THE RESPONSE OF OLDER WOMEN TO STRENGTH TRAINING AND ITS RELATIONSHIP TO PHYSICAL SELF-EFFICACY

by

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Abstract

The effects of weight training on the strength, power and size of arm flexor muscles in older women and the relationship between physical self-efficacy and changes in strength and power were investigated. Being reasonably strong is clearly desirable for older women to be able to live independently and safely; both strength and power are important. Although most older people living alone are women, very little research has been concerned with strength or power, or with training for strength, in older women.

A 2 (experimental and control groups) x 2 (before and after training) experimental design was used. Subjects (N = 68) were randomly assigned to the 2 groups. Right arm strength (6RM), peak power, fat-free cross-sectional area (FCA), and Physical Self-efficacy (PSE) were measured before and after 12 weeks training, which was carried out at home. The experimental group trained elbow flexors 3 times a week, using dumbells; the control group trained for increased flexibility, for a similar amount of time weekly. For various reasons (no-shows, drop-outs, medical, incomplete cases) only 50 cases were available for analysis, 30 in the experimental group and 20 in the control group. Eighteen of these 50 subjects had initially reported minor disorders such as controlled hypertension or joint problems. Adherence was approximately 92%. In the experimental group, 6RM increased 20% more than in the control group, but peak power was slightly lower in both groups. There was no change in FCA.

PSE was not correlated with the increase in 6RM, but was significantly linearly correlated with peak power.

These results, and particularly the different response to training for strength and power in this group, are discussed. The mean reduction in peak power over the training period was not expected; possible reasons are discussed. The expectation of a relationship between PSE and changes in physical performance was not realized, although there was a statistically significant correlation between PSE and peak power. Possible reasons for this are discussed.

In general, it was concluded that, after twelve weeks of training, the increase in weight-lifting performance using arm flexors:

- shows that older women can, through a simple programme of progressive weight training done at home, improve the amount of weight they can lift.
- was not accompanied by hypertrophy of arm flexors.
- was not accompanied by an increase in peak power of the arm flexors.
- was not related to physical self-efficacy as measured in this study.

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INTRODUCTION

This study has a number of aspects. It is concerned with questions about strength of older women: whether or not traditional training methods can be adapted for use by older women and will result in increases in strength and power; whether or not a change in strength will be accompanied by a change in power; and whether or not short-term (12 weeks) training results in hypertrophy of the trained muscle. It is also concerned with the relationship between the mental attitude of older women and their response to training.

Very few previous studies have been concerned with any of these questions, although strength training for older people is being recommended by physical educators (Sale, 1986). Strength training as rehabilitation for people who have been sick or injured has been intensively studied (Vandervoort, Hayes, & Belanger, 1986), yet strength training to improve the physical competence of older people has been generally neglected.

The individual's mental approach to a physical activity can be a determining factor in performance (Dishman & Gettman, 1980). For this reason, psychological variables as well as physiological ones were considered in the present study.

Importance of Strength and Power for Older Women

Some of the strength loss in older people appears to be inevitable, but Smith and Gilligan (1983) believe that

"disuse accounts for about 50% of the [general] functional decline" (p.92), and that the loss is, at least partly, reversible with increased activity.

It is reasonable to propose that older women, especially urban and predominantly sedentary ones, should maintain levels of muscle strength and power adequate for them to undertake enjoyable physical activities and to maintain independent living as long as possible. Bosco and Komi (1980) found women between ages 51 and 64 lost 19% of strength but 62% of power when compared with a younger group. This degree of strength and power loss implies considerable difficulty in doing things like opening heavy swing doors or lifting a heavy weight up to counter level.

The alternative to independence, some form of long-term care, means high economic costs to society and often high psychological costs to the individuals as they learn their new dependent roles (Kuypers & Bengsten, 1973) and begin to underestimate their physical capabilities (Myers & Huddy, 1985).

This is becoming an increasingly important social and medical concern as the number of women over 55 increases yearly and the proportion of the population they comprise becomes larger (Canada. National Health & Welfare, 1982; Valbona & Baker, 1984).

Physiological Variables

Diminution of Strength and Power with Ageing

Strength diminishes quite rapidly after the age of 50 (Canada Fitness Survey, 1983). Few studies are concerned with

changes in power with age, though power has been found to diminish even more than strength (Bosco & Komi, 1980).

Choice of Study Population. Subjects in studies of physiological change with ageing have usually been delimited by selection or screening to comparatively very healthy members of the population (Canada Fitness Survey, 1983), and the studies have almost always been cross-sectional (Damon, 1965); in both cases generalizability is restricted. For the present study, it was decided to screen out only women with clear contraindications (Piscopo, 1979) for the physiological measures and strength training programme used, so that the results would be as widely generalizable as possible.

The Measurement of Strength and Power

The concept "strength" is not simple; different authors have used different definitions, making interpretation of studies difficult. Choice of a measurement method was also difficult. No one variable can be used to measure overall strength. Contemporary theorists and practitioners in the area of strength development, such as Heyward (1983), differentiate between strength, endurance and power. Some authors have applied factor analysis to strength measurements and reported factors varying in number from five (Jackson, 1971) to eleven (Liba, 1967). Many other workers discuss isometric, isotonic, isokinetic or dynamic strength measurement (Clarke, 1973; Pipes & Wilmore, 1975) and often define strength as a maximum voluntary contraction (Sale & Norman, 1982). This measure is not necessarily relevant to activities of daily living for older women, which often involve the application of strength in lifting and carrying

weights, and moving them by pushing, i.e., must involve power and endurance as well as static strength if they are to be carried out comfortably. Kulig, Andrews, and Hay (1984) restricted their definition of strength and the generalizability of the findings to a specific muscle group in a particular set of exercise conditions. No direct measurement of power has been carried out with older women.

For the present study, therefore, it was considered desirable to measure both strength and power.

Muscle Bulk and Ageing

Decrease in muscle bulk accompanies the general decline in strength and power with ageing, and is believed to be in part responsible for it (Stones & Kozma, 1985). Moritani and de Vries (1980) suggested that neural facilitation of muscle function can in part compensate for the loss of muscle mass. Other researchers suggested that muscle fibres increase in cross-sectional area with training (Aniansson, Ljundberg, Rundgren, & Wettequist, 1984; Larsson, 1982a).

Weight Training

Training for increased strength and muscle bulk (i.e., weight training) has been extensively investigated (Atha, 1981), yet there are few studies of strength training with older people, and older women in particular (Aniansson et al., 1984). Change in power with training in older women has not previously been investigated. It has been stated that strength training can improve speed, and therefore power (Stegemann, 1981, p.277), but other research has shown that strength and arm speed are not correlated (Smith, 1969). In the present study an experimental dynamometer of novel

design, capable of measuring power during a dynamic movement, was used. It was intended to show whether or not older women in the study group who increased strength also increased power.

Muscle changes with training. Evidence for increase in muscle bulk with training in older people is contradictory.

Some investigators working with older subjects have reported impressive gains in muscle size as well as strength with weight training (Dobrev, 1978); others consider that changes in strength result from increased muscle activation level alone, i.e., there is no hypertrophy. This view is supported by evidence of contralateral transfer of strength gains (Moritani & de Vries, 1979). It may be that most studies have been too short and not intense enough to cause hypertrophy; Dobrev's (1978) study lasted two years, while most others last six to twelve weeks (Aniansson, 1980, Aniansson, Grimby, & Rundgren, 1980; Johnson, 1982; Kauffman, 1985; Liemohn, 1975; Moritani & de Vries, 1980; Perkins & Kaiser, 1961). Only one study of weight training has involved older women specifically (Aniansson et al., 1984), but neither power nor muscle bulk were measured.

Young women do increase muscle mass in response to strength training but not nearly as much as men do (Fox, 1979); it is not known whether this difference is also found in older people. In the present study, girths and skinfolds of the upper arms of the subjects were measured before and after training, and used to calculate fat-free cross-sectional area, a measure of muscle bulk (which it was not thought would increase with only 12 weeks training).

Psychological Variables

The term "self-concept" is often used for the way people describe themselves in relation to others and to the environment (Layman, 1974), but there is little consensus about the meaning. It is not clear whether or not self concept changes with ageing (Breytspraak & George, 1979). Some aspect of the individual's self-concept (measured by scales such as the Tennessee Self-concept Scale) is thought to influence response to physical activity (Tucker, 1984). However, researchers investigating the association between self-concept and physical activity do not agree about what aspect of self-concept to measure, or how to measure it (Bandura, 1978; Dishman & Gettman, 1980; Morgan, 1985; Wylie, 1974, 1979). It would be useful for programme planning to have some general psychological measure related to participation in physical activity, particularly if it could predict performance or training response.

Self-efficacy

Bandura (1977) proposed the concept of self-efficacy as a unifying mediator in human action, and specifically in behavioural change. An individual's perception of self-efficacy includes beliefs about whether or not a task can be completed successfully, and about what the outcome will be. In Bandura's view, how people perceive their own efficaciousness governs in part what they choose to do, how much effort to put into particular activities, and how long to persevere at them in the face of obstacles. These choices

are both theoretically and practically important in determining individual response to physical training, and therefore to the outcome of the training.

Physical Self-efficacy

Self-efficacy has been used experimentally in a wide variety of applications, including some relating it to physical activities and linking better performances to higher scores on self-efficacy measures (Bandura & Cervone, 1983; Barling & Abel, 1983; Feltz, Landers, & Raeder, 1979; Gould & Weiss, 1981). This relationship was investigated by Ryckman, Robbins, Thornton, and Cantrell (1982); they developed and carefully validated their Physical Self-efficacy Scale (PSE) reported to be a reliable predictor of performance on tasks requiring physical skill.

The report of predictive validity for PSE has been supported by subsequent investigations (Ryckman, Robbins, & Thornton, 1983; McAuley & Gill, 1983), but no studies were found relating PSE and training outcomes. Since self-efficacy is reported to determine choices about what to do and how much effort to apply, PSE was expected to be related to training outcome in the present study.

Design of the Experiment

Subjects for the study, women over 50 years of age recruited from the community, were randomly allocated to an experimental group (which completed a 12 week programme of training for strength of forearm flexors) and a control group (which followed a flexibility training programme unrelated to strength development). Each subject carried out the training at home.

Strength, power, and bulk of the right forearm flexors, trunk flexibility in flexion, and PSE (a psychological variable believed to be related to physical performance), were measured at the beginning and end of the study. The data were analysed to determine whether or not there were significant differences between experimental and control groups in the physiological measures before and after training, and whether or not scores on the PSE were related to these differences. The flexibility data were not analysed.

Purposes

The purposes were to determine whether or not women over 50 can increase muscle strength, power and bulk as a result of short-term weight training, and whether or not PSE is related to the outcome of the training.

Hypotheses

1. After training, subjects in the experimental groups will gain significantly in strength of the right arm compared to the control group, as measured by the change in 6RM.
2. After training, subjects in the experimental group will gain significantly in power of the right arm compared to the control group, as measured by the change in peak power.
3. After training, the right upper arms of the subjects in the experimental group will not change significantly in fat-free cross-sectional area as derived from anthropometrical measurement.
4. Higher initial scores for PSE will be associated with higher gains in 6RM and peak power after training in the experimental group.

Delimitations

The study was delimited to:

1. A primarily middle-class group of volunteers.
2. Strength training of the elbow flexors of the right arm only.
3. The use of 6RM as the criterion measurement for training progression.
4. Peak power of the elbow flexors as the criterion measurement for power.
5. The use of the Physical Self-efficacy Scale developed by Ryckman et al. (1982) as the psychometric instrument.

Limitations

The study was limited by:

1. The use of a volunteer group of subjects rather than one chosen by random sample.
2. The use of one exercise and one muscle group.
3. Restriction of training to 12 weeks.
4. The lack of close personal control of training.
5. The use of only one psychological measure.

II

REVIEW OF THE LITERATURE

Introduction

Topics reviewed were: strength, power, and muscle bulk; their importance in relation to age; the problems involved in their measurement; the effect on them of training; and the possible relationship between physical self-efficacy and the results of strength training.

In spite of common acceptance of their close relationship, physiological and psychological aspects of human beings, especially as related to physical performance, are usually studied in mutual isolation. Furthermore, the structure of the English language makes it difficult to discuss them in any other context. Thus, it has been necessary to deal with psychological and physiological variables separately. This dualist approach is not likely to represent the way things really are, but is thought to be the only one possible in the circumstances.

Outline of the Review

The importance of strength for the growing number of older women living independently is recognized (Bassey, 1978). Strength, power and muscle bulk decrease with age, significantly so for the individual after age 50 to 60 (Vandervoort, Hayes, & Belanger, 1986). Most studies measuring or investigating strength have been based on samples from very healthy populations (e.g., Canada. Fitness Survey, 1983) and there is lack of agreement about how to interpret the differences in results of cross-sectional and longitudinal studies (Clement, 1974; Damon, 1965).

Strength has many aspects, and both definition and measurement are difficult. Power is also hard to measure for technical reasons (Heyward, 1983); in the present study, a dynamometer was developed in order to measure power under desired conditions.

Training is known to increase the weight-lifting ability of older people (Aniansson, Ljunberg, Rudgren & Wettenquist, 1984). It is not clear whether this increase in strength is accompanied by increase in muscle size or is related only to neural factors (Larsson, 1982a; Moritani & de Vries, 1980). The training method should resemble the testing method (Sale & Macdougall, 1981). Measures themselves and training methods are reviewed in the Methods section.

Aspects of personality are believed to be related to physical peformance (Kane, 1972), and to results achieved by training. The many personality measures used have made comparative study difficult (George & Bearon, 1980). In the present study a general measure, physical self-efficacy, was used (Ryckman, Robbins, Thornton, & Cantrell, 1982), for reasons described in the section on Psychological Variables and Physical Training (p.53).

Importance of Strength, Power and Muscle Bulk for Older Women

Physical activity of many kinds has been shown to be beneficial to people at all ages; lack of activity can lead to physiological ageing (Bortz, 1982; Brunner & Jokl, 1970; Meusel, 1984; Smith & Gilligan, 1983). Bassey (1978) stated that "quality of life in old age is crucially dependent on the ability to pursue a variety of physical activities" (p.66). Physical activity increases life satisfaction (Price

& Luther, 1980; Shephard, 1984), helps dissipate stress (Beran, 1984), improves flexibility (Frekany & Leslie, 1975), mobility, co-ordination, strength, endurance (Meusel, 1984), reaction time, and balance (Piscopo, 1980; Stacey, Kozma & Stones, 1985), and possibly delays the bone loss which results in osteoporosis (Falch, 1982; Montoye, 1983).

However, strength is a prerequisite for older people to be able to persevere in classes for improvement of fitness (Davidson & Murphy, 1984; Stirling, Miller, Barker, Rowden, & Meehan, 1984) as well as for everyday activities (Aniansson, 1980; Myers & Huddy, 1985). McAvoy (1976) found a large sample of older people in Minnesota gave "lack of physical ability" three times more often than any other (p.3898A) as a factor preventing them from taking part in desired activities. Cureton (1947) commented on the importance of strength for such tasks as "opening tight bottles, raising or lowering stuck windows,...moving furniture, and carrying coal, water or wood" (p.356). Today's equivalent of coal, water and wood might be groceries, luggage, and firelogs.

Adequate power is necessary to open stuck windows and move furniture; its maintenance may be a major factor in confident, safe management of tasks of daily living. The proposition (discussed on p.15-16) that diminution of physical ability is more noticeable the more the available power decreases (Stones & Kozma, 1985), was developed through the study of performance in older athletes. It can just as well be applied to non-athletes, and emphasizes the desirability of strength and power maintenance. Maintenance of muscle bulk during ageing is believed to

delay losses of strength and power, as well as being important for joint stability (Shephard, 1984) and probably in postponement of osteoporosis (Falch, 1982).

Effect of demographic changes. The number of women in the ageing population is likely to have increased substantially by the year 2000; a high percentage of them will, if trends continue, be living independently. Unless they are able to preserve their independence, housing and caring for them could create a problem for society that will become more serious with time.

Projections suggest that the number of Canadians over 60 years of age will have grown from 3.2 million in 1980 to 4.5 million by the year 2000. Almost 12% of the population will be 65 or older. Over the same period, the ratio of men to women in all age groups will decline steadily; in the group aged 60 and over it will fall from about 80 to 73 (men per 100 women). In 1980, of those in the 55-59 age group living alone in their own homes, about 12% were women and only 6% were men. In the 70-74 age group, the figure rose to 34% for women and 15% for men (Canada. National Health & Welfare, 1982; Stone & Fletcher, 1981). Clearly, it will be to society's advantage as well as to their own if these women maintain their physical competence as long as possible (Bassey, 1978; Valbona & Baker, 1984).

Important points for the present study were:

- Strength, power, and muscle bulk are important to older women.
- The number of women living alone will continue to increase.

- These women need strength adequate for enjoyable daily living.

Diminution of Strength, Power and Muscle Bulk with Ageing

Diminution of Strength

Vandervoort et al. (1986) have reviewed studies of strength differences in people of varying ages as measured by maximal voluntary contraction (MVC) or isokinetically; all studies were cross-sectional. The MVC of both men and women in their seventies was at least 20% less than that of young adults; isokinetic strength measures showed similar results but only at lower velocities.

Brown and Harrison (1981) found little difference in strength between untrained women in age-groups 17-26 (N = 42) and 40-49 (N =41). Strength loss was not apparent until after the age of fifty.

Johnson (1982) compared the strength of knee extensors in women aged 20-29 (N = 15) and 50-80 (N = 15) as measured both isometrically and isokinetically, using a Cybex II. Mean strength in the older age group was about 40% less than in the younger group with either method of measurement ($p < .01$). Isometric strength was about 33% greater than isokinetic strength in both age groups.

Relationship between strength and power. Bosco and Komi (1980) studied of the interaction of age and sex with strength and power with 113 men and 113 women, all still in the work force. Leg strength and power were measured by vertical jumps on a force platform; scores on both measures both peaked in the age group 18-26. Results for women are shown in Table 1. In this study, strength diminished earlier

than was reported in other studies, and more completely. Power also fell very early, and differentially from strength. Possibly the unfamiliar and strenuous nature of the test method affected the result. No other studies of strength and power changes during ageing in women were found.

Age Group	N	Force (N)	% change	Power (W)	% change
18-26	41	478.7		1188.7	
34-40	10	341.3	28	764.9	35
41-48	15	316.2	33	716.5	39
51-64	11	226.3	52	466.1	61
71-73	14	229.1	52	328.0	72

Table 1. Changes in force and power of women in various age groups. Adapted from Bosco and Komi (1980). (Percentage changes are reductions from values in age group 18-26.)

Shock and Norris (1970) compared strength and power in 218 men aged 20 - 89. Power output (measured by an arm-cranking test) began to decline at age 40, and for men in their 80's (N = 4) had declined by 45% (30% when corrected for body weight) compared to that of young adults. In the same group, strength (measured isometrically) had been relatively well maintained, declining by 28% (19% when corrected for body weight) compared to young adults. The greater degree of power loss as opposed to strength loss was attributed to reduced co-ordination ability with ageing.

Diminution of Power

Stones and Kozma (1985) hypothesized that the diminution of physical ability with ageing is more noticeable the more the *available* power is challenged, i.e., the nearer the individual is to working at maximum; this effect is greater for maximal than for submaximal performance. The ratio between momentary power output to power available is critical; the higher this ratio the greater the effect. They gave as an example the relative demand on power output of running and walking. Evidence supporting this hypothesis was found in cross-sectional studies of declines in performance. Annual declines were appreciably smaller for habitual activities such as walking (-.5% proportionate performance change) than for high power demand activities such as Masters' competition in track and field (-1.6% proportionate performance change); in this group, the decline seemed to start at age about fifty. They also considered that longer distances constituted a higher power demand relative to power availability and showed a greater decline with age (Stones & Kozma, 1982). Welford (1985) commented on the difficulty of reconciling this view with the traditional one, that declines with age are greatest for sprints.

Hartley and Hartley (1986) also held a different view from that of Stones and Kozma (1985). They believed that losses related to age were due primarily to reduced muscle strength, and not to reduced available power. They compared the top 10 1976 and 1981 sprint swimming speeds (4 different strokes) at the Masters' level in age classes 25-29 to 65-69 (men and women). There was no general change in speeds. The 1976 speed

for each age group was compared with the 1981 speed for an age class 5 years older (i.e. the 60-64 class in 1976 was compared with the class aged 65-69 in 1981). There was a significant difference by age. As hypothesized, speeds for the stroke calculated to have the heaviest load (butterfly) showed the largest change with age, and were larger for women than men. The stroke calculated to make the heaviest power demand (breaststroke) showed the smallest speed differences. This was interpreted as showing that decrease in sprint swimming speed with age can be attributed to reduced muscle strength, not to reduced availability of power.

Diminution of Muscle Bulk

Muscle mass or bulk is known to decrease during ageing (Grimby, Aniansson, Zetterberg, & Saltin, 1984; Larsson, Grimby, & Karlsson, 1979). Reduction in bulk with age has been related to reduction in muscle strength (Aniansson, 1980), and power (Stones & Kozma, 1985). Aniansson (1980) investigated maximal strength and body mass in a group of 52 men (aged 66-76) and 13 women (aged 67-71). Strength and body cell mass (calculated from whole body potassium count) correlated .45 in men and .63 in women ($p < .05$ in both). Aniansson, Hedberg, Henning, and Grimby (1986) in a follow-up to an earlier study (Aniansson et al. (1981), re-measured 23 men aged from 73 to 83 after seven years. Of the original 49 men, eight had died, five were medically unfit, and twelve were not interested. Body weight had declined 2% and quadriceps muscle size by 10-22% (varying with subject), $p < .05$. However, in another study (Maclennan, Hall, Timothy, & Robinson, 1980) with 158 men and 112 women aged 65 to 74,

fat-free mass declined only marginally with age, although grip strength declined significantly.

Both Maclennan et al. (1980) and Larsson et al. (1979) suggested that muscle atrophy was disguised by a increase in the amount of fat and connective tissue in the muscle. Larsson et al. (1979) studied strength and joint extension velocity in 114 male subjects aged 11 to 70. Men aged 20 - 30 were compared with men over 65. The maximum extension velocity (unloaded) of the knee extensors declined in the older group by 7%, and strength by 25%. Power was not measured. The strength decline was not accompanied by any measurable change in thigh circumference. If this is so, fat-free mass may be a less accurate measure of change in muscle bulk in older people than has been believed.

Effect on Data of Delimitation through Screening

The maximum strength of older women has been shown to decline by 16% to 23% in age groups 60-70 and 71-80 respectively (Canada Fitness Survey, 1983; Clement, 1974; Montoye & Lamphiear, 1977). In many large studies screening of subjects happens. It may be unavoidable, but limits their generalizability. The Canada Fitness Survey is such study and must be interpreted as being delimited to a population of people healthier than the population as a whole. It is, however, our only source of information on the decline of strength with ageing in the Canadian population.

The Tecumseh Community Health Study 1962-1965 included strength measurements of 3,345 females. Mean grip strength in women was at a maximum of 52.2 kg in the age group 20-29 (N = 192), and diminished to 44 kg in the age group 50-59 (N = 88),

a loss of 16%. However, 29% of the potential subjects (males and females) were screened out for medical or other reasons (Montoye & Lamphiear, 1977).

Clement's (1974) cross-sectional data from a large group of healthy females aged from 16 to over 96 showed that the grip strength of women diminished from a mean of 30.3 kp in age group 31-35 (*N* = 20) to 21.3 kp in age group 71-75 (*N* = 77), and further to 15.6 kp in age group 81-85 (*N* = 47), differences of 23% and 48% respectively. "Not less than 70% participation in each age group" (p.424) was obtained; the subjects tested are likely to have been the healthier ones.

