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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**

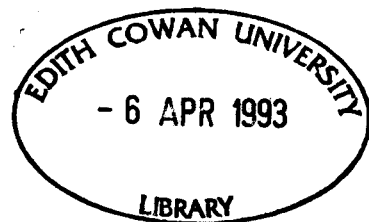
BY

Carmel A. Shipway

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

The Use of Thesis statement is not included in this version of the 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 $\dot{V}O_2$, 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

Date18-1-93.....

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Chapter 1

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 oligomenorrhoea. 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 trials 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 VO₂ 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 VO₂. 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/cm².

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.

Assumptions and limitations to study

Assumptions:

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 | 172.9 | 65.0 | 63.4 | 99.4 | 80.3 | 3.8 | 3.7 |
| ± 1.3 | ± 1.7 | ± 1.2 | ± 1.3 | ± 2.2 | ± 5.8 | ± 0.1 | ± 0.1 |
| | | | * | | ** | | |

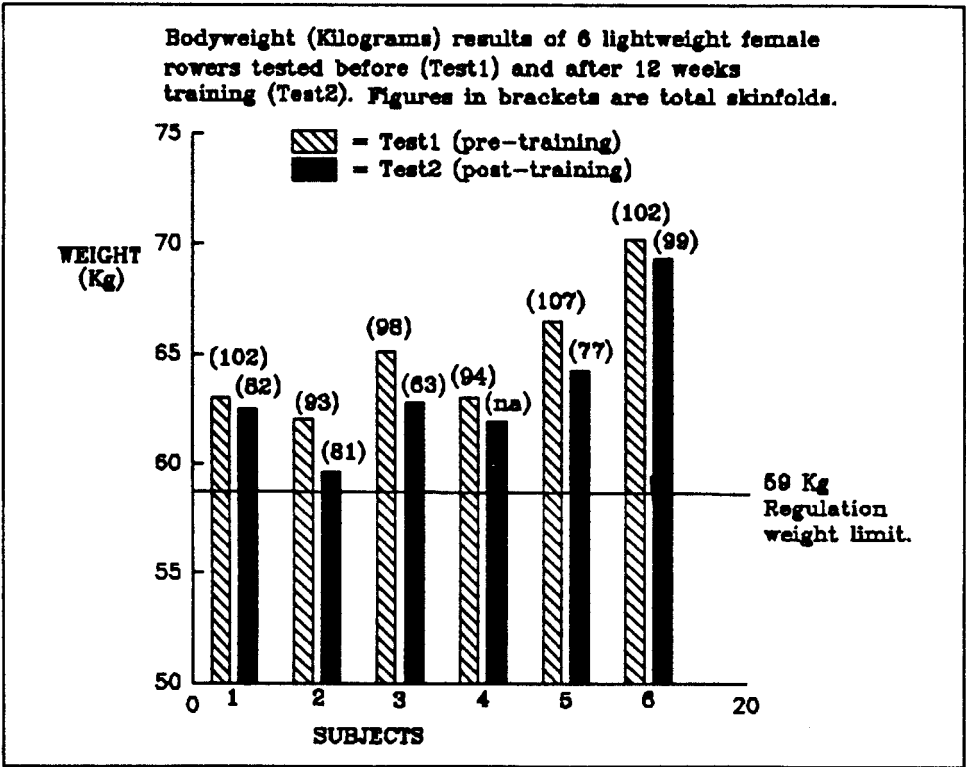
^a = subject unavailable for testing.

Group values expressed as mean \pm SE.

* = significant at <0.05 level.

** = significant at <0.05 level.

Figure 1



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 | 20.7 | 64.5 | 107.8 |
| 15 | 1.051 | | +/-0.0 | +/-1.4 | +/-1.2 | +/-6.3 |
| 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 |
| <hr/> | | | | |
| 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 |
| <hr/> | | | | |
| 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 |
| <hr/> | | | | |
| 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 |
| <hr/> | | | | |
| 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 |
| <hr/> | | | | |

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 | | Post-training | |
|---------|--------------|--------|---------------|--------|
| | R | L | R | 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 |
| <hr/> | | | | |
| | 1.0 | 1.0 | 1.0 | 1.0 |
| | +/-0.0 | +/-0.0 | +/-0.0 | +/-0.0 |
| <hr/> | | | | |
| 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 |
| <hr/> | | | | |
| | 0.9 | 0.9 | 1.0 | 1.0 |
| | +/-0.0 | +/-0.0 | +/-0.0 | +/-0.0 |
| <hr/> | | | | |
| 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 |
| <hr/> | | | | |
| | 0.7 | 0.8 | 0.8 | 0.8 |
| | +/-0.0. | +/-0.0 | +/-0.0 | +/-0.0 |
| <hr/> | | | | |
| 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 |
| <hr/> | | | | |
| | 0.7 | 0.7 | 0.8 | 0.7 |
| | +/-0.0 | +/-0.0 | +/-0.0 | +/-0.0 |
| <hr/> | | | | |

