ADAPTATIONS TO AEROBIC TRAINING IN OLD AGE

Submitted to the University of London
for the degree of Ph.D.

by

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ABSTRACT

Are direct measurements of maximal aerobic power (V\text{O}_2\text{ max}) feasible and reproducible in the ‘oldest old’? 26 men and women (79 to 87 years) performed three progressive cycle ergometer tests. Criteria for attainment of V\text{O}_2\text{ max} (a respiratory exchange ratio $\geq 1$ and subjective judgement that a subject had worked to maximal effort) were fulfilled by 21 subjects on at least one occasion. Measures of V\text{O}_2\text{ max} were obtained in 10 subjects at 2 test points, no significant differences were seen between repeated tests for any variables measured. Tests to determine V\text{O}_2\text{ max} in the ‘oldest old’ are feasible and reproducible.

Can maximal aerobic power be increased through endurance training in the ‘oldest old’? How do responses differ from young subjects trained using the same relative intensity? Data were obtained from 19 old (80 to 91 years) and 21 young subjects, who completed 24 weeks of endurance training. Measurements were taken before and after a control period and following 12 and 24 weeks of training. A significant improvement in V\text{O}_2\text{ max} was seen in the old women after 24, but not 12 weeks of training. V\text{O}_2\text{ max} increased in the young women after both 12 and 24 weeks of training. Training had no effect on the V\text{O}_2\text{ max} of the old men. Possible explanations for this finding are discussed. Even very elderly women can improve V\text{O}_2\text{ max} with endurance training, but improvements may take longer to occur than in young people.

Does endurance training improve the quality of life of the ‘oldest old’. A selection of questionnaires to measure different components of quality of life were completed by the old subjects before and after the control period and following training. Training resulted in significant improvements in self perceived pain levels, morale and some aspects of mood. However, some improvements were also seen following the control period, suggesting social contact may have been responsible for some of the improvements seen.
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    - Men
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PUBLICATIONS ARISING FROM WORK PRESENTED IN THIS THESIS

FULL PAPERS:-

1. MALBUT-SHENNAN, K.E., DINAN,S., GLEESON,M., ENNION,S. AND YOUNG,A. Endurance training in the 'oldest old':- the effect of 24 weeks of aerobic training. (Submitted for publication)

2. MALBUT-SHENNAN, K.E., DINAN,S. AND YOUNG,A. Do women over 80 take longer to respond to endurance training than young women trained at the same relative intensity? (In preparation)

3. MALBUT-SHENNAN, K.E., DINAN,S. AND YOUNG,A. The effect of 24 weeks of endurance training on the Quality of Life of the ‘oldest old’ (In preparation)

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First I would like to thank my supervisor, Professor Archie Young, for his constant advice, support and encouragement throughout the period of my research and the preparation of this thesis.

My thanks to Professor Mike Gleeson and Dr Steve Ennion with whom I collaborated during the training study. Thanks also to Dr Dawn Skelton who was always there to listen and give advice and to Susie Dinan for her invaluable help and friendship over the last few years. Additional gratitude is owed to Dr Harald Verhaar who assisted with the screening of the subjects, and Dr Steve Harridge, Dr Carolyn Greig and Trish Labro for their support over the past few years.

I am indebted to the Sir Halley Stewart Trust for their financial support and commitment to this work, to Research into Ageing who provided the running costs of the project, and to Forza Fitness International who supplied the cycle ergometers and the body bars.

I would also like to thank Caroline Sabin for her advice on the statistical analysis, and my friends Dr Tania Webb, Dr Gaynor Miller and Roger Carpenter - not least for being willing guinea pigs! Immense gratitude goes to all the subjects who took part in the studies for their enthusiasm and commitment.

Last, but most important I would like to thank my husband Chris, without whose love and encouragement this work would never have been completed, and also my little girl Sophie who helps keep life in perspective!
DECLARATION AND ETHICAL APPROVAL

I declare that this thesis has been composed by myself and that the books and papers cited were all consulted by me personally, except where it is otherwise stated.

The experimental work described was all carried out by myself or under my direct supervision, except where stated. The publications arising from the work presented in this thesis were written by me (Appendix 1A). Sections of this thesis have been used in the preparation of the ‘Reviews’ described (Appendix 1A) for which I was main author. All other studies described in the ‘Supplementary Publications’ (Appendix 1B) were not carried out by myself, but had my input as a joint supervisor or author.

All studies in this thesis were conducted with the approval of the Royal Free Hospital ethical practices subcommittee and all subjects gave written informed consent (Appendix 1C)
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<td>1RM</td>
<td>1 repetition maximum</td>
</tr>
<tr>
<td>2,3 DPG</td>
<td>2,3 diphosphoglyceric acid</td>
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<tr>
<td>ANOVA</td>
<td>Analysis of variance</td>
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<tr>
<td>BP</td>
<td>Blood pressure</td>
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<tr>
<td>CCO</td>
<td>Cytochrome c oxidase</td>
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<td>CV</td>
<td>Coefficient of variation</td>
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<td>DFLE</td>
<td>Disability free life expectancy</td>
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<tr>
<td>ECG</td>
<td>Electrocardiogram</td>
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<tr>
<td>FEV1</td>
<td>Forced expiratory volume in one second</td>
</tr>
<tr>
<td>GDS</td>
<td>Geriatric Depression Scale</td>
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<tr>
<td>GHQ</td>
<td>General Health Questionnaire</td>
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<tr>
<td>HAD</td>
<td>3 Hydroxacyl CoA dehydrogenase</td>
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<td>HAP</td>
<td>Human activity profile</td>
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<td>HRmax</td>
<td>Maximal heart rate</td>
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<td>HRR</td>
<td>Heart rate reserve</td>
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<td>IEFS</td>
<td>Isometric elbow flexor strength</td>
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<td>IKES</td>
<td>Isometric knee extensor strength</td>
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<td>LA</td>
<td>Blood Lactate</td>
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<td>LAmx</td>
<td>Maximal blood lactate</td>
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<td>LDH</td>
<td>Lactate dehydrogenase</td>
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<td>LEP</td>
<td>Lower limb extensor power</td>
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<tr>
<td>MEFR</td>
<td>Maximal expiratory flow rate</td>
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<td>MHC</td>
<td>Myosin heavy chain</td>
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<td>MHIQ</td>
<td>McMaster Health Index Questionnaire</td>
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<td>MOS</td>
<td>Medical outcomes study</td>
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<tr>
<td>mRNA</td>
<td>Messenger RNA</td>
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<tr>
<td>mtDNA</td>
<td>Mitochondrial DNA</td>
</tr>
<tr>
<td>MVV</td>
<td>Maximal voluntary ventilation</td>
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<tr>
<td>nDNA</td>
<td>Nuclear DNA</td>
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<td>NHP</td>
<td>Nottingham Health Profile</td>
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<td>NTMx</td>
<td>Non maximal test</td>
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Abbreviations
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<tr>
<td>PCR</td>
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<td>PFK</td>
<td>Phosphofructokinase</td>
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<td>PGCMS</td>
<td>Philadelphia Geriatric Center Morale Scale</td>
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<td>POMS</td>
<td>Profile of Mood States</td>
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<td>QOL</td>
<td>Quality of life</td>
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<td>RBC</td>
<td>Red blood cell</td>
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<td>RER</td>
<td>Respiratory exchange ratio</td>
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<td>RERmax</td>
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<td>RPE</td>
<td>Ratings of perceived exertion</td>
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<td>Residual volume</td>
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<td>Short form of health survey questionnaire</td>
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<td>SD</td>
<td>Standard deviation</td>
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<td>Sickness Impact Profile</td>
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<td>TMx</td>
<td>Maximal test</td>
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<td>UCH</td>
<td>University college hospital</td>
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<td>UK</td>
<td>United Kingdom</td>
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<tr>
<td>VC</td>
<td>Vital capacity</td>
</tr>
<tr>
<td>VO(_2)</td>
<td>Oxygen consumption</td>
</tr>
<tr>
<td>VO(_2) max</td>
<td>Maximal oxygen intake/uptake</td>
</tr>
</tbody>
</table>
CHAPTER ONE
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THE AGEING POPULATION

The percentage of the United Kingdom (UK) population who are aged 65 years and over has risen sharply in the past 30 years (Kinsella, K 1996). Of the aged population the greatest increases have been seen in those aged 80 and over i.e. the ‘oldest old’. Indeed, whilst in 1965 only 2% of the total population were aged 80 or over, this figure rose to 4% in 1995 and is predicted to rise still further to 6.2% by 2025 (Kinsella, K 1996).

Although advances in medicine mean that people are tending to live longer, the quality of these ‘extra’ years may well be poor. Whilst in youth most physiological functions have a generous spare capacity, increasing age is characterized by a progressive erosion of these ‘safety margins’. Even healthy ageing sees physiological changes in muscle and the cardiovascular system which can affect exercise tolerance and everyday functional ability. In elderly women in particular, maximal aerobic power and muscular strength and power may fall to such levels that independence is put at risk.

