
W
E
R
(Watts)
90
120
150
180
210
240
ANGULAR VELOCITY (degrees/second)
o = R leg, test1 (pre-training)
● = L leg, test1 (pre-training)