The results of the Canada Fitness Survey (1983) showed strength levels for girls peaking in the late teens, and then declining with age. Mean grip strength fell from 62 kg in the age group 20-29 (*N* = 1562) to 52 kg in age group 60-69 (*N* = 201), a loss of 16%, comparable to that found in the Tecumseh Community Health Study. Muscular endurance and power were also tested, using sit-ups and push-ups. Performance on these tests also peaked in the late teens for women, with mean scores of 35 repetitions for sit-ups and 21 for push-ups, then declined "steadily and rather completely" to scores of 5 sit-ups and 6 push-ups in age group 60-69 (Canada Fitness Survey, 1983, p.25). However, the subjects in this survey were also screened, and a very large percentage in the older age groups were not tested on any of the performance items - about 55% of the age group 60-69, for example. As a result, this study was narrowly delimited to a population enjoying good health.

Another type of screening occurs when volunteer populations are sampled. Volunteers tend to be more sociable and intelligent, better educated, and of higher socio-economic status than non-volunteers (Borg & Gall, 1979). However, the large study by Clément (1974) revealed no correlation between strength and intelligence, intellectual performance, physical activity level, or occupation. Perhaps strength is more generalizable from volunteer populations than some other variables.

Important points for the present study were:

- women lose about 20% of strength by age 65.
- they also lose up to 60% of muscular power.
- power loss begins earlier than strength loss.
- muscle bulk is also lost, but how much is less clear.
- the relative contribution of strength and power to decrements in performance is not clear.
- screening and use of volunteers means performance decrements may be underestimated in many studies.
- strength may be more generalizable than other variables

Cross-sectional Versus Longitudinal Studies

Smaller losses in cross-sectional studies? It is reasonable to expect cross-sectional studies to show smaller strength losses than longitudinal ones. In cross-sectional studies, the older subjects tested are survivors and tend also to be the vigorous ones. The younger group can be expected to include a higher proportion of weaker members and to be relatively weaker. In longitudinal studies, the same subjects are tested at different ages, so that whether the

individuals are strong or weak, the composition of the group is constant. As Damon (1965) points out, cross-sectional studies describe age *differences between groups* which cannot be assumed to correspond with age *changes in individuals*. Studies by Clement (1974), Asmussen (1975), Bruce (1984), and Dehn and Bruce (1972) support the view that cross-sectional studies indicate smaller strength losses.

Clement's (1974) study of changes in strength with increasing age compared cross-sectional and longitudinal methods. He tested grip strength in healthy subjects, 1139 male and 716 female, aged from 16 to over 96. For the longitudinal study, some subjects were retested after 5 years (369 men and 162 women), some of these after 10 years (109 men and 55 women), and "a few" after 15 years. From these measures, he calculated theoretical values for changes in strength by age group from 25 to 90 years, and stated that "the true decline is considerably larger than that expected on the basis of the cross-sectional study" (p.427).

Asmussen's (1975) follow-up study of 25 former athletes (19 men and 6 women) showed large losses in grip strength after 40 years. In the women, 36.6% of former strength had been lost; approximately 20% commonly decrease is commonly reported in cross-sectional studies (Vandervoort et al., 1986). Comparison with testing 10 years earlier (after 30 years) showed that most of the loss in all subjects occurred after the age of fifty.

Bruce (1984) held a similar view of the difference between cross-sectional and longitudinal studies. He stated that the decline in VO2max during ageing is substantially

lower in cross-sectional studies than in longitudinal studies. Dehn and Bruce (1972) reported that 40 men in the age group 40-72, retested after 2.3 years, showed a change in VO2max of -.94 ml/kg/min a year when measured longitudinally. A control group, consisting of men of varying ages all tested at the same time, showed a change of -.28 ml/kg/min a year of age. Since aerobic metabolism is proportional to muscle mass (Mathews & Fox, 1976, p.458), the findings of these studies support those of Clement (1974). However, as Sidney and Shephard (1978) point out, such decrements could not be representative of a lifetime of annual losses, but would be specific to the age group involved.

Greater losses in cross-sectional studies? Contrary views to the preceding are expressed by Damon (1965) and by Stones and Kozma (1982).

Damon (1965) reviewed discrepancies between longitudinal and cross-sectional studies; at least 15 longitudinal studies were in progress at the time, including the Framingham Heart Study of the U.S. Public Health Service, the Tecumseh Community Study of the University of Michigan, and the Thousand Aviator Study of the U.S. School of Aviation Medicine. He found that all cross-sectional studies show decreases with age in height, grip strength, and vital capacity. For height, he showed that the loss could at least partly be accounted for by the general long-term height increase, which resulted in young men being on average taller than old men. Another possibility was that shorter people live longer, so that older people would naturally be shorter.

He further suggested that the cross-sectional declines in grip strength and vital capacity might themselves be related to long-term changes in population height rather than to age per se. Coefficients of correlation between grip strength and height in older men ranged from .36 to .46, and between height and vital capacity from .56 to .78. It follows that older men, because they are shorter than young ones, would have lower grip strength and vital capacity, unrelated to age. In the study by Dehn and Bruce (1972) referred to above, the subjects were aged 40 to 72. One cause suggested for the smaller decrease in vital capacity in the cross-sectional study was "uncontrolled population truncation" (p.805). However, if the survivors were shorter, the apparent loss of vital capacity should have been larger (using Damon's (1965) argument). It seems these authors may be using the same explanation for contradictory results.

Damon and Sheldon, in unpublished data (quoted by Damon, 1965), recorded results of re-studying 187 Columbia College men (aged 56) who had been studied at age 18-19. Only 27 showed height loss. The mean difference in grip strength was 2.8 kg, and in vital capacity was 169 cc, both higher at the older age. Damon acknowledged that height, grip strength and vital capacity might have increased after age 18-19. Even taking this into account, he considered that cross-sectional studies would predict decrements by age 56, not the increases (in grip strength and vital capacity) found in this study. Perhaps the decreases do not show until after that age.

Stones and Kozma (1982), in a study analysing performance data for athletes at the Masters age level,

included a comparison between cross-sectional and longitudinal data for long jump, which is in part a measure of strength and power. Over a 5-year period, subjects in age groups 40-49, 50-59, and 60+ were compared. The cross-sectional decline (expressed as a yearly percentage performance change) was approximately twice as steep as the longitudinal decline. The authors interpret this to indicate that trends from cross-sectional data reflect a contribution due to differences in life experiences approximately equal to that from age changes. However, the study lasted only 5 years, and the subjects were athletes in training, some of whom could be expected to improve their performance. The best individual performances per event per year did in fact improve in the two older age groups.

Evidence is conflicting. Obviously, researchers disagree about the differences between the results of cross-sectional and longitudinal studies. Cross-sectional studies are said to show changes which reflect differences between old and young in education, life experience, motivation, expectations, and familiarity with testing situations rather than in age (McPherson, 1983). Older people are thought to do less than their best during testing, so that their true decline would be *smaller* than many studies show; the work of Damon (1965) and Stones and Kozma (1982) supports this view. It seems from the longitudinal studies of Clement (1974) that in the case of strength this is not so, and that the true decline with age may be *greater* (and the situation of older people even worse), than is suggested by cross-sectional studies. However, the evidence is conflicting, and it is not

possible to come to a conclusion. Arenberg (1982) has offered suggestions for avoiding bias from attrition in planning studies.

Important points for the present study were:

- longitudinal and cross-sectional studies yield differing results.
- differences related to age and to long-term changes in populations may be confounded.

Measurement of Strength and Power

Strength and power are inter-related in a complex manner. Both decline with age (Grimby et al., 1984; Larsson, 1982a), especially in women. The variance from the mean remains about the same in absolute terms during ageing; this implies greater heterogeneity in older populations (Clement, 1974). In measuring such a population, it is essential that the measure should be suitable for and acceptable to the whole group, otherwise the sample will become less representative. "This is particularly likely to happen when a...test is used with a group of old people. It would probably exclude just those individuals...of most interest in this study, either because the test would be prejudicial to their health or because they would feel disinclined to do it" (Bassey, 1978, p.69).

The measures in the present study needed to be safe, simple, and (for the convenience of the subjects) appropriate to do in street clothes. General aspects of measurement are discussed below.

Strength Measurement

A difficulty in research involving measurement of strength is the complexity of the concept. The Concise Oxford dictionary gives 6 definitions, including "toughness", "durability", and "intensity, as of sound". In common usage we have expressions such as "strong-minded". So even in popular use, strength is seen as possessing several attributes, including immaterial ones.

Reviews by Heyward (1983) and Macintosh (1974) provided background for the present study and illustrate the complexity mentioned above. Heyward (1983) reviewed muscle testing for planning and implementing strength training programmes. Macintosh (1974) reviewed research dealing with the multidimensional nature of strength and its implications for strength measurement, and discussed the relationship between force and the velocity of movement. Strength, endurance, and power were described as the three components of muscular fitness. Another view of strength described three similar components: explosive (as in jumping or throwing), dynamic (as in lifting up or pulling the body weight), and static or isometric strength (Fleishman, 1964).

Other investigators have also considered strength to be multi-dimensional. Different numbers of factors have been reported by researchers using factor analysis; e.g., 11 (Liba, 1967) and 7 (Jackson, 1971). More recent studies (Linden, 1977; Jackson & Frankiewicz, 1975) described fewer and more general factors. Nicks and Fleishman (1962) reviewed factor analysis studies and considered it "not worth while"

(p.82) to look for factors of static strength. Interest in factorial analysis has not continued in recent years.

Power Measurement

Power is the rate of doing work, or the product of force and velocity; accurate measurement of power is considered difficult (Heyward, 1983). The difficulties involved are discussed in the later section on Issues in Measurement of Power (p.32-33). The relationship of movement speed to muscle strength and power (the force-velocity curve) was described and discussed by Sale and Norman (1982). In concentric contractions, force decreases as velocity increases; power is greatest when velocity is less than 50% of maximum. Thus, strength and velocity are poorly correlated; Smith (1969) reported negligible correlations (-.06 to -.14 at different joint angles) in unloaded forearm flexion.

Correlation becomes significant when the limb is moving a substantial mass (Eckert, 1965; Macintosh, 1974). Whitley and Smith (1963) studied force and velocity in adductive movement of the arm. They found that the addition of weight to the limb resulted in increasing correlation between isometric strength and velocity - stronger subjects could move the heavier weight more quickly than weaker subjects. The weight of the arm plus load was increased from 1.999 kg to 11.37 kg; the coefficient of correlation between strength and volocity increased from .37 to .73. When the combined weight of the arm and load became so great that it could not be moved, any contraction would be static. To demonstrate a correlation between strength and power, the load had to be

heavy enough for power to be developed, but not so heavy as to slow the movement down.

Eckert (1965) considered that each individual had a fixed amount of energy, which she called force-energy, available for a single muscle contraction; maximal force-energy could only be exerted when opportunity was provided by the load or range of motion or both. In the present study range of motion was fixed. Thus, the selection of an appropriate load to allow each individual to exert maximum force-energy was very important, and is discussed in the Methods section.

Important points for the present study were:

- strength, power, and muscle bulk are inter-related.
- velocity correlates low with strength but high with power.
- appropriate measures for strength and power are critical.

Issues in Measurement of Strength and Power

The ideal movement for measuring strength and power would be similar to the one used in training and to the movement for which increased strength is desired (Pipes, 1978; Sale & MacDougall, 1981). Similarity is also desirable in velocity (Moffroid & Whipple, 1970), and in contraction type (eccentric, concentric, isometric, isodynamic, or isokinetic); the human muscle adapts contractile properties differently according to the type of training (Duchateau & Hainut, 1984). In preparation for the present study, test methods and criteria were reviewed so that the measures which best met the requirements noted above could be selected.

Issues in Measurement of Strength

General. Strength has long been of interest to physical educators, therapists, and others: as a component of physical fitness, as a means of identifying the need for and results of remedial treatment or rehabilitation, and as a factor in the measurement of functional age (Shock, 1981). In consequence, many methods of measurement have been developed, including test batteries, isometric methods (including grip strength), isokinetic methods, and dynamic methods.

Test batteries. Most early work was concerned with male students in school or college; batteries of tests were devised (Clarke, 1945; Cureton, 1947; McCloy, 1938; Rogers, 1926; Sargent, 1897). The measures used in these batteries included one lift of the maximum weight possible or Repetition Maximum (1RM), grip strength, and pullups and pushups as tests of strength endurance (the maximum number performed to exhaustion) or power (the number completed in a fixed time).

In 1897, Sargent published his Intercollegiate Strength Test, derived from strength measures of handgrip, back, and legs, together with pullups and pushups. Rogers (1926) used the same test items as Sargent, combined them for his Strength Index, and published norms for its use. He reported it to be highly correlated (r = .70) with his Athletic Index, a performance measure. All measures showed high inter-correlations, from r = .81 (grip strength with back strength) to r = .59 (arm strength with leg strength). He thought strength tests should minimize skill and emphasize strength per se, and did not discuss the possibility that

individual differences in strength might result in part from learning or experience.

McCloy (1938) proposed changes in the items in Rogers' Strength Index, and noted the lack of data for females. Clarke (1945, 1950) modified Rogers' Index, and devised alternatives to regular pushups and pullups for girls.

Cureton (1947) reduced the battery of tests to four dynamometer tests (right and left grips, back and leg) to give the Total Proportional Strength Index. It correlated highly (r = .77) with strength per pound of body weight (measured by an unspecified method), but lower with measures of motor performance (r = .4 to .5). The test items were intercorrelated (r = .90). He commented on the educability of individuals in relation to strength tests, differing from Rogers (1926) on this point.

Modern overall strength measurement protocols show the influence of these earlier studies. The Canada Fitness Survey (1983), for instance, used grip strength (the item which correlated most highly with Rogers' (1926) Athletic Index), as a measure of overall strength, and pushups (together with situps) as a measure of strength endurance. Heyward (1983) describes tests of static strength corresponding exactly with those of Cureton (1947), and gives very similar norms.

Isometric methods: MVC. Isometric testing and training became popular after the publication of Hettinger's work on strength physiology (1961). An isometric contraction measures the force or torque developed by a muscle group working against a fixed resistance without change in muscle length. It is the measure preferred by many educators (e.g., Sale &

Norman, 1982) and researchers (e.g., Kroemer, 1970). It is reliable and relatively easy to standardize. Heyward (1983) described measurement of isometric (or static) strength, using dynamometer, cable tensiometer, or the Cybex II machine. Though grip strength measurement involves movement, it is really a special type of isometric measurement, taken at maximum static contraction.

Results of measurement in which muscle length and joint angle remain the same (isometric) differ fundamentally from those in which muscle length and joint angle change, e.g., using free weights (Inman & Ralston, 1954; Rutherford & Jones, 1986). This is particularly important for investigation of changes in strength with age or training. If measurement is to be isometric, training should also be isometric.

However, isometric methods are not considered suitable for testing or training older people. Sustained muscular contractions can result in large increases in blood pressure, not found during rhythmic exercise (Lind & MacNicol, 1967). Piscopo (1979) recommended against very strong muscle contractions in exercises for older people as tending to impede circulation as well as increase blood pressure.

Isokinetic method. The Cybex II isokinetic dynamometer and other machines such as the Mini-Gym and Kin-com (Ariel, 1985) measure torque at constant speed with angular velocities that can be varied (from 0° to 300°/sec in Cybex). These machines can be used for measures including isometric strength (at 0°/sec), isokinetic strength, and isokinetic endurance (Heyward, 1983). At lower velocities, approaching

no movement at all, an isokinetic movement becomes like an isometric contraction.

The Cybex dynamometer is considered accurate and reliable. It is relatively easy to standardize positioning, load, and angular velocity, and there is no need to "hunt" for a maximum load (Heyward, 1983; Sale & Norman (1982). On the other hand, isometric and isokinetic movements are not like movements used in everyday life or in weight training.

Dynamic methods: RM. Dynamic (or isotonic) strength is commonly measured as the maximum weight that can be lifted once only, or at 1RM (repetition maximum). This measure is relatively difficult to standardize, especially with untrained subjects; in addition, it is necessary to "hunt" for maximum load. Berger and Hardage (1967) found four or five trials were needed to determine 1RM for college students familiar with the lift used. Rose and Beatty (1957) found "more than three or four lifts were seldom necessary" to establish the maximum value (p.157). Like isometric methods, 1RM is not considered suitable for older people.

A larger number of repetitions, often 6, at a lower load, usually a percentage of 1RM, is also often used. It is necessary to determine 1RM first (Sale & Norman, 1982), followed by measurement of 6RM. The large number of repetitions may cause fatigue for the subject. In some studies it is not clear how the weight appropriate for a series of repetitions was arrived at. Perkins and Kaiser (1961) for instance, simply stated that 10RM was "the maximum resistance a subject could move through a full range of motion ten times" (p.633). O'Shea (1966) said his subjects

"handled maximum weight loads for the number of repetitions they were required to perform" (p.97). Neither author gave additional details. Dynamic methods can readily be related to activities of daily living.

Issues in Measurement of Power

General. Power is a function of force and speed, but no method for the direct measurement of speed during a free movement was reported. Indirect measures of power include various types of performance tests, isokinetic tests, and weight lifting. Sale and Norman (1982) suggested an apparatus instrumented to measure power directly during weight lifting. The comments on choice of movement for strength and power tests on p.24-25 above are pertinent here.

Performance tests. Operational tests, such as timed situps for abdominal muscle power (Canada. Fitness Survey, 1983), length of throw as in the sitting shot put, height of vertical jump (Heyward, 1983) or jump force measured by a force platform (Bosco & Komi, 1980), distance of standing broad jumps (Stones & Kozma, 1982), and timed sprints (Stones & Kozma, 1985) have been used. Their validity has not been established (Considine, 1971), nor are they appropriate for older women.

Isokinetic methods. Isokinetic devices, such as Cybex, allow measurement of power (usually as torque) at constant preset velocity, and provide resistance which increases as the applied muscle force increases. Larsson et al. (1979) used this method to study movement speed and strength (of knee extensors) with a group of males (aged 11 - 70+). Velocities studied were 30°, 60°, 120° and 180 /sec. Torque declined

with age, and was greater at the lower velocities in all age groups. It is difficult to reconcile the use of an isokinetic movement, controlled at a constant velocity, with the need for specificity of training and testing method.

Weight lifting. To obtain accurate measures of power developed during lifting, it is necessary to measure not only the force developed but also the velocity of movement (Sale & Norman, 1982). There are difficulties in obtaining the velocity measure. High speed cinematography could be used, but requires frame by frame analysis to determine distance moved and speed of movement (Heyward, 1983). For the present study, a novel dynamometer was developed capable of direct measurment of angular velocity and force. It is described fully in Appendix 2.

Important points for the present study were:

- measures should be related to natural movement and to training movement.
- many measures are unlike natural movement.
- some common measures are too strenuous for older people.
- no satisfactory established measure was available for power measurement.

Measurement of Muscle Bulk

Most researchers consider that the cross-sectional fat-free area of a limb is a satisfactory estimate of its muscle area (the major variable in change in muscle bulk). Anthropometric methods are generally used for this purpose (Ross & Marfell-Jones, 1982).

Anthropometric Methods.

Measures of skinfolds and girth have been used to derive estimates of the fat-free cross-sectional area (FCA) of a limb. The limb is treated as if it were a cylinder and the girth used to calculate the cross-sectional area. Skinfold measures are used to estimate the average thickness of fat, and the area is corrected to give the fat-free area. It includes bone and connective tissue as well as muscle.

Moritani and de Vries (1980) measured five young men and five old men, using four skinfold measurements of the upper arm at 90o intervals (the specific sites were not identified, but appear to be biceps, triceps and two intermediate sites). The average of the four was used, together with arm circumference, to calculate the "cross-sectional area of muscle" (p.675) by which they must have meant fat-free cross-sectional area. They described the method as possibly creating large errors, but unlikely to do so for changes brought about by training.

FCA is often estimated from measurement of arm girth and only one skinfold measurement (triceps). This method is considered adequate for comparative assessment purposes, and was used by Burr and Phillips (1984), Bishop, Bowen, and Ritchey (1981), and Frisancho (1981).

Burr and Phillips (1984) measured only arm circumference and triceps skinfold, in 298 men and 516 women aged from 65 to over 85, living in South Wales. Norms were developed for these populations. However, since the triceps skinfold is usually at least twice as thick as is the biceps skinfold, large absolute negative errors in estimation of the muscle

area must result. This probably partly explains why, in their study, the average FCA for men in the age group 65-69 was only 43.20 cm^2, much lower than the 64.45 cm^2 reported by Moritani and de Vries (1980) for their five old men subjects; and the average for women in the age group 65-69 was 33.50 cm^2 also much lower than the 49.25 cm^2 found initially for women in the present study, whose average age was 62.3 years.

Data from the U. S. Health and Nutritional Examination Survey, 1971-74 were analyzed by Bishop, Bowen, and Ritchey (1981) and by Frisancho (1981), using very large samples (28,043 and 19,047 respectively), in order to develop norms for nutritional assessment. They used measurements of circumference and triceps skinfold to calculate upper arm muscle circumferences. Recalculation shows muscle area for women in age range 55-75 to be about 40 cm^2 in both these studies. Chumlea, Roche, and Mukherjee (1986) found similar measurements for a sample of 150 elderly women indicated an average FCA of about 44 cm^2 at ages 65 to 70.

These studies show that different populations, measured differently, cannot properly be compared. The lower values in the U.S. studies may relate to exaggeration of subcutaneous fat (reducing the apparent FCA) because of the use of triceps skinfold only, and not necessarily to the population involved.

Brozek and Kinzey (1960) investigated changes in skinfold compressibility with ageing in men. They measured sites including triceps and found marked variability and decreased compressibility in older ages (40-69). No data were

found for women, but it seemed likely that skinfold measures for women in the present study would show the same tendency.

Variances like these would be disturbing if group means were being compared, but for individual change over time with training and provided that the measurements are taken by the same experienced observer, the measures may be considered "serviceable" (Burr & Phillips, 1984, p.165).

Other Methods of Measurement.

Ultrasound techniques for measurement of subcutaneous fat have been investigated by a number of workers. Haymes, Lundegren, Loomis, and Buskirk (1976) compared ultrasound and skinfold measures at four sites. At the triceps site in women, the measures correlated .83 (N = 20).

Borkan et al. (1982) compared A-scan ultrasound and skinfold measurements in 39 men aged 41-76 for estimating subcutaneous fat and predicting total body fat. The predicted total body fat was compared with the total measured by whole body potassium counting. Their results suggested that skinfolds were more effective for assessing subcutaneous fat than this technique. B-mode scan techniques were investigated by Weiss and Clark (1985) with college-aged men and women. For women, the predictions from fat sonograms and triceps skinfolds correlated .81, but a criterion measure (such as whole body potassium count) was not obtained.

Booth, Goddard, and Paton (1966) compared ultrasound, anthropometry, and electrical conductivity. They concluded that ultrasound in the hands of an experienced operator was the most accurate, but "could not be recommended for occasional estimation" (p.724). Anthropometry was considered

to be very satisfactory, if an experienced observer and appropriate equiment were available (Burr & Phillips, 1984). *Important points for the present study were:*

- FCA estimated from anthropometrical measurement shows considerable between subject variability.
- for intra-subject comparison the method is very satisfactory when used by an experienced measurer.

Effects of Strength Training

Training, an organized effort to increase one or more measures of physical fitness, has been shown to improve muscular strength and working capacity in older people comparably with the young (Muravov, 1966; Piscopo, 1985). Training should be specific; cardiovascular training will not result in increases in strength (Shephard & Sidney, 1978).

Books and articles with information about strength training for older women are beginning to appear in popular literature. Some books about exercise fitness include a section on weight training for older people (e.g., Burke, 1980), and there are occasional articles on the topic in magazines (e.g., Darden, 1983; Todd, 1984). A popular book about weight training indicated no age limitations for training for either sex (Reynolds, 1982, p.9). However, scientific investigations of strength training in older people are few, though guidance should be provided for class leaders, practitioners, and therapists.

Training and Strength

Training to increase strength, both remedially and for fitness or athletic performance, has been extensively studied. Reviews by Atha (1981), Clarke (1973), and Westcott (1982) provided general background for the present study.

Various combinations of weight and repetitions have been tried. DeLorme (1945) maintained the best way to build strength was to use heavy weight and few repetitions. Many practitioners in the field (e.g., Anderson & Kearney, 1982; Berger & Hardage 1967) have confirmed Delorme's findings, although not with older subjects. This principle was used in selecting the training method for the present study, since no preferred method for training in older people has been established.