Disability free life expectancy (DFLE) is the average number of years that a person of a given age may expect to live free of disability i.e. any restriction to perform activity in the manner or within the range considered normal for the human being (World Health Organisation, 1980). Whilst the life expectancy of a woman is longer than that of a man, in general a greater part of a man’s life will be spent free from any disability (Bebbington, 1988). For example, the average life expectancy in the UK for men at age 80 is 6.1 years, and on average 36% of this time will be spent free of disability. In contrast, whilst the average life expectancy of an 80 year old women is longer, at 7.9 years, it is likely that only 29% of this time will be spent free of disability (Bebbington 1992).

It is well documented that even frail elderly women can increase muscular strength and power in response to resistance training (Skelton et al.1995; Fiatarone et al.1994)
and that functional gains are made if the performance of strengthening exercises is accompanied by the practice of specific functional skills (Skelton & McLaughlin, 1996). The responsiveness of very elderly people to aerobic training remains unclear. If maximal aerobic power can be increased, this too may help many very elderly people to maintain their independence for longer and maintain or increase their quality of life.

The main aim of this thesis is to determine whether maximal aerobic power can be increased with training in the 'oldest old', and to determine the effects of such training on their quality of life. This chapter sets the scene by addressing the changes seen in maximal aerobic power with age, by exploring the possible causes of such changes and the effect they have on everyday functional ability, and by reviewing what is known about aerobic training in old age. It also briefly addresses the effects of age and training on muscular strength and power.

MAXIMAL AEROBIC POWER

Maximal aerobic power or maximal oxygen intake/uptake (VO₂ max) is an important component of fitness. It can be defined as the maximum rate that oxygen can be taken up and utilised by an individual, and depends upon the capacity of the lungs and the cardiovascular system to provide the working muscles with oxygen and on the ability of those muscles to extract and utilize the oxygen provided.

Effect of ageing

Both cross-sectional and longitudinal studies have demonstrated a decline in VO₂ max with advancing age of around 10% per decade. When expressed in absolute terms (L.min⁻¹) the decline is seen from the mid 20s (Hagberg, 1987) although when expressed relative to body weight (ml.kg⁻¹.min⁻¹) there appears to be a uniform decrement throughout life (Dehn & Bruce, 1972) (figure 1). The explanation for the decline could lie in known age-related changes in one, or more, of any of the systems
which are responsible for the transport and uptake of oxygen. Alternatively, it could be the result of changes due to decreasing activity levels i.e. disuse.

1. The oxygen transport system

A. Pulmonary system

Changes in the respiratory system (e.g. loss of elastic recoil, increased anatomical and physiological dead space, decreased diffusion capacity, decreased compliance of the chest wall and respiratory muscles, a progressive loss of cartilaginous support and reduced sensitivity of respiratory centres to stimuli (reviewed by Mueisan et al. 1971, and Shephard, 1997)) mean that there is a decrease in ‘pulmonary reserve’ with age. Vital capacity (VC), forced expiratory volume in 1 second (FEV1), maximal voluntary ventilation (MVV) and maximal expiratory flow rate (MEFR) decline whilst residual volume (RV) increases. These changes are seen even in healthy individuals and appear to start from around the mid 20s (Muesan et al. 1971). Although the respiratory system appears to remain more than adequate to meet the demands of everyday submaximal activities in healthy elderly people, the extent to which these changes limit maximal performance remains unclear (Mahler et al. 1986).

B. Maximal heart rate, stroke volume and cardiac output

Maximal heart rate (HR max) declines from around age 20 (Rodeheffer et al. 1984), most probably because of a decreased responsiveness to β-adrenergic stimulation (Fleg, 1985; Fleg et al. 1994). The decline in HRmax is seen even in those who have remained very physically active (Heath et al. 1981), but there is significant inter-individual variation at all ages (Rodeheffer et al. 1984) (figure 2).
Figure 1: Decline in maximal oxygen uptake (\( \dot{V}O_2 \max \)) with age, calculated from 700 observations in boys and men in 17 studies. Taken from Dehn and Bruce (1972).
Figure 2: Maximal heart rate at different ages (in individuals free of coronary artery disease) - taken from Rodeheffer et al. (1984)
In healthy elderly people, screened for cardiovascular disease, there is no decline in stroke volume (SV) at rest or during submaximal exercise. Although maximal stroke volume probably declines with age (Ogawa et al. 1992), a study by Rodeheffer et al. (1984) reported that aging had little effect on maximal stroke volume, indeed they reported that in some subjects there was an increase in maximal stroke volume, with an increased reliance on the Frank Starling mechanism.

Cardiac output during submaximal exercise is maintained in healthy old age but there is conflicting evidence as to what happens in maximal exercise. Although Rodeheffer et al. (1984) reported that some elderly people (in their 70s) are able to maintain cardiac output at maximal exercise, compensating for the decreased HRmax by an increased stroke volume, the majority of studies report a decrease in maximal cardiac output with age (Hossack & Bruce, 1982; Higginbotham et al. 1986; Seals et al. 1994). In addition, older people may be less able than younger ones to redirect blood to the working muscles from viscera and skin (Kenney & Ho, 1995) which could reduce the potential oxygen available to the working tissues.

C. Oxygen carrying capacity of blood

Age appears to have little effect on circulating red blood cells or the haemoglobin content/concentration of blood (Davies, 1972; Ericsson, 1970; Purcell & Brozovic, 1974; Timiras & Brownstein, 1987). Purcell and Brozovic (1974) reported a drop in levels of 2,3 diphosphoglyceric acid (2,3-DPG) levels in red blood cell (RBC) when comparing a group of 322 young (18-24) and older (65-74, 75-84 and 85 and over) adults. A drop in 2,3-DPG levels would have the effect of shifting the oxyhaemoglobin curve to the left. This would make offloading oxygen to the working tissues more difficult. However, Tweeddale et al. (1976) found no decline in the levels of 2,3-DPG in RBC in a group of 62 men and women aged 18 to 89 years.
D. Declining muscle mass

Even in healthy ageing skeletal muscle mass declines from middle age (figure 3) (Young, 1996). The explanation for most of the loss of muscle (also known as sarcopenia or muscle cachexia) is an apparent obligatory loss of muscle fibres, probably as a result of incompletely compensated denervation. In addition, in older people there may also be impaired regeneration of muscle after damage (Brooks & Faulkner, 1990). Atrophy of surviving muscle fibres is variable, perhaps reflecting individual variation in habitual activity (reviewed by Harridge and Young (1997) and Faulkner et al. (1990)).

The declining muscle mass may in part explain the decline in VO$_2$ max. Indeed, there is evidence to suggest that when VO$_2$ max is expressed relative to muscle mass, estimated by creatinine excretion (after factoring out the confounding effect of age) the age-related decline in VO$_2$ max is greatly diminished (Fleg & Lakatta, 1988).

E. Aerobic potential of muscle

There is conflicting evidence as to whether the potential for aerobic metabolism (capillary density and oxidative enzyme activities) of the remaining muscle mass is maintained into old age. It seems that much of the confusion has arisen because the subjects used in the various studies differed in their levels (or intensity) of training.

(i) Capillary density

Coggan et al. (1992b) reported a decreased muscle capillarisation in "sedentary" older subjects when compared to "sedentary" younger ones. However, the matching of activity levels was not totally convincing, with sedentary defined very broadly as "no activities other than low intensity recreational sports". Other studies report no difference in muscle capillarisation but have compared active older with sedentary younger subjects (Jakobsson et al. 1990) or have taken data from a group of old people
and compared them with data in the literature obtained from younger subjects (Grimby et al. 1982).

Coggan et al. (1990) also compared master (i.e. veteran) athletes with young runners, matched for amount and absolute intensity of training exercise. However, although the master athletes were found to have a higher capillary to fibre ratio, and a higher number of capillaries in contact with each muscle fibre than the young runners, the master athletes were training at a higher percentage of their VO\textsubscript{2} max and therefore were perhaps more highly trained than the young runners.

(ii) Oxidative enzyme activity

Mitochondria possess an independent genetic system necessary for the morphogenesis of the energy transduction system i.e respiratory chain and ATP synthetase (Ozawa, 1997). Mitochondrial DNA (mtDNA) has been reported to have a less efficient repair system than nuclear DNA (nDNA). Mutated mitochondrial genomes are reported to accumulate in cells, particularly in stable tissues such as nerve and muscle and it has been suggested that these random mutations in mtDNA are a major contributor to a gradual loss of cellular bioenergy capacity reported in tissues and organs with age (Linnane et al. 1989); reviewed by Ozawa (1997). In support of this, many randomly distributed muscle fibres (taken from elderly human skeletal muscle) reportedly show no cytochrome oxidase (encoded by mtDNA) activity (Müller-Höcker, 1990) whilst the majority of studies suggest unchanged succinate dehydrogenase (encoded by nDNA) activity with age (Müller-Höcker, 1990; Hsieh et al. 1994).