Figure 2.a

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

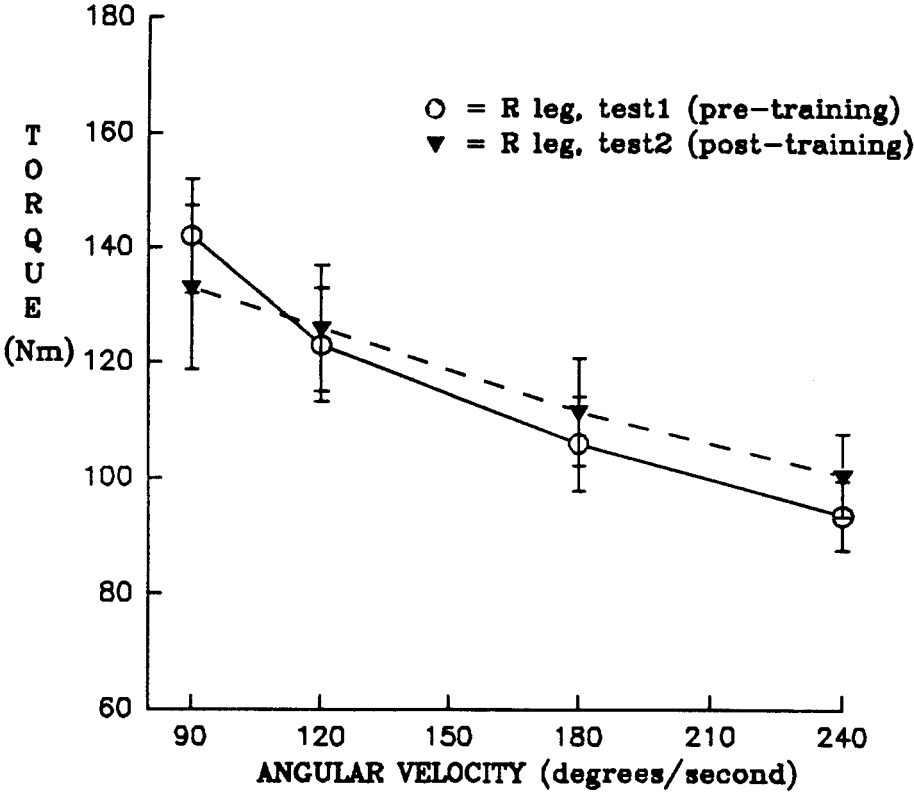


Figure 2.b

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

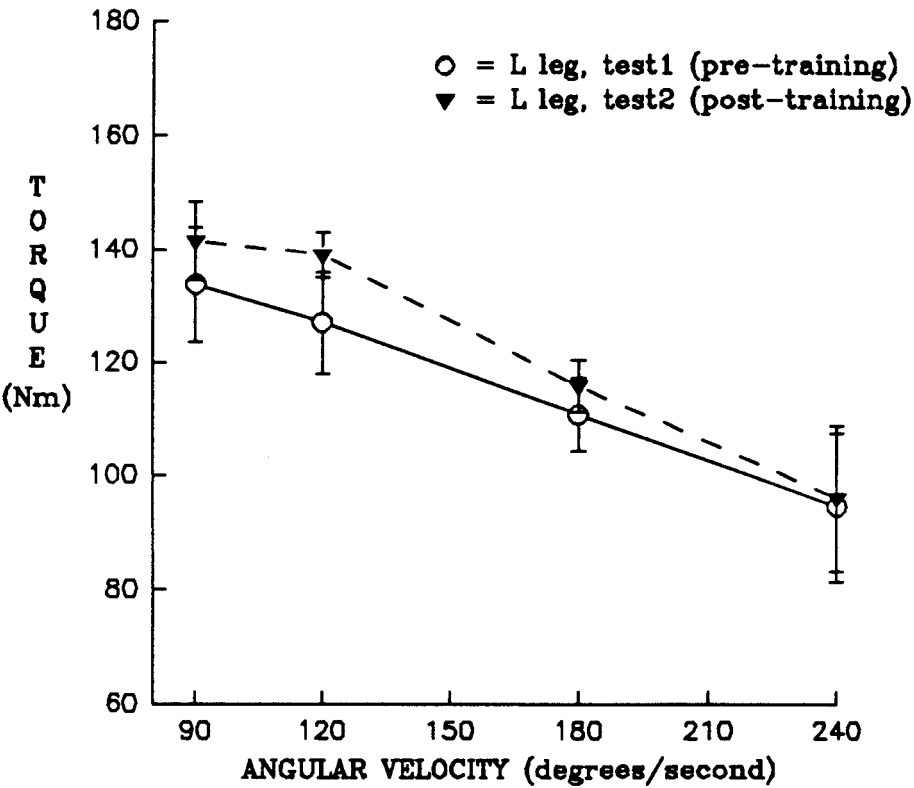


Figure 3.a

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

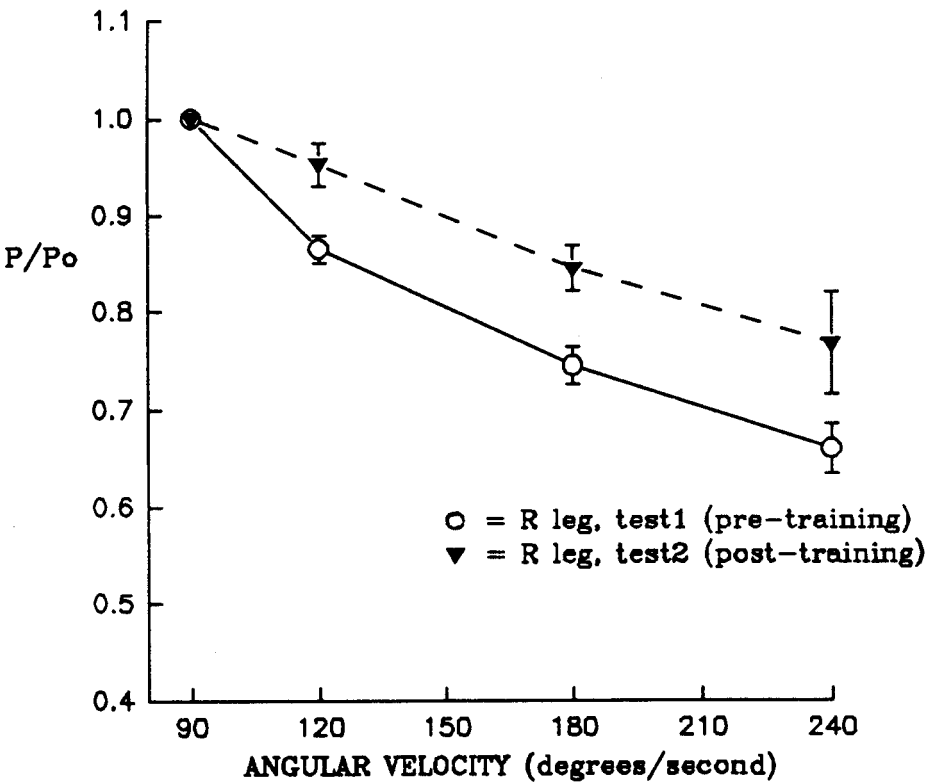
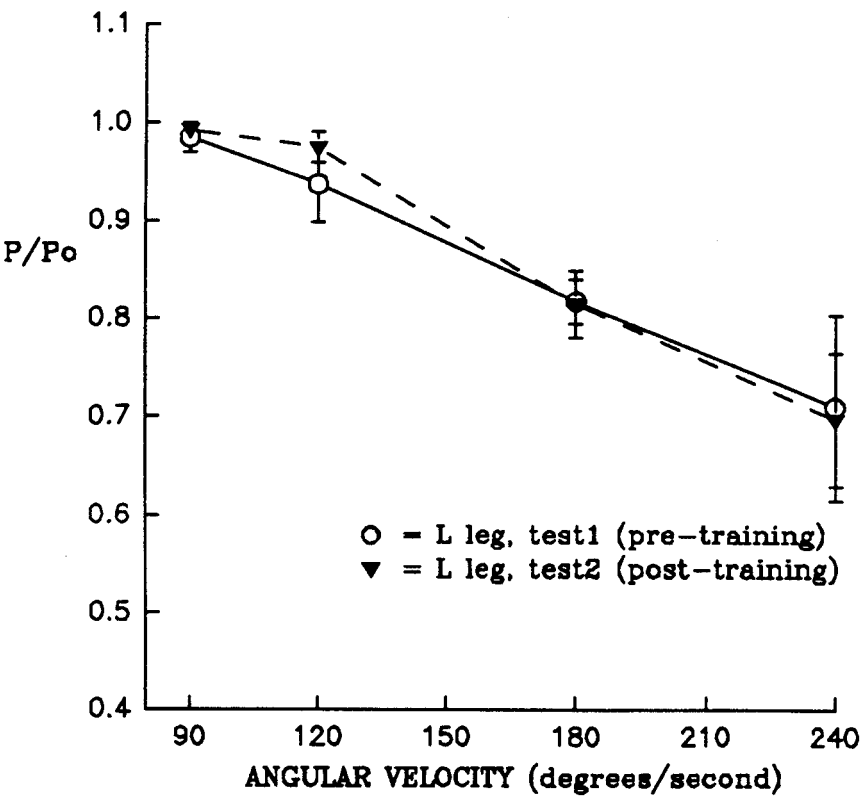


Figure 3.b

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 \pm se, n=4)

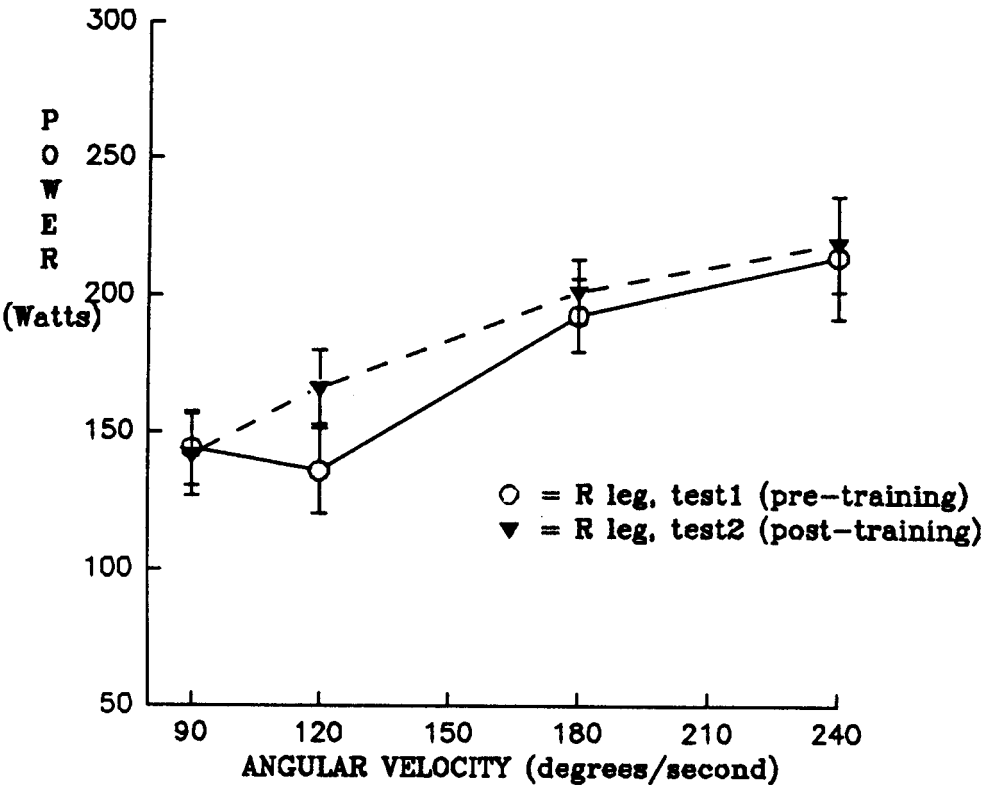
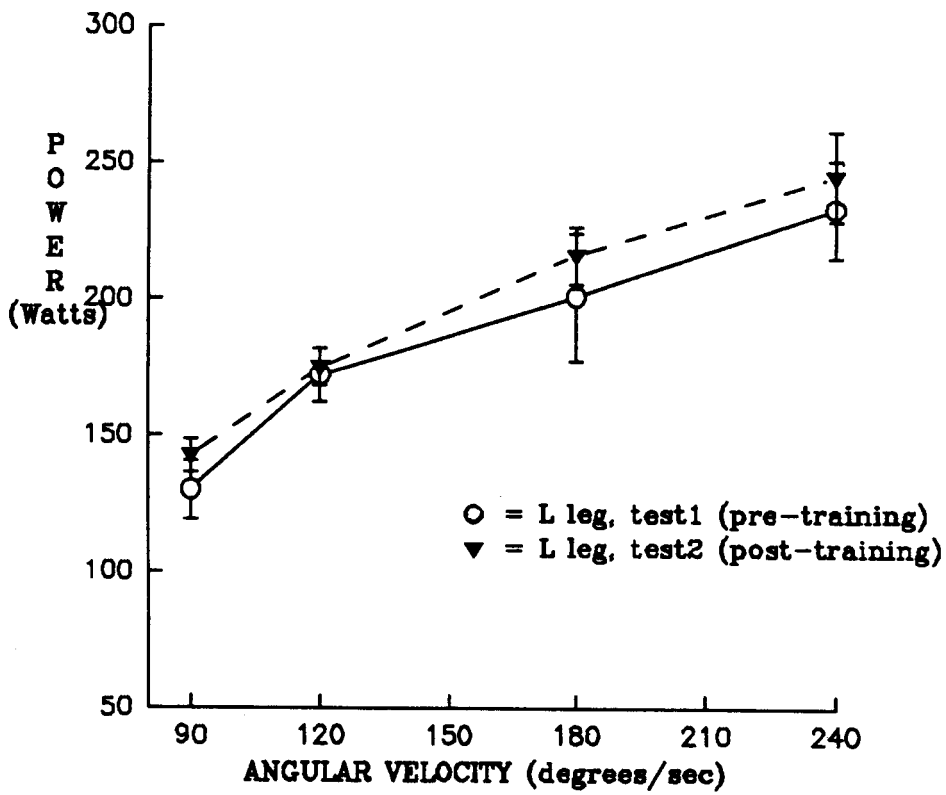


Figure 4.b

Average Power at angular velocities of 90 to 240 degs/sec in the left legs of female rowers.
(means \pm se, n=4)



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 | 22.5 | 19.7 | 1953.5 | 2396.8 | 22.7 |
| | +/-3.6 | +/-1.9 | | +/-254.0 | +/-182.0 | |

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 | 9:61.8 |
| | ± 6.18 | ± 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 comparative 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 occurring.