In spite of a great deal of interest in weight training generally, only a few studies have been concerned with older people. Of these, very few were with women (Aniannson et al. 1984; Kauffman, 1985), and only a few more with men (Aniansson, 1980; Dobrev, 1978; Moritani & de Vries 1979, 1980). Deshin (1968) and Perkins and Kaiser (1961) conducted studies with groups including both men and women. No studies using a control group with older women were found.

Vandervoort et al. (1986) reviewed studies of strength training in older men and women, involving muscle action at different joints (knees, hips and fingers), and different types of training (isometric, calisthenics, and weight lifting). In women, increases in strength after training of from 10% to 72% were reported. Factors which contributed to

these differences included initial strength level, motivation of subjects, muscle groups involved, duration of training, training method, and measurement method (most were isometric).

Strength has been shown to correlate with body weight, and to some extent with height. Johnson (1982) found correlations between strength and both height and weight in a young group (20 - 29), but not in an older group (50 - 80). Clement (1974) found correlations but no age pattern. In women, correlations of strength with weight ranged from .51 to .19 (average = .33), and with height from .64 to -.06 (average = .29). Similar averages were found by Fisher and Birren (1947).

Comparative studies of strength training and age. Brown and Harrison (1986) investigated differences in results of 12 weeks weight training in young (aged 17-26) and middle-aged (aged 40-49) women. This was the only study found to use controls. In each age group, subjects were randomly assigned to experimental and control groups. Strength gains after training were significantly greater in the experimental subjects than in the controls. There was no significant difference between the two age groups, indicating that response to strength training is similar in middle-aged and young women. Age differences are probably not significant until after the age of 50.

Kauffman (1985), in one of only two studies of training in older women, investigated the effect of isometric training of the non-dominant *abductor digiti minimi* muscles in younger and older women. Ten student nurses (ages 20-26 years) and 10

older women (ages 65 to 73 years) trained the muscle with isometric contractions three times a week for six weeks. Differences between the isometric strength of the two groups before and after training were insignificant. The younger group was 2.9% stronger than the older group before training, and 14% stronger after training; these small differences were not considered compatible with the age-dependent strength loss reported by others (Burke et al., 1953; Clement, 1974). Surprisingly, *both* groups showed significant strength increases with training ($p < .001$); the absolute strength increase for the older group was 74.1% of that of the younger group.

Suggested reasons for these results included a training stimulus high compared to those in most other studies, the co-operativeness and probable high motivation of the older group, and the possibility that the older group may not have been old *enough* (at an average age of 69) for age-related change in strength to have developed. Possibly this muscle was virtually unexercised in all the subjects so that high gains would be expected. Furthermore, the sample may have been too small to show significance with such relatively small differences between groups. This study casts doubt on the generally accepted view that older muscles are necessarily weaker. The author, however, cautioned against generalizing from this small muscle to other muscles. He evidently considered that small and large muscles respond differently to training, although the topic does not seem to have been investigated.

Perkins and Kaiser (1961) compared the effect of strength training in 20 older people (15 women and 5 men, ages 62 to 74) randomly assigned to two groups, one trained isometrically and one isotonically. The muscles trained were the antigravity muscles of the legs (ankle plantar flexors, knee extensors and hip extensors). Training followed the DeLorme (1945) method, and was continued until the subject reached a plateau in strength, usually at six weeks. Strength was measured as the maximum weight that could be held up against gravity for six seconds, and tested weekly. The group trained isometrically gained 56.9% and the one trained istonically gained 45.8%. Results were not separately reported for men and women. It is disappointing that no details of the strength calculation were given, and the results were not statistically analysed. Furthermore, all testing was isometric; considerations of specificity of training (Sale & MacDougall, 1982) suggest that different results might have been obtained if testing had been isotonic.

Moritani and de Vries (1980) studied strength training in a group of five young men (aged 18 to 26 years) and one of five older men (aged 67 to 72 years). Progressive resistance (dumbell) training was carried out only with the dominant arm; the non-dominant arm served as an untrained control. After eight weeks, older subjects gained an average of 22% ($p < .001$) and younger subjects 30% ($p < .002$). Muscle hypertrophy and increase in neural activation level were considered as possible contributors to the strength increases. There was hypertrophy in the young group but not

in the older group. The authors concluded that neural factors alone were responsible for the changes in the older group. This view is supported by relatively large absolute strength increases in the older group during the first three weeks of training, before hypertrophy could have been significant. The relationship between age, neural factors, and hypertrophy is discussed below (p.46-49).

Moritani and de Vries (1980) were surprised to find strength increases in the two groups were comparable, and wondered whether the older group might initially have been inhibited from exerting maximum effort, or have been significantly below potential maximum strength when compared with the young group. However, more troublesome aspects of the study are the small number of subjects (5 in each group), the use of isometric testing with a dynamic training regime, and repetition of testing at 2, 4, and 6 weeks, with the possibility that learning affected the final test scores. Warshal (1979) has commented on the confounding influence of repeated isometric assessment on measurement of strength gain, although McDonagh, Hayward, and Davies (1983) reported no effect of training on elbow flexor strength in a group tested isometrically once a week for five weeks.

Older women and strength training. A study by Aniansson et al. (1984) was the second of the two studies concerned with training for muscle strength in older women subjects. It involved 15 women pensioners aged from 63 to 84 who trained twice a week for 10 months. No control group was used. They used their own body weight and elastic bands for resistance. Both static and dynamic strength of knee extensors, as

measured by the Cybex II dynamometer, increased. For Cybex velocities of 0°, 30°, 100° and 180°, gains were 7 - 13% ($p < .02 - .001$). The group included five women with some cardiovascular problem, and one with a locomotor problem, i.e., not all subjects with disabilities were screened out. Thus, the findings may be more generalizable than those of some other studies. Again, the lack of a match between training method (dynamic) and test method (isometric) could have obscured actual changes (Sale & McDougall, 1982).

Long-term strength training. Deshin (1968), reported in Gore (1972), studied a group of 6 men and 16 women; 10 were aged 51-55 and the rest over 55 at the beginning of the study. After 10 years of a regimen including group exercises twice a week and daily general exercise, subjects showed increases in strength measured by operational tests such as sit-ups, press-ups and vertical jumps (e.g., the number of repetitions of press-ups for women increased from none to an average of eight). These changes occurred at a time of life when diminution in strength would normally be expected, suggesting a reversal of the usual course of strength loss with age.

Important points for the present study were:

- older women can increase strength with training.
- strength may be correlated with body weight and height.
- the amount of increase may be related to factors such as age, weight, height, initial strength, length of training, motivation, and method of measurement.

Training and Power

No studies of changes in power with training in older women were found.

Power is lower in women than in men. De Konig, Binkhorst, Vos and van 't Hof (1985) examined the force-velocity relationship of arm flexion in males and females. Groups of untrained males (*N* = 123), and females (*N* = 110) aged 15 to 36 were compared with arm-trained athletes (*N* = 48) aged 22 -32. The mean maximal power of the women was 43% lower than that of the untrained males. The mean maximal power of the athletes was 30% higher than that of the untrained males. There was no age effect.

Studies have been made of the effect of training on force-velocity characteristics of muscle groups. Urbanik and Ubukata (1983) compared the changes in force and velocity after concentric or eccentric training, and the effect of different external loads on velocity. Two groups of nine students (non-athletes) trained hip and leg muscles for six weeks. One group used concentric contractions and the other group used eccentric contractions. Loads were equalized for kinetic energy output, and varied in an unspecified weekly cycle. The maximum increase in moment of force for hip extensors was 15%, for knee extensors 12%, and for plantar flexors 25%. The eccentric and concentric groups varied in the time course of the strength gain, but not in its amount. Velocity of knee extension was also tested during the study, using external loads varying from 20 to 140 Nm. The velocity increased over time and with the test load, by between 4 and

16% after training - not statistically significant. Force rather than velocity changed with strength training.

Viitasalo (1983) examined the results of training on force-velocity characteristics in high jumpers and volleyball players. Training, from March to October, followed the normal pattern for the athletes. A force platform with an external timer was used in measurement. The upward displacement of the centre of gravity was used to measure velocity. Extra loads on the shoulder extended the force part of the curve. Height of vertical jumps increased significantly (p = .01) after high jump (N = 5) and volleyball training (N = 12), indicating an upward displacement of the force-velocity curve with training. Higher velocity was achieved at all loads.

Important points for the present study were:

- no studies of the effect of training on power in older men or women were found.
- power can be developed with training in young subjects.
- force and velocity respond differently to training.

Training and Muscle Bulk

Changes in the human muscle system during ageing have been reviewed by Larsson (1982b). Almost all studies of changes in bulk with training used young men as subjects; no studies reporting separate data for women were found.

There is a theoretical relationship between muscle size and the force the muscle can exert (other things being equal) (Astrand, 1977, p.371). This agrees with our everyday observation that "strong" people have large muscles. People often associate weight training with muscle hypertrophy - some women actually avoid training because they fear the

development of muscle bulk (Rose, Radzyminski, & Beatty, 1957). But weight training can increase strength without muscle hypertrophy (Moritani & de Vries, 1980). Factors other than increased muscle size must account for these increases. Individual differences in factors such as natural endowment (Cureton, 1947, p.362), motivation (Astrand, 1977, p.106), skill (Astrand, 1977 p.114), and decreased inhibition (Ikai & Steinhaus, 1961), may be involved when low correlations are reported between strength and muscle size in a group of people.

There are conflicting opinions about the likelihood that the muscles of older people will hypertrophy with training.

Increased muscle bulk reported. Noble (1971), reviewed research on the effect of resistive exercise on muscle size in adults and found only 13 studies. All subjects were under 30 years of age. Two studies used groups consisting of both men and women, the rest men only. Training periods varied from 6 to 12 weeks. Wide differences in responses to training were reported. Over the 13 studies, the maximum change in girth of thigh and upper arm showed increases of 3.3 cms (4.4%) and 1.93 cms (4.9%) respectively. Holmdahl and Ingelmark (1948), referred to by Wiswell (1980), found muscle hypertrophy associated with exercise during ageing.

Dobrev (1978) followed 25 subjects aged 50 to 80 (mean age 65) during two years of weight training, and found positive changes in all anthropometric measurements, including a 4.4% decrease in body weight and a 10.5% decrease in waist circumference. Considerable hypertrophy of arm, shoulder and leg muscles (10% to 15%) resulted from a

"systematic and purposeful functional load by means of exercise with weights", e.g., "right armpit flexor circumference" (pp.28-29) increased by 3.9 cm or 12.2%. Details of training are lacking and it is not clear whether only men or both men and women took part.

Larsson (1982a) compared the effect of training in sedentary men at different ages. Eighteen men aged 22 to 65 trained knee extensors intensively (60 - 80 min) three times a week for 15 weeks, emphasizing endurance strength (low weight and high repetitions). Isometric and isokinetic strength (at four different velocities) were measured before and after training. Strength increases were small relative to those in some other studies (Larsson et al., 1979; Moritani & de Vries, 1980), and significant ($p < .05$) only at 60° angular velocity (but not at 0°). The largest increase (7.5%) was in the oldest age group. Biopsies of vastus *lateralis* were made before and after training. Muscle fibre size (and therefore muscle cross-sectional area) increased after training, most evidently in the oldest participants (age 55-65, $N = 6$, $p < .05$). Larsson concluded that these men were able in part to regain through exercise the muscle fibre area atrophied by disuse.

Neural factors or hypertrophy?. Larsson's (1982a) conclusions appear to conflict with those reached by Moritani and de Vries in their (1980) study. In that study, two groups, one of older and one of younger men, trained elbow flexors using dumbells three times a week for eight weeks. The group of older men showed no hypertrophy after training. Strength increase, measured isometrically, was comparable in

the two groups and averaged 20%. The authors concluded that gains in strength in older subjects were the result of neural factors alone. In discussing the point, Larsson suggests that the increase in muscle fibre area in older men was achieved with loss of intramuscular fat and/or connective tissue, i.e., after training, there were larger fibres and less fat or connective tissue in the muscle. This is supported by his finding that, in his subjects, thigh circumferences after training were unaltered, despite the increase in muscle fibre area shown by biopsy. The Moritani and de Vries (1980) study lasted eight weeks, and used progressive resistance at two-thirds of maximum, compared to 15 weeks with low weight and high repetitions for Larsson's (1982a) study. Both these factors may be related to the difference in strength gains reported (20% and 7.5% respectively) and perhaps to the increase in fibre area.

Nevertheless, the views of Moritani and de Vries (1980) were supported by their measures of neural activity using integrated electromyography. Strength gains resulting from neural factors alone should be associated with increased neural activity during contraction. More fibres contract, but with *no change in the force* exerted per fibre. On the other hand, strength gains from hypertrophy alone would show *no change in neural activity* but increased force per muscle fibre. Thus, if force increased while neural activity remained the same (i.e., the same muscle groups were active to the same extent) hypertrophy would be indicated. In older subjects, muscle activation level was higher after training, but there was no hypertrophy. The increase in strength, as

measured by Cybex, was comparable to that in the younger group. The authors concluded that neural factors, or "the interaction of facilitatory and inhibitory phenomena acting at various levels of the nervous system" (p.681), were alone responsible for the strength change in older subjects. In their study, each group had only five subjects, and in Larsson's (1982a) study there were only six: rather few for general conclusions to be drawn from the statistical results. These studies should be repeated with larger numbers, and for women.

Learning and co-ordination. Another theory about the mechanism by which strength increases with training has been suggested by Rutherford and Jones (1986). They investigated central changes associated with three training regimes varying in the complexity of skill and co-ordination required. Three groups were formed among 22 young men and nine young women; all trained the knee extensors of one leg only, three times a week for 12 weeks. The first group (six men aged 23-27) trained isometrically (least complex), and the second (five men, 19-37) trained concentrically (more complex). The third (11 men and 9 women, aged 21-40) trained both concentrically and eccentrically with no support for the upper body (most complex). Other muscle groups co-operated to stabilize the training muscle. MVC was measured every two to three weeks and at the end. For men in the first group, isometric training resulted in a 40% increase in MVC. For men in the 2nd and 3rd groups, the weight that could be lifted in leg extension increased by about 200%, but MVC only by 15-

20%. For women in the 3rd group the weight that could be lifted increased by 240%, but MVC by only 4%.

Fourteen subjects were tested by superimposition of an electrical (twitch) stimulus, and indicated full voluntary activation before training. The authors believed that subjects could fully activate quadriceps voluntarily (i.e., that the isometric test was a valid measure of intrinsic strength), and were highly motivated. They concluded that the increase was the result of improved co-ordination of all the muscle groups, not of increased neural activation as suggested by Moritani and de Vries (1980). It is interesting that the young women in this study showed such a small increase (4%) in MVC. No report of changes in muscle bulk were given, so it is not possible to relate strength changes to hypertrophy. These investigators may have confounded training method (isometric or dynamic) with complexity.

It seems probable that the muscles of older women respond to training in much the same way as those of older men, and do not show visible changes in muscle bulk.

Contralateral transfer of training. The view that neural factors are at least in part responsible for strength increase with training is supported by studies in which one arm or leg is trained and strength is found to increase not only in the trained limb but also in the untrained (contralateral) one. In the Moritani and de Vries study (1980), the five older men increased significantly in mean strength and neural activation level for both the trained and the untrained arm. The cross-sectional area of the arm muscle did not change in either arm. The five younger men also

increased significantly in mean strength and neural activation level for both trained and untrained arms, and, in addition, cross-sectional area increased significantly in the trained arm, i.e., there was a significant increase in both hypertrophy ($p < .001$) and neural activation level $p < .01$). There was no significant change in muscle area in the untrained arm. However, there was no control group in this study, and it is theoretically possible that, in both groups, both arms were strengthened as a result not of contralateral transfer but of some other factor, e.g., an increase in physical activity level in all subjects. Again, the small numbers suggest that the results cannot be generalized.

Christ, Hildebrandt, Kriebel, and Rohrbach (1979 studied the transfer of the effects of grip strength training from one forearm to the other. A group of six young men trained one arm daily for seven days, with the contralateral arm immobilized. The effects of training were transferred to the immobilized limb and it did not atrophy as might have been expected. Neural factors were considered responsible for the training effect. Muscle tension in the immobilized arm produced by involuntary co-innervation was too weak to be a training stimulus. Similar conclusions were reached by Houston, Froese, Valeriote, Green, and Ranney (1982), who studied the effect of training the knee extensors of one leg in a group of young men. Training was transferred to the contralateral leg, but muscle fibre changes occurred only in the trained leg. The effects were reversed with detraining.

Important points for the present study were:

- visible hypertrophy does not occur in older people.
- hypertrophy in older women has not been studied.
- strength can increase without muscle hypertrophy.
- disuse atrophy may be reversible with training.
- possible mechanisms for increased strength in older people include increased neural activation, improved co-ordination, and increased fibre size; all three may contribute.

Psychological Variables and Physical Training

The mental attitudes of people, as assessed by measures of psychological variables, are believed to be associated with the results of training.

Many terms have been used for "psychological variables", including personality, motivation, volition, self-confidence, self-esteem, self-perception, self-image. In this review, self-concept has been used as a generic term. The role played in performance by a high sense of self-concept is recognized in athletics and sports, as shown by the use of psychological techniques in the preparation of athletes.

Self-Concept and Physical Performance.

Attempts to demonstrate a relationship between self-concept and physical performance (e.g., Kane, 1974; Weingarten, 1975) show little consensus about either what should be investigated or what psychometric measures should be used.

Many measures have been used in research with older people, often only once or twice (George & Bearon, 1980), and mostly with people either in institutions or being assessed

for entry into them (Kane & Kane, 1981). Measures of physical self-concept lack psychometric validity (Sonstroem 1984; Wylie 1974, 1979). Validation has often been carried out only with young subjects; very few studies have been done with relatively healthy older women, and it is not clear whether (in adults) there is a relationship between age per se and self-concept (Breytspaak & George, 1979).

Most investigators have assessed aspects of self-concept using a battery of tests (Dishman & Gettman, 1980; Massie & Shephard, 1971; Tucker, 1984). This practice is time-consuming for both subject and investigator, and makes it difficult to compare results from different studies. A general measure that would allow comparison of results would be useful.

Some researchers have investigated changes over time in the self-concept as a results of training, e.g., strength training (Brown & Harrison, 1986) and aerobic exercise (Perri & Templer, 1985). Changes in scores on a psychological measure may be related to an experimental treatment, but this does not necessarily mean that a change in self-concept has occurred or that the change is related to a physiological effect. The change may be only in scores, not in self-esteem per se, and it is not clear which agent is responsible for the result (Sonstroem, 1984). Self-concept has also been viewed as related to or predicting performance (Feltz & Brown, 1984; Scanlan, Lewthwaite, & Jackson, 1984). This appeared to be the more useful approach for treatment or programme planning, and was preferred for the present study. In strength training, initial strength level is inversely

related to strength gain, especially in initially untrained subjects. Thus, if lower self-concept predicted lower strength at the beginning of training it might be related to higher improvement. On the other hand, lower self-concept might reflect a person not expecting success in strength training, and therefore less likely to succeed than more confident people. Self-concept is also related to the willingness of people to persevere with physical activities (Dishman & Gettman, 1980). Since perseverence with training is a major factor in increasing strength, higher self-concept should be related to higher strength gain with training. On balance, it is more reasonable to expect higher self-efficacy to be related to greater strength gains.

Bandura's Theory of Self-efficacy

Bandura (1977) proposed self-efficacy as a unifying mediator in human agency and specifically in behavioural change. His concept of self-efficacy somewhat resembles White's (1959) concept of "effectance" as the motivational drive towards competence in dealing with the environment. It has two aspects: an individual's beliefs about whether or not he or she can successfully complete the task or maintain the behaviour involved (efficacy expectations), and beliefs about the outcome (outcome expectations). Individuals who believe they have the skills and ability to accomplish a task are likely to be right, and *can* do it, but their perception of the probable outcome may determine whether or not they *will* do it.

Bandura believed that it is partly on the basis of self-efficacy that people choose what to do, how much effort to

invest, and how long to persevere with it. This concept corresponds with observation of how people actually behave - they are likely to avoid activities unless they believe they have the necessary ability and are confident that it can be applied in the particular situation. They will not invest much time or effort if they do not feel the outcome will be rewarding in some way. The rewarding outcome of physical activity, for instance, might be to improve their health, or give them pleasure or approbation.

Thus, self-efficacy should theoretically be a good predictor of behaviour and this was shown to be so in a wide range of tasks (Bandura, 1982).

Bandura's work has not been without its critics, who have questioned both the centrality Bandura claims and the distinction between efficacy and outcome expectations (Eastman & Marzilier, 1984; Kirsch, 1985; Tryon, 1981). Nevertheless, the concept has been of growing interest to researchers in fields where the relationship between psychological factors and physical or physiological factors is important, e.g., physical therapy or athletic training. Bandura's model has been empirically tested by researchers interested in physical education (Mcauley, 1985; Weinberg, Gould, & Jackson, 1979) with encouraging results.

Comparative Studies of Self-efficacy and Physical Activities

A number of studies have shown a relationship between self-efficacy and physical performance, without claiming prediction. Most (like the following) used measures which were *specific to the activity*. Bandura and Cervone (1983) studied self-efficacy and strenuous activity (arm-cranking)

in a group of 45 men and 45 women students, with and without goal-setting and feedback. Higher self-efficacy was associated with improved performance. More highly self-efficacious subjects scored higher on a second trial than less efficacious ones when both groups had set goals and were receiving feedback ($N = 20$, $r = .45$, $p < .025$).

Barling and Abel (1983) found tennis self-efficacy to be related consistently to success in some measures of tennis performance, though other psychological measures (response-outcome, valence) were not.

Two studies involving water skills investigated the possibility that mastery of a skill would enhance self-efficacy. Feltz, Landers, and Raeder (1979) compared two modelling techniques for teaching a back dive; self-efficacy increased after a successful performance. Hogan and Santomier (1984) studied swim self-efficacy in a group of men and women over 60 years of age, using the Swim Skills Efficacy Scale (SSES) devised for the study. Subjects who attended swim classes five times a week increased mean SSES scores significantly, when compared to a control group ($p < .05$). This was not surprising, since the items in the SSES were specifically related to swimming skills (e.g., float on front; swim the pool width; swim two pool lengths). However, most subjects (78%) also reported changes in feelings about their general ability to perform or achieve. This report was the only one found to suggest a generalized increase in self-efficacy as a result of learning a physical skill. This could be important to individuals as a means of improving their view of their physical abilities in general.

Gould and Weiss (1981) compared the muscular endurance of groups of women college students (N = 150). Subjects were randomly assigned to five groups, one of which was a control. Self-efficacy was manipulated by the use of confederate models who demonstrated the endurance measure. Specific self-efficacy for the endurance task was measured. Muscular endurance was measured as the time during which they could maintain a leg in extension against a load. In all groups, higher self-efficacy scores were correlated with higher levels of endurance ($p < .05$).

Specific Self-efficacy and Prediction

Other workers have investigated specific self-efficacy measures as predictors of performance.

McAuley (1985) tested Bandura's (1977) model with women undergraduates without gymnastic experience. Subjects were randomly allocated to two treatment groups and one control (N = 13 in each). The two treatment groups watched demonstrations by two different methods and then attempted the gymnastic task. A measure of gymnastic self-efficacy immediately before performance was a significant predictor of differences in performance between treatment and control groups ($p < .001$). It was concluded that Bandura's model was a better fit to the data than an anxiety-reduction model.

Ewart, Taylor, Reese, and DeBusk (1983) studied exercise testing and self-perception in older subjects (40 men aged 43 to 61, post myocardial infarction). They compared prediction from specific treadmill self-efficacy with prediction from actual performance on a treadmill test. Self-efficacy was the better predictor of performance on a second treadmill test.

Strength Self-efficacy and Prediction. A number of studies were concerned with specific self-efficacy as a predictor of strength performance. Weinberg, Gould, and Jackson (1979), in an empirical test of Bandura's (1977) theory, randomly assigned 112 undergraduates (56 men and 56 women) to two groups. The levels of strength self-efficacy in the two groups were experimentally manipulated (by the use of confederates) to be relatively high or low. Subjects whose self-efficacy expectations were higher were able to maintain leg extension significantly longer against gravity than the group whose self-efficacy was lower ($p < .001$). There was no significant efficacy difference between sexes.