However there remains some discrepancy between studies. In a recent study Brierley et al. (1997) compared muscle from old and young athletes and showed no significant difference in enzyme levels either in those which are mtDNA encoded (complex I (NADH dehydrogenase) and complex IV (cytochrome oxidase)) or those which are nDNA encoded (complex II (succinate dehydrogenase) and citrate synthase).
Figure 3: Transverse computerised tomography scans at mid thigh in a healthy woman in her 20s (left) and a healthy woman in her 80s (right) (Young, 1996).
Other studies have studied oxidative enzyme levels in groups of subjects who they had attempted to match for activity levels. Coggan (1992b) compared "sedentary" old with "sedentary" young subjects and demonstrated lower oxidative enzyme levels in succinate dehydrogenase, citrate synthase and β hydroxyl Co A dehydrogenase (all encoded by nDNA) in the older subjects. However, as previously mentioned, the matching of activity levels was not totally convincing. Örlander and colleagues (1978) studied a group of men between the ages 22-65 years, defined as sedentary on the basis that all were white collar workers who did no, or only light physical activity in their spare time, and also a group of pensioners defined as "comparatively active for their age". Within the sedentary group they found no overall decrease in oxidative enzyme activity with age either in the enzymes encoded by nDNA (3-hydroxyl Co A dehydrogenase and citrate synthase) or in cytochrome oxidase (encoded by mtDNA). Moreover, they found higher levels of cytochrome oxidase in the active group of pensioners.

In the study by Coggan et al. (1990), which compared master athletes with young runners matched for amount and absolute intensity of training exercise the biopsies from the master athletes were found to have higher oxidative enzyme activities (succinate dehydrogenase and β hydroxyl Co A dehydrogenase - both encoded by nDNA), although close examination of the master athletes might suggest that they were perhaps more highly trained than the young runners.

From the evidence so far available, it appears that in skeletal muscle most of the differences reported in capillarity as well as most of the changes demonstrated in the oxidative enzyme capacity of skeletal muscle may owe more to differing relative levels of physical activity than to ageing.
2. Physical activity levels

Opinion remains divided as to whether the rate of decline of maximal oxygen uptake with age can be slowed by regular, vigorous physical activity (Heath et al. 1981; Rogers et al. 1990; Kavanagh et al. 1989; Shephard, 1987)).

Elite, veteran sportsmen are an interesting and highly selected group of people. The top performers are highly motivated, have a very high level of customary physical activity and are probably free of significant exercise-limiting disease. Studies of such individuals could be said to offer a glimpse of the effect of 'pure ageing' on maximal exercise performance. Rogers et al (1990) remeasured VO$_2$ max in sedentary men and in master athletes and found that while VO$_2$ max had declined at a rate of 12% per decade in the sedentary group, the decline was only 5.5% in the master athletes suggesting that regular training may help to slow the rate of decline in VO$_2$ max.

However other evidence does not support these findings. Saltin (1986) reports that inactive and still active former élite orienteers differ in their VO$_2$ max values, but not in the rates of decline of VO$_2$ max. Similar rates of decline (about 10 per cent per decade) are also seen in cross-sectional comparisons of the running speeds (figure 4) and the swimming speeds (figure 5) of older, age-related record holders. Although the individual performances are extraordinary, these data suggest that a high level of physical activity does not slow the decline in VO$_2$ max with increasing age.

In summary, maximal aerobic power declines even in health. The explanations for the decline remain controversial. Although maintaining a high level of customary activity does not appear to slow the rate of decline, it is important to remember that a highly active person is likely to have a higher value of VO$_2$ max than a sedentary one at each equivalent age.
Figure 4: Veteran world records for 3000m indoor run (Autumn 1996).

Courtesy of the British Veteran Athletic Federation
Figure 5: World records for 1500m freestyle - extracted from Tanaka & Seals (1997)
Functional consequences

Whatever the cause, the reduction of \( \dot{VO}_2 \) max with advancing age means that a given task or activity will require a greater proportion of maximal aerobic power. Thus, activities with a low absolute oxygen cost may yet demand a high proportion of an old person's \( \dot{VO}_2 \) max. This situation is exacerbated by the fact that the absolute energy cost of some activities increases with age. The increasing absolute energy cost of walking (Bassey & Terry, 1986), for example, may be explained by the shortening of stride length as age increases (Himann et al. 1988).

The gender difference in body composition means that women are particularly disadvantaged for weight-bearing activities, as their aerobic power/weight ratio is less than that of men of the same age. Many elderly people, in particular women, have such low values of \( \dot{VO}_2 \) max that it would need only a small, further reduction to render some everyday activities either unpleasant or impossible to perform.

The oxygen cost of walking at 3mph is reported to be approximately 12.5 ml.kg\(^{-1}\).min\(^{-1}\) (Skelton et al. 1999) and at 2mph approximately 9ml.kg\(^{-1}\).min\(^{-1}\) (Durnin & Passmore, 1967a). For prolonged walking to remain comfortable, the oxygen cost probably needs to be less than 50% of the maximal aerobic power/weight ratio (Skelton et al. 1999). That is, one would need a \( \dot{VO}_2 \) max of 18ml.kg\(^{-1}\).min\(^{-1}\) to walk comfortably at 2mph, and of 25ml.kg\(^{-1}\).min\(^{-1}\) to walk comfortably at 3mph. In the English National Fitness Survey, 80% of women (but only 35% of men) aged 70 to 74 had a maximal aerobic power/weight ratio below 25ml.kg\(^{-1}\).min\(^{-1}\). There is a paucity of information regarding the \( \dot{VO}_2 \) max of the 'oldest old'. Figures from the only study to have directly measured \( \dot{VO}_2 \) max in very elderly women viz. Foster et al. (1986) in 8 women aged 73-86 years, and those reported in this thesis (page 60) suggest a typical maximal aerobic power/weight ratio of about 14 ml.kg\(^{-1}\).min\(^{-1}\) for healthy 80-year-old women. It seems likely that walking comfortably at 3mph is impossible for most women in their early 70s and that even just 2mph (with comfort) is impossible for a majority of 80-year-old women.
Inactivity, whether chosen or enforced (perhaps as a result of illness), may reduce $\dot{V}O_2$ max by a further 10-20% (Saltin et al. 1968). Surgery results in similar reductions in $\dot{V}O_2$ max (evidence, mostly from younger age groups, reviewed by Young 1990). Figure 6 illustrates the drastic consequences of a 15% reduction in $\dot{V}O_2$ max for an average healthy 80-year-old woman. Just sitting quietly would then require around 35% of her $\dot{V}O_2$ max (a similar percentage of $\dot{V}O_2$ max to the rate of energy expenditure averaged over an 8 hour shift by workers in heavy industry e.g. coal-face miners (Durnin & Passmore, 1967b)).

Functional ability is one of the factors affecting the quality of life of an individual (see chapter 3, pg 8). The effects on functional ability of a decreasing $\dot{V}O_2$ max may eventually lead to a loss of independence and possible institutionalisation of an individual. This may have a devastating effect on their quality of life.

**Effect of endurance training**

1. **Physiological effects**

$\dot{V}O_2$ max can be increased in younger adults by endurance training. Training also greatly improves the ability to sustain exercise at a fixed, submaximal, absolute level of energy expenditure. The improvement occurs as a result of the enlargement of cardiorespiratory dimensions (central adaptation) and from an increased content of intramuscular oxidative enzymes and an increased capillarization of muscle (peripheral adaptations).

The ability to respond to endurance training appears to be maintained into the 70s with improvements in $\dot{V}O_2$ max of 10 to 20% (Seals et al. 1984; Cunningham et al. 1986; Tonino & Driscoll, 1888; Hagberg et al. 1989; Cress et al. 1991; Warren et al. 1993) (table 1). These percentage changes are similar to the improvements seen in response to equivalent training in young adults with the expected central (Stratton et al. 1994; Seals et al. 1984) and peripheral (Örlander et al. 1980; Suominen et al. 1977b; Coggan et al. 1992a; Meredith et al. 1989) adaptations.
Figure 6: Implications of a 15% fall in maximal oxygen uptake such as might follow surgery in an otherwise healthy 80 year old woman - from (Young, 1990).
<table>
<thead>
<tr>
<th>Age range* (years)</th>
<th>N</th>
<th>Duration (weeks)</th>
<th>Δ O₂ max (%)</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>61-67</td>
<td>11</td>
<td>52</td>
<td>30</td>
<td>Seals <em>et al.</em> (1984a)</td>
</tr>
<tr>
<td>60-65</td>
<td>33</td>
<td>52</td>
<td>10</td>
<td>Cunningham <em>et al.</em> (1986)</td>
</tr>
<tr>
<td>62-79</td>
<td>9</td>
<td>12</td>
<td>8</td>
<td>Tonino and Driscoll (1988)</td>
</tr>
<tr>
<td>70-79</td>
<td>16</td>
<td>26</td>
<td>22</td>
<td>Hagberg <em>et al.</em> 1989</td>
</tr>
<tr>
<td>65-86</td>
<td>17</td>
<td>50</td>
<td>16</td>
<td>Cress <em>et al.</em> 1991</td>
</tr>
<tr>
<td>71-76</td>
<td>14</td>
<td>12</td>
<td>13</td>
<td>Warren <em>et al.</em> 1993</td>
</tr>
</tbody>
</table>

Table 1. Changes in the directly determined maximal oxygen uptake of healthy elderly subjects undergoing endurance training prior to 1994. Ignoring the length of training the average % change in VO₂ max is 17%.