The power produced during the whole of a rowing stroke is perhaps a more relevant 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 | 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 | |
| <hr/> | | | | |
| 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

| SIDE(S) TESTED / DATE | R | 07/09/1992 | R | 07/12/1992 | PROGRESS |
|-------------------------|------|------------|------|------------|----------|
| BW (kgs) / MAX GET (Nm) | 62 | 2 | 6 | 0 | |
| REPS | 6 | 6 | 6 | 6 | 6 |
| SPEED(S) (deg/sec) | 90 | 120 | 180 | 240 | 240 |
| PEAK TORQUE (Nm) | 166 | 149 | 129 | 107 | 104 |
| PEAK TORQUE % BW | 267% | 240% | 208% | 172% | 173% |
| ANGLE OF PEAK TORQUE | 46 | 54 | 57 | 47 | 45 |
| TORQUE @ 40 deg | 163 | 148 | 125 | 105 | 105 |
| TORQUE @ 60 deg | 151 | 140 | 125 | 98 | 102 |
| ACCEL TIME (sec) | 0.01 | 0.03 | 0.04 | 0.05 | 0.04 |
| TOTAL WORK (BNR) (J) | 193 | 172 | 144 | 114 | 115 |
| TOTAL WORK (BWR) % BW | 311% | 277% | 232% | 183% | 188% |
| AVG POWER (BWR) (watts) | 170 | 98 | 216 | 269 | 247 |
| AVG POWER (BWR) % BW | 274% | 158% | 348% | 433% | 404% |
| TAE (J) | 17.1 | 21.6 | 33.6 | 46.2 | 43.5 |
| ASD (Nm) | 4 | 3 | 4 | 3 | 3 |
| SET TOTAL WORK (J) | 1105 | 968 | 822 | 646 | 651 |

| SIDE(S) | TESTED / DATE | L | 07/09/1992 | L | 07/12/1992 | PROGRESS |
|-------------------------|---------------|------|------------|------|------------|----------|
| BW (kgs) / MAX GET (Nm) | 62 | 6 | 0 | 61 | 0 | 6 |
| REPS | | | | | | |
| SPEED(S) (deg/sec) | 90 | 120 | 180 | 240 | 120 | 180 |
| PEAK TORQUE (Nm) | 163 | 151 | 129 | 118 | 162 | 122 |
| PEAK TORQUE % BW | 262% | 243% | 208% | 190% | 265% | 200% |
| ANGLE OF PEAK TORQUE | 49 | 51 | 46 | 60 | 57 | 58 |
| TORQUE @ 40 deg | 160 | 147 | 128 | 96 | 141 | 113 |
| TORQUE @ 60 deg | 148 | 137 | 121 | 118 | 160 | 121 |
| ACCEL TIME (sec) | 0.02 | 0.03 | 0.04 | 0.05 | 0.02 | 0.04 |
| TOTAL WORK (BWR) (J) | 125 | 164 | 134 | 110 | 136 | 110 |
| TOTAL WORK (BWR) % BW | 282% | 264% | 216% | 177% | 288% | 226% |
| AVG POWER (BWR) (watts) | 160 | 196 | 268 | 276 | 160 | 222 |
| AVG POWER (BWR) % BW | 258% | 316% | 432% | 445% | 262% | 353% |
| TAE (J) | 17.6 | 24.6 | 35.7 | 47.2 | 17.5 | 34.0 |
| ASD (Nm) | 3 | 4 | 4 | 3 | 4 | 4 |
| SET TOTAL WORK (J) | 1014 | 914 | 764 | 627 | 1004 | 783 |
| | | | | | | 623 |

SUBJECT 1 (Cont)

| SIDE(S) TESTED / DATE | R | 07/09/1992 | R | 02.12.1992 | PROGRESS |
|-------------------------|------|------------|------|------------|----------|
| BW (Kgs) / MAX SET (Nm) | 62 | 2 | 62 | 2 | |
| REPS | 60 | | 60 | | |
| CONCENTRIC EXTENSORS | | | | | |
| SPEED(S) (deg/sec) | 90 | | 90 | | 90 |
| PEAK TORQUE (Nm) | 159 | | 160 | | 6% |
| PEAK TORQUE % BW | 256% | | 258% | | |
| ANGLE OF PEAK TORQUE | 45 | | 51 | | |
| TORQUE Å deg | | | | | |
| TORQUE Å 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 | | | | | |

| SIDE(S) TESTED / DATE | R 07/09/1992 | | | F 12/1992 | | | PROGRESS |
|-------------------------|--------------|------|------|-----------|------|------|----------|
| | 61 | 6 | 6 | 61 | 6 | 6 | |
| BW (kgs) / MAX GET (Nm) | 61 | 6 | 6 | 61 | 6 | 6 | |
| REPS | 6 | 6 | 6 | 6 | 6 | 6 | |
| CONCENTRIC EXTENSORS | | | | | | | |
| SPEED(S) (deg/sec) | 90 | 120 | 180 | 240 | 90 | 120 | 180 |
| PEAK TORQUE (Nm) | 147 | 126 | 102 | 88 | 139 | 126 | 105 |
| PEAK TORQUE % BW | 240% | 206% | 167% | 144% | 236% | 206% | 172% |
| ANGLE OF PEAK TORQUE | 41 | 41 | 42 | 56 | 40 | 48 | 47 |
| TORQUE A 40 deg | 147 | 126 | 101 | 82 | 127 | 121 | 99 |
| TORQUE A 60 deg | 124 | 105 | 87 | 88 | 117 | 104 | 90 |
| ACCEL TIME (sec) | 0.04 | 0.03 | 0.04 | 0.05 | 0.03 | 0.04 | 0.05 |
| TOTAL WORK (BWR) (J) | 146 | 133 | 105 | 91 | 149 | 143 | 111 |
| TOTAL WORK (BWR) % BW | 242% | 218% | 173% | 149% | 244% | 204% | 181% |
| AVG POWER (BWR) (watts) | 146 | 145 | 179 | 227 | 143 | 173 | 197 |
| AVG POWER (BWR) % BW | 239% | 237% | 293% | 372% | 234% | 266% | 322% |
| TAE (J) | 17.4 | 20.9 | 27.8 | 37.5 | 16.5 | 20.3 | 30.6 |
| ASD (Nm) | 6 | 6 | 2 | 3 | 2 | 3 | 2 |
| SET TOTAL WORK (J) | 852 | 751 | 608 | 514 | 840 | 742 | 644 |
| | | | | | -1% | 6% | 5% |
| | | | | | | | 4% |

| SIDE(S) TESTED / DATE | L 07/09/1992 | | | | L 12/1992 | | | | PROGRESS |
|-------------------------|--------------|------|------|------|-----------|------|------|------|----------|
| BW (kgs) / MAX GET (Nm) | 61 | 6 | 6 | 6 | 61 | 6 | 6 | 6 | |
| 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) | 132 | 110 | 102 | 96 | 134 | 133 | 110 | 103 | |
| PEAK TORQUE % BW | 216% | 180% | 167% | 157% | 218% | 214% | 180% | 168% | |
| ANGLE OF PEAK TORQUE | 46 | 52 | 62 | 59 | 42 | 43 | 41 | 36 | |
| TORQUE @ 40 deg | 132 | 110 | 99 | 73 | 134 | 142 | 110 | 84 | |
| TORQUE @ 60 deg | 117 | 95 | 102 | 95 | 124 | 117 | 106 | 103 | |
| ACCEL TIME (sec) | 0.02 | 0.02 | 0.03 | 0.04 | 0.05 | 0.04 | 0.05 | 0.06 | |
| TOTAL WORK (BWR) (J) | 137 | 121 | 99 | 84 | 141 | 141 | 110 | 94 | |
| TOTAL WORK (BWR) % BW | 224% | 198% | 162% | 137% | 240% | 214% | 180% | 154% | |
| AVG POWER (BWR) (watts) | 115 | 170 | 160 | 207 | 140 | 171 | 199 | 241 | |
| AVG POWER (BWR) % BW | 188% | 278% | 262% | 339% | 229% | 266% | 325% | 395% | |
| TAE (J) | 17.2 | 21.9 | 31.1 | 40.0 | 17.2 | 21.3 | 31.6 | 40.7 | |
| ASD (Nm) | 10 | 3 | 2 | 3 | 4 | 3 | 3 | 3 | |
| SET TOTAL WORK (J) | 765 | 669 | 572 | 495 | 816 | 713 | 640 | 548 | |
| | | | | | 6% | 17% | 11% | 10% | |