In a subsequent study, Weinberg, Yukelson, and Jackson (1980) used a similar design and the same numbers of subjects. Levels of strength self-efficacy were again manipulated, but this time subjects could not see the confederates. They were also asked to state before testing how well they expected to perform during the leg extension test. Only the males showed a significant efficacy effect ($p < .001$). The authors explain the sex difference (not found in the earlier study) by theorizing that women may be less competitive with themselves than men are, i.e., since they could not see the confederate, they did not feel a need to compete. No theoretical explanation was given for this conclusion, which seems rather unlikely. Possibly the overt statement of beliefs about performance could have different implications for men and women.

Wilkes and Summers (1984), studied the relationship between mental preparation methods (including self-efficacy

enhancement) and strength performance. They assigned 60 male undergraduate subjects randomly to four groups according to mental preparation method (arousal, attention, imagery or self-efficacy) and to a control group. The subjects completed an initial test of isokinetic leg strength, followed by mental preparation and a second test of strength. With the effect of initial strength level controlled, subjects in the self-efficacy group showed significant increases in strength on the second test (16.7%), but in the control group there was a decrement of 5% ($p < .05$). Preparation using arousal showed the greatest increase (17.8%).

Kavanaugh and Hausfeld (1986) investigated the possibility that mood (happy or sad) would affect handgrip strength, and that specific self-efficacy would be related to this effect. Subjects (20 men and 31 women) who scored higher on a handgrip efficacy scale also scored significantly higher in grip strength ($p < .001$) than those whose self-efficacy scores were lower. Gender and mood were not related to strength. The authors commented on the resilience of the self-efficacy concept to minor changes in the measurement scale from that used by Bandura (1977).

Prediction of training results. Ewart, Stewart, Gillilan, and Kelemen (1986) studied strength gains after circuit weight training in men with coronary artery disease. Forty subjects were allocated randomly to two groups. The strength of muscle groups in upper and lower body was measured dynamically on a weight training machine. Both groups trained by jogging; in addition, one group did circuit weight training and the other played volleyball. For men in

the weight training group, the initial level of weight lifting self-efficacy significantly predicted strength gains ($p < .001$). This was the only study found reporting a relationship between self-efficacy and results of training.

Generalized Self-efficacy (PSE) and Prediction

The usefulness of measures such as the above is restricted. They can be used only with the activity for which they were designed. Results from studies using different measures cannot be compared.

The only generalized measure of physical self-efficacy so far proposed has been that of Ryckman et al. (1982). They wanted to be able to measure individual differences in general physical self-efficacy and to use the measure to predict performance in a broad range of physical activities. They developed and validated their 22-item Physical Self-efficacy Scale (Appendix 6), and reported that it did in fact predict performance. It had two factors, Perceived Physical Ability (PPA) and Physical Self-presentation Confidence (PSPC).

In a study with a group of men and women undergraduate students ($N = 128$), Ryckman, Robbins, Thornton, and Kaczor found the PPA was a better predictor than PSPC of subjects' involvement in various types of exercise (aerobic, flexibility and muscle endurance) and sports. Women scored lower on PSE than men and had lower involvement in exercise and sports ($p < .001$). In a follow-up study by Ryckman, Robbins, and Thornton (1982), the gender difference was again investigated with men and women students. It was found, as hypothesized, that women ($N = 136$) had weaker perceptions (as

measured by the PPA) of their physical competence than men (N = 160) ($p < .001$), and less confidence (as measured by the PSPC) in using their skills in the presence of others ($p < .01$).

McAuley and Gill (1983) investigated the reliability, validity and predictive ability of the PSE scale. Fifty-two women gymnasts completed the PSE before competing in an inter-university meet; mean scores were not reported. Internal consistency of the measure was tested, using coefficient alpha (Cronbach, 1951); the value of .72 was considered to show adequate reliability. To be valid, PSE should be related to other measures of self-efficacy for the task. However, the authors found only a weak relationship between PSE scores and measures of gymnastic self-efficacy, and did not consider it valid for this sample. The gymnastic self-efficacy measures were better predictors of performance scores than PSE, accounting for 52% of the variance compared to 10% for PSE. Subjects were better predictors of their own performances than either PSE or the gymnastic self-efficacy measure. These authors did not agree with Ryckman et al. (1982) that PSE significantly predicted performance. However, their subjects were a very select group of competitive gymnasts with considerable experience in assessing their performances. The PSE, on the other hand, was validated with subjects performing novel tasks. McAuley's (1985) study (described above), using subjects without gymnastic experience, did show a significant relationship between a self-efficacy measure (not PSE) and performance. This difference in samples could have, in part, accounted for the

difference in predictive ability. Means and standard deviations of PSE, for comparison with those in the original work (Ryckman et al., 1982), would have been helpful.

Gayton, Metthews and Burchstead (1986) reported PSE predicted results in marathon running. PSE correlated negatively with predicted ($r = -.38$, $p < .05$) and actual ($r = -.43$, $p < .01$) finishing times, for 22 men and 11 women.

The influence of age and sex on PSE was examined by Godin and Shephard (1985). Subjects (44 women and 41 men) of average age 60.2 (range 45-74) completed PSE. To extend the age range, PSE scores were compared with the initial scores for undergraduates in the original reliability study by Ryckman at al. (1982). Results did not show any significant trend in PSE with age, suggesting that up to age 74, perceived physical self-efficacy does not decline. However, women had lower PSE ($p < .005$) and lower PPA ($p < .01$) than men. This was interpreted as, in part, the result of cultural restraints during earlier life on women now over 45; i.e., it was social rather than biological.

Important points for the present study were.

- specific self-efficacy measures can predict physical performance including strength.
- one study reports a self-efficacy measure predicted training results.
- PSE has been reported to be a predictor of general physical performance.
- PSE does not appear to change with age, but women do not score as high as men on this measure.

III

METHOD

Subjects

Sixty-eight women aged 50-74 were recruited through publicity in community newspapers and TV public service announcements, and by direct contact with groups of older women, such as the Mature Women's Network and the UBC Summer Programme for Retired People. Most came from middle income groups, and were living independently in the western area of Vancouver. Nineteen of them were working. All were reasonably healthy and active.

Design of the Experiment

Subjects were randomly allocated to experimental and control groups. Their right arm strength, right arm power, right and left arm FCA, and PSE were measured. The left arm FCA was measured to control for possible changes unrelated to training. The experimental group followed a weight training programme for 12 weeks, and the control group followed a flexibility training programme taking a comparable daily amount of time. The measures were repeated after training. The data were analysed for significance of initial differences between experimental and control groups, and before and after training in experimental and control groups; and for correlation between scores on PSE and changes in arm strength or arm power.

Selection of Physiological Measures

Measures of Strength

The ideal method for testing strength would be clearly related to the training method, and both methods would be

related to real life activities in which increased strength would be useful. In selecting the method that would be nearest to the ideal, the following were considered: grip strength, situps and pushups, isokinetic torque, isometric methods, and weight lifting (RM).

Grip Strength. This test has been used as a measure of overall strength for many years (Burke et al., 1953; Canada Fitness Survey, 1983; Montoye & Lamphiear, 1977). Rogers (1926) found a correlation of .70 between a combination of right and left grip strength and his Athletic Index (a measure including running, throwing and jumping) indicating a relationship between grip strength and general physical ability. The grip strength test is quick and simple to administer, but is basically isometric. Training for increase in grip strength would be difficult to quantify and in the circumstances would not provide feedback to the subject. For these reasons it was thought inappropriate for the present study.

Situps and Pushups. The total number of situps or pushups completed in a given time or to exhaustion can be used as a measure of strength. Clearly, a basic level of strength is essential for completion of these tests; however, the results of the Canada Fitness Survey (1983) show that many older women are probably unable to complete even one situp. In any case, these tests are quite strenuous, and were rejected for use in the present study.

Isometric Methods. By its nature, an isometric contraction is limited to one angle, and an isometric measure of strength is specific to the angle at which it is made

(Gardner, 1963). Furthermore, it has been shown that an increase in dynamic strength resulting from training with free weights does not result in a comparable increase in isometric strength (Rutherford & Jones, 1986). Isometric contractions are strenuous, and may not be safe for older people. For these reasons, isometric methods were considered inappropriate for the present study.

Isokinetic Torque. As measured by the Cybex II Dynamometer, iosokinetic torque is probably the most popular measure currently used in strength testing. However, because of the specificity attending strength training (Sale & MacDougall, 1981), strength measured by Cybex is not likely to increase as a result of training with free weights, in which both contraction method and body positioning are different. In addition, the results of a pilot study (two women) showed that a large increase in the amount of weight that could be lifted after training could not be demonstrated using Cybex. Thus, the method was considered unsuitable for the present study.

Weight Lifting (RM). The use of 1RM as a measure was rejected for reasons similar to those indicated for isometric methods. However, 6RM avoids the danger of overload, and the fatigue of repeating many sets of a large number of repetitions (as in 10RM) when "hunting" for the maximum appropriate weight. 6RM as a measure of strength has the advantage of being identical with the traditional training regime (Berger, 1962) and was the measure used in the present study (Appendix 1). Only concentric contraction strength was

to be measured, as is usual, and to help to isolate the movement (Sale & McDougall, 1982).

Measures of Power

In making the selection, the desirability of direct measurement (in a free movement) of the force and velocity components of power was recognized. The following indirect measures of power were considered: performance tests, isokinetic tests, and weight lifting.

Performance Tests. Indirect methods, such as jumping, throwing, and timed pushups and situps, give at best only gross power measures. They cannot be clearly related to specific muscle groups, and have not been validated (Considine, 1971). In any case, they were considered too strenuous to be appropriate for the older women in the present study.

Isokinetic Torque. The isokinetic method (used in machines such as Cybex II) is said to be able to simulate speed of movement in actual performance (Heyward, 1983), but normal movements are not made at constant speed. If the angular velocity is set high, maximum power is not developed. As the speed is reduced, the isokinetic movement approaches more and more closely to an isometric one and at zero speed becomes isometric. The appropriate velocity for maximum power varies between individuals. The measure is accurate only if the Cybex is calibrated for each change in velocity (Sale & Norman, 1982). For these reasons, the method was considered unsuitable for the present study.

Weight-lifting (RM). In weightlifting, 1RM with no record of lifting velocity is the commonest measure of power.

It provides direct feedback about progress. However, if a measurement of velocity is desired, it is difficult to obtain, even with cinematographic methods.

Sale and Norman (1982) discussed the lack of a means of measuring velocity and force in weight lifting. They suggested the possibility of mounting a displacement potentiometer on a weight-lifting machine to measure velocity, with a strain gauge to measure actual force. A productive approach would be to measure force at various weights, with two to three trials at each weight, and so to determine a force- and power-velocity relationship. They stressed the need for a standardized position and range of movement and for using an isolated concentric contraction to reduce the variability caused by the rebound effect.

A similar idea independently arrived at led to the development of the experimental dynamometer used in the present study (Haydock, Brown, & Robertson, 1985). It is fully described in Appendix 2.

Measures of Muscle Bulk

A measure of change in arm muscle size over time was needed. Anthropometric and ultrasound methods were considered. Ultrasound is believed to be accurate (Booth, Godddard, & Paton, 1966) but requires expensive apparatus which was not available. Anthropometric measurements (girth and skinfolds) are reliable for within-subject changes, and were considered to be satisfactory for the present study, since an experienced observer and appropriate equipment (Harpenden calipers) were available (Burr & Phillips, 1984).

Physiological Measures Used in the Study

Strength: 6RM. Strength was measured operationally by determining the maximum weight in kg that the subject was prepared to lift six times and no more, using a biceps curl, keeping a steady rhythm and good form (6RM). Weights were used in increments of .5 kg from 2.5 to 5.5 kg. As a result some scores were truncated to the next lower weight, and the average maximum 6RM was probably lower than the true maximum.

A standardized position for the subject (leaning back against the wall with the feet forward) and a standard protocal for administration were used (Appendix 1). This test was administered by the researcher.

Power. Power was measured using the experimental dynamometer (Appendix 2) and expressed as the peak power in W exerted by the subject in right elbow flexion averaged over five trials. The dynamometer was designed using accepted mechanical and electronic engineering principles to record instantaneous measures of force and angular velocity. Each subject lifted a weight established (by nine preliminary trials at varying loads) as being satisfactory for her (the established load). This was the weight that was heavy enough to slow the movement down and to allow the development of power (Eckart, 1965), but not so heavy as to be almost impossible to lift. Weights were used in increments of .5 kg. Care was taken to familiarize each subject with the equipment before data were recorded; each subject completed at least 10 practice trials, and the nine preliminary trials which were used determining the appropriate load for her. The

dynamometer was adjusted to the height and forearm length of each individual. The test position was standardized with the subject leaning against a back rest, and stabilized with Velcro straps around shoulders and upper arm. Force and angle were sampled over 3 sec at 50 Hz and filtered at 6 Hz; peak power was computed from these data (Appendix 4). The test was administered by the adviser or researcher, using a standard protocol. A research assistant operated the computer. The procedure is more fully explained below (p.76) and in Appendix 3.

Flexibility. The control group was required to carry out a flexibility training programme comparable (in frequency and in time involved) to the strength training for the experimental group. Flexibility was measured at the beginning and end of the training period as being likely to maintain adherence by the control group, rather than as an experimental variable. The data were not analysed. The sit and reach method described by Wells and Dillon (1952) was used and administered by the researcher.

Muscle Bulk. The FCA of both upper arms was estimated by a modification of the method used by Moritani and de Vries (1980) using two skinfolds (biceps and triceps), instead of four. Most studies with adults have been carried out using only one skinfold (triceps); norms using this method have been published (Bishop, Bowen, & Ritche6y, 1981; McEvoy & James, 1982).

In the present study, only change over time was of interest. Anthropometric methods have been used to demonstrate changes in muscle bulk relating to maturation

(Ross & Marfell-Jones, 1982) and training (Moritani & de Vries, 1980). The method is considered reliable in the hands of an experienced person (Burr & Phillips, 1984). In the present study all anthropometric measures were made by an experienced measurer. Correlations indicated the reliability of the measurement (subject reliability). In the combined groups, right and left FCA were correlated (r = .91 for initial testing and r = .86 for final testing). In the control group, initial and final FCA were correlated r = .91 for left FCA and .93 for right FCA. The calculation used is shown in Appendix 5.

The Psychological Measure

Physical Self-efficacy

A possible relationship between perceived self-efficacy for physical activity and strength changes as a result of training was investigated.

The physical self-efficacy scale (PSE) developed by Ryckman et al. (1982) has two factors: (1) Perceived Physical Ability (PPA) which assessed perception of physical abilities, strength and fitness; and (2) Physical Self-Presentation Confidence (PSPC), which assessed confidence in the public presentation of these abilities. A series of studies by Ryckman et al. (1982) showed that the PPA was a better predictor of involvement in sport and of skill performance than PSPC.

Other studies in the series investigated consistency, reliability, convergent validity and predictive validity. They yielded the following satisfactory results:

(1) internal consistencies for the scales, assessed by coefficient alpha (Cronbach, 1951) were .81 for PSE, .84 for PPA, and .74 for PSPC.

(2) test-retest reliability after six weeks (r = .80; p < .001).

(3) convergent validity, tested by examining correlations between PSE and other measures of physical self-concept. The strongest correlation was that with the Tennessee Physical Self-concept Scale (TPSC) (r = .58, p = < .001).

(4) predictive validity of the scale, investigated by three studies:

(a) relating PSE scores to a measure of sports experience reported by the subjects (N = 96) and of their present sports involvement, and

(b) relating PSE scores to performance of the same subjects on a test of physical skill (darts-throwing). In both (a) and (b) PSE was a better predictor than the TPSC subscale or the Health Locus of Control.

(c) A final study related PSE scores and a test of reaction-time (N = 22); students whose PSE scores were favourable had faster reaction times (p < .03).

<u>The Physical Self-efficacy Scale</u>

The scale consists of 22 statements (Appendix 6) to which subjects respond on a six-point Likert-type scale, from 1 (strongly agree) to 6 (strongly disagree). Higher scores reflect a stronger sense of physical self-efficacy. To control for acquiescence response set, positive responses require agreement in half the questions and disagreement in half (Ryckman et al., 1982). The 9th item in the Ryckman

scale ("I am never intimidated by the thought of a sexual encounter") was put last in the present study. During pilot testing it was observed older women were often startled by this item, and frequently did not respond to it. It was feared that reaction to the item might cause a change in attitude during measurement. This measure was administered by the researcher, using a standard protocol (Appendix 7).

A pilot study for the present investigation, in which the PSE was administered to a group of 56 older women, found the scores (M = 88.57, SD = 13.6) somewhat lower than, but similar to, those found by Ryckman et al. in their pilot study with 83 male students (M = 98.54, SD = 13.85). An investigation by Godin and Shephard (1985) indicated lower mean scores in women than in men but no evidence of an age effect. No studies relating PSE and strength training were found, but Gayton, Matthews and Burchstead found PSE significantly correlated with times in marathon races in 22 men and 11 women ($r = -.47$, $p < .01$) and Ewart et al. (1986) found specific self-efficacy to be related to strength gains after training in 20 older men ($p < .001$). The results of the examination of convergent validity reported by Ryckman et al. (1982) were considered adequate evidence of test validity. As already noted, the subjects in that study were college age students; older women may respond differently.

To see whether or not the two factors (PPA and PSPC) reported by Ryckman et al. (1982) were present, the initial data from the 56 study subjects were combined with data from 56 older women who took part in a pilot study (total N = 112). Principle components analysis with varimax rotation

using the BMD program P4M (Dixon, 1985, p.480) did not identify any factors.

Internal reliability of the PSE for older women was assessed by coefficient alpha (Cronbach, 1951) with data from the same 112 subjects used in factor analysis. The contribution of individual test items to the variance was examined, since it seemed possible that items which contributed to the variance when used with men subjects might not do so when used with older women. Coefficient alpha was increased from .69 to .71 by the exclusion of two items; in the study by Ryckman et al. (1982) a coefficient alpha of .81 was obtained. The items excluded were item 10 (I am not hesitant about disagreeing with people bigger than me) and item 17 (Sometimes I feel uncomfortable shaking hands because my hands are clammy). It seemed reasonable to suppose that neither of these would be as important to women, especially older women, as to the young men subjects in the (1982) study by Ryckman et al.; most women are accustomed to being smaller than at least half the population, and older women are probably less likely than men to consider handshaking an important social habit. All the original 22 items were included in the questionnaire used, but the PSE score for statistical analysis was the sum of the responses to 20 items, i.e., minus items 10 and 17.

Procedure

Each subject was randomly allocated to experimental or control groups before the first meeting with the researcher, but was not informed which group she was in until initial testing had been completed. Thus, there would be no chance

that this knowledge could affect her performance especially in the strength and power measures (she might think them less important if she knew she was "only" in the control group). No way was found to control for this effect in the final measure.

Subjects were arranged in five groups of approximately 12 according to the day and time they were available.

Initial Measurements

Each of the five groups attended at the UBC Biomechanics Laboratory, each subject on two occasions a week apart. Subject Record Sheets (Appendix 8a & 8b) were maintained for each subject and all data recorded thereon. Street clothes could be worn, but subjects were asked to wear comfortable dress, with short sleeves.

First Day. On the first visit, subjects began by completing PAR-Q (Appendix 9), a physical readiness questionnaire (B.C. Ministry of Health, 1978), to identify those for whom the training might pose a medical problem. Two subjects were advised to withdraw at this stage for medical reasons.

After giving informed consent (Appendix 10), subjects saw demonstrations of the training and measurement procedures, i.e., dumbell training, measurement of 6RM, and use of the experimental dynamometer. Heights and weights of the subjects were measured and recorded and appointments made at 15 min intervals over the following 3 1/2 hours for them to complete the testing.

At the appointed times, anthropometric measures were taken of height (from the floor) of radiale and dactylion.

Radiale height was used to adjust the platform setting, and both measures to calculate the length of the forearm (Appendix 15), and from that to estimate the correct handle setting. Each subject was familiarized with the apparatus and methods to be used and given considerable practice on the dynamometer.

Two related measures were determined for each subject:

(1) The maximum weight each was prepared to lift at 6RM; this was the dependent measure of *strength*. The procedure used is fully described in Appendix 1. This weight minus .5 kg was the beginning weight used during dumbell training by the subjects in the experimental group.

(2) The maximum dynamometer weight each could lift without straining, a factor in the dependent measure of *power*. The procedure included ten practice trials and three recorded trials at each of three different weights (beginning with 6RM minus 1.0 kg), and is fully described in Appendix 3. The weight thus determined was the subject's established load.

On completion, appointments were made for subjects to return a week later, at approximately the same time of day, to complete testing. It would have been quite tiring for the subjects to complete the familiarization process (ten trials), the determination of established load (nine trials), and the measurement of 6RM and peak power all on the same day.

Second Day. On this occasion, the final one for the initial measurements, each subject first completed the PSE (Appendix 6). A standard introduction to the questionnaire was used (Appendix 7).

Anthropological measures were then made: right and left biceps and triceps skinfolds, right and left arm girth. Peak power at the established load on the dynamometer, and flexibility were measured. Almost all subjects were able to attend on the days appointed, but special arrangements had to be made for three stragglers.

Training Period

On completion of data collection, each subject was informed whether she was in the experimental group or in the control group. All subjects were asked to begin training (at home) after a day or two of rest, three times a week, either Monday, Wednesday and Friday, or Tuesday, Thursday and Saturday, for 12 weeks. This was a convenient period, ending before the Christmas holidays, and short enough to keep subjects involved.

Some departures from the training regime were accepted as inevitable, but tolerable since the convenience of training at home was expected to encourage adherence (Gettman, Pollock, & Ward, 1983). An effort was made to limit these departures from training procedure by checking each subject in both groups in person at least three times during the period.

The training for the two groups was as follows:

Experimental Group. The weight-training method (biceps curls in sets of 6), already practiced during measurement of 6RM, was reviewed. Each member of the group was given written instructions for training (Appendix 11), a strength training Record Sheet on which to record dates and times of training (Appendix 12) and a dumbell of the appropriate weight (6RM

less .5 kg). Each person began training using one set of six repetitions, and worked up to three sets. During the first week, each subject was checked to ensure that the weight was appropriate. In three cases, the weight was increased by .5 kg at this time. During the training period, weights were increased by .5 kg three times, at approximately three, six, and nine weeks; it was impractical to keep exactly on schedule for these changes. Most subjects were ready to increase weight on schedule, and all except two did increase three times. Each subject in the group was seen and training method checked at these times.

Control Group. Each member of the control group was shown how to perform Phase I of the flexibility training and given written instructions (Appendix 13a), and a flexibility training Record Sheet on which to record training (Appendix 14). Each subject was contacted in person or by telephone at about three weeks and nine weeks to answer questions and review progress. Two phases of training were used to provide progression and maintain interest. At about six weeks all subjects were seen at a central location, and shown how to do Phase II. Written instructions were provided (Appendix 13b).

Final Measurement

At the end of the 12 weeks of training, all subjects returned, as far as possible in the original five groups, to the central location. PSE, 6RM, peak power, skinfolds, arm girths, and flexibility were all measured again, and weight was recorded. PSE was included as in the first measurement in order to keep the test conditions uniform. Although an effort was made to repeat the testing on the same day of the week

and at the same time for each subject, it was not always possible. Again some special arrangements had to be made for stragglers. All training Record Sheets were collected. Subjects in the control group were offered strength training, and those in the experimental group were offered flexibility training.

Data Analysis

Overview of Data

To assess normality and check for extreme values, descriptive statistics and histograms of all measured variables were computed for the combined groups and for the experimental and control groups separately, using the BMD program P3D (Dixon, 1985, p.94). Only complete cases were used.

In addition, a matrix of correlations was computed (Pearson product-moment correlation coefficients) between all variables (and for change scores for 6RM and peak power) for both the experimental and the control group, and for the combined groups. The BMD program P8D (Dixon, 1985, p.209) was used. These matrices gave a general exploratory view of the relationship between the variables.