* Published range or calculated as mean ± 2SD.

Studies have been included only if they included an adequate control group or control period.

Chapter one
The functional implications of improvements in maximal aerobic power are clear; a given everyday task or activity will require a lower proportion of maximal power and may therefore be performed for much longer and with greater ease, thus alleviating functional limitation.

There are very few controlled studies in which the subjects have been more than 70 years of age and none where the mean age was over 80 years, arguably those whose everyday life would benefit most from such changes.

A pilot study (unpublished, Greig et al.1993) (Appendix 2A) failed even to suggest any submaximal adaptations i.e in the heart rate and oxygen consumption measured during a submaximal exercise treadmill test and in a timed self paced walking test and a timed self paced stair climbing test during which heart rates were measured, in 7 women aged 78-85 years following 12 weeks of predominantly aerobic training. This was despite increases in muscular strength (15% p<0.05) and in explosive power (21% p<0.05) (Malbut et al.1993). However full gas data were obtained in only 3 subjects (due mainly to intolerance of the mouthpiece) and \( \dot{V}O_2 \) max was not measured. Whilst training studies in younger people make direct measurements of \( \dot{V}O_2 \) max before and after training, reports of direct measurement of \( \dot{V}O_2 \) max in very elderly people are rare.

Possible explanations for the lack of response are as follows: First, had the subjects been working hard enough during each training session? Examination of the data showed that only 1 subject had been working above 50% of predicted heart rate reserve (HRR); Second, perhaps the training period was not long enough, perhaps very elderly people need to train for longer for adaptations to take place? Last, perhaps with increasing age there comes a point when the body is no longer able to respond to an aerobic training stimulus. This would imply a failure to adapt both at central and peripheral levels.

The questions raised by this work played a major part in the design of the main study.
2. Effect on quality of life variables

There is conflicting evidence as to whether or not aspects of quality of life can be improved through physical exercise in older people. While some studies have demonstrated an effect of training on psychological variables (Hill et al. 1993; Lavie & Milani, 1995) others have not (Sheldahl et al. 1993; Stanton & Arroll, 1996). In addition there is some evidence to suggest that it may not be the exercise per se but the social contact of an exercise group which improves mood and well being (Hassmén & Koivula, 1997; Brown et al. 1995) (discussed more fully in chapter 9, pg 235).

MUSCULAR STRENGTH AND EXPLOSIVE POWER

This thesis is concerned primarily with the effects of training on maximal aerobic power and quality of life. However, muscular strength and explosive power are also fundamental in enabling an individual to perform everyday activities, therefore this thesis would not be complete without a brief examination of the effects of age and training on muscular strength and explosive power.

Effects of ageing

Muscular strength can be defined as the maximum amount of force (Newtons or Newton metres if expressed in the form of torque about a joint) that a muscle can generate during a single isometric contraction (Harridge & Young, 1997). One of the consequences of the declining muscle mass previously described is a loss of muscle strength. Additionally older muscle may be weak for its size (Harridge & Young, 1997). Strength begins to decline in late middle age and cross-sectional data imply that across the age range 65 to 89 even healthy men and women lose strength at a rate of 1-2% (of a 77 year old’s value) per year (Skelton et al. 1994).
The loss of muscular power (the combination of force of contraction and speed of movement) is even greater, with cross-sectional data consistent with loss at a rate of 3-4% per year (as measured using the Nottingham power rig (Skelton et al. 1994)).

A reduction in the intrinsic ‘speed’ of the muscle can also contribute to a reduction in explosive power. This occurs during cooling (e.g. in those elderly people who are immobile, thin and living in poorly heated accommodation). It also occurs as a result of a reduction in the relative amount of fast contracting myosin heavy chain (MHC) isoforms expressed in older human muscle (Harridge, 1997).

**Functional consequences**

Large numbers of healthy elderly women have power below, or near to, functionally important thresholds and so have lost, or are in danger of losing, the ability to perform some important everyday tasks. For example, measurements of lower limb extensor power made in the English National Fitness Survey, showed that nearly half of the women (but only 15% of the men) aged 70 to 74 had a unilateral power/weight ratio below 1.5W.kg\(^{-1}\) (Skelton et al. 1999), the least value to be confident of being able to mount a 30cm step without using the hands (Levy et al. 1994). Not only are frail elderly people weak, but, when moving their body weight, their weakness is such that they must use a contraction velocity below the peak of their power/velocity curve. The greater the resistance against which power must be developed, the greater the ‘extra’ loss of explosive power. For example, the maximal plantar flexor power of a 70-year old man might be only some 20% less than that of a young man when developing a 10Nm torque, but would be some 90% less than that of the young man when developing a 70Nm torque (*figure 7*) (Harridge & Young, 1997).

The gender difference in power/weight ratio helps explain the greater prevalence of disability, of falls and of restricted independent mobility amongst elderly women than amongst elderly men (Skelton et al. 1994; Skelton et al. 1999).
Figure 7: Power/torque curves for the plantar flexors of young and elderly men. Data derived, by interpolation, from measurements of torque and instantaneous power recorded at 25 degrees of plantar flexion in relation to the angular velocity of rotation of the ankle joint (Harridge & Young, 1997).
Effects of resistance training

It is well documented that young adults can increase their muscular strength and power in response to resistance training. The improvement has been described as having three overlapping components (Jones et al. 1989). The first is an increased skill in the action under study. This is why increases in 1RM (1 repetition maximum - the greatest weight that can be lifted once) are greater than those in isometric or isokinetic strength. The second component is an increase in the force developed per unit cross sectional area of the muscle and the third is growth of the muscle.

Randomized, controlled trials have shown improvements in strength and power can also be gained by older people (Skelton et al. 1995), even by those who are frail (Fiatarone et al. 1994). Because of the weakness of older people, effective strength training can be achieved with very little specialized equipment - even just using body weight may be enough.

Strength training does not halt the underlying loss of muscle fibres but the improvements in isometric strength are equivalent to 15 to 20 years ‘rejuvenation’ and may prevent an individual falling beneath functionally important thresholds. Although training may result in an improvement in selected functional abilities, functional gains are more likely if the performance of strengthening exercises is accompanied by the practice of specific functional skills (Skelton & McLaughlin, 1996).
AIMS OF THESIS

This thesis addresses the following questions:-

1. Can direct measurements of \( \dot{V}O_2 \text{max} \) be obtained from the ‘oldest old’? Are the results of such tests reproducible?

2. What are \( \dot{V}O_2 \text{max} \) values in relatively healthy (health status clearly defined) very elderly people?

3. Which are the best questionnaires to use to measure the quality of life in healthy very elderly people?

4. Can men and women aged 80 years and over increase their \( \dot{V}O_2 \text{max} \) in response to aerobic training?

5. What adaptations to aerobic training occur in:-
   (i) Submaximal indicators of aerobic fitness i.e heart rate at a set oxygen consumption
   (ii) Oxidative muscle enzyme levels, and mRNA levels for those enzymes
   (iii) Muscular strength and power
   (iv) Body composition

6. Does aerobic training have any effect on the quality of life of healthy people aged 80 or over?

7. Do old and young adults differ in their physical responses to aerobic training when trained using the same relative intensity?

8. Does the training period for old people need to be longer than for younger people before adaptations to aerobic exercise occur?
CHAPTER TWO

MEASURING \( \dot{V}O_2 \) MAX IN THE 9th DECADE:-
FEASIBILITY AND REPRODUCIBILITY

- INTRODUCTION
- METHODS
  - Subject recruitment
  - Test procedure
    - Determination of a maximal test
  - Data analysis
- RESULTS
  - ‘Maximal’ tests
  - ‘Non maximal’ tests
  - Reproducibility of data
- DISCUSSION
  - Subject recruitment
  - Choice of ergometer
    - Feasibility and reproducibility of maximal effort tests
- CONCLUSION
INTRODUCTION

Maximal aerobic power (\(\dot{V}O_2\) max) can either be measured directly (by working an individual to maximal effort on a treadmill or cycle ergometer) or estimated (by using a predicted value for HRmax) and extrapolating from the submaximal oxygen consumption and heart rate data. Estimating \(\dot{V}O_2\) max has the advantage that the tests are easier to perform and may not require such highly trained personnel. However, there are two major disadvantages. The first is the reliance on the use of predicted HRmax. It is well documented that predicting an individual's HRmax is unreliable at all ages (Londeree & Moeschberger, 1982; Whaley et al. 1992; Howley et al. 1995) and may become even more unreliable in older people (Cooper et al. 1977). Second, the extrapolation relies on a linear relationship between heart rate and oxygen consumption. There is some evidence that at near maximal work rates elderly people show a disproportionate increase in heart rate relative to oxygen intake (Sidney & Shephard, 1977b).