SUBJECT 2 (cont)

| SIDE(S) TESTED / DATE | | S | | 07/09/1992 | | 07/12/1992 | | PROGRESS |
|-------------------------|--------------|------|---|------------|---|------------|--|----------|
| BW (kg) | MAY GET (Nm) | 61 | 3 | 41 | 3 | | | |
| REPS | | 50 | | 50 | | | | |
| CONCENTRIC EXTENSION | | | | | | | | |
| SPEED(S) (deg/sec) | | 90 | | 90 | | | | 90 |
| PEAK TORQUE (Nm) | | 125 | | | | | | 0% |
| PEAK TORQUE % BW | | 256% | | 256% | | | | |
| ANGLE OF PEAK TORQUE | | 38 | | 38 | | | | |
| TORQUE A deg | | | | | | | | |
| TORQUE A deg | | | | | | | | |
| ACCEL TIME (sec) | | 0.02 | | 0.02 | | | | |
| TOTAL WORK (BWR) (J) | | 141 | | 141 | | | | 3% |
| TOTAL WORK (BWR) % BW | | 231% | | 231% | | | | 3% |
| AVG POWER (BWR) (watts) | | 144 | | 144 | | | | |
| AVG POWER (BWR) % BW | | 236% | | 236% | | | | 3% |
| TAE (J) | | 15.5 | | 15.5 | | | | |
| ASD (Nm) | | 4 | | 4 | | | | |
| SET TOTAL WORK (J) | | 5045 | | 5045 | | | | 19% |
| ENDURANCE RATIO | | 65% | | 65% | | | | |
| 20% FATIGUE WORK (J) | | 1253 | | 1253 | | | | 47% |
| 20% FATIGUE TIME (sec) | | 12 | | 12 | | | | 50% |
| 20% FATIGUE REPS | | 11 | | 11 | | | | 36% |

| 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 |
| SPEED(S) (deg/sec) | | 90 | 120 | 90 | 120 |
| PEAK TORQUE (Nm) | | 187 | 167 | 178 | 167 |
| PEAK TORQUE % BW | | 287% | 256% | 273% | 256% |
| ANGLE OF PEAK TORQUE | | 57 | 65 | 52 | 46 |
| TORQUE @ 40 deg | | 171 | 148 | 163 | 162 |
| TORQUE @ 60 deg | | 185 | 163 | 149 | 144 |
| ACCEL TIME (sec) | | 0.01 | 0.01 | 0.01 | 0.02 |
| TOTAL WORK (BWR) (J) | | 208 | 189 | 141 | 149 |
| TOTAL WORK (BWR) % BW | | 320% | 290% | 216% | 229% |
| AVG POWER (BWR) (watts) | | -199 | 233 | 165 | 205 |
| AVG POWER (BWR) % BW | | 306% | 358% | 253% | 315% |
| TAE (J) | | 20.1 | 26.2 | 32.9 | 39.8 |
| ASD (Nm) | | 14 | 6 | 7 | 8 |
| SET TOTAL WORK (J) | | 1158 | 1042 | 876 | 854 |
| | | | 925 | 707 | 705 |
| | | | | | 601 |

| SIDE(S) TESTED / DATE | | R 07/09/1992 | |
|-------------------------|--|--------------|---|
| BW (kgs) / MAX GET (Nm) | | 65 | 6 |
| REPS | | 60 | 6 |

| | |
|-------------------------|------|
| SPEED(S) (deg/sec) | 90 |
| PEAK TORQUE (Nm) | 147 |
| PEAK TORQUE % BW | 226% |
| ANGLE OF PEAK TORQUE | 62 |
| TORQUE @ deg | |
| TORQUE @ 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) | 672 |
| ENDURANCE FATIG | 81% |
| 20% FATIGUE WORK (J) | 3309 |
| 20% FATIGUE TIME (sec) | 35 |
| 20% FATIGUE REPS | 32 |

| SIDE(S) TESTED / DATE | R | 07/09/1992 | R | 12/1992 | 06/03/1993 |
|-------------------------|------|------------|------|---------|------------|
| BW (195) / MAY GET (Nm) | 63 | 6 | F1 | 7 | |
| REPS | 60 | | 100 | | |
| CONCENTRIC EXTENSORS | | | | | |
| SPEED(S) (deg/sec) | 90 | | 90 | | 90 |
| PEAK TORQUE (Nm) | 134 | | 128 | | 128 |
| PEAK TORQUE % BW | 212% | | 200% | | 200% |
| ANGLE OF PEAK TORQUE | 59 | | 50 | | 50 |
| TORQUE a deg | | | | | |
| TORQUE A deg | | | | | |
| ACCEL TIME (sec) | 0.03 | | 0.02 | | |
| TOTAL WORK (BWR) (J) | 164 | | 162 | | 16 |
| TOTAL WORK (BWR) % BW | 250% | | 248% | | 18 |
| AVG POWER (BWR) (watts) | 174 | | 174 | | 18 |
| AVG POWER (BWR) % BW | 244% | | 244% | | 7% |
| TAE (J) | 19.2 | | 20.4 | | |
| ASD (Nm) | 4 | | 3 | | |
| SET TOTAL WORK (J) | 7164 | | 7241 | | 18 |
| ENDURANCE RATIO | 82% | | 82% | | |
| 20% FATIGUE WORK (J) | 2570 | | 2570 | | -11% |
| 20% FATIGUE TIME (sec) | 24 | | 24 | | 0% |
| 20% FATIGUE REPS | 18 | | 18 | | -11% |

| SIDE(S) TESTED / DATE | 29/09/1992 | | | | | |
|-------------------------|------------|------|------|------|------|------|
| | 66 | 0 | 6 | 6 | 6 | 6 |
| BW (kgs) / MAX GFT (Nm) | 66 | 0 | 6 | 6 | 6 | 6 |
| REPS | 6 | 0 | 6 | 6 | 6 | 6 |
| CONCENTRIC EXTENSORS | | | | | | |
| SPEED(S) (deg/sec) | 90 | 120 | 180 | 240 | 180 | 240 |
| PEAK TORQUE (Nm) | 118 | 103 | 90 | 80 | 90 | 80 |
| PEAK TORQUE % BW | 178% | 156% | 136% | 121% | 136% | 121% |
| ANGLE OF PEAK TORQUE | 40 | 53 | 42 | 56 | 42 | 56 |
| TORQUE @ 40 deg | 110 | 102 | 88 | 65 | 88 | 65 |
| TORQUE @ 60 deg | 106 | 94 | 84 | 73 | 84 | 73 |
| ACCEL TIME (sec) | 0.02 | 0.02 | 0.06 | 0.06 | 0.02 | 0.06 |
| TOTAL WORK (BWR) (J) | 112 | 100 | 86 | 71 | 100 | 86 |
| TOTAL WORK (BWR) % BW | 170% | 152% | 130% | 107% | 150% | 128% |
| AVG POWER (BWR) (watts) | 107 | 128 | 162 | 167 | 128 | 162 |
| AVG POWER (BWR) % BW | 162% | 195% | 245% | 253% | 195% | 245% |
| TAE (J) | 13.8 | 17.5 | 25.4 | 33.4 | 17.5 | 25.4 |
| ASD (Nm) | 3 | 2 | 2 | 2 | 2 | 2 |
| SET TOTAL WORK (J) | 642 | 619 | 495 | 397 | 619 | 495 |
| PROGRESS | | | | | | |
| | 90 | 120 | 180 | 240 | 180 | 240 |
| | -16% | -3% | 0% | 5% | -16% | -3% |

| SIDE(S) TESTED / DATE | 07/12/1992 | | | | | |
|-------------------------|------------|------|------|------|------|------|
| | 66 | 0 | 6 | 6 | 6 | 6 |
| BW (kgs) / MAX GFT (Nm) | 66 | 0 | 6 | 6 | 6 | 6 |
| REPS | 6 | 0 | 6 | 6 | 6 | 6 |
| CONCENTRIC EXTENSORS | | | | | | |
| SPEED(S) (deg/sec) | 90 | 120 | 180 | 240 | 180 | 240 |
| PEAK TORQUE (Nm) | 118 | 117 | 101 | 92 | 106 | 106 |
| PEAK TORQUE % BW | 178% | 177% | 153% | 139% | 168% | 168% |
| ANGLE OF PEAK TORQUE | 44 | 52 | 54 | 51 | 48 | 48 |
| TORQUE @ 40 deg | 115 | 104 | 99 | 72 | 92 | 105 |
| TORQUE @ 60 deg | 104 | 99 | 98 | 68 | 87 | 84 |
| ACCEL TIME (sec) | 0.02 | 0.04 | 0.04 | 0.06 | 0.02 | 0.02 |
| TOTAL WORK (BWR) (J) | 109 | 111 | 94 | 77 | 92 | 80 |
| TOTAL WORK (BWR) % BW | 165% | 168% | 142% | 115% | 146% | 120% |
| AVG POWER (BWR) (watts) | 114 | 148 | 190 | 200 | 146% | 200% |
| AVG POWER (BWR) % BW | 172% | 224% | 287% | 303% | 217% | 317% |
| TAE (J) | 17.4 | 23.2 | 33.0 | 39.7 | 23.2 | 33.0 |
| ASD (Nm) | 3 | 2 | 3 | 5 | 2 | 4 |
| SET TOTAL WORK (J) | 631 | 642 | 536 | 435 | 642 | 536 |
| PROGRESS | | | | | | |
| | 90 | 120 | 180 | 240 | 180 | 240 |
| | 11% | 16% | 4% | 15% | 11% | 16% |
| | 14% | 22% | -7% | 45% | 14% | 22% |
| | -22% | -34% | -62% | -61% | -22% | -34% |
| | 4% | 6% | -2% | 6% | 4% | 6% |
| | 14% | 17% | 5% | 0% | 14% | 17% |
| | 5% | 0% | 0% | 6% | 5% | 0% |
| | 1% | 0% | -2% | 2% | 1% | 0% |