Physiological variables

Measures of three dependent variables (6RM, peak power, and FCA) were used to investigate muscle changes over time with training.

Because they were potentially correlated, significance was tested by multivariate analysis of variance (MANOVA), using the BMD program P4V (Dixon, 1985, p.388, 395). One grouping factor (experimental and control) and one within

factor (time) were used, with repeated measures on the three dependent variables. For analysis to continue, a significant Hotelling's *T*2 was required between groups. The analysis after a significant MANOVA consisted of analysis of variance for the three dependent variables separately.

Physical Self-efficacy (PSE)

The matrix of correlations already referred to was used to determine whether or not PSE was correlated with mean changes in 6RM or in peak power.

IV

RESULTS

The women who took part in the study followed their programmes very conscientiously. Adherence (calculated from record sheets as the percentage of possible training sessions reported to have been completed) was 92.4% in the experimental group. Three subjects in this group did not return record sheets, and were scored as having 50% adherence. Most training lapses occurred in the last week of training, during which testing was beginning.

Data were analysed using $p < .05$ as the criterion for significance in all statistical tests. A change of 10% in strength or power was considered of practical importance. Such a change is considered to be of therapeutic significance (Wessel, 1985). Aniansson (1984) reported 7 - 13% strength gains in her group of older women after ten months. An increase of 5% in FCA was considered to be of practical importance. Moritani and de Vries reported gains in FCA of 9% in their young men subjects; young women generally show less hypertrophy with training than men, and 5% was considered conservative.

When initial and final measurements were compared, the main findings were as follows:

(1) Strength of the right arm in flexion increased significantly in the experimental group as compared to the control group.

(2) Arm power was slightly lower and FCA almost unchanged in both experimental and control groups.

(3) Initial scores on PSE were not found to be related to the changes in 6RM or to peak power.

In the following, "combined groups" refers to the total subjects, experimental plus control groups.

Description of Subjects

The subjects were representative of the population of the generally upper middle class area from which they came. In answer to the question "Are you over age 65 and not accustomed to vigorous exercise?" (PAR-Q. B.C. Ministry of Health, 1978), of those over 65, ten replied "Yes" and ten replied "No". Subjects were screened only for contra-indication for arm flexor training, and included women with disorders such as arthritis, osteoporosis, controlled hypertension, circulatory problems, and obesity. For women in their age group, these are "normal" disorders, but are of the type often screened out in population studies of fitness. The sample was large enough for physiological variables to be near the population averages for Canada. The 68 subjects originally recruited were randomly assigned (before interview, to avoid experimenter bias) to experimental and control group, 34 in each group. There were 13 drop outs or withdrawals, reducing the total to 55: nine did not keep the first appointment for testing, two were advised to withdraw for medical reasons after completing PAR-Q (British Columbia. Ministry of Health), and two dropped out during training. Unfortunately, 11 of these had been assigned to the control group and only two to the experimental group. Thus the control group had 23 subjects and the experimental group 32, a total of 55.

Five of the 55 cases were incomplete, so that there were 50 complete cases for analysis, 30 in the experimental group and 20 in the control group. Of the 50, 18 had reported minor medical disorders, nine in each of the groups. For one subject in the experimental group, the initial measure of PSE was incomplete, so that there were 29 complete cases in the experimental group for PSE, and 20 in the control group. The means of the five incomplete cases for age (60.2 years), height (160.51 cm), weight (66.73 kg) and PSE (93) were similar to those of the combined groups. Although flexibility was measured and recorded the data were not used in analysis.

Age, height, and weight data for the subjects is given in Table 2. Subjects were on average slightly taller than the population average of about 159 cm for women aged 60-69. The experimental group was slightly lighter and the control group

Table 2

Age (yrs), Height (cm), and Body Weight (kg) of Subjects Before Training

		Mean	*sd*	Maximum	Minimum
Exptl.	Age (yrs)	63.3	4.9	76	55
(*n*=30)	Height (cm)	161.1	5.9	171.5	148.0
	Weight (kg)	63.0	7.1	79.8	49.0
Control	Age (yrs)	60.8	4.7	68	50
n=20	Height (cm)	161.5	5.2	172.1	151.8
	Weight (kg)	67.0	11.3	87.5	50.4
Total	Age (yrs)	62.3	4.9	76	50
(*n*=50)	Height (cm)	161.3	5.6	172.1	148.0
	Weight (kg)	64.6	9.1	87.5	49.0

slightly heavier than the population average of about 64 kg for women aged 60-69 (population averages from Canada Fitness Survey, 1983).

The initial differences between the means for age, height, weight, FCA and PSE (both forms) for the two groups were not found to be statistically significant when analysed by MANOVA.

As part of the initial analysis, the Levene test for equality of variance was made between variables in the experimental group and those in the control group. The variances were homogeneous except those for final weight, for initial left and right FCA, and for final right FCA ($p > .05$ but $< .10$ in all four cases). A moderate departure from homegeneity such as this should not seriously affect the validity of the analysis of variance (Ferguson, 1977, p.246). The subjects were considered to be an appropriate sample for this study.

Correlation. The correlation matrices for all variables (separately computed for experimental, control, and combined groups) indicated no correlation supporting the hypotheses for the study (Tables 3, 4, and 5, p.85-87).

Strength, Power and FCA: Hypotheses 1, 2, and 3

Changes over Time. Means and standard deviations for 6RM (kg), peak power (W) and (right) FCA (cm2), and for changes in these variables in the combined, experimental, and control group before and after training are shown in Table 6. These changes were analysed by multivariate analysis of variance (MANOVA).

Table 3: Correlation Matrix for all Variables: Experimental Group.

		AGE 1	HEIGHT 2	WT1 3	WT2 4	RM1 5	RM2 6	FLEX1 7	FLEX2 8	PEAK1 9	PEAK2 10
AGE	1	1.0000									
HEIGHT	2	-0.2064	1.0000								
WT1	3	-0.3638	0.1555	1.0000							
WT2	4	-0.3760	0.0985	0.9702	1.0000						
RM1	5	-0.2683	0.2828	0.4684	0.4168	1.0000					
RM2	6	-0.3426	0.2009	0.4632	0.4298	0.5200	1.0000				
FLEX1	7	-0.2097	-0.0367	0.1679	0.1117	0.0074	0.2858	1.0000			
FLEX2	8	-0.2762	0.0444	0.0380	-0.0504	-0.0003	0.2408	0.8898	1.0000		
PEAK1	9	-0.4030	0.3232	0.5892	0.5881	0.6415	0.5608	0.2210	0.1699	1.0000	
PEAK2	10	-0.4890	0.2713	0.5061	0.5231	0.4531	0.5078	0.2348	0.1562	0.8582	1.0000
ARML1	11	-0.0209	-0.1993	0.6006	0.6170	0.0550	0.3031	0.1705	0.0434	0.2645	0.3393
AMRL2	12	0.1273	-0.2148	0.4501	0.4657	-0.0200	0.3645	-0.0191	-0.0682	0.1046	0.1055
ARMR1	13	0.0486	-0.2980	0.5149	0.5517	-0.0718	0.2351	0.1819	-0.0254	0.2114	0.2345
ARMR2	14	-0.0486	-0.1875	0.4485	0.5084	-0.1275	0.2665	0.1625	0.0013	0.1440	0.1753
PSE1	15	-0.1976	0.1418	-0.1078	-0.0138	-0.0301	-0.0430	0.0017	-0.0814	0.2514	0.2435
PSE2	16	-0.5023	0.2407	0.1075	0.1525	0.2753	0.1933	-0.0676	-0.0968	0.4851	0.4319
RM	17	-0.1671	-0.0060	0.1383	0.1432	-0.2379	0.7060	0.3188	0.3008	0.1057	0.2017
PEAK	18	0.0493	-0.2188	-0.3818	-0.3544	-0.5608	-0.3246	-0.0764	-0.0951	-0.6488	-0.1663

		ARML1 11	AMRL2 12	ARMR1 13	ARMR2 14	PSE1 15	PSE2 16	RM 17	PEAK 18
ARML1	11	1.0000							
AMRL2	12	0.7742	1.0000						
ARMR1	13	0.8177	0.7736	1.0000					
ARMR2	14	0.7440	0.7754	0.8653	1.0000				
PSE1	15	0.0692	-0.0664	0.1680	0.2083	1.0000			
PSE2	16	0.0294	-0.1657	0.0192	0.0932	0.7291	1.0000		
RM	17	0.2990	0.4311	0.3269	0.4088	-0.0243	-0.0038	1.0000	
PEAK	18	-0.0051	-0.0445	-0.0585	-0.0166	-0.0986	-0.2510	0.0959	1.0000

Abbreviations for Variables

ARML1	Left FCA, Initial	PSE1	PSE, Initial
ARML2	Left FCA, Final	PSE2	PSE, Final
ARMR1	Right FCA, Initial	RM1	6RM Score, Initial
ARMR2	Right FCA, Final	RM2	6RM Score, Final
FLEX1	Flexibility, Initial	Peak	Difference: PEAK2 - PEAK1
FLEX2	Flexibility, Final	RM	Difference: RM2 - RM1
PEAK1	Peak Power, Initial		
PEAK2	Peak Power, Final		

Table 4: Correlation Matrix for all Variables: Control Group.

		AGE 1	HEIGHT 2	WT1 3	WT2 4	RM1 5	RM2 6	FLEX1 7	FLEX2 8	PEAK1 9	PEAK2 10
AGE	1	1.0000									
HEIGHT	2	-0.3119	1.0000								
WT1	3	-0.0832	-0.0236	1.0000							
WT2	4	-0.0382	-0.0153	0.9209	1.0000						
RM1	5	-0.3898	-0.0379	0.4697	0.4680	1.0000					
RM2	6	-0.3220	0.0643	0.4533	0.4022	0.7869	1.0000				
FLEX1	7	0.1053	0.1457	-0.5595	-0.5573	-0.0803	0.0911	1.0000			
FLEX2	8	0.0403	0.1251	-0.3579	-0.3980	0.1368	0.1456	0.8498	1.0000		
PEAK1	9	-0.5256	0.0613	0.5801	0.4693	0.5869	0.6841	-0.0591	0.1953	1.0000	
PEAK2	10	-0.5238	0.2074	0.5948	0.4869	0.6535	0.7180	-0.0344	0.2137	0.9378	1.0000
ARML1	11	0.0051	-0.0720	0.7488	0.5366	0.3089	0.4864	-0.1346	0.0650	0.6995	0.6117
AMRL2	12	0.0106	-0.1231	0.8653	0.7411	0.3584	0.4297	-0.2915	-0.1087	0.6503	0.5829
ARMR1	13	0.1114	-0.1904	0.7318	0.5570	0.3096	0.5043	-0.1497	0.0530	0.6724	0.5630
ARMR2	14	-0.0218	-0.1923	0.7894	0.6209	0.3949	0.5189	-0.2402	-0.0067	0.7553	0.6842
PSE1	15	-0.2631	0.0192	-0.1054	-0.1413	0.1773	0.2723	0.2145	0.3537	0.4446	0.4573
PSE2	16	-0.1280	-0.2198	-0.0017	-0.0169	0.0275	0.2681	-0.0113	0.0279	0.3986	0.3685
RM	17	0.1218	0.1556	-0.0485	-0.1227	-0.3712	0.2809	0.2620	0.0063	0.1167	0.0640
PEAK	18	0.2417	0.3104	-0.2280	-0.1713	-0.1109	-0.2308	0.0839	-0.0456	-0.5957	-0.2799

		ARML1 11	AMRL2 12	ARMR1 13	ARMR2 14	PSE1 15	PSE2 16	RM 17	PEAK 18
ARML1	11	1.0000							
AMRL2	12	0.9081	1.0000						
ARMR1	13	0.9721	0.8849	1.0000					
ARMR2	14	0.8948	0.8951	0.9271	1.0000				
PSE1	15	0.0750	0.0696	0.0421	0.1502	1.0000			
PSE2	16	0.1422	0.1002	0.1607	0.2129	0.7632	1.0000		
RM	17	0.2514	0.0893	0.2773	0.1667	0.1340	0.3607	1.0000	
PEAK	18	-0.5192	-0.4498	-0.5571	-0.5059	-0.1714	-0.2500	-0.1747	1.0000

Abbreviations for Variables

ARML1	Left FCA, Initial	PSE1	PSE, Initial
ARML2	Left FCA, Final	PSE2	PSE, Final
ARMR1	Right FCA, Initial	RM1	6RM Score, Initial
ARMR2	Right FCA, Final	RM2	6RM Score, Final
FLEX1	Flexibility, Initial	Peak	Difference: PEAK2 - PEAK1
FLEX2	Flexibility, Final	RM	Difference: RM2 - RM1
PEAK1	Peak Power, Initial		
PEAK2	Peak Power, Final		

Table 5: Correlation Matrix for all Variables: Combined Groups.

		AGE 1	HEIGHT 2	WEIGHT 3	RM1 4	RM2 5	FLEX1 6	FLEX2 7	PEAK1 8	PEAK2 9	ARML1 10
AGE	1	1.0000									
HEIGHT	2	-0.2448	1.0000								
WEIGHT	3	-0.2593	0.0729	1.0000							
RM1	4	-0.3307	0.1528	0.4717	1.0000						
RM2	5	-0.1761	0.1231	0.2811	0.5066	1.0000					
FLEX1	6	-0.0752	0.0241	-0.1915	-0.0349	0.2240	1.0000				
FLEX2	7	-0.1647	0.0699	-0.1313	0.0524	0.1850	0.8733	1.0000			
PEAK1	8	-0.4751	0.2181	0.5928	0.6196	0.4519	0.0913	0.1741	1.0000		
PEAK2	9	-0.5254	0.2422	0.5740	0.5583	0.4149	0.1002	0.1710	0.9001	1.0000	
ARML1	10	-0.0477	-0.1234	0.7038	0.2074	0.2538	0.0077	0.0499	0.5145	0.5096	1.0000
AMRL2	11	0.0359	-0.1602	0.7090	0.1937	0.2821	-0.1510	-0.0810	0.4077	0.3854	0.8586
ARMR1	12	0.0269	-0.2343	0.6540	0.1393	0.2181	0.0200	0.0081	0.4634	0.4313	0.9079
ARMR2	13	-0.0684	-0.1760	0.6657	0.1663	0.2611	-0.0373	-0.0019	0.4823	0.4728	0.8403
PSE1	14	-0.2224	0.0844	-0.0984	0.0824	0.0746	0.0971	0.1017	0.3528	0.3560	0.0749
PSE2	15	-0.3119	0.0517	0.0216	0.1458	0.2444	-0.0398	-0.0528	0.4055	0.3611	0.0686
RM	16	0.0810	0.0090	-0.0823	-0.2740	0.6904	0.2791	0.1674	-0.0159	-0.0056	0.1090
PEAK	17	0.1122	-0.0496	-0.2883	-0.3771	-0.2609	-0.0229	-0.0802	-0.6103	-0.2042	-0.2295

		AMRL2 11	ARMR1 12	ARMR2 13	PSE1 14	PSE2 15	RM 16	PEAK 17
AMRL2	11	1.0000						
ARMR1	12	0.8380	1.0000					
ARMR2	13	0.8497	0.9012	1.0000				
PSE1	14	0.0157	0.0997	0.1755	1.0000			
PSE2	15	-0.0396	0.0668	0.1351	0.7314	1.0000		
RM	16	0.1521	0.1264	0.1517	0.0140	0.1489	1.0000	
PEAK	17	-0.2154	-0.2571	-0.2239	-0.1298	-0.2423	0.0254	1.0000

Abbreviations for Variables

ARML1	Left FCA, Initial	PSE1	PSE, Initial
ARML2	Left FCA, Final	PSE2	PSE, Final
ARMR1	Right FCA, Initial	RM1	6RM Score, Initial
ARMR2	Right FCA, Final	RM2	6RM Score, Final
FLEX1	Flexibility, Initial	Peak	Difference: PEAK2 - PEAK1
FLEX2	Flexibility, Final	RM	Difference: RM2 - RM1
PEAK1	Peak Power, Initial		
PEAK2	Peak Power, Final		

Table 6

6RM, Peak Power,and (Right) FCA. Means, Standard Deviations, and Changes Before and After Training

		Experimental *N* = 30			Control *N* = 20		
		Before	After	Change	Before	After	Change
6RM	*M*	4.28	5.46	1.18	4.40	4.73	.32
(kg)	*SD*	.56	.78	.68	.68	.66	.44
*Peak power	*M*	36.27	33.05	-3.21	40.66	37.35	-3.29
(W)	*SD*	11.69	9.02	6.08	13.78	11.53	4.98
Right FCA	*M*	48.60	49.57	.97	51.32	51.63	.31
cm2)	*SD*	6.37	5.94	**	8.64	9.00	**

* Mean of 5 trials ** Not calculated

Analysis of Variance. Table 7 summarizes the MANOVA analyses. A repeated measures 2 x 2 MANOVA (group x time), with the dependent variables 6RM, peak power and (right) FCA, yielded an overall significant group effect, F (3,46) = 4.9, $p < .005$; i.e., there was a significant difference between experimental and control groups when the sums of initial and final scores on all three variables were compared. Follow-up univariate tests of group effect approached significance only for 6RM, F (1,48) = 3.15 $p < .082$, and were not significant for peak power, F (1,48) = 1.87, $p > .17$, or for FCA, F (1,48) = 1.34, $p > .25$.

The MANOVA also showed a significant overall time effect, F (3,46) = 30.82, $p < .0001$; i.e., the change over time in the sum of the scores on all three variables for the combined groups was significant. Thus, follow-up univariate tests for the dependent variables were examined. The

univariate test of time effect was significant for 6RM, F (1,48) = 75.74, $p < .0001$, and for peak power, F (1,48) = 15.88, $p < .002$, but not for FCA, F (1,48) = 1.83, $p > .18$. Peak power changed (decreased) in both experimental and control groups. FCA did not change in either group or differentially between groups.

Table 7

Summary of MANOVA and Follow-up ANOVAs
Variables: 6RM, Peak Power, and FCA

Source	SS	*df*	*F*	*p*
Between Groups:				
All	15.3705	3, 46	4.91	.0048
6RM	2.31882	1, 48	3.15	.0823
Peak power	455.219	1, 48	1.87	.1778
FCA	136.995	1, 48	1.34	.2524
Within Times				
All	96.4826	3, 46	30.82	.0001
6RM	13.5901	1, 48	75.74	.0001
Peak power	253.760	1, 48	15.76	.0002
FCA	9.90732	1, 48	1.83	.1821
Interaction (Time x Group)				
All	24.982	3, 46	7.98	.0002
6RM	4.386	1, 48	24.44	.0001
Peak power	.02996	1, 48	.01	.9658
FCA	2.5742	1, 48	.48	.4934

The MANOVA overall group by time interaction was significant, F (3,46) = 7.98, $p < .0002$; univariate tests of

this effect were significant for 6RM, F (1,48) = 24.44, p < .0001, but not for peak power, F (1,48) < 1.00 or for FCA, F (1,48) < 1.00; i.e., there was a significant difference in change over time between the experimental and control groups, related only to 6RM (Figure 1).

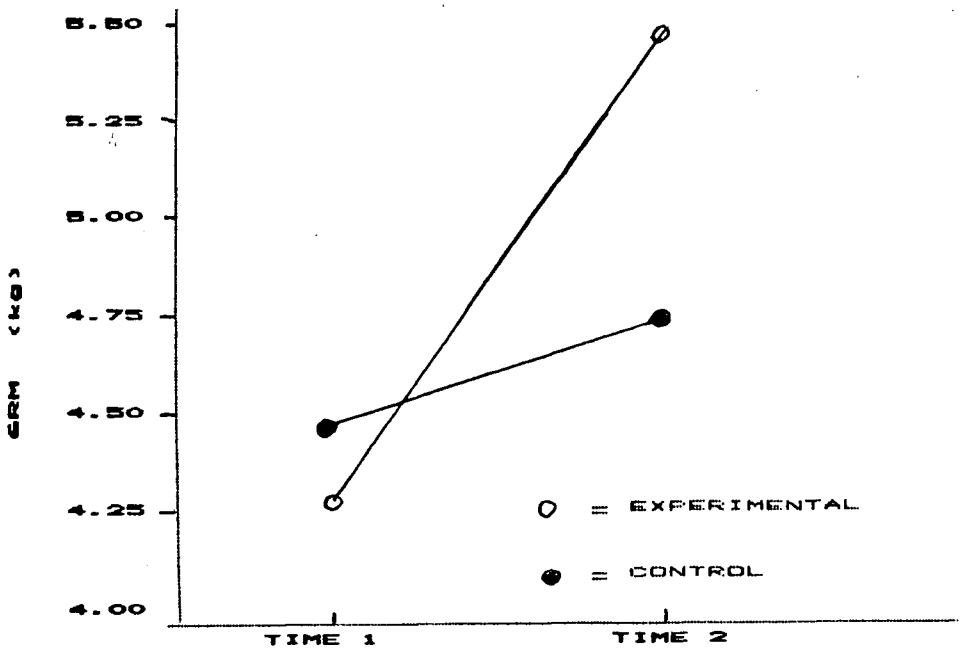

Figure 1. 6RM: group by time interaction.

The change in mean score over time for 6RM was 1.18 kg (SD = .68). Under the test conditions, some subjects did not complete 6RM at the training weight they had been using, but some used a higher weight. Because of the large variance, a frequency distribution of these changes was prepared. Although leptokurtic, it was otherwise normal (Figure 2). In the control group, initial and final scores were correlated .79.

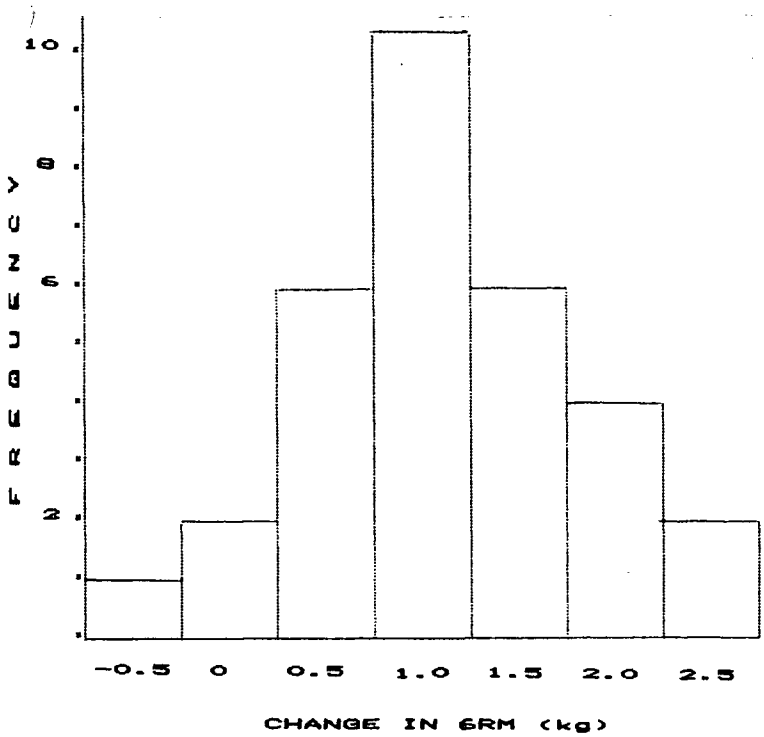

Figure 2. Frequency distribution for change in 6RM after 12 weeks training.

Physical Self-efficacy: Hypothesis 4

The mean initial score in the combined groups for PSE (*N* = 49) was 92.47 (*SD* = 12.80) when all 22 items were included, and 81.98 (*S.D.* =12.78) when items 10 and 17 were excluded (see p. 74). The five incomplete cases (excluded in the data analysis) had mean initial PSE scores (all 22 items included) of 92.80 (*S.D.* = 11.79) and (with items 10 and 17 excluded) of 82.60 (*S.D.*) = 11.35. Ryckman (1982) reported a mean score of 98.54 (*SD* = 13.85) for his young men subjects. Godin and Shephard (1985) reported a mean PSE score of 86.8 for older women.