If an accurate measure of \(\dot{V}O_2\) max is required, it is therefore preferable to measure \(\dot{V}O_2\) max directly. Direct measurements of \(\dot{V}O_2\) max are often made in young people but are less common in old age. In studies which have included subjects over 80 years of age the mean age of the subjects has been 63yrs (Sidney & Shephard, 1977b), 72 years (Cress et al. 1991), 64 years (Coggan et al. 1992a) and 72.5 years (Warren et al. 1993). Only one study has examined subjects with a mean age of 80 years viz. Foster et al. (1986) in 8 women aged 73-86 years.

It is conceivable that expecting very elderly people to perform maximal tests is not realistic. The aim of this study was therefore to test the feasibility of directly measuring \(\dot{V}O_2\) max in very elderly men and women and to test the reproducibility of such measurements.
METHODS

Subject recruitment

Subjects were recruited from three sources:

A. From a volunteer database held in the University Department of Geriatric Medicine at the Royal Free Hospital Medical School. The database had a list of approximately 700 men and women aged 65 and over who had expressed a willingness to take part in research. Potential subjects i.e those in their 80th year or older who had been categorised as "medically stable" or "healthy" (Greig et al. 1994) (Appendix 3A) on the basis of questionnaires or previous visits to the department, were identified. These subjects were approached by letter (Appendix 3B) to ask if they would be interested in taking part in the study. Those who expressed an interest were invited to come to the department for a preliminary visit. During this, additional verbal information about the study was given to the subjects, health questionnaires were updated and all subjects had basic lung function tests (FEV1 and FVC), resting blood pressure (BP), resting electrocardiogram (ECG), height and weight measured.

B. Via word of mouth from the volunteers already contacted. Any interested individuals were sent a health questionnaire to complete. On the basis of these questionnaires subjects likely to be eligible as "healthy" or "medically stable" were selected. These potential subjects were invited to attend the department for a preliminary visit as described above.

C. From an article placed in a local newspaper. Following the article the department was contacted by people who were interested in taking part in the study. These subjects were asked to complete health questionnaires as above. Those who seemed likely to fulfill the health criteria on the basis of the questionnaires were asked to attend the department for a preliminary visit as described previously.
Fifty six potential subjects volunteered to take part in the study. Following the preliminary visit 33 subjects fulfilling the set criteria were identified. These went on to have a medically supervised exercise ECG on a cycle ergometer. On the basis of this 5 subjects were excluded, 1 because of ischaemic changes seen during the exercise test and 4 because they had difficulty in pedalling the cycle.

The physical characteristics of the remaining 28 subjects are in table 2.

An electrically braked cycle ergometer (Cybex) was chosen for the study as it provided stability for the more frail subjects and allowed ancillary measurements to be taken more easily (figure 8). All subjects were familiarised with the procedures on two visits to the laboratory (during which the assessment and exercise ECG took place) prior to definitive measurements being made. Each subject then performed three progressive tests (T1, T2 and T3) on three separate occasions. For each individual subject, tests were performed at the same laboratory temperature and at the same time of day (Shephard 1984).

Test procedure

Subjects were asked to abstain from any caffeine intake (i.e. coffee, tea or chocolate) for at least 2 hours prior to the test. Each test was supervised by the same two testing staff, both of whom had been trained in cardiopulmonary resuscitation. Test 1 (T1) started at a work rate of 25W and progressed in 15W increments every 2.5 mins until the subject could no longer continue, despite urging from testing staff, or if criteria for termination of a test were reached (Appendix 3C). Subsequent tests were adapted from T1 to try to get the subject to maximum within 10 to 12.5 minutes i.e 25W increments were used instead of 15W where appropriate.

Expired gas was collected via a nasal and mouthbreathing face mask (Hans Rudolph type 7930 or 7940), chosen as older people have been found to experience problems when wearing a mouthpiece (Greig et al. 1994). Expired gas passed into a mixing chamber from which samples were drawn through gas analyzers. Heart rate (Hewlett
Packard), CO₂ concentration (infra red; PK Morgan), O₂ concentration (paramagnetic; PK Morgan) and inspired volume (Harvard dry gas meter) were measured during the last minute of a 2.5 minute rest period, every 30 seconds during exercise and at peak exercise. ECG was monitored continuously (Datascope) for safety. The CO₂ and O₂ analyzers were calibrated using room air and two different gas mixtures of known concentrations. The dry gas meter was calibrated by pumping through known gas volumes using a 1 litre syringe (PK Morgan).

Fingertip samples (intact whole blood) were taken (where possible) in the last 30 seconds of each stage, at peak exercise and 5-7 mins post exercise. These were analyzed for lactate concentration (LM5 Analox Instruments). The analyzer was calibrated using two samples of known lactate concentration; a lactate/pyruvate quality control serum and a lactate standard (both Analox Instruments).

Determination of a maximal test

A plateau in oxygen consumption is used as the primary criterion that VO₂ max has been reached in tests with younger people. It has been reported that many older people are unable to meet this criterion (Sidney & Shephard, 1977b). The use of secondary criteria i.e. maximal respiratory exchange ratio (RERmax) ≥1.1, maximal blood lactate (LAmax) ≥8mmol.l⁻¹, HRmax within 10 beats of age predicted max, are also not suitable for use with older people. Estimating HRmax is unreliable (Cooper et al. 1977), whilst both blood lactate levels (Massé-Biron et al. 1992) and RER (Sidney & Shephard, 1977b) have been shown to decline with age. In their assessment of criteria for use with older people (mean age 63 years) Sidney and Shephard (1977b) reported that most (although not all) subjects considered to have made a ‘good effort’ when tested on a treadmill achieved an RER ≥1.0. For purposes of this study a test was judged as maximal if RER ≥1.0 and the subject was judged subjectively to have made a maximal effort. Our findings with regard to the attainment of traditional criteria are discussed in chapter 3.
<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Age (years)</th>
<th>Height (m)</th>
<th>Weight (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Median</td>
<td>Range</td>
<td>Median</td>
</tr>
<tr>
<td>Women</td>
<td>16</td>
<td>82</td>
<td>79-91</td>
<td>1.56</td>
</tr>
<tr>
<td>Men</td>
<td>12</td>
<td>80</td>
<td>79-87</td>
<td>1.68</td>
</tr>
</tbody>
</table>

Table 2:- Subject characteristics
Figure 8: An 80 year old man performing a maximal effort exercise test on a cycle ergometer.
Data analysis

\( \dot{VO}_2 \) max (in those performing a maximal (TMx) test) or \( \dot{VO}_2 \) peak (in those who did not achieve a maximal test (NTMx test)) was taken as the highest value of \( \dot{VO}_2 \) achieved during a test. Values for maximal (or peak in those subjects performing a NTMX test) HR, RER and LA were taken as the highest value achieved during the test. In all cases for RER and HR these values coincided with \( \dot{VO}_2 \) peak whilst in two cases the lactate values taken at 5-7 mins post exercise were the highest values.

An unpaired t test was used to compare the men and the women who performed TMx tests, using the data from each individual’s longest TMx test. Data from each individual’s longest test were also used to compare those women who had performed a TMx test with those who had not (unpaired t test).

In those subjects who performed more than one TMx test, the data from the last two TMx tests were compared using a paired t test. Coefficients of variation (CV) were calculated for HRmax, RERmax, LAmax and \( \dot{VO}_2 \) max.

RESULTS

Data from each subject’s longest test are displayed in table 3.

'Maximal tests' (TMx)

Ten of the 12 men and 11 of the 16 women performed at least 1 TMx test. In the men \( \dot{VO}_2 \) max values for the men ranged from 13.4 to 31.19ml.kg\(^{-1}\).min\(^{-1}\), HRmax from 120 to 180bpm, RERmax from 1.0 to 1.17 and LAmax from 3.1 to 7mmol.l\(^{-1}\). In the women \( \dot{VO}_2 \) max values ranged from 10.07 to 17.75ml.kg\(^{-1}\).min\(^{-1}\) (seen in an 89 year old woman), HRmax from 105 to 160bpm, RERmax from 1.02 to 1.2 and LAmax from 2.7 to 5.2 mmol.l\(^{-1}\).
VO₂ max was significantly higher in the men than in the women (p<0.01) but there was no significant difference for HRmax, RERmax or LAmx.

'Non maximal tests'

Two of the men failed to perform any TMx tests. Their data for peak VO₂ are reported in table 3.

Five of the women were judged not to have succeeded in performing any TMx tests. The peak VO₂ of these women ranged from 7.3 to 17.36 ml.kg⁻¹.min⁻¹; Peak HR from 96 to 130bpm and peak RER from 0.89 to 0.97. Peak lactate samples were available in only 1 of these subjects (3.6mmol.l⁻¹).