| SIDE(S) TESTED / DATE | R | 29/09/1992 | R | 12/12/1992 | PROGRESS |
|-------------------------|------|------------|------|------------|----------|
| BW (kgs) / MAX GET (Nm) | 66 | 0 | 63 | 3 | |
| REPS | 60 | | 60 | | |
| CONCENTRIC EXTENSORS | | | | | |
| SPEED(S) (deg/sec) | 90 | | 90 | | 90 |
| PEAK TORQUE (Nm) | 99 | | 101 | | 20 |
| PEAK TORQUE % BW | 150% | | 160% | | |
| ANGLE OF PEAK TORQUE | 58 | | 50 | | |
| TORQUE A deg | | | | | |
| TORQUE A deg | | | | | |
| ACCEL TIME (sec) | 0.02 | | 0.01 | | |
| TOTAL WORK (BWR) (J) | 109 | | 101 | | -7% |
| TOTAL WORK (BWR) % BW | 163% | | 160% | | |
| AVG POWER (BWR) (watts) | 104 | | 109 | | 4% |
| AVG POWER (BWR) % BW | 157% | | 173% | | |
| TAE (J) | 13.5 | | 14.6 | | 24% |
| ASD (Nm) | 3 | | 5 | | |
| SET TOTAL WORK (J) | 4672 | | 4472 | | -3% |
| ENDURANCE RATIO | 68% | | 68% | | |
| 20% FATIGUE WORK (J) | 2075 | | 2457 | | 18% |
| 20% FATIGUE TIME (sec) | 26 | | 27 | | 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 | 6 | 71 | 11 | 6 |
| REPS | | 6 | 6 | 6 | 6 | 6 | 6 |
| SPEED(S) (deg/sec) | | 70 | 120 | 180 | 90 | 120 | 180 |
| PEAK TORQUE (Nm) | | 144 | 134 | 114 | 138 | 122 | 114 |
| PEAK TORQUE % BW | | 202% | 188% | 160% | 194% | 171% | 160% |
| ANGLE OF PEAK TORQUE | | 53 | 48 | 52 | 55 | 46 | 53 |
| TORQUE à 40 deg | | 115 | 124 | 92 | 106 | 117 | 99 |
| TORQUE à 60 deg | | 130 | 128 | 73 | 128 | 115 | 92 |
| ACCEL TIME (sec) | | 0.02 | 0.02 | 0.08 | 0.01 | 0.02 | 0.00 |
| TOTAL WORK (BWR) (J) | | -120 | 114 | 87 | 117 | 107 | 98 |
| TOTAL WORK (BWR) % BW | | 169% | 160% | 122% | 164% | 150% | 138% |
| AVG POWER (BWR) (watts) | | -106 | 161 | 137 | 108 | 129 | 180 |
| AVG POWER (BWR) % BW | | 149% | 226% | 192% | 152% | 181% | 253% |
| TAE (J) | | 19.8 | 25.5 | 33.6 | 17.1 | 23.4 | 31.6 |
| ASD (Nm) | | 3 | 2 | 3 | 6 | 4 | 26 |
| SET TOTAL WORK (J) | | 685 | 655 | 501 | 536 | 608 | 469 |
| | | | | | | | 346 |

| SIDE(S) TESTED / DATE | | L 24/09/1992 | | |
|-------------------------|--|--------------|----|----|
| BW (kgs) / MAX GET (Nm) | | 71 | 60 | 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 BWR | | | | |

CYBEX TEST : SUBJECT 7

| SIDE(S) TESTED / DATE : | | R 07/09/1992 | | | L 07/09/1992 | | |
|---------------------------|--|--------------|------|------|--------------|------|------|
| BW (kgs) / MAX GET (Nm) : | | 66 | 6 | 6 | 66 | 2 | 6 |
| REPS | | 6 | 6 | 6 | 6 | 6 | 6 |
| CONCENTRIC EXTENSORS | | | | | | | |
| SPEED(S) (deg/sec) | | 90 | 120 | 180 | 240 | 40 | 120 |
| PEAK TORQUE (Nm) | | 137 | 126 | 109 | 105 | 143 | 126 |
| PEAK TORQUE % BW | | 207% | 190% | 165% | 159% | 216% | 190% |
| ANGLE OF PEAK TORQUE | | 29 | 29 | 33 | 51 | 44 | 50 |
| TORQUE @ 40 deg | | 133 | 121 | 103 | 92 | 138 | 121 |
| TORQUE @ 60 deg | | 103 | 101 | 99 | 75 | 128 | 115 |
| ACCEL TIME (sec) | | 0.02 | 0.02 | 0.03 | 0.05 | 0.01 | 0.02 |
| TOTAL WORK (BWR) (J) | | 147 | 132 | 110 | 96 | 136 | 133 |
| TOTAL WORK (BWR) % BW | | 222% | 200% | 166% | 145% | 206% | 201% |
| AVG POWER (BWR) (watts) | | 147 | 176 | 215 | 241 | 148 | 172 |
| AVG POWER (BWR) % BW | | 222% | 266% | 325% | 365% | 224% | 260% |
| TAE (J) | | 14.8 | 20.5 | 31.6 | 41.5 | 17.2 | 25.2 |
| ASD (Nm) | | 6 | 6 | 8 | 6 | 10 | 12 |
| SET TOTAL WORK (J) | | 814 | 766 | 614 | 545 | 789 | 709 |
| SIDE(S) TESTED / DATE : | | | | | | | |
| BW (kgs) / MAX GET (Nm) : | | R 07/09/1992 | | | L 07/09/1992 | | |
| REPS | | 66 | 60 | 60 | 66 | 60 | 60 |
| SPEED(S) (deg/sec) | | 90 | 90 | 90 | 90 | 120 | 180 |
| PEAK TORQUE (Nm) | | 122 | 122 | 122 | 122 | 126 | 118 |
| PEAK TORQUE % BW | | 184% | 184% | 184% | 184% | 190% | 178% |
| ANGLE OF PEAK TORQUE | | 50 | 50 | 50 | 50 | 56 | 53 |
| TORQUE @ deg | | | | | | | |
| TORQUE @ deg | | | | | | | |
| ACCEL TIME (sec) | | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| TOTAL WORK (BWR) (J) | | 134 | 134 | 134 | 134 | 133 | 110 |
| TOTAL WORK (BWR) % BW | | 203% | 203% | 203% | 203% | 201% | 166% |
| AVG POWER (BWR) (watts) | | 125 | 125 | 125 | 125 | 148 | 207 |
| AVG POWER (BWR) % BW | | 189% | 189% | 189% | 189% | 224% | 313% |
| TAE (J) | | 14.4 | 14.4 | 14.4 | 14.4 | 17.2 | 23.8 |
| ASD (Nm) | | 6 | 6 | 6 | 6 | 10 | 10 |
| SET TOTAL WORK (J) | | 5506 | 5506 | 5506 | 5506 | 609 | 525 |
| ENDURANCE RATIO | | 70% | 70% | 70% | 70% | 70% | 70% |
| 20% FATIGUE WORK (J) | | 2408 | 2408 | 2408 | 2408 | 2408 | 2408 |
| 20% FATIGUE TIME (sec) | | 24 | 24 | 24 | 24 | 24 | 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 |
| CONCENTRIC EXTENSORS | | | | | |
| SPEED(S) (deg/sec) | 90 | 120 | 180 | 240 | |
| PEAK TORQUE (Nm) | 148 | 144 | 120 | 110 | 240 |
| PEAK TORQUE % BW | 227% | 221% | 184% | 169% | 102 |
| ANGLE OF PEAK TORQUE | 51 | 44 | 52 | 51 | 156% |
| TORQUE @ 40 deg | 145 | 143 | 118 | 95 | 53 |
| TORQUE @ 60 deg | 138 | 121 | 110 | 91 | 83 |
| ACCEL TIME (sec) | 0.01 | 0.02 | 0.03 | 0.04 | 98 |
| TOTAL WORK (BWR) (J) | 156 | 136 | 120 | 96 | 0.05 |
| TOTAL WORK (BWR) % BW | 240% | 209% | 184% | 147% | 88 |
| AVG POWER (BWR) (watts) | 138 | 183 | 200 | 248 | 135% |
| AVG POWER (BWR) % BW | 212% | 281% | 307% | 381% | 162 |
| TAE (J) | 19.2 | 24.6 | 34.8 | 46.2 | 249% |
| ASD (Nm) | 6 | 6 | 6 | 3 | 40.7 |
| SET TOTAL WORK (J) | 873 | 795 | 675 | 571 | 6 |

| SIDE(S) | TESTED / DATE | R | 07/09/1992 |
|-------------------------|---------------|-----|------------|
| BW (kgs) / MAX GET (Nm) | 65 | 12 | |
| REPS | 60 | 90 | |
| SPEED(S) (deg/sec) | 90 | 138 | |
| PEAK TORQUE (Nm) | 212% | 59 | |
| PEAK TORQUE % BW | | | |
| ANGLE OF PEAK TORQUE | | | |
| TORQUE @ deg | | | |
| TORQUE @ 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 |
| PEAK TORQUE (Nm) | | ~147 | 128 | 114 | 102 | 141 | 132 |
| PEAK TORQUE % BW | | 219% | 191% | 170% | 152% | 210% | 197% |
| ANGLE OF PEAK TORQUE | | 57 | 51 | 53 | 63 | 55 | 46 |
| TORQUE @ 40 deg | | 130 | 121 | 102 | 95 | 130 | 129 |
| TORQUE @ 60 deg | | 144 | 126 | 106 | 102 | 138 | 122 |
| ACCEL TIME (sec) | | 0.02 | 0.02 | 0.03 | 0.04 | 0.02 | 0.02 |
| TOTAL WORK (BWR) (J) | | ~160 | 144 | 124 | 107 | 159 | 155 |
| TOTAL WORK (BWR) % BW | | 238% | 214% | 185% | 159% | 237% | 231% |
| AVG POWER (BWR) (watts) | | ~125 | 162 | 203 | 213 | 150 | 161 |
| AVG POWER (BWR) % BW | | 186% | 241% | 302% | 317% | 223% | 240% |
| TAE (J) | | 21.0 | 23.6 | 32.2 | 40.0 | 17.2 | 22.9 |
| ASD (Nm) | | 7 | 4 | 3 | 3 | 7 | 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 | 0 | |
| REPS | | 60 | | |

| | |
|-------------------------|------|
| SPEED(S) (deg/sec) | 90 |
| PEAK TORQUE (Nm) | 128 |
| PEAK TORQUE % BW | 191% |
| ANGLE OF PEAK TORQUE | 57 |
| TORQUE @ deg | |
| TORQUE @ 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 | 10 |