Initial scores for PSE (as amended by deletion of items 10 and 17) in the experimental group were not significantly linearly related to changes over time in 6RM,

r (49) = .06 p > .10, or in peak power (r (49) = -.10, p > .10, using the Pearson product-moment correlation. However, there was a linear correlation in the combined groups between PSE and peak power: between initial PSE and initial peak power, r (47) = .35, p < .01; between initial PSE and final peak power, r (47) = .36, p < .01; and between final PSE and final peak power, r (47) = .36, p < .01. There was also a correlation between final PSE and initial peak power, r (47) = .41, p < .01. These correlations are considered in the Discussion section.

V

DISCUSSION

The results of the study supported the hypotheses that weight training would result in increased strength as measured by 6RM, but not in increased muscle bulk. They did not support the hypotheses that such training would result in increased power as measured on the dynamometer or that PSE would be related to changes in strength or power.

Strength (6RM) Increase with Training

Strength as measured by 6RM increased in the experimental group by 1.18 kg, an improvement of 27.5% over the initial score, significant both statistically as shown by MANOVA (Table 7; $p < .0001$) and practically. There was an increase of 7.3% in the control group. Thus, strength increased by 20% more in the experimental group than in the control group. The change was very substantial after only 12 weeks. In the only earlier study that related training to strength improvement in older women, Aniansson (1984) reported increases in maximum knee extensor torque (tested by Cybex) after 10 months of twice-weekly dynamic training. Increases varied from 7-13%, inversely with testing velocity; the maximum increase was observed in isometric measurement. In the present study, the close match between training and measurement method may explain the relatively large increase.

Measures of 6RM were affected by the discrete nature of the data. The steps of the scale (.5 kg) were relatively large, and there were only seven of them, (from -.5 to 2.5 kg). This resulted in some scores being truncated. Thus, the measures of 6RM reported may actually be low and the changes

in 6RM reported either low or high, theoretically by nearly .5 kg.

It could be argued that in the measure of 6RM, "keeping good form" was a matter of judgement, not measurement, and might introduce experimenter bias. However, when the judgements were being made, it was evident that subjects knew very quickly, and would comment, when a weight was too heavy or too light. Furthermore, the mean change in 6RM as measured was 1.18 kg, although in most cases the training weight had increased by 1.5 kg. This difference in 6RM was the result of differences between test and home training conditions, the test conditions for body positioning being more stringent.

Body Weight, Age, and Strength

Body weight was a predictor of performance, though not of change over time. On initial tests in the combined groups, body weight correlated .47 with 6RM and .59 with peak power, while 6RM correlated .62 with peak power. The partial correlation between 6RM and peak power with the effect of weight removed was .48, i.e., weight accounted for 40% of the association.

In the combined groups, the correlation between initial score for 6RM and age was low ($r = -.33$). There was little difference in strength measured as 6RM between younger subjects and those aged 70. Many studies have suggested strength beginning to diminish sharply as early as age 50 (Aniansson, 1980; Fisher & Birren, 1947) and for both isometric and dynamic measures (Larsson, Grimby, & Karlsson, 1979). Most cross-sectional studies show strength, however measured, continuing to decline with age (Vandervoort et al.

1986). Grip strength has been shown to decline with age, beginning in the mid-twenties and continuing to age 75 at about 6% a year (Burke et al., 1953). Clement (1974) found grip strength correlated (r = -.67) with age in women (N = 716) aged 16 to 96 years - a much larger age range. The use in the present study of a more "natural", dynamic movement rather than an isometric or isokinetic one might explain the difference in findings.

Power and Training.

No studies of power changes with training in older people were available for comparison.

The measure of power

Because an experimental dynamometer was used to measure power, discussion of some characteristics of the measure itself is appropriate.

The reliability of the measure. Since the control group was tested twice without intervening training, the correlation between initial and final scores after 12 weeks serves as a measure of reliability (subject stability). This was .90. In the original pilot work, the test-retest reliability (one week apart), for ten subjects was .96 (Appendix 2).

Variability of individual subjects' test scores. Means and standard deviations of the initial and final five peak power measurements for each subject were calculated for each subject. The overall means for the combined groups were

37.7 W initially and 34.3 W finally. The maximum individual standard deviation was 6.9. Frequency distributions of these standard deviations were positively skewed, but otherwise approached normality. This indicated the stability of subjects' performance from trial to trial.

Variance of changes in peak power. The standard deviation of change scores for peak power was greater than the mean change itself. This is partly explained by several "extreme" negative changes. The three subjects (one aged 55 two aged 65) who had the largest negative changes in peak power also had higher than average initial scores. The frequency distribution of change scores (Figure 3) was reasonably normal except for these scores.

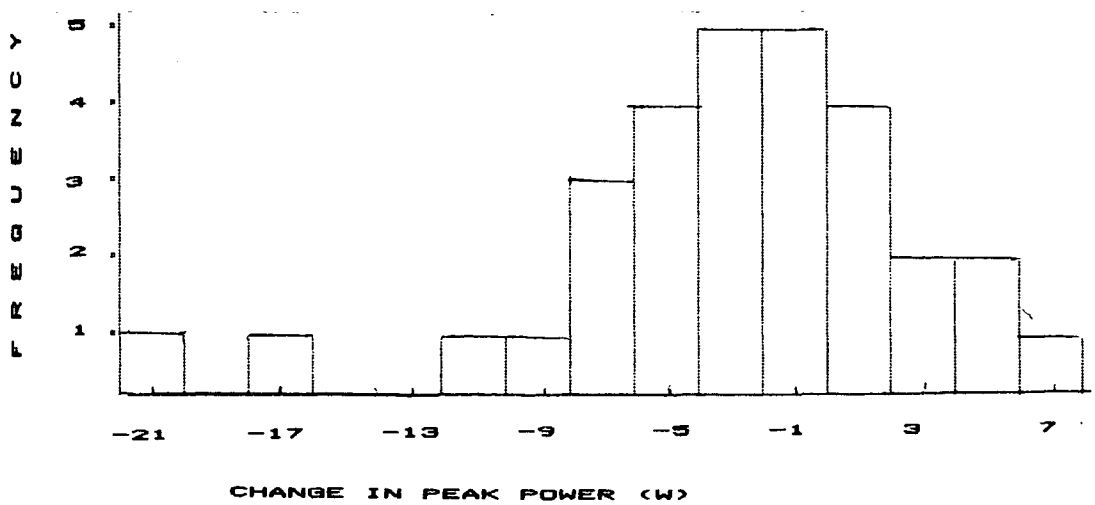

Figure 3. Frequency distriution for change in peak power after 12 weeks training.

Power and FCA

It is logical that FCA, a measure of muscle area, should be positively correlated with peak power. In the combined groups, the correlations between FCA (right and left) and peak power were: .46 (right) and .51 (left) initially, (p < .01) and .47 (right) and .39 (left) finally (p < .01). These correlations were larger than those between FCA and 6RM,

which were not significant. No reason for this difference between 6RM and peak power is offered. In the control group, the correlations between FCA and peak power were larger both initially and finally, (r = .56 and .75, p < .01), than those in the experimental group, (r = .10 and .26, not significant at p < .05). A possible explanation is that the variability in peak power (W) was larger in the control group (M = 40.66, $S.D.$ = 13.78) than in the experimental group (M = 36.23, $S.D.$ = 11.69). The reason for this is unknown.

Power changes after training

The arm action employed on the dynamometer during testing was similar to the arm action in training (specific match), and force was measured directly by means of the strain gauge. These two features of the dynamometer were expected to allow any real changes in peak power to be demonstrated. However, mean peak power actually declined slightly in both experimental and control groups (9.7% for the experimental group and 7.9% for the control group). The following were considered to be possible causes:

(1) The power of all subjects declined during the study for some reason (unknown). The most feasible of "unknown" reasons was considered to be:
(1a) A seasonal effect (shortening days) affected power.

(2) Subjects were inhibited in some way other than by the test conditions from displaying their peak power on the second test.

(3) A systematic error in operation of equipment or

in computation occurred which gave all subjects a constant or proportionally lower score than otherwise possible.

(4) Test administration differed between the two test sessions, i.e., the conditions of the initial test were not as conducive to the expression of peak power as those of the final one.

Of these, (1) seemed unlikely; (1a) seemed unlikely, since it would have meant a seasonal effect on power different from that on 6RM; (2) seemed possible - some final testing was done with the Christmas holiday approaching and subjects may have been preoccupied; (3) seemed possible but unlikely - the equipment was being used by the researcher from time to time throughout the study to measure peak power during calibration and no unexplainable changes in the measure were noticed. During the course of the experiment, the mean variation from full scale deflection was .13% for angle and .4% for force. The dynamometer had been shown to be a valid instrument for measurement of force (by static calibration) and of velocity (by dynamic calibration). It had been shown by dynamic calibration to respond at least as rapidly and accurately to changing forces and velocities as a Kistler force platform, and to have excellent test-retest reliability (Appendix 2). Avis et al. (1985), who also used a dynamometer employing a strain gauge, reported correlations between test and re-test ranging from .88 to .93 (N = 53), increasing with increasing load; (4) seemed possible, since subjects had used the dynamometer during preliminary testing a week before the initial test of peak power but not before the final test.

Test administration. Little has been written about the amount of familiarization required in physical testing generally. Cardus (1978) commented "Testing reproducibility with the subject as part of the system has received limited attention" (p.48). Heyward (1983) reviewed muscle testing without mentioning learning effect.

In the present study, great care was taken to ensure that the same method was used for each test administration. All testing was carried out in the same location, with the same personnel, using the same equipment, and in the same conditions of lighting and ventilation. Subject positions were standardized and stabilized throughout. The PSE and other tests were completed during the second session in the same order as in the first.

The only known difference was that, on the initial testing (but not on the final testing), each subject had used the dynamometer one week earlier, when the weight she would use as the load during testing on the dynamometer was being established. This point was considered when procedure for the study was being decided. Warshal (1979) found a group of 14 men (mean age 21) showed apparent increases in knee extensor strength after repeated isometric measurement. Three measures on consecutive days resulted in an 8% increase. After a one week interval, a further measure showed a further 15% increase over the original strength. The men were not involved in other strength training, and the change was attributed to learning. The points of relevance to the present study were: (1) subjects improved after repeated measurement with no training, and (2) there was a large

increase in strength after a one week interval with no training.

So that the first effect could be avoided, subjects in the present study were not tested repeatedly on the dynamometer. Repeated tests are often used in order to establish the time course of changes, but the practice is incompatible with the need to avoid learning effect - a single case study using the dynamometer had shown a continued learning effect over trials one week apart, beginning to show a plateau after 7 weeks. The second effect was not found during the dynamometer reliability study, in which ten women (ages 20 - 60) each completed two sets of ten trials a week apart; no significant change in peak power was found (1.4 W or 3%, $p > .99$). Thus, preliminary use of the dynamometer a week before the initial test was not expected to influence the second test. A possible reason for the difference between this result and that of Warshal (1979) was that in her study the measure was strength, while in the present study it was power.

Why no power increase? It seems possible that the velocity of the biceps curl used in training was not high enough to give a training effect for power, although subjects were encouraged to increase speed in the biceps curl as they increased training loads. However, it seemed risky to place great stress on speed with older women working unsupervised.

For power to increase, either force or velocity or both must increase. Increased force could result from increased muscle fibre area, increased activation, relaxation of inhibition, or improved co-ordination, or from some

combination of these. Velocity could increase only through increased speed of contraction, either intrinsic or the result of better co-ordination.

Subjects in the experimental group were capable of producing more force - they could lift more weight. However, they were apparently not able to show this increased force by increased power when lifting the same (original) weight on the dynamometer. If the weight that is lifted is the same, the only way to display increased power is by increased velocity. The strain gauge ring used in the dynamometer was specifically designed to be capable of responding to the relatively low forces exerted by older women, and was shown by tests and regular calibration to be sensitive and reliable. This suggests that either:

(1) subjects could not show this increased force (which would result in higher velocity) as peak power while using the dynamometer, or

(2) weight training did not result in increased muscle contraction speed.

Weight training has been reported to improve vertical jump height (a measure of power) in young men, but other studies reported the reverse or no effect (Clarke, 1978). No studies directly relating weight training and power or contraction speed were found for any age group.

Muscle Bulk and Training.

As hypothesized, muscle bulk measured as fat-free cross-sectional area did not increase with training. This agrees with the findings of Moritani and de Vries (1982). It does not, however, rule out the possibility that there were

changes during training in muscle fibre area or in the relative percentage of fast and slow twitch fibres, as found by Aniansson (1980) and Larsson (1979). Changes of this kind are also believed to occur during ageing (Aniansson, 1980; Grimby et al., 1983). In older people, the distinction between age-related strength loss (meaning a reduced number of functional muscle fibres) and loss caused by inactivity (meaning reduced contractile ability in the individual fibres) is not clear. Presumably only the latter could be reversed by training. This point is currently under investigation, e.g., by Aniansson et al. (1986).

Norms for FCA vary with the number of skinfolds, the degree of muscularity, and the experience of the measurer, and between populations. Burr and Phillips (1984) reported FCA of 33.50 cm for women (in South Wales) aged 65 to 69 (*N* = 53), measuring triceps skinfold only. Bishop et al. (1981) reported FCA of 43.68 cm for women (in the U.S.) aged 55-64 (*N* = 669) and of 40.31 cm for women aged 65-74 (*N* = 1822) using the same method. However, the use of two or more skinfolds, rather than the usual single skinfold (triceps), gives lower (and more accurate) estimates of subcutaneous fat, and thus a higher FCA. For women in the present study, the mean FCA was 49.60 cm . In an example, recalculation using only triceps skinfold reduced FCA from 51.50 to 42.1 cm . Moritani & de Vries (1980), using four skinfolds, reported FCA of 64.45 cm in a group of five men aged 67-72, compared with 43.20 cm for men aged 65 to 69 (*N* = 46) reported by Frisancho (1981). The subjects in the present study were probably close to North American norms for FCA.

Variances Related to Age and Body Weight.

Most of the variability was between subjects, and could largely be explained by differences in age and weight. In the combined groups, 6RM was correlated with body weight (r = .47 initially and .28 finally), and there was a weak negative correlation between 6RM and age (r = -.33 initially and -.18 finally). The lower correlations with the final measurements of 6RM reflected the increase in 6RM over time in the experimental group.

Peak power was correlated with both age and weight. In the combined groups, peak power was correlated with weight (r = .59 initially and .57 finally) and negatively with age (r = -.48 initially and -.52 finally). The multiple correlation of initial peak power with age and weight was calculated, and accounted for 46% of the variance (R = .68). Height was not significantly correlated with either peak power (r = -.22) or 6RM (r = .15), though correlation might have been expected in a population where height and weight were correlated (Astrand & Rodahl, 1977, p.371). In the present study the correlation between height and weight was low (r = .07).

Changes in 6RM and peak power were unrelated either to age or to weight.

Peak Power and 6RM.

6RM and peak power behaved differently.

- 6RM increased with training, but peak power did not.
- Peak power was related to age in the combined groups, but 6RM was not.
- There was a significant correlation in the combined

groups between PSE and peak power, but no correlation between PSE and 6RM (see below, p.104).

In this study, peak power and 6RM appeared to behave in some respects as different entities, though they are connected with one another by muscle function and behaviour, and by the integrative function of the nervous system. Understanding these data would require further studies.

Physical Self-efficacy.

PSE was not found to be linearly related to strength as measured by 6RM, or to changes in strength or peak power with training. However, for the combined groups, initial and final PSE scores were both linearly correlated with initial and final peak power, $r = .35$ to $.41$ ($p < .01$).

No studies relating PSE and strength training were found. However, Ewart et al. (1986) found *specific* self-efficacy to be a predictor of improvement in strength after training in older men. Tucker (1983), in a study of weight-lifting, found that in general there was a significant relationship between strength relative to body weight and the "global self-concept" (p.1356) of his subjects ($N = 142$, $p < .01$). *Specific* physical self-efficacy (e.g., gynmastic or treadmill self-efficacy) has been reported to predict performance (Ewart et al., 1983; McAuley, 1985), and endurance strength in young people (Kavanaugh & Hausfeld, 1986, Weinberg et al., 1982; Wilkes & Summers, 1982). Ryckman et al. (1982) reported PSE (a more general measure) to be a significant predictor of performance on physical tasks (dart-throwing, visual discrimination, and catching a ball in a cup) in young men. Gayton et al. (1986) found PSE to be

significantly correlated with marathon running performance.

In the present study, no such relationships between PSE and the strength measure (6RM) or change in 6RM with training were found. (No significant changes in peak power were found). Bandura's (1982) claim that self-efficacy is related to persistence and amount of effort suggested a theoretical relationship between self-efficacy and adherence, and therefore between self-efficacy and training gains. In the present study, the high adherence (92.4% in the experimental group) may in part explain the lack of linear relationship found between PSE and change in 6RM. Gettman et al. (1983) reported an attrition rate of 35% in an unsupervised exercise programme with men age 36 to 42 years. Only one study was found dealing with adherence of older women to exercise programmes (Stirling, et al. 1984). These authors emphasized the importance of convenience for the subjects and of rapport between the instructor and the participants. In the present study, attention was given to making the testing and training as convenient as possible for the subjects. Perhaps partly because the researcher was in the same age group as the participants, they also developed a strong feeling of involvement in her investigation, which was a factor in maintaining adherence.

The possiblity that subjects' physical performances were affected in some way by the nature of questions in PSE was considered purely speculative. It is conceivable that those who were high or low in perceptions of self-efficacy might have had their perceptions reinforced by considering the test

items. This was not expected to have any effect on changes in scores over time, since PSE was administered before both measurement sessions.

Another possibility was that the lack of correlation between PSE and change in 6RM or in peak power was related to the gender or age of the subjects. There is, however, evidence to show that PSE scores do not vary significantly with age or with the interaction of age and gender (Godin & Shephard, 1985). In their study, women scored significantly lower (M = 86.8, $S.D.$ about 12) in self-efficacy than men ($p < .005$); there was no age effect. Data for women were not separately analysed by age. In the present study, the mean score for PSE using all 22 items was 92.47 ($S.D.$ = 12.80), and there was a low correlation between age and PSE ($r = -.22$ initially and $-.31$ finally, $p > .05$). Perhaps PSE is not related to physical performance in older women because the items in PSE have a connotation for them different from that for young men subjects. Ryckman et al. (1982) also found that the subjects who scored higher on PSE reported more varied and intensive sports experience, and more current sports involvement. Although the relationship between PSE and general physical activity was not formally investigated in the present study, it was known that very few of the subjects were actively engaged in sports. Historical, cultural, and social differences between younger and older samples are also likely to affect results. Ryckman et al. (1982) have suggested the use of PSE for diagnosis and assessment of older people. Further investigation would be necessary to assess the value of PSE for these purposes.

In the present study, both measures of PSE (initial and final) in the combined groups were positively correlated (p = .01 in each case) with both measures of peak power (initial PSE, .35 with initial peak power and .37 with final peak power; final PSE, .41 with initial peak power, and .36 with final peak power). It might be speculated that those who were able to display a higher peak power (i.e., could move more quickly) felt more competent and capable of dealing with their environment, and thus more self-efficacious. This relationship requires further investigation.

Conclusions.

In older women (aged 50-76):

(1) Weight-lifting ability can improve with training, using a simple programme carried out at home.

(2) The change in weight-lifting ability after twelve weeks training is not accompanied by muscular hypertrophy.

(3) Muscular power does not increase after twelve weeks weight training.

(4) Changes in 6RM are not associated with PSE; there is, however, a statistically significant linear correlation between peak power and PSE.

(5) Strength (6RM) is more closely associated with body weight than with age.

The older women in this study had a fair share of the disorders that are "normal" in their age group (described in the Results section), and the results may be more generalizable than those in studies where subjects were more stringently screened, such as the Canada Fitness Survey (Canada. National Health & Welfare, 1983).

Recommendations

When the literature relating to strength in older subjects was reviewed, no study using a control group was found. This seems to be a notable deficiency in research of this kind. Without the control group in this study, interpretation of data for peak power and PSE would have been virtually impossible.

Further studies are required to clarify the results of this investigation. The questions needing resolution are (1) was the lack of preliminary trials in the final test of peak power related to the decrease in peak power? (2) would there be a learning effect from using the dynamometer for testing peak power at intervals, with no training?

A study to investigate both of these questions would involve comparison of groups of subjects with and without training between tests, and of groups measured after familiarization with the dynamometer with other groups who had not received such familiarization.

The association between PSE and peak power should also be investigated, and this could be done in conjunction with the study suggested above, by including measurement of PSE for the groups.

Further investigation of the relationship between strength and PSE is a problem, because of the difficulty of measuring strength in older women. It appears that PSE is not related to gains in 6RM, and another perspective is required. It is difficult, however, to envisage using measures such as 1RM bench press or MVC (either of which might be used with men) in a study with older women.

Two studies of importance to the present investigation (Moritani & de Vries, 1980; Ryckman, 1982) need supplementation by additional work. The study by Moritani and de Vries (1980) is extensively quoted, but appears not to have been replicated. The study compared a group of older men and a group of younger ones before and after strength training. Both increased in strength, but only the young group showed hypertrophy. The strength increase in the older group was considered to result from increased neural activity. The study should be repeated with larger groups and with women, since it is known that women respond differently to training from men. Groups should be larger than those used by Moritani & de Vries (1980) and controls should be included.

More studies of PSE are needed. The study in which Ryckman et al. (1982) validated this measure should be replicated with older men, and with both young and older women, and should include the same performance tests used in the original study.

The dynamometer used in this study has many attractive points. In its present form, it allows the isolation of the muscle group in a simple movement for study, but could readily be developed for use in other movements, with other muscle groups, and with people of varying strength. Studies investigating the characteristics of strength and power could be undertaken, and some interesting and fundamental questions examined. Examples include: the relationship between strength and power in younger and older groups; the effect of training

on the time course of force and power development; the relationship between training and power in groups of younger and older people (non-athletes); the behaviour of strength and power in relation to age, training and PSE; and determination of the force-velocity curve, as a check against the conventional *in vitro* curve (Wilkie, 1950) which has long been used in teaching.

Summary

This study was concerned with questions about strength in older women: whether or not strength and power would increase with weight training, and what training and measurement methods would be appropriate. A 2 (experimental and control groups) x 2 (times) experimental design was used; subjects were randomly assigned. There were 30 complete cases for analysis in the experimental group and 20 in the control group. Subjects, aged 50 to 76 years (M = 62.3), included 18 who indicated one or more of the disorders (such as controlled hypertension, arthritis, and osteoporosis) considered "normal" in such a population, but often used to screen out subjects for a study.

An extensive review of the literature about strength in older people and its measurement revealed some problems. Most studies, especially large ones such as the Canada Fitness Survey (Canada. Health and Welfare. 1983), are carried out with samples from populations restricted by screening to individuals more healthy and physically active than average. Cross-sectional studies are used to predict strength loss with ageing, which leads to confusion. Only a small number of studies have been carried out with older subjects, and very

few with older women. Although considerations of specificity require that training and testing should be as similar as possible, many investigators have used MVC to measure strength increases after dynamic training; results must have been affected.

Different definitions of strength and methods of testing it have been used by different workers, so that results of studies may not be comparable. None of the established methods was considered satisfactory for this study. Two ways of measuring strength were used: 6RM, and power as measured by an an experimental dynamometer developed and validated for this purpose. Very few studies have been concerned with the association between training and increase in power, and none have involved older women. The dynamometer was expected to allow investigation of this association, and provide more information than could be obtained from 6RM alone. Results showed that the mean score on 6RM increased significantly in the experimental group; however, mean peak power decreased slightly in both groups.

Another question of interest was whether or not older women who trained by weight-lifting would gain muscle bulk. With the measurement method used, only total cross-sectional fat-free limb area could be assessed, i.e., not muscle volume or composition. It was not expected to change, and did not.

It was believed that physical self-efficacy would be related to persistence in an activity (e.g., adherence to a training programme), and thus scores on the Physical Self-efficacy Scale (Ryckman et al., 1982) were expected to be

associated with the amount of increase in strength and in power. This was not the case, perhaps because of the high (92.4%) adherence in the experimental group. The measure was found to be significantly linearly correlated with peak power in the combined groups (N = 49).