Comparing their results to those of the 11 women performing a TMx test there was no significant difference for peak VO₂ (VO₂ max for those performing a TMx test) but there was a significant difference for peak HR (p<0.01), with those performing TMx tests having higher values. Lactate values were not available in enough subjects to make a comparison possible.
<table>
<thead>
<tr>
<th></th>
<th>n</th>
<th>HR(bpm)</th>
<th>V̇O₂ (ml.kg⁻¹.min⁻¹)</th>
<th>Lactate(mM)</th>
<th>RER</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Men</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TMx tests</td>
<td>10</td>
<td>141 (20)</td>
<td>22.4 (6.2)</td>
<td>4.5 (1.3)</td>
<td>1.04 (0.07) (n=8)</td>
</tr>
<tr>
<td>NTMx tests</td>
<td>2 (i)</td>
<td>100</td>
<td>17.6</td>
<td>-----</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td>(ii)</td>
<td>135</td>
<td>20.13</td>
<td></td>
<td>0.93</td>
</tr>
<tr>
<td><strong>Women</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TMx tests</td>
<td>11</td>
<td>129 (15)</td>
<td>14.1 (2.4)</td>
<td>4.1 (1.1)</td>
<td>1.07 (0.05) (n=5)</td>
</tr>
<tr>
<td>NTMx tests</td>
<td>5</td>
<td>106 (16)</td>
<td>12.6 (3.8)</td>
<td>-----</td>
<td>0.90 (0.07)</td>
</tr>
</tbody>
</table>

Table 3: Greatest values achieved in each subject's longest TMx or NTMx test. Results for NTMx tests in men reported for each individual subject. All other results expressed as mean (standard deviation).

Greatest values achieved in the longest TMx or NTMx test.

HR = heart rate; RER = respiratory exchange ratio

Chapter two
Table 4:- Comparison of data from T2 and T3 in those subjects performing more than one TMx test; results expressed as mean (SD)

<table>
<thead>
<tr>
<th></th>
<th>n</th>
<th>HRmax (bpm)</th>
<th>RERmax</th>
<th>Lactate max (mmol. l⁻¹)</th>
<th>( \bar{V}O_{2\text{max}} ) (ml.kg⁻¹.min⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T2</td>
<td>10</td>
<td>136 (13)</td>
<td>1.03 (0.02)</td>
<td>4.3 (1.1) (n=6)</td>
<td>21.33 (6.5)</td>
</tr>
<tr>
<td>T3</td>
<td>10</td>
<td>136 (14)</td>
<td>1.06 (0.05)</td>
<td>4.3 (0.9) (n=6)</td>
<td>20.6 (6.6)</td>
</tr>
</tbody>
</table>
Figure 9, A to D: Reproducibility of maximal heart rate (HRmax), maximal lactate, respiratory exchange ratio (RERmax) and maximal oxygen uptake (VO₂ max) between Test A and Test B. Coefficients of variation were 1.9% for HRmax, 3.1% for RERmax, 9.6% for LAMax and 8.9% for VO₂ max. (Closed symbols men, open symbols women).
Reproducibility of data

Seven of the men and 3 of the women were judged to have performed more than 1 TMx test. There was no significant difference between each individual's two longest TMx tests for any of the variables measured (table 4, figure 9). Coefficients of variation were as follows: - HRmax 1.9%; \( \bar{V}O_2 \) max 8.9%; RERmax 3.1%; LAMax 9.6%.

The coefficient of variation for RERmax must be viewed with caution as (i) RER > 1.0 was used as a criterion that \( \bar{V}O_2 \) max had been reached and (ii) values of RER will be limited to not much more than 1.0.

DISCUSSION

Subject recruitment

Difficulties in the recruitment of suitable older subjects to participate in research studies has been reported previously (Greig et al. 1994; Skelton, 1995); chronic disease is common in old age and healthy elderly people may be less inclined to volunteer for studies in a "clinical environment" (Lye, 1982). Previous difficulty in recruitment led to the development of a database (used in this study) of subjects aged 65 and over who had expressed an interest in taking part in a research project (Skelton, 1995).

Recruitment of suitable subjects for the present study proved difficult. Although the database proved invaluable, even this together with a newspaper article and word of mouth identified only fifty six potential subjects. After the initial assessment only 33 of these proved suitable for inclusion in the study, whilst after the exercise ECG a further 5 subjects were excluded, leaving only 28 subjects to take part in the study.
Choice of ergometer

For performance of maximal effort tests the most common ergometers of choice are the treadmill and the cycle ergometer. The advantage of the treadmill is that it mimics walking, an everyday activity (Greig et al. 1994). However, for elderly subjects in particular, the treadmill can be a daunting piece of equipment. Subjects may feel unable to stop safely at will and therefore do not feel in control. Additionally, they may grip the handrail for support thereby potentially affecting the oxygen consumption and heart rate data (Greig et al. 1994). Although the cycle ergometer necessitates (in most cases) the older subjects performing an unfamiliar activity, it has the advantage that it provides a stable base for the frail elderly person, and also allows ancillary measurements to be taken easily. Furthermore, it has the advantage that subjects can stop at will and safely; knowing this may well encourage subjects to push themselves further than they would if using a treadmill.

In the present study using the cycle ergometer resulted in the exclusion of 4 potential subjects who had difficulty in pedalling the cycle. None of the other subjects experienced any difficulties, most had cycled in their youth (when cars were rare) and picked up the technique easily. Feedback from the subjects suggested that they felt confident in using the cycle ergometer. Subjects felt they could give their maximum effort without worrying about tripping or falling. Using the cycle ergometer also allowed fingertip blood samples, for analysis of lactate levels to be taken with ease.

Feasibility and reproducibility of directly measuring $\dot{V}O_2$ max in the ‘oldest old’

The aim of this study was to test the feasibility and the reproducibility of directly measuring $\dot{V}O_2$ max in very elderly men and women. Of the 28 subjects who took part in the study, 21 performed at least one maximal test. The mean value of 14.3 ml.kg$^{-1}$.min$^{-1}$ for $\dot{V}O_2$ max of the women performing a TMx test is at least as high as that of a slightly younger group of women (aged 73-86) tested on a treadmill (Foster et al. 1986) viz. 13.6 ml.kg$^{-1}$.min$^{-1}$.
Data for determination of the reproducibility of data were only available in 7 men and 3 women. There were no significant differences seen between maximal tests for any of the variables measured. The results support the findings of Foster et al. (1986) who reported no significant difference in HRmax or VO\textsubscript{2} max between maximal effort tests performed using a treadmill in a group of 8 women aged 73 to 86 years.

However, good reproducibility also depends upon a low coefficient of variation, with respect to the size of the change you might wish to detect. In the present study we wished to determine the reproducibility of measuring VO\textsubscript{2} max in very elderly people, with a view to using maximal tests to determine if VO\textsubscript{2} max could be increased in response to training in people aged 80 and over. Table one (chapter 1 pg 5) reported changes in VO\textsubscript{2} max in response to training in older people. The mean % increase in VO\textsubscript{2} max (ignoring the length of the studies) was calculated to be 17%. The CV of 8.9% seen for VO\textsubscript{2} max in the present study is therefore acceptable.

The probability that a test will produce a significant difference at a given significance level is called the power of a test (Appendix 3E). A good power is one which is 80% or more. Using an expected increase of 17% power was calculated to be 82%.

**CONCLUSION**

The results of the present study indicate that with healthy subjects, maximal exercise testing using a cycle ergometer is possible in very elderly people, and that the reproducibility of data obtained in such tests are acceptable.
CHAPTER 3

DETERMINATION OF VO$_2$ MAX IN THE 9th DECADE:
EXAMINATION OF AVAILABLE CRITERIA

- INTRODUCTION
- RESULTS
  - Plateau in oxygen consumption
  - Maximal heart rate
  - Maximal blood lactate
  - Maximal respiratory exchange ratio
- DISCUSSION
- CONCLUSION
INTRODUCTION

Criteria traditionally used in young individuals for determining if a subject has reached \( \dot{V}O_2 \) max, may not be suitable for use with older people. Studies which have included older people have used varying criteria to determine if a test is maximal (table 5), with little attempt to justify their choice of criteria. Sidney and Shephard (1977b) assessed potential criteria in a group of men and women in the seventh, eighth and ninth decades of life, however the mean age of their subjects was only 63 years. No study has assessed criteria in subjects older than this. In the feasibility/reproducibility study outlined in chapter 2 we graded each subject’s performance (at the end of each test, before any of the data had been examined) as either a ‘maximal effort’, or as a ‘non maximal effort’ test. By examination of the data obtained we have attempted to gain further information on the suitability of potential criteria.

RESULTS

The results from the longest test of every subject are displayed in tables 6 and 7.