CYBEX TEST : SUBJECT 10

| SIDE(S) TESTED / DATE | L | 08/03/1992 | P | 08/03/1992 |
|-------------------------|------|------------|------|------------|
| BW (Kgs) / MAX GET (Nm) | 65 | 0 | 65 | 2 |
| REPS | 6 | 6 | 6 | 6 |
| CONCENTRIC EXTENSORS | | | | |
| SPEED(S) (deg/sec) | 90 | 120 | 180 | 240 |
| PEAK TORQUE (Nm) | 132 | 113 | 102 | 90 |
| PEAK TORQUE % BW | 203% | 181% | 156% | 138% |
| ANGLE OF PEAK TORQUE | 60 | 53 | 52 | 64 |
| TORQUE @ 25 deg | 99 | 90 | 77 | 69 |
| TORQUE @ 65 deg | 124 | 111 | 86 | 88 |
| ACCEL TIME (sec) | 0.02 | 0.04 | 0.05 | 0.04 |
| TOTAL WORK (BWR) (J) | 156 | 143 | 118 | 98 |
| TOTAL WORK (BWR) % BW | 240% | 220% | 181% | 150% |
| AVG POWER (BWR) (watts) | 138 | 103 | 184 | 232 |
| AVG POWER (BWR) % BW | 212% | 156% | 283% | 356% |
| TAE (J) | 15.8 | 19.5 | 25.9 | 35.5 |
| ASD (Nm) | 3 | 3 | 2 | 3 |
| SET TOTAL WORK (J) | 910 | 804 | 681 | 572 |

| SIDE(S) TESTED / DATE | L | 08/09/1992 |
|-------------------------|------|------------|
| BW (Kgs) / MAX GET (Nm) | 65 | 0 |
| REPS | 60 | 0 |
| SPEED(S) (deg/sec) | 90 | |
| PEAK TORQUE (Nm) | 128 | |
| PEAK TORQUE % BW | 196% | |
| ANGLE OF PEAK TORQUE | 55 | |
| TORQUE @ 25 deg | 91 | |
| TORQUE @ 65 deg | 118 | |
| ACCEL TIME (sec) | 0.02 | |
| TOTAL WORK (BWR) (J) | 153 | |
| 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 | 63% | |
| 20% FATIGUE WORK (J) | 4100 | |
| 20% FATIGUE TIME (sec) | 34 | |
| 50% FATIGUE WORK (J) | 2050 | |
| 50% FATIGUE TIME (sec) | 17 | |

CYBEX TEST : SUBJECT 11

| SIDE(S) TESTED / DATE : | R 08/09/1992 | | | L 08/09/1992 | | |
|-------------------------|---------------------------|------|------|--------------|------|---|
| | BW (kgs) / MAX GET (Nm) : | 58 | 6 | 58 | 6 | 6 |
| REPS | | 6 | 6 | 0 | 6 | 6 |
| CONCENTRIC EXTENSORS | | | | | | |
| SPEED(S) (deg/sec) | | 90 | 120 | 180 | 240 | |
| PEAK TORQUE (Nm) | | 134 | 124 | 110 | 95 | |
| PEAK TORQUE % BW | | 231% | 213% | 189% | 163% | |
| ANGLE OF PEAK TORQUE | | 47 | 48 | 52 | 74 | |
| TORQUE @ 60 deg | | 129 | 115 | 98 | 83 | |
| TORQUE @ 40 deg | | 132 | 122 | 102 | 92 | |
| ACCEL TIME (sec) | | 0.02 | 0.02 | 0.04 | 0.04 | |
| TOTAL WORK (BWR) (J) | | 179 | 160 | 136 | 114 | |
| TOTAL WORK (BWR) % BW | | 308% | 275% | 234% | 196% | |
| AVG POWER (BWR) (watts) | | 155 | 187 | 243 | 266 | |
| AVG POWER (BWR) % BW | | 267% | 322% | 418% | 458% | |
| TAE (J) | | 17.3 | 21.8 | 29.8 | 36.8 | |
| ASD (Nm) | | 4 | 4 | 3 | 2 | |
| SET TOTAL WORK (J) | | 1017 | 909 | 776 | 651 | |

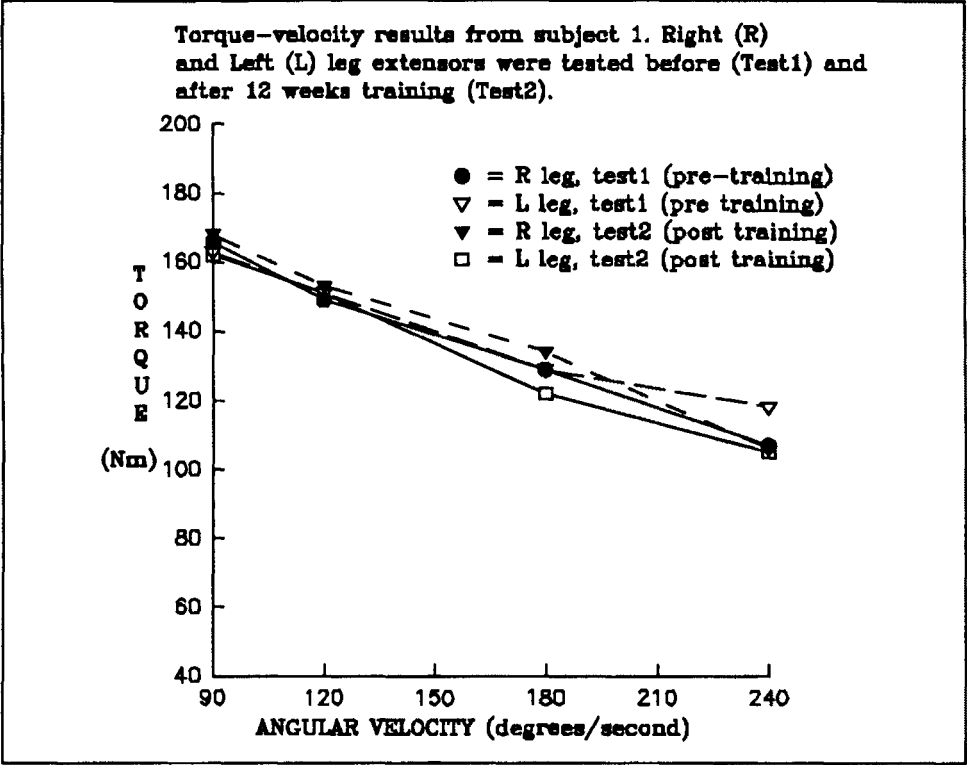
| SIDE(S) TESTED / DATE : | R 08/09/1992 | | |
|-------------------------|---------------------------|------|---|
| | BW (kgs) / MAX GET (Nm) : | 58 | 6 |
| REPS | | 60 | 6 |
| CONCENTRIC EXTENSORS | | | |
| SPEED(S) (deg/sec) | | 90 | |
| PEAK TORQUE (Nm) | | 140 | |
| PEAK TORQUE % BW | | 241% | |
| ANGLE OF PEAK TORQUE | | 43 | |
| TORQUE @ 60 deg | | | |
| TORQUE @ 40 deg | | | |
| ACCEL TIME (sec) | | 0.02 | |
| TOTAL WORK (BWR) (J) | | 179 | |
| TOTAL WORK (BWR) % BW | | 306% | |
| AVG POWER (BWR) (watts) | | 131 | |
| AVG POWER (BWR) % BW | | 223% | |
| TAE (J) | | 15.7 | |
| ASD (Nm) | | 4 | |
| SET TOTAL WORK (J) | | 1017 | |

CYBEX TEST : SUBJECT 12

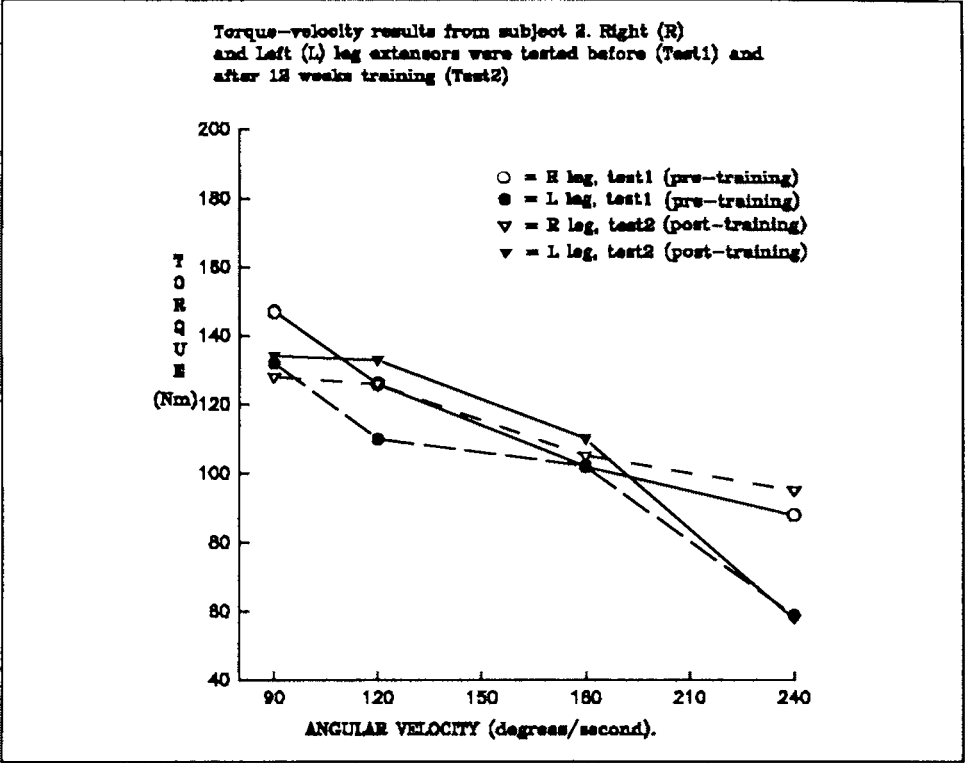
| SIDE(S) TESTED / DATE | RI | 20/08/1992 | LU | 20/08/1992 | |
|-------------------------|------|------------|------|------------|------|
| BW (Kgs) / MAX GET (Nm) | 62 | 0 | 62 | 0 | |
| REPS | 6 | 6 | 6 | 6 | 6 |
| CONCENTRIC EXTENSORS | | | | | |
| SPEED(S) (deg/sec) | 90 | 120 | 90 | 120 | 180 |
| PEAK TORQUE (Nm) | 125 | 109 | 117 | 113 | 87 |
| PEAK TORQUE % BW | 201% | 175% | 188% | 182% | 140% |
| ANGLE OF PEAK TORQUE | 53 | 44 | 65 | 61 | 65 |
| TORQUE @ 25 deg | 103 | 98 | 68 | 68 | 60 |
| TORQUE @ 75 deg | 84 | 79 | 106 | 95 | 72 |
| ACCEL TIME (sec) | 0.03 | 0.04 | 0.01 | 0.02 | 0.04 |
| TOTAL WORK (BWR) (J) | 148 | 134 | 137 | 125 | 106 |
| TOTAL WORK (BWR) % BW | 238% | 216% | 220% | 201% | 170% |
| AVG POWER (BWR) (watts) | 118 | 146 | 116 | 133 | 162 |
| AVG POWER (BWR) % BW | 190% | 235% | 187% | 214% | 261% |
| TAE (J) | 12.2 | 16.4 | 12.7 | 17.0 | 24.8 |
| ASD (Nm) | 4 | 4 | 3 | 4 | 3 |
| SET TOTAL WORK (J) | 841 | 749 | 793 | 713 | 572 |
| | | 625 | | 494 | 377 |