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Appendix 1

Measurement of 6RM

The measure of 6RM was defined in one of two ways: it could be either:

1) a weight that the subject could lift six times but not more, or
2) a weight such that the subject could lift it more than six times but could not lift a heavier weight.

Weights. A set of dumbells weighing from 2.5 to 5.5 kg were used, and a 1 kg practice dumbell. The dumbells were plastic, with handles that could be screwed into hollow end-pieces filled with sand and lead shot, in varying proportions according to the weight needed. Since four weights were needed for each women in the experimental group, it was considerably less expensive to use this method than to buy ordinary dumbells with a series of metal weights. In addition, weights could be incremented by changing the proportions of sand and shot in the end-pieces. A large weighscale was used for accuracy when preparing and changing weights. The maximum weight (end-pieces filled entirely with lead shot) was 7.4 kg.

Method. Subjects, who knew the purpose of the measure, first watched a demonstration of the dumbell lift.

The subject leaned back against the wall with her feet apart and comfortably forward (about 18 in, varying with the height of the subject). She took a dumbell weighing 1 kg in the right hand, thumb on top, and held it by her side, arm extended but not stiff. For practice and warm-up, she was instructed as follows:

Do 10 lifts with this light weight. Try to keep your elbow by your side, and bring the weight close to your shoulder. Try to maintain a steady rhythm and breathe evenly.

The subject was watched and coached until the tester was satisfied that she understood what was required, and was performing the movement correctly.

The subject was then given a weight judged to be close to her maximum, usually 3 or 3.5 kg. By successive trials with good form and a one minute rest between trials, 6RM as defined above was determined. Subjects had to be reminded not to "cock" the wrist at the top of the lift. The criteria for satisfactory form were:

(1) The weight did not to wobble in the hand.

(2) The elbow remained near the side, i.e., the shoulder muscles were involved as little as possible.

Some subjects with poor body awareness were instructed to hold a piece of plastic foam about an inch thick against the wall behind the elbow to keep it from coming forward, thus restricting the contraction as far as posssible to arm flexors.

All trials were recorded on the Record Sheet. The 6RM weight minus 1 kg was used as the basis for the initial loading on the dynamometer. The training weight was 6RM minus .5 kg.

The final test followed the same procedure except that weights from 3.0 to 7.5 kg were used; they were coded from A to J so that subjects could not tell what weight they were lifting.

Appendix 2

Description of the Dynamometer

The decision to design the experimental dynamometer was prompted by the desire for a measure that would:

(1) Measure force and velocity during a dynamic muscle contraction.

(2) Use a movement that could be simulated in training.

(3) Present a constant load at all angles of the movement.

(4) Allow instantaneous recording of data during the movement.

Many dynamometers (e.g., grip strength dynamometer and tensiometer) measure only static strength - velocity cannot be measured. This limitation means that power cannot be measured directly. Devices for measurement under isokinetic or varying conditions have been described (Ariel, 1983), but they all have disadvantages, e.g., velocity is not measured directly or is determined by the setting of the equipment as in Cybex.

Sale and Norman (1982) discussed the need for a means of measuring velocity and force if weight lifting were to be used as a means of measuring power.

> In order to obtain a measure of power in weight lifting, a means of measuring velocity of movement must be incorporated into the test apparatus.... The actual force could be measured by instrumenting the apparatus with strain gauges or an accelerometer (p.18-19).

The dynamometer used in the present study was developed from a similar idea arrived at independently. An early (1972) attempt to develop a dynamometer using this method was unsuccessful because of difficulties in data recording (Brown, 1985).

The problem of measuring strength continuously during a muscle contraction was described by Doss and Karpovich (1965). They developed a machine similar in appearance to the one used in the present study, consisting of a cable attached to a large pulley wheel. The cable passed through the pulley of a strain gauge bolted to the floor to a windlass operated by a tester. The subject rotated the wheel, winding in the cable against resistance supplied by the tester, who also controlled the velocity. The angular changes were measured by a potentiometer (electrogoniometer) on the axle of the wheel and the force by the strain gauge. The machine was adjustable to the varying dimensions of the subjects, but they were not stabilized. The major disadvantages of this apparatus appear to have been that the measures could only have been reliable when the same tester was used, and that the contraction time was unnaturally long (18 s).

A superficially similar method of strength testing was described by Butler and Kempson (1980). They were concerned only with providing constant resistance throughout the range of movement, and did not measure force or angle.

A dynamometer for measurement of force and velocity in leg extension was described by Avis, Hoving, and Toussaint (1985). Velocity was measured by a potentiometer and force by

a strain gauge. This machine could be used for both static and dynamic measures; in the latter the body was displaced as in rowing.

For the present study, the purpose was to measure forearm flexor power of older women before and after weight training. The body position and the movement used in the measurement were to be as similar as possible to the training movement (a biceps curl), thus meeting the requirement for specificity of testing and training. The movement was to be dynamic rather than isometric or isokinetic. The dynamometer was described by Haydock, Brown, and Robertson (1985).

Design

The design specifications were:

(1) To provide a variable load (for people of varying strength).

(2) To measure directly the velocity and relatively low force involved.

(3) To simulate the arm movement of a biceps curl.

(4) To record data instantaneously.

Figures 4 and 5 show the general arrangement of the dynamometer. It consists of a pulley wheel, 50 cm in radius, mounted vertically with the horizontal axle rotating in precision bearings, with a handle whose distance from the centre is adjustable to suit the forearm length of each subject. A similarly adjustable counterpoise opposite to the handle balances the wheel. A steel cable attached to the rim of the wheel passes over a pulley, 2 inches (5.1 cm) in diameter, mounted 8 ft (2.44 m) above the floor and 5 ft (1.5 m) away horizontally from the centre of the wheel. At floor

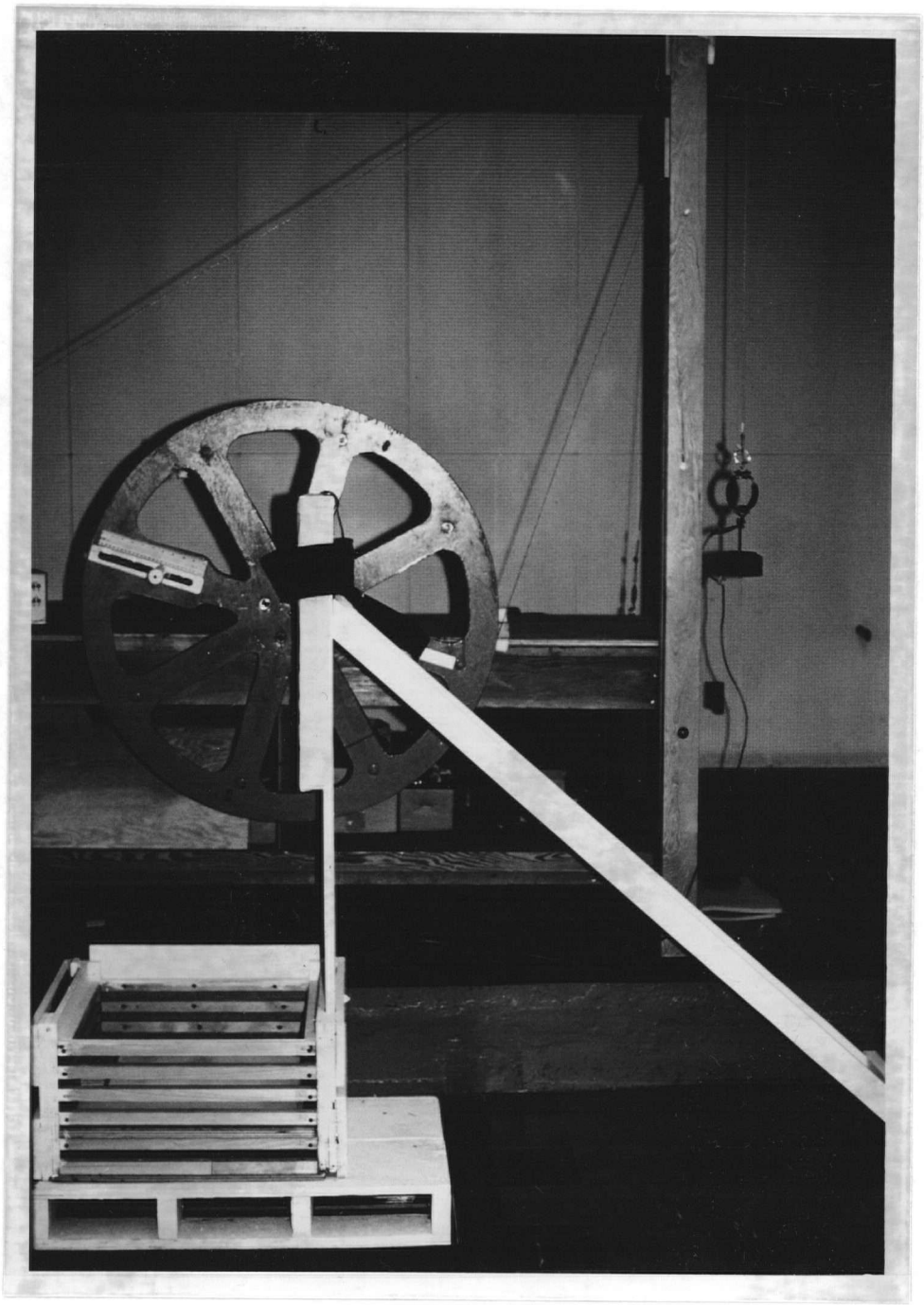


Figure 4. General view of dynamometer.

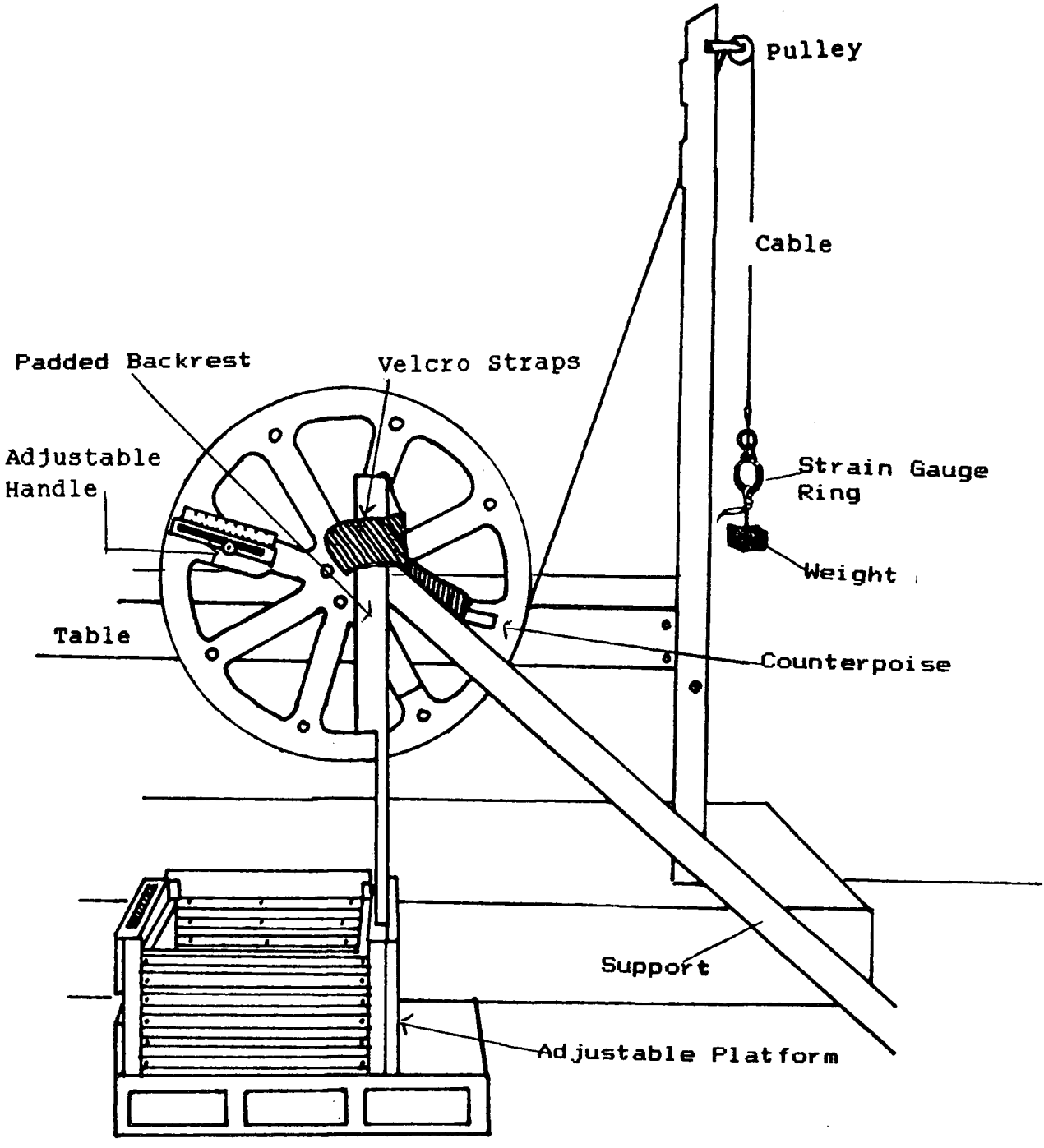


Figure 5. Dynamometer: parts identified.

level, directly below the upper pulley, the free end of the cable is attached to a strain ring, which in turn carries a weight holder. Loads from .5 to 4.5 kg can be used, in increments of .5 kg.

A platform for the subject can be adjusted vertically so that the axis of the subject's elbow joint is in line with the centre of the wheel as she stands with her side towards it. The subject leans back against a support, with the feet 17 inches (43.2 cm) forward against a stop. With the back thus solidly supported, Velcro straps are used to stabilize the shoulders and right upper arm.

An appropriate load (i.e., one that will be heavy enough to allow development of optimal force) is placed on the weight holder. For the present study, this weight was determined by a series of trials at different weights as described below (Appendix 3). The subject grasps the handle with arm extended downward and on command flexes the arm, rotating the wheel and bringing the handle close to the shoulder (Figure 6). As the wheel is turned the weight is lifted; the force exerted is transmitted through the cable to the strain ring, in which a voltage proportional to the force is developed. A potentiometer mounted on the axle of the wheel measures voltage proportional to the angular displacement. The two measures are displayed on a CRT for feedback to the subject. Data are sampled at 50 Hz over 3 s, and analog-to-digital converted; angular velocity, force, moment and power are computed digitally (Appendix 4). Curves derived from the data for one subject are shown in Figure 7.

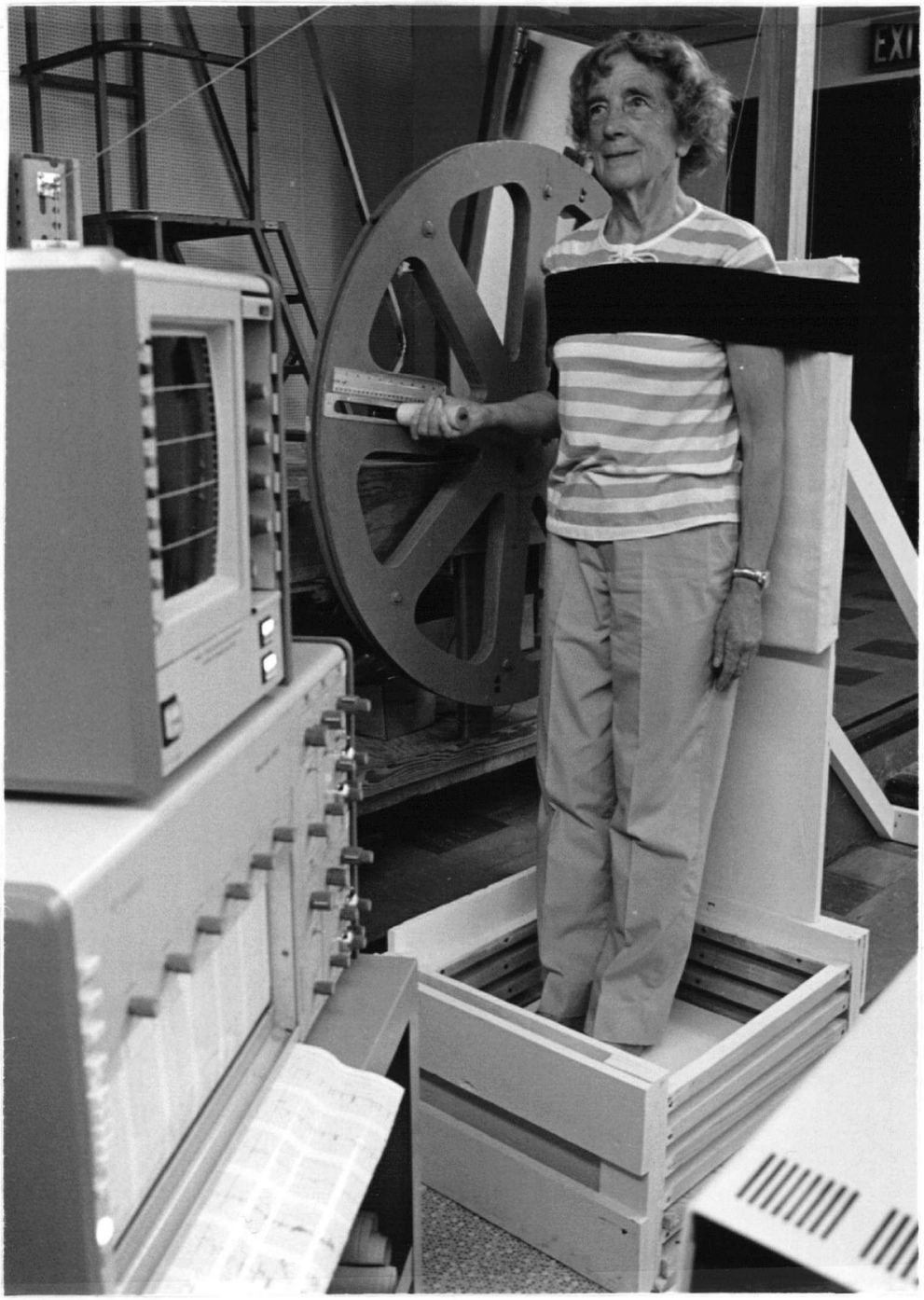


Figure 6. Dynamometer in use.

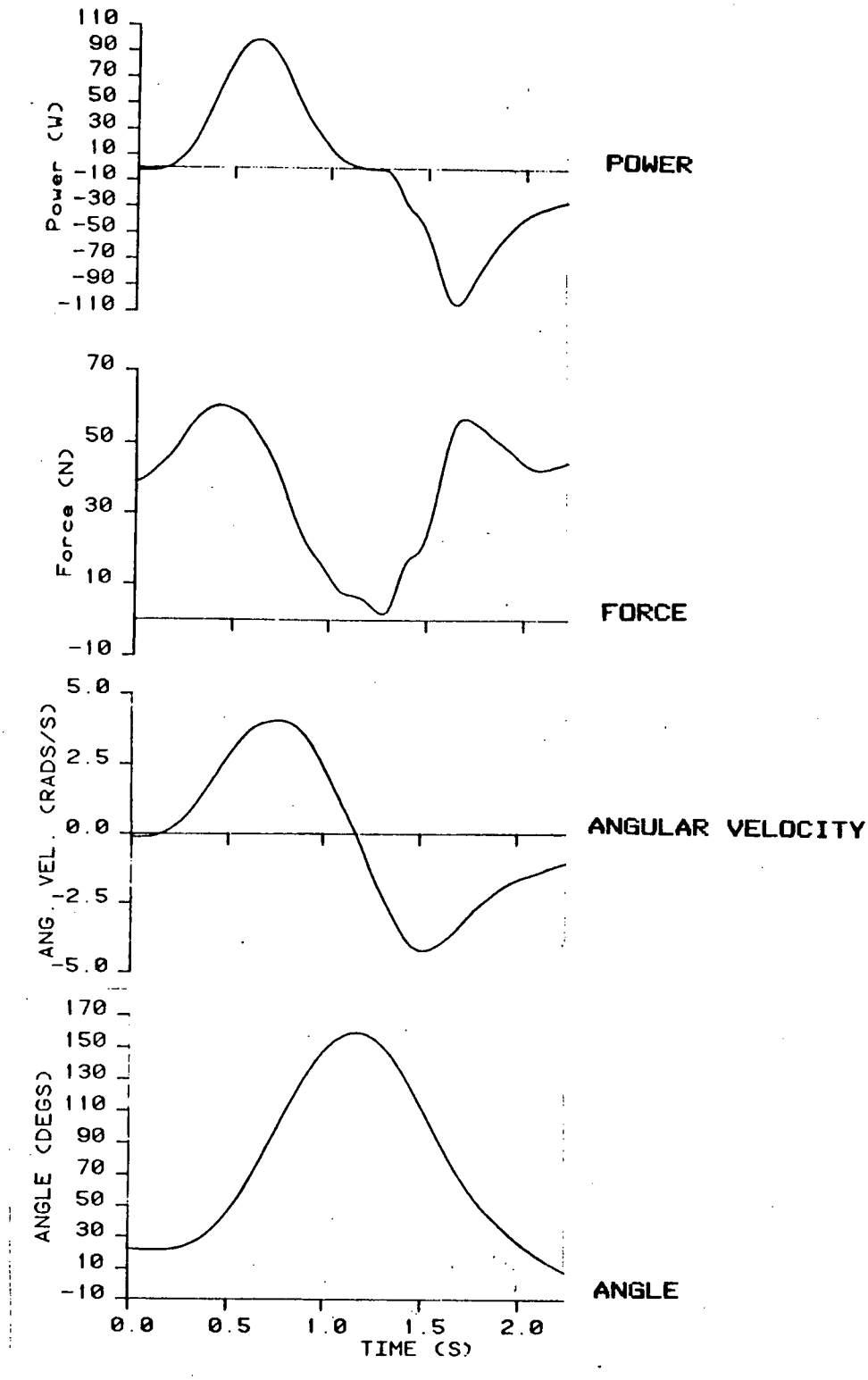


Figure 7. Instantaneous values of angle, angular velocity, force, and power from one trial by the same subject, sampled over 2 s at 50Hz with a load of 2 kg.

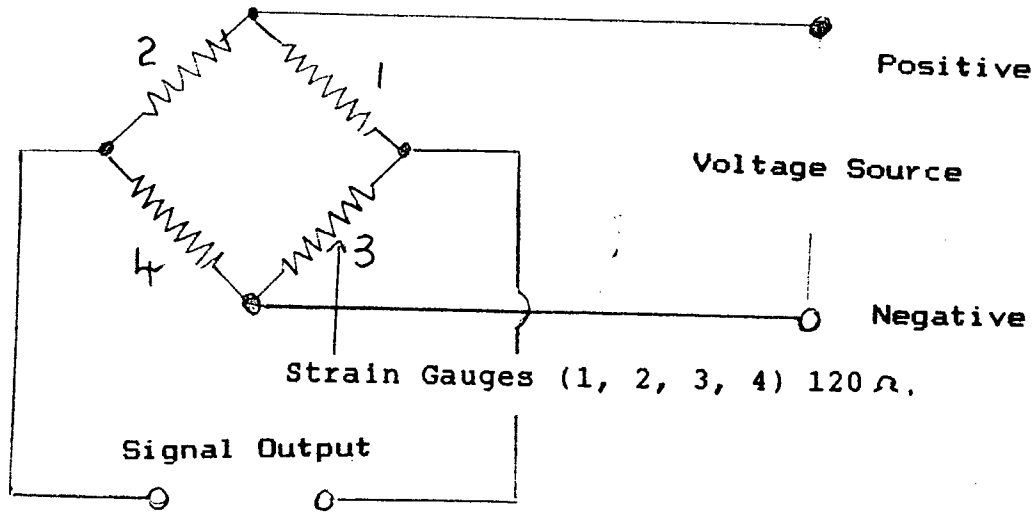
Strain Gauge Ring The ring was designed to operate with an applied load of up to 25 lb. This allowed a range of loads appropriate for the women who were measured in the present study. A full Wheatstone bridge was used to give maximum sensitivity with temperature compensation. Four 120 ohm strain gauges were mounted on the inside of an aluminum ring, and wired as shown in Figure 8. Physical size and environmental conditions did not pose design problems.