Eleven of the 12 men and 12 of the 16 women were judged subjectively to have performed a ‘maximal effort’ test. The mean values for \( \dot{V}O_2 \), HRmax, RERmax and LAmax for both ‘maximal effort’ tests and ‘non maximal effort’ tests are displayed in table 8.
<table>
<thead>
<tr>
<th>Author</th>
<th>Subject age</th>
<th>Criteria used</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cress et al</td>
<td>65-86</td>
<td>2/3 of following:- RER &gt; 1.0; Attainment of age-adjusted HRmax (not defined); Increase in O₂ consumption &lt; 1.75ml.kg⁻¹.min⁻¹ with an increase in work rate (calculated to be equivalent to 3ml.kg⁻¹.min⁻¹)(Schauer &amp; Hanson, 1987)</td>
</tr>
<tr>
<td>(1991)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Foster et al</td>
<td>73-86</td>
<td>Achievement of plateau, defined as an increase in O₂ consumption with increasing work rate less than the average increase computed for submaximal work rates.</td>
</tr>
<tr>
<td>(1986)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rogers et al</td>
<td>47-84</td>
<td>1/2 of the following:- No further increase in O₂ consumption (not defined) with an increase in work rate (according to Bruce protocol for sedentary subjects and an increase in gradient by 2% for athletes); RER ≥ 1.15</td>
</tr>
<tr>
<td>(1990)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Warren et al</td>
<td>67-85</td>
<td>All of the following:- RER &gt; 1.0; HRmax within 12 beats of predicted values (220-age); inability of subject to continue despite urging by testing staff</td>
</tr>
<tr>
<td>(1993)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hagberg et al</td>
<td>70-79</td>
<td>2/3 of the following:- an increase in O₂ consumption &quot;&lt; 100ml in the final min of exercise&quot; (following a modified Naughton protocol); RER &gt; 1.1; Heart rate considered to be maximal for a subjects age (not defined).</td>
</tr>
<tr>
<td>(1989)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coggan et al</td>
<td>60-70</td>
<td>2/3 of the following:- a plateau in O₂ consumption despite an increase in treadmill speed and/or gradient (using individually adjusted walking or running protocol; RER &gt; 1.1; Heart rate within 10 beats of age-predicted maximum (not defined).</td>
</tr>
<tr>
<td>(1992a)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 5: Criteria used for attainment of VO₂ max in studies with elderly subjects -prior to 1993 (when present study took place). Studies have only been included if they include subjects over 70 years of age.
1. Plateau in oxygen consumption

The submaximal data from all subjects was combined and the average increase in \( \dot{V}O_2 \) with each increase in submaximal work rate calculated. The average increase in \( \dot{V}O_2 \) with an increase in work rate of 15W was computed to be 3.05 ml.kg\(^{-1}\).min\(^{-1}\) (SD 1.3) whilst for an increase in work rate of 25W it was computed to be 4.73 ml.kg\(^{-1}\).min\(^{-1}\) (SD 1.64). A plateau was defined as

A. an increase in oxygen consumption by less than the mean increase with an increase in work rate (i.e by less than 3.05 ml.kg\(^{-1}\).min\(^{-1}\) for an increase of 15W and by less than 4.73 ml.kg\(^{-1}\).min\(^{-1}\) for an increase of 25W).

or

B. an increase in \( \dot{V}O_2 \) by less than (mean-1 standard deviation (SD)) with an increase in work rate (i.e by less than 1.75 ml.kg\(^{-1}\).min\(^{-1}\) for an increase of 15W and by less than 3.09 ml.kg\(^{-1}\).min\(^{-1}\) for an increase of 25W).

Using definition A, 9 of the 11 men and 9 of the 12 women who performed a ‘maximal effort’ test achieved a plateau in oxygen consumption. However, 3 of the 4 women who performed a ‘non maximal effort’ test also satisfied this criterion.

Using definition B, 4 of the 11 men and 5 of the 12 women who performed a ‘maximal effort’ test achieved a plateau. One of the 4 women who performed a ‘non maximal effort’ test also satisfied this criterion. An example of both a subject demonstrating a clear plateau in \( \dot{V}O_2 \) and one in whom a plateau failed to be demonstrated can be seen in Appendix 3D.

2. Maximal heart rate

Eight of the 11 men and 8 of the 12 women who performed a ‘maximal effort’ test had a HRmax within 10 beats of age predicted maximum (220-age). One of the 4 women performing a ‘non maximal’ test also satisfied this criterion.
<table>
<thead>
<tr>
<th>Male Subject</th>
<th>Max or Non max effort test</th>
<th>RER</th>
<th>Lactate</th>
<th>HRmax within 10 beats of (220-age)</th>
<th>Plateau defined as &lt; mean increase</th>
<th>Plateau defined as &lt; mean increase -1SD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>≥1</td>
<td>≥1.05</td>
<td>≥3</td>
<td>≥3.5</td>
<td>≥6</td>
</tr>
<tr>
<td>1</td>
<td>Max</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>2</td>
<td>Max</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>3</td>
<td>Max</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>4</td>
<td>Max</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>N</td>
</tr>
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<td>5</td>
<td>Max</td>
<td>Y</td>
<td>N</td>
<td>N</td>
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<td>6</td>
<td>Max</td>
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<td>7</td>
<td>Max</td>
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<td>8</td>
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<td>10</td>
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<td>N</td>
<td>N</td>
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<td>11</td>
<td>Max</td>
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<td>Y</td>
<td>N</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>12</td>
<td>Non Max</td>
<td>Y</td>
<td>N</td>
<td>N</td>
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</table>

**Table 6:** Examination of criteria - attainment of different values (Y=yes; N=No) by each individual male.
<table>
<thead>
<tr>
<th>Female Subject</th>
<th>Max or Non max effort test</th>
<th>RER</th>
<th>Lactate</th>
<th>HRmax within 10 beats of (220-age)</th>
<th>Plateau defined as &lt;mean increase -1SD</th>
<th>Plateau defined as &lt;mean increase -1SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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<tr>
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<td>Max</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>Y</td>
</tr>
<tr>
<td>3</td>
<td>Max</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>N</td>
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<td>4</td>
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<td>N</td>
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Table 7: Examination of criteria - attainment of different values (Y=yes; N=No) by individual women.
<table>
<thead>
<tr>
<th></th>
<th>n</th>
<th>HR (bpm)</th>
<th>$\dot{V}O_2$ (ml.kg$^{-1}$.min$^{-1}$)</th>
<th>LA$\text{max}(\text{mm.L}^{-1})$</th>
<th>RER</th>
</tr>
</thead>
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<tr>
<td><strong>Men</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>-Max effort</td>
<td>11</td>
<td>140 (19)</td>
<td>22.2 (5.9)</td>
<td>4.5 (1.3) (n=8)</td>
<td>1.05 (0.06)</td>
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<tr>
<td>-Non max effort</td>
<td>1</td>
<td>100</td>
<td>17.6</td>
<td>-----</td>
<td>1.0</td>
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<tr>
<td><strong>Women</strong></td>
<td></td>
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<td></td>
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<td></td>
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<tr>
<td>- Max effort</td>
<td>12</td>
<td>129 (14)</td>
<td>14.1 (2.3)</td>
<td>4.0 (1.0) (n=6)</td>
<td>1.06 (0.07)</td>
</tr>
<tr>
<td>-Non max effort</td>
<td>4</td>
<td>100 (11)</td>
<td>12.2 (4.2)</td>
<td>-----</td>
<td>0.91 (0.09)</td>
</tr>
</tbody>
</table>

**Table 8:** Results from ‘maximal effort’ and ‘non maximal effort’ tests. Results for the one ‘non maximal’ test in the men reported for the individual subject. All other results expressed as mean (standard deviation)
3. Maximal blood lactate

None of the subjects who performed a 'maximal effort' test, and in whom samples for analysis of lactate levels were available (8 men and 6 women) had a LAmax ≥ 8mmol.l^{-1} (achievement of LAmax ≥ 8mmol.l^{-1} is one of the secondary criteria used to determine if VO_{2}max has been reached in younger people). Indeed, only 5 of the men and 2 of the women had LAmax levels ≥4mmol.l^{-1}.

4. Maximal Respiratory Exchange Ratio

Only 3 of the men and 4 of the women who were judged to have performed a 'maximal effort' test achieved an RER ≥1.1. Five of the men and 6 of the women who performed a 'maximal effort' test achieved an RER max ≥1.05. None of those performing a 'non maximal effort' test had RERmax values ≥1.05. Ten of the 11 men and 11 of the 12 women performing a 'maximal effort' test achieved an RERmax of ≥1.0. However the one man who performed a 'non maximal effort' test also satisfied this criterion.

DISCUSSION

The classical way to determine if VO_{2}max has been reached is to demonstrate a plateau in oxygen consumption. However, even in youth a VO_{2} max plateau is not always attained in subjects completing a maximal graded exercise test (Howley et al. 1995; Duncan et al. 1997) therefore secondary criteria for use in determining if VO_{2} max has been reached have been developed (Howley et al. 1995) viz. HRmax within 10 beats of age predicted maximum; RER ≥1.1 (or ≥1.15) and blood lactate levels ≥8mmol.l^{-1}. Although these secondary criteria are widely used in studies of younger subjects, it seems that if these are to be used in studies with older people there needs to be some age adjustment. Individual criteria are discussed below.
Plateau in oxygen consumption

Criteria used to define a plateau in oxygen consumption in older subjects vary from study to study (table 5). Smaller increments in work rate are often used when testing older people, in these cases it is likely that variation due to the relatively large measurement error may conceal, or may wrongly suggest, the presence of a plateau. Possibly the best approach to define a plateau is to calculate the average increase in \( \dot{V}O_2 \) (from a group of subjects in the desired age group) with each increase in submaximal work rate (Foster et al. 1986), and to define a plateau as either A) an increase in \( \dot{V}O_2 \) less than this mean, or B) to increase specificity, as an increase in \( \dot{V}O_2 \) by less than the mean - 1SD. In the present study 80% of the subjects judged to have performed a 'maximal effort' test achieved a plateau when definition A was used. However, a plateau was also demonstrated in over half of the subjects who were not thought to have performed a 'maximal effort' test. When definition B was used as the criterion for a plateau, only 9 of the 23 subjects (40%) felt to have performed a 'maximal effort' test satisfied this criterion. Sidney and Shephard (1977b) in their study of older subjects (mean age of 63 years) also reported that many older people are unable to demonstrate a plateau. They found that 31% of men and 34% of women considered to have performed a 'good effort' in a treadmill test failed to demonstrate a plateau in oxygen consumption. Although Foster et al. (1986) reported that 75% of their subject's (mean age of 80 years) satisfied the criteria for a plateau in oxygen consumption, they defined a plateau as an increase in \( \dot{V}O_2 \) by less than the mean increase at submaximal workloads. Using this definition, 80% of our subjects achieved a plateau, but so did more than half the subjects judged to have performed a 'non maximal effort' test.