INDIVIDUAL PEAK TORQUE GRAPHS

Subject 1

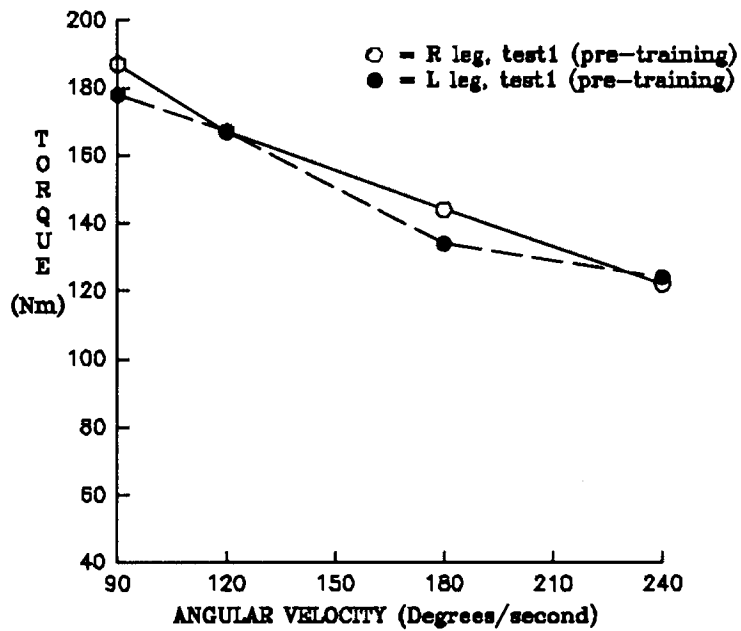


Subject 2

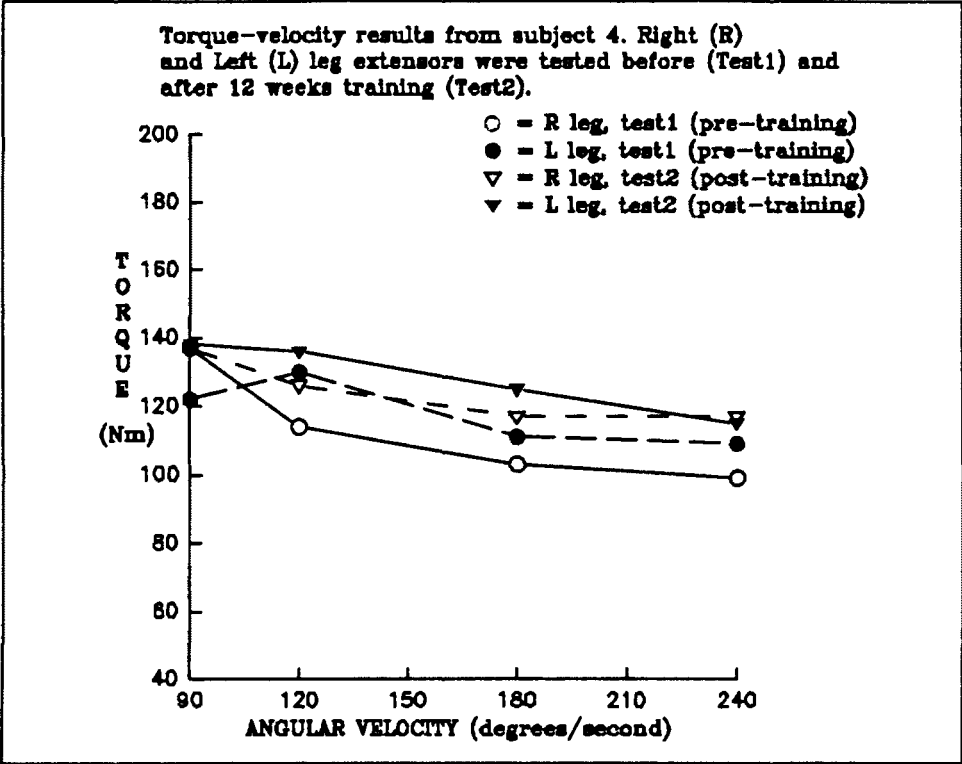


Subject 3

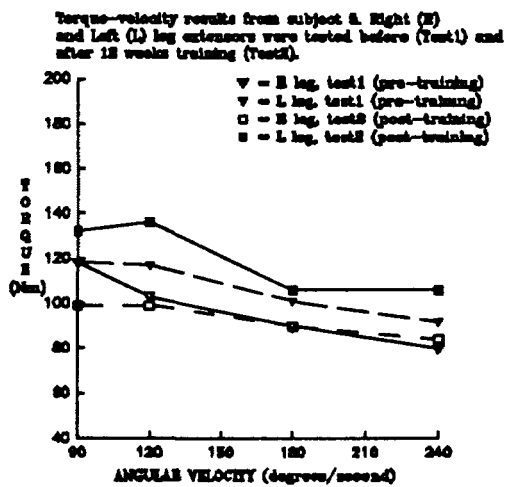
Torque-velocity results from subject 3. Right (R) and Left (L) leg extensors were tested before (Test1), subject unavailable for Test2 after 12 weeks training.



Subject 4

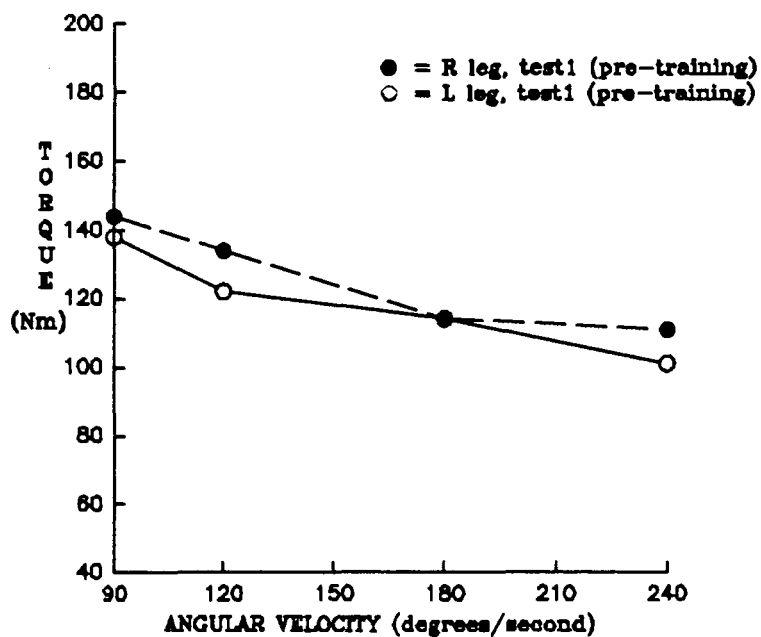


Subject 5



Subject 6

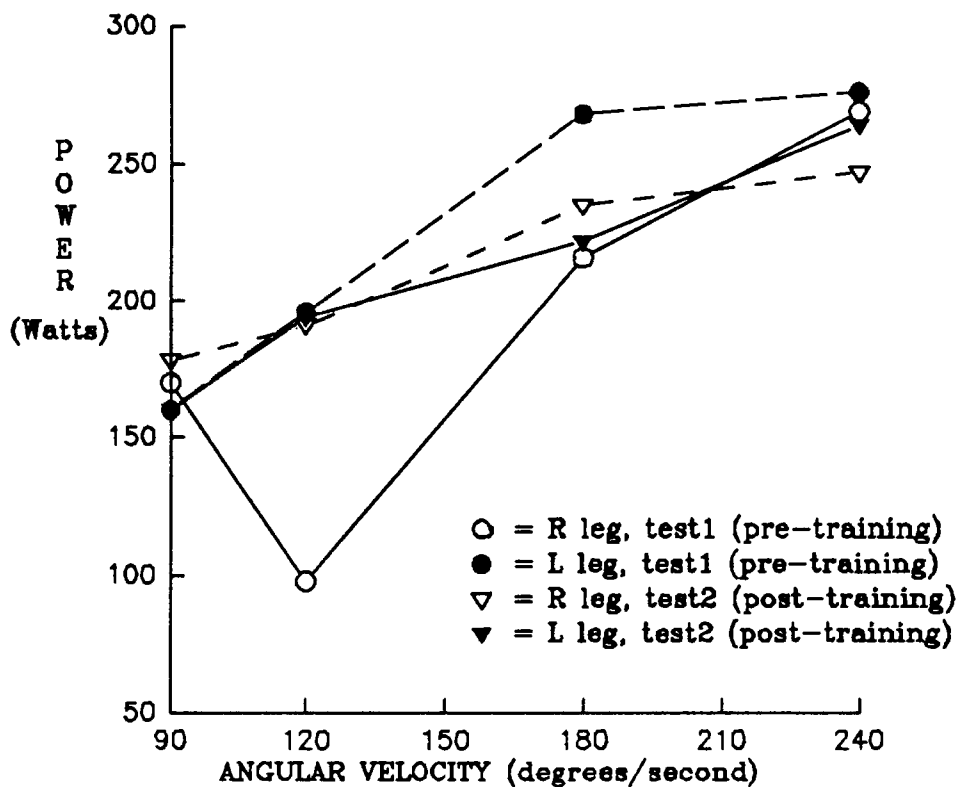
Torque-velocity results from subject 6. Right (R) and Left (L) leg extensors were tested before (Test1), subject unavailable for Test2 after 12 weeks training.