Reliability

Forearm flexor power averaged over 10 trials was measured in a group of 10 women aged 20 to 60, and repeated after one week; test/retest reliability was excellent ($r = .96$).

Calibration

Angle and force were calibrated directly. For angle, the wheel was turned through a complete rotation, and the voltage developed by the potentiometer was recordedevery 10o of angle. Each change of one degree in angle resulted in a scale deflection of 45 units. For force, the cable was loaded with weights in .5 kg steps from .5 kg to 4.5 kg, and the voltages developed in the strain gauge were measured. Each .5 kg change resulted in a scale deflection of 28 units. The correlation between voltage developed and both angle and force was very high ($r = 1.00$). Hysteresis was .125% of maximum deflection for angle, and .2% for force. Regular calibration checks during the course of the study showed a maximum variation from full-scale deflection of .13% for angle, and .4% for force.



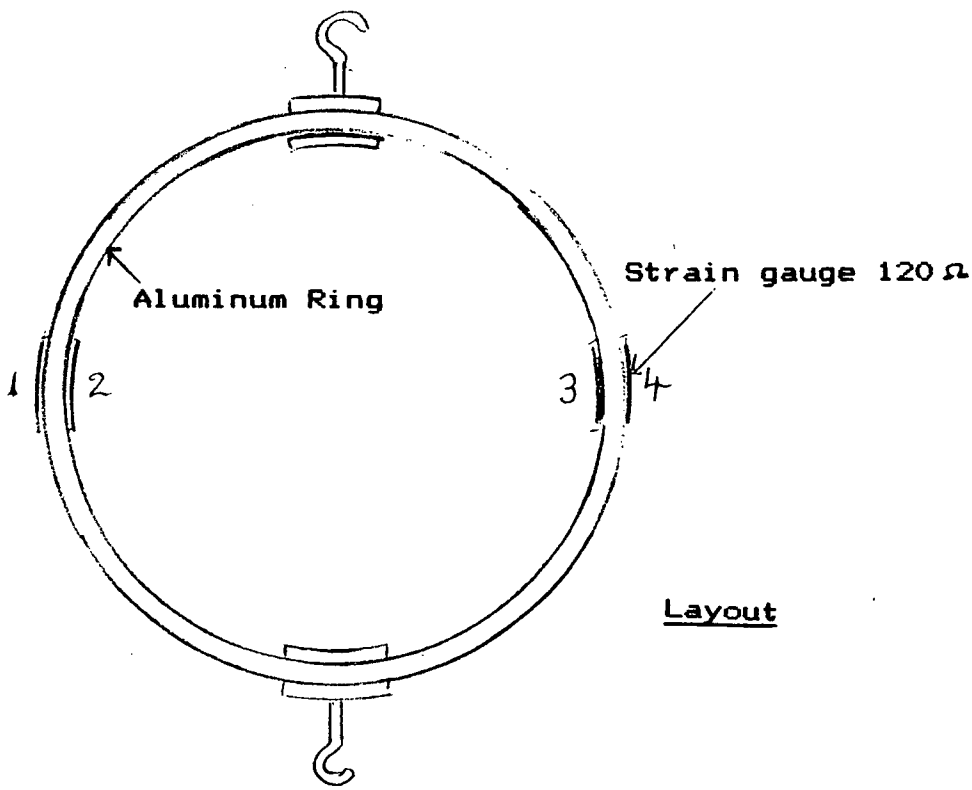


Figure 8. Wiring diagram for strain ring.

The dynamic response of the strain ring was compared with that of a Kistler force platform. A 20 kg weight on the platform was linked to the strain gauge, which was in turn linked through a cable to a metal bar. The bar was briefly vibrated at a frequency of about 7 Hz. Voltages developed in the strain gauge and force platform were sampled simultaneously at 50 Hz for 3 s. There was a high correlation between the responses from the force platform and the strain gauge (r = .995), with minimal phase lag and amplitude distortion (< 2%). Figure 9 shows sample response curves.

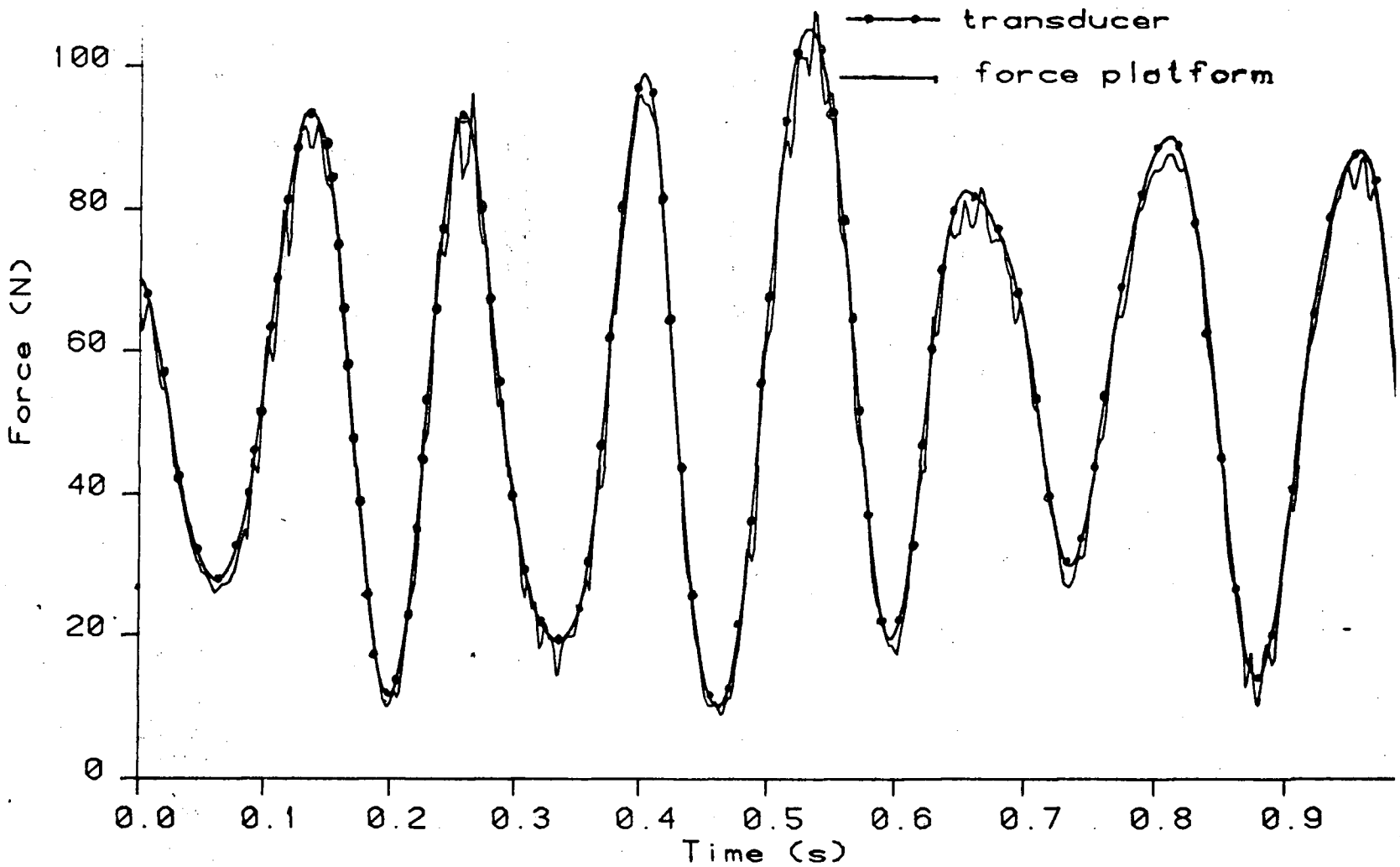


Figure 9. Instantaneous values of vibratory force recorded for 1 s at 50 Hz by a Kistler force platform and the strain gauge (transducer).

Appendix 3

Measurement of Power

Adjustment of Dynamometer

The dynamometer was adjusted to each subject, using the dimensions already calculated (for method see Appendix 5) and entered on her Record Sheet (p.75).

1) The platform height was set.

2) The handle length was set.

3) The counterpoise was set to balance the handle.

Determination of Dynamometer Loading.

Procedure was as follows:

(1) Each subject was correctly positioned.

(2) She completed 10 practice trials.

(3) The appropriate load for her to use in measurement of power was established.

Positioning. Having seen a demonstration, the subject was assisted onto the platform and positioned leaning against the back rest, with feet forward 17 inches against a stop. The handle length was checked for comfort over the range of forearm flexion, and adjusted if necessary. In this position, her back was firmly and safely supported. Additional support and stabilization were given by Velcro straps, one fastened firmly around the shoulders and another, cushioned on the inside, round the upper arm. The arm strap had to be firm, but not so tight as to constrict the muscle when the subject bent her arm. This protocol was followed in all subsequent testing.

Practice Trials. The dynamometer was loaded with a 1 kg weight and each subject performed 10 practice trials, raising and lowering the weight with a distinct pause after each trial. Subjects were encouraged to move up quickly (for maximum force) and down slowly (to avoid banging weights on the floor at the end). During the movement, subjects kept their eyes on the oscilloscope trace showing the angular displacement of the wheel. They were instructed to make the trace go up as steeply as possible. This not only gave them feedback, but also helped to ensure standard positioning of the head. Subjects were coached for their best efforts.

Determining the Established Load. The dynamometer was then loaded with a predicted weight 1 kg less than the individual's 6RM (Appendix 2). This approximation was arrived at pragmatically during preliminary testing of the dynamometer.The tester said:

> We will do two practices with this weight which should be about right for you. I will say "take the weight" - you take hold of the handle firmly and get ready to pull. I will say "go" - you will pull the handle up to your shoulder as quickly as you can, then return it to the bottom and rest. Try to make the trace go up steeply.

On the command "take the weight" the subject lifted the weight just off the floor (about 10o of angle), preloading the muscles and positioning the arm so that the rotatory component of the muscle force could be exerted. The tester

said "go" as soon as the subject was steady. For some subjects, the predicted weight was decreased or increased - if it was clearly too high (the subject could not lift it) or too low (it was not heavy enough to slow the movement down so that power could be developed).

After two successful practices, nine trials were completed, three at each of three weights. The order of trial weights was:

(1) predicted weight (adjusted if necessary).

(2) first weight plus .5 kg.

(3) first weight minus .5 kg.

For example, if the predicted weight was 3.0 kg the initial weight would be 3.0 kg, the second would be 3.5 kg and the third 2.5 kg.

When the dynamometer was correctly loaded, the tester said:

> Now we will start recording data. We will have three trials at each weight, 40 seconds apart. Remember, I am going to say "take the weight", and "go".

The trial then continued as in the practice trials. As the subject began to move the handle, the computer operator started the sampling of angle and force data (for 3 s at 50 Hz).

Peak power was computed for each of the nine trials and averaged over trials for each of the three weights. The weight at which the average peak power developed was greatest was used as that subject's established load for initial and final measures of power.

The Measurement of Peak Power

For the initial and final power measurements each subject completed:

1. ten warm-up practices with a 1 kg weight, and
2. five recorded trials, at the established load.

Peak power for each trial was computed. The average of the five trials was calculated and recorded on the Record Sheet as the measure of peak power for that subject.

Appendix 4

The Calculation of Power and Other Derivatives

Force, angle and radius were measured:

Force (F) in N.

Angle (theta) in rad.

r = radius of the wheel.

Angular velocity, moment, power, and work were calculated.

Angular velocity (omega) = Change over time in angular displacement x theta (rad/s).

Moment (M) = rF (Nm).

Power (P) = M.omega (W).

Work = sum of P x dt (J)

Appendix 5

Estimation of Fat-free Cross-sectional Arm Area

Measures used:

1. Arm circumference (maximum, relaxed) . . . . (C)
2. Biceps skinfold . . . . . (f_1)
3. Triceps skinfold . . . . . (f_2)

Let r' = actual radius

Let r = corrected radius

Let A = FCA

$C = 2\pi r'$

$$r' = \frac{C}{2\pi} \quad \ldots\ldots\ldots\ldots \quad (1)$$

$$r = r' - \frac{f_1 + f_2}{2} \quad \ldots\ldots\ldots \quad (2)$$

$$r = \frac{C}{2\pi} - \frac{f_1 + f_2}{2} \quad \ldots\ldots\ldots \quad (3)$$

$$\text{Area of circle } A = \pi r^2 \quad \ldots\ldots \quad (4)$$

Substituting (3) $A = \pi \left[\frac{C}{2\pi} - \frac{f_1 + f_2}{2} \right]^2$

Since the area of bone does not change, any change in A (fat-free cross-sectional area) for an individual over time may be considered to represent a change in muscle cross-sectional area. Measures were made by the same individual using the same instrument (Harpenden calipers).

Questionnaire - your physical self

No.____

This is a standardized questionnaire consisting of statements about how you feel about your physical self generally. You are asked to indicate whether you agree or disagree with them as they apply to you now. Record your answer according to the following scale from 1 to 6, indicating how strongly you agree or disagree.

1	2	3	4	5	6
strongly agree		moderately agree			strongly disagree

Try this as an example.

	Score
I am stronger than most women of my age	_____

If you strongly agree, you would record 1 in the blank. If you moderately agree, you might mark 3 or 4. If you strongly disagree you would mark 6. Please answer every question. There should be a number in each blank when you have finished.

Physical Self-efficacy Scale

	Score
1. I have excellent reflexes	_____
2. I am not agile and graceful	_____
3. I am rarely embarrassed by my voice	_____
4. My physique is rather strong	_____
5. Sometimes I don't hold up well under stress	_____
6. I can't run fast	_____
7. I have physical defects that sometimes bother me	_____
8. I don't feel in control when I take tests involving physical dexterity	_____
9. People think negative things about me because of my posture.	_____
10. I am not hesitant about disagreeing with people bigger than me	_____
11. I have poor muscle tone	_____

1	2	3	4	5	6
strongly agree		moderately agree			strongly disagree

12. I take little pride in my ability in sport _____

13. Athletic people usually do not receive more attention than me. _____

14. I am sometimes envious of those better looking than me. _____

15. Sometimes my laugh embarrasses me. _____

16. I am not concerned with the impression my physique makes on others _____

17. Sometimes I feel uncomfortable shaking hands because my hands are clammy. _____

18. My speed has helped me out of some tight spots. _____

19. I find that I am not accident prone. _____

20. I have a strong grip. _____

21. Because of my agility, I have been able to do things which many others could not do. _____

22. I am never intimidated by the thought of a sexual experience. _____

Please check to make sure that you have not accidentally left any blanks.

Appendix 7

Administration of PSE

After the subjects had been greeted and shown around, the administrator said:

> This is a standardized questionnaire consisting of statements about how you feel about your physical self generally. You answer by indicating whether you agree or disagree that the statements are good descriptions of you. Score each statement from 1 to 6, from strongly agree to strongly disagree.
>
> There is a practice example which says: 'I am stronger than most women of my age'. Is this a good description of you? If you strongly agree you would mark...? Yes, 1 is right. If you strongly disagree, you would mark...? Yes, 6 that's right. If you feel it is only partly like you, or not like you, choose one of the other numbers. If no statement exactly matches you, choose the closest. Here's a hint - your first reaction is usually the best.

The administrator distributed the test, and asked the subjects to put their code numbers only on the form. She then said:

> Please do the practice example, and then go ahead. Please answer them all. Feel free to ask questions.

When they had finished, they were reminded about putting their code number in the space and this was checked as the tests were collected. Tests were scored according to the method used by Ryckman et al. (1982).

Appendix 8a

Record Sheet No:_____

Informed consent:_____ PAR Q_____ PSE _____ Group _____

Height (cms) _____ Platform setting _____

(1) Radiale	(2) Dactylion	(3) (1) - (2)	(4) 75% of (3)	(5) Setting: 23.2- (4)

Counterpoise _____ 6RM wt_____ Kg Dynamometer loading _____

Weight (Kg)	2	2.5	3	3.5	4	4.5	5	5.5
Repetitions								

Dynamometer:	Trial 1	Trial 2	Trial 3
Weight			
Weight			
Weight			

Computer Code:
E$TAxxl - 9
(xx is subject's number)
(2) E$TTxxl - 9
(3) E$TRxxl-9

Measurements

Date:				
Weight (Kg)				
Skinfolds (mm) Left Biceps				
Triceps				
Right Biceps				
Triceps				
Arm girth (cms) Left				
Right				
6RM (Kg)				
Plexibility (cms)				
Peak power (W)				
PSE Score				
Arm Girth adjusted Left (cms)				
Right				

Record Sheet Part 2 No:_____

PSE _____ Date:_____

Dynamometer loading:_____

Computer code: E$Cxx1 to E$Cxx5 (xx is subject's number)

Weight	A	B	C	D	E	F	G	H
Repetitions								

$\frac{A - R}{2}$: L ____ R ____

Measurements

Date:				
Weight (Kg)				
Skinfolds (mm)				
Left Biceps				
Triceps				
Right Biceps				
Triceps				
Arm girth (cms)				
Left				
Right				
6RM (Kg)				
Flexibility (cms)				
Peak power (W)				
PSE Score				
Arm Girth adjusted (cms) Left				
Right				

NAME

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PHYSICAL ACTIVITY READINESS QUESTIONNAIRE (PAR-Q)*

A Self-administered Questionnaire for Adults

PAR Q & YOU

PAR-Q is designed to help you help yourself. Many health benefits are associated with regular exercise, and the completion of PAR-Q is a sensible first step to take if you are planning to increase the amount of physical activity in your life.

For most people physical activity should not pose any problem or hazard. PAR-Q has been designed to identify the small number of adults for whom physical activity might be inappropriate or those who should have medical advice concerning the type of activity most suitable for them.

Common sense is your best guide in answering these few questions. Please read them carefully and check the ☑ YES or NO opposite the question if it applies to you.

YES	NO	
☐	☐	1. Has your doctor ever said you have heart trouble?
☐	☐	2. Do you frequently have pains in your heart and chest?
☐	☐	3. Do you often feel faint or have spells of severe dizziness?
☐	☐	4. Has a doctor ever said your blood pressure was too high?
☐	☐	5. Has your doctor ever told you that you have a bone or joint problem such as arthritis that has been aggravated by exercise, or might be made worse with exercise?
☐	☐	6. Is there a good physical reason not mentioned here why you should not follow an activity program even if you wanted to?
☐	☐	7. Are you over age 65 and not accustomed to vigorous exercise?

If You Answered

YES to one or more questions

If you have not recently done so, consult with your personal physician by telephone or in person BEFORE increasing your physical activity and/or taking a fitness test. Tell him what questions you answered YES on PAR-Q, or show him your copy.

programs

After medical evaluation, seek advice from your physician as to your suitability for:

- unrestricted physical activity, probably on a gradually increasing basis.
- restricted or supervised activity to meet your specific needs, at least on an initial basis. Check in your community for special programs or services.

NO to all questions

If you answered PAR-Q accurately, you have reasonable assurance of your present suitability for:

- A GRADUATED EXERCISE PROGRAM - A gradual increase in proper exercise promotes good fitness development while minimizing or eliminating discomfort.
- AN EXERCISE TEST - Simple tests of fitness (such as the Canadian Home Fitness Test) or more complex types may be undertaken if you so desire.

postpone

If you have a temporary minor illness, such as a common cold.

Reference: PAR-Q Validation Report, British Columbia Ministry of Health, May, 1978.

* Produced by the British Columbia Ministry of Health and the Department of National Health & Welfare.

Informed Consent

The purpose of the investigation is to examine the effect of training on older women (over 55). There will be two groups, one training for strength in arm muscles and one for flexibility of hips and back. The investigator is Eleanor Haydock, under the supervision of Professor Stanley Brown, Ph.D.

A detailed description of the programme of activities in which volunteer participants will be involved is attached. We expect the individual experimental testing referred to will take about half an hour. Free parking should be available.

It is hoped that this study will add significantly to knowledge of the response to training of older women, and also that participants will gain in understanding of their individual capacities. Other benefits are the expected increase in arm strength or flexibility as a result of the training. The only side effects we can foresee would be muscle stiffness if you try too hard. This should not happen if you follow instructions carefully.

You will be asked to complete a form asking questions about your state of health. If, at this point or after the preliminary testing, you do do not feel you wish to complete the training, please discuss the matter with one of the investigators, and feel free to withdraw from the study at any time without question and without prejudice to future participation in studies offered by the School of Physical Education, and you may refuse to answer any question.

Data from pencil and paper tests and questionnaires and measures stored in the computer will be analysed. Only the investigators will have access to it, and anonymity will be preserved by using coding. Data will be destroyed when they have served the purposes of the study.

Your signature indicates that you consent to take part in the study and that you have received a copy of this document with one sttachment.

Date _____ Signature _____

Witness _____

No:___

Week	Day & date	Wt. used	Reps	Sets	Comments
1	1				
	2				
	3				
2	1				
	2				
	3				
3	1				
	2				
	3				
4	1				
	2				
	3				
5	1				
	2				
	3				
6	1				
	2				
	3				
7	1				
	2				
	3				
8	1				
	2				
	3				
9	1				
	2				
	3				
10	1				
	2				
	3				
11	1				
	2				
	3				
12	1				
	2				
	3				

Flexibility training for back and hips

PLEASE NOTE:
You will get most benefit from these routines if you do NOT strain or struggle to reach a goal. The movements should be easly and pleasant, and may be very small. Keep your neck soft and loose, and remember to breathe while moving. Work with your shoes off, and start by doing each movement 10 times. Gradually work up to 20 times. Always REST for about a minute between each group of movements.

Think about what you are doing. Try to make the movements simpler and easier. Ask yourself where the movement starts - what do you do first when making the movement.

There are two phases of about six weeks each.

PHASE I

1) Get into a hands and knees position, with your knees right under your hips, feet apart, toenails down, and your hands right under your shoulders. Your head should be in its normal position, and your eyes looking at the floor. This is the start position, to which you will return many times.

2) Now begin to move your seat in the direction of your heels, keeping your hands in place, breathing out, and going only as far as is comfortable for you. Let your head hang loosely and your back be softly rounded. Return to the start position. Do this movement 10 times to start with, gradually increasing to 20. Keep breathing. REST for a minute.

3) From the start position, lift your left knee, carry it behind you, and place it to the right of your right knee. The outside of your left leg is close to the outside of your right one. Keep your shoulders in place over your hands. Return to the start position. Do this 10 times to start and gradually increase to 20 times. Keep breathing. REST.

4) Repeat the same sequence of movements with the right knee. Repeat the very first movement once or twice - move your seat in the direction of your heels. It may be easier now.

Practice this phase three times a week (preferably Monday-Wednesday-Friday or Tuesday-Thursday-Saturday). You may find you are coming much closer to actually sitting on your heels.

(Adapted from one of the lessons of Moshe Feldenkrais)

No:___

Week	Day & date	Flexibility Phase I	Reps	Time	Comments
1	1				
	2				
	3				
2	1				
	2				
	3				
3	1				
	2				
	3				
4	1				
	2				
	3				
5	1				
	2				
	3				
6	1				
	2				
	3				
		Phase II			
7	1				
	2				
	3				
8	1				
	2				
	3				
9	1				
	2				
	3				
10	1				
	2				
	3				
11	1				
	2				
	3				
12	1				
	2				
	3				

Appendix 15

Calculation of Dynamometer Settings

For each subject, height from the floor to radiale and dactylion were measured.

A table relating radiale height and the appropriate setting of the adjustable platform was calculated, and used to estimate the platform level for the subject.

To estimate the handle setting, 75% of the difference between radiale and dactylion heights was used as an estimate of the distance from the axis of the elbow to the inside hand grip. A table relating this length to the distance from the centre ofthe wheel to the handle was calculated, and used to estimate the setting for the handle.

Adjustments to these estimates were seldom required.