INDIVIDUAL AVERAGE POWER GRAPHS

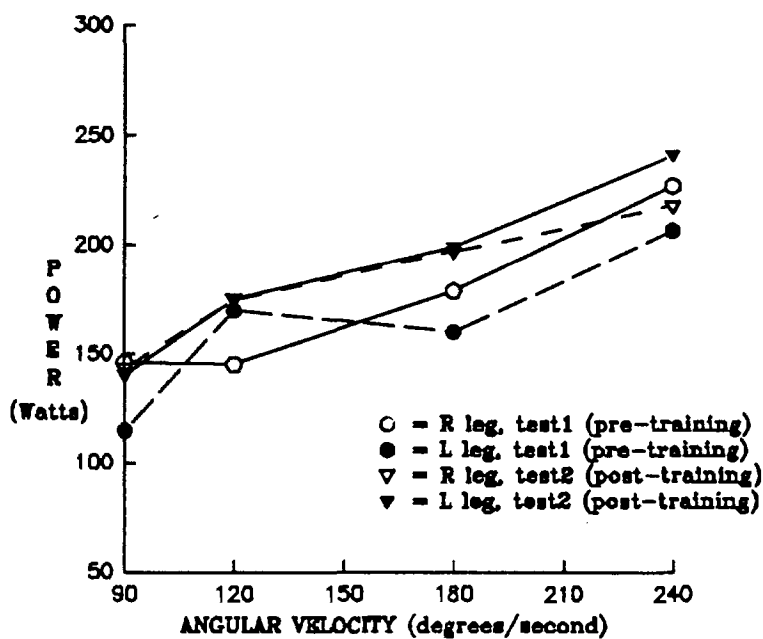
Subject 1

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

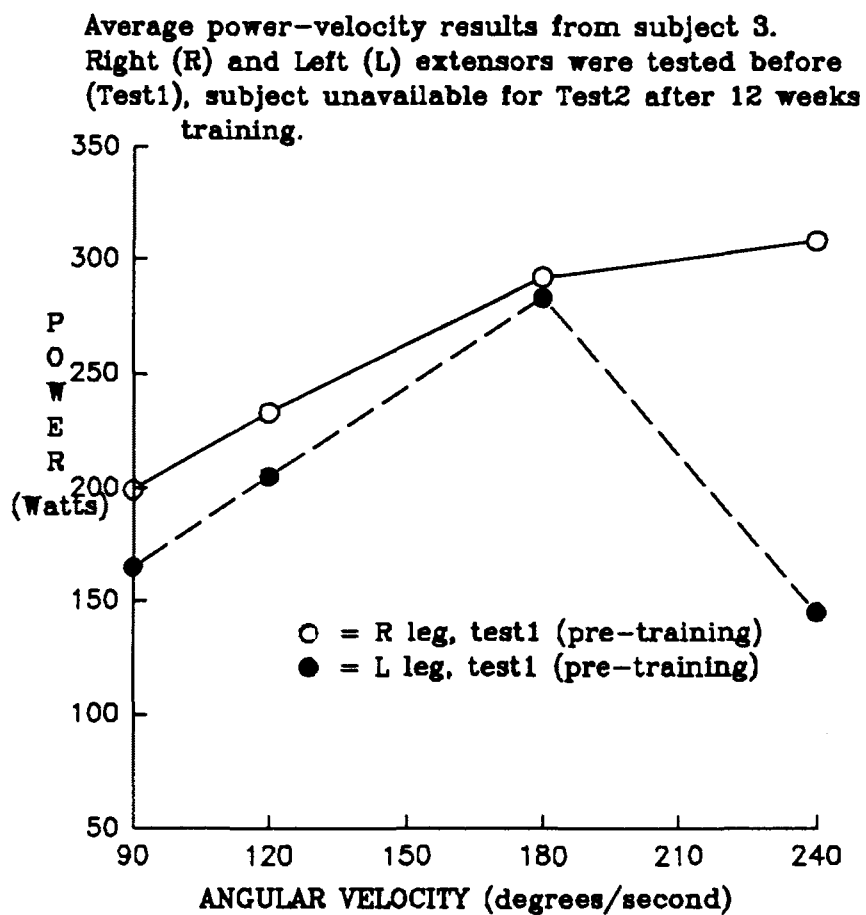


Subject 2

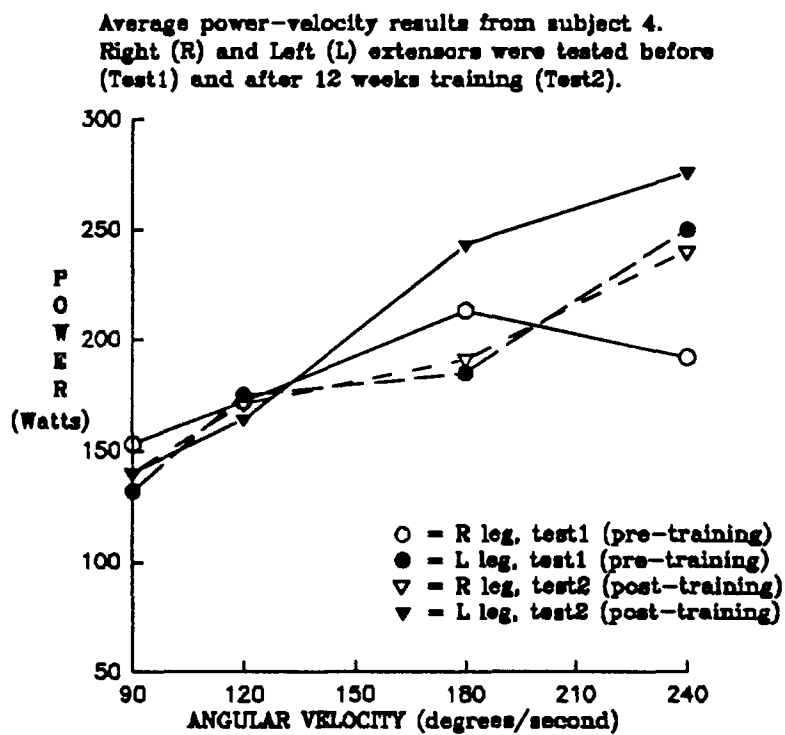
Average power-velocity results from subject 2.
Right (R) and Left (L) extensors were tested before
(Test1) and after 12 weeks training (Test2).



Subject 3

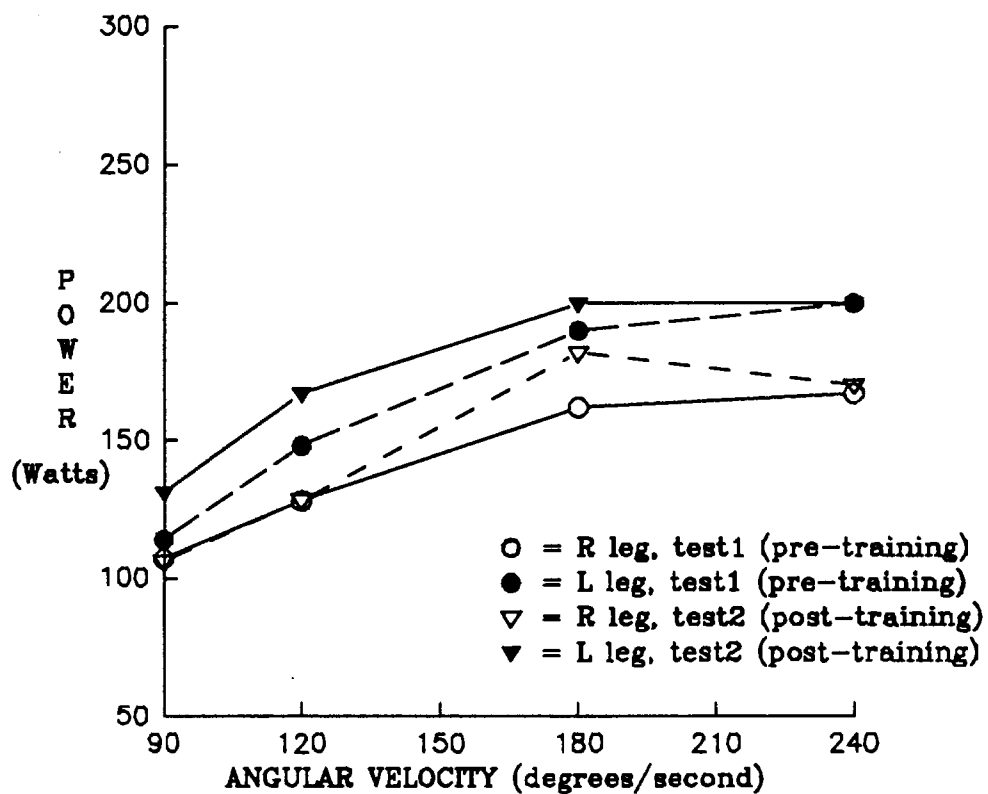


Subject 4



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).



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.