One possible reason that so few of our subjects were able to demonstrate a plateau, (defined as an increase in \( \dot{V}O_2 \) by less than the mean - 1SD), was that we used a continuous test to measure \( \dot{V}O_2 \) max. Workloads were increased every 2.5 minutes, to ensure that steady state was reached by the end of every stage. Analysis of the data showed that oxygen consumption continued to rise throughout the first 1.5 minutes of each stage and only plateaued, i.e. reached steady state, in the last minute. If data
were used from the first part of a stage, when oxygen consumption was continuing to rise, it would perhaps fulfil the criteria for a plateau. To ensure a plateau had been reached, a subject needed to continue to the end of a stage to ensure that steady state had been reached. This is perhaps an unrealistic expectation with some elderly people who are unable to exercise for long. For example, in order to reach the end of a stage, a subject whose maximal test lasts only 6 minutes would have to continue for a further 1.5 minutes i.e 1/4 again of the length of their original test time.

One possible way of overcoming this problem would be to use an intermittent test, where subjects rest between each stage, or where stages are performed on subsequent days. However, such tests are extremely time consuming and therefore not practical where a large number of subjects need to be tested within a short time period. Intermittent tests would also have greatly increased the time commitment of each subject. This may well have reduced the number of subjects who were willing to participate in the study. In addition, in the present study, transport was offered to all subjects, partly to encourage adherence and partly because some of the subjects experienced difficulty in using public transport. If stages had been performed on different days this would have increased the cost of the project significantly.

**Attainment of a percentage of predicted HRmax**

Predicting an individual’s HRmax is unreliable at all ages (Londeree & Moeschberger, 1982; Whaley et al.1992; Howley et al.1995) and may become increasingly so with age (Cooper et al.1977). Although many studies have tried to develop equations to predict individual HRmax more accurately by taking into account not only age but, for example, fitness level (Cooper et al.1977) sex, body weight and smoking status (Whaley et al.1992), all report that there still remains a large inter-individual variation in HRmax.

In the present study it was found that although HRmax (in those judged to have performed a maximal effort test) was very reproducible for individual subjects (CV 1.9%) and mean values (140bpm in the men and 129bpm in the women) were very
similar to mean predicted values (140bpm in the men and 138bpm in the women calculated using equation 220-age (Fox et al.1971)) there was a large inter-individual variation in both the men (120-180bpm) and in the women (105-160bpm) who performed a 'maximal effort' test. In addition, 8 subjects achieved maximal heart rates that were greater than predicted. It would seem that attainment of predicted HRmax is an unreliable indicator that \( \dot{V}O_2 \) max has been reached.

**Lactate max**

There is evidence that lactate levels at \( \dot{V}O_2 \) max decline with age (Massé-Biron et al.1992). This was reflected in the present study where mean LAmax values in those judged to have performed a 'maximal effort' test (4.7 (SD 1.2) mmol.l\(^{-1}\) in the men and 4.0 (SD 0.9) mmol.l\(^{-1}\) in the women) were lower than reported for younger subjects. Although Sidney and Shephard (Sidney & Shephard, 1977b) reported a mean maximal lactate level of 11mmol.l\(^{-1}\) in men and 9mmol.l\(^{-1}\) in women judged to have performed a 'good effort', the mean age of their subjects was only 63 years. In the only other study to have measured lactate levels in subjects with a similar age to our subjects (mean age 80 years) (Foster et al.1986), the mean maximal lactate level was only 1.89mmol.l\(^{-1}\).

Although differences in sampling technique and site of sampling could partly explain the differences in maximal lactate values between studies (Williams et al.1992), they cannot explain the decline seen with age. The explanation most likely lies in changes which affect the production or the clearance of lactate, as outlined below.

(i) One factor which could affect the production of lactate is the decreasing muscle mass seen with age (Grimby & Saltin, 1983). This has been correlated with decreasing blood lactate levels (Grassi et al.1988). In addition, there is some evidence to suggest that there is preferential atrophy of the type II fibres with advanced ageing (Lexell et al.1988). As type II fibres are net producers of lactate (whilst type I fibres tend to be net consumers) (Jorfeldt, 1970) this could result in lower blood lactate values.
(ii) There may be a time lag between lactate production in the working muscles and its appearance in the blood. Although levels of circulating epinephrine (which increases lactate output from the muscles and decreases removal of lactate by other tissues (Stainsby & Brooks, 1990)) are higher in older people in response to exercise at the same percentage of $\dot{V}O_2$max (Fleg, 1985), there is evidence to suggest that there is a decreased responsiveness of receptors to epinephrine with age (Fleg, 1985). This may delay the increase in blood lactate concentration. However, we also measured the lactate levels 5-7 mins after exercise and found that in only 2 subjects was the value higher than that seen at peak exercise, and then the difference was only slight (<1 mmol.l$^{-1}$).

It seems likely that if LAmax is to be used as a criterion that VO$_2$max has been reached there needs to be some age adjustment.

**Maximal RER**

Studies which have looked at RER values at peak exercise in older people have reported lower values than in younger people (Sidney & Shephard, 1977b; Foster et al.1986) with one study reporting RER values <1.0 at peak exercise in subject's aged 73-86 years (Foster et al.1986). Results from the present study also report lower values of RER than would be expected in younger subjects with only 7 subjects felt to have performed a ‘maximal effort’ test achieving an RERmax ≥1.1.

Changes in RER with exercise have been reported to be associated with reciprocal changes in blood lactate and plasma bicarbonate (Naimark et al.1964; Bouhuys et al.1966). Indeed RER has been used as a non-invasive method of determining the degree to which anaerobic glycolysis contributes to total energy expenditure (reviewed by Anderson and Rhodes 1989 and Howley et al.1995). It is perhaps not surprising therefore that a decline in maximal lactate values with age would be associated with declining values of RERmax.

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It is clear that if RER is used as criterion that VO₂max has been reached there must be some age adjustment. Sidney and Shephard (1977b) reported that most subjects who performed a ‘good effort’ in a treadmill exercise test achieved maximal RER values ≥1.0 but Foster et al. (1986) reported maximal RER values <1.0 in subjects with a similar age to the ones used in the present study. We found that 91% of subjects judged to have performed a ‘maximal effort’ test achieved maximal RER values ≥1.0. However, the one man judged not to have performed a maximal effort test also had a maximal RER value ≥1.0. Although it seems that most subjects performing a ‘maximal effort’ test will have a maximal RER ≥1.0, using this criterion on its own is not ideal, as it may result in some false positive and some false negative tests.

CONCLUSION

Demonstrating a plateau in oxygen consumption is not always possible in very elderly people, even when they are felt to have performed a ‘maximal effort’ test. Secondary criteria, commonly used with younger people, are not suitable for use with older people. Many older people achieve maximal heart rates higher than predicted, making the attainment of the common criterion of ‘achievement of heart rate within 10 beats of age predicted HR’ an unreliable indicator that VO₂max has been reached. There needs to be some age adjustment if maximal lactate or RER values are to be used to determine if VO₂max has been reached, and although RER≥1.0 appears to identify most subjects felt to have performed a ‘maximal effort’ test, using this criterion on its own is not ideal as it may result in some false positive or negative tests. Using intermittent tests may enable a plateau in oxygen consumption to be demonstrated more easily. This is worthy of further investigation.
CHAPTER FOUR

MEASURING QUALITY OF LIFE IN OLDER PEOPLE

- INTRODUCTION

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  - Reliability
    - Multiple form reliability
    - Split form reliability
    - Test - retest and between observer reproducibility
  - Validity
    - Criterion validity
    - Content validity
    - Construct validity
  - Sensitivity to change
  - Additional requirements

- IDENTIFICATION OF POTENTIAL INSTRUMENTS
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  - 2. The Profile of Mood States
  - 3. The SF-36
  - 4. The Sickness Impact Profile
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  - 7. The McMaster Health Index Questionnaire
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- FINAL SELECTION
  - Testing of chosen questionnaires on a group of elderly people
    - Results
INTRODUCTION

There is no clear definition of Quality of Life (QOL). It is a combination of subjective components which include life-satisfaction, self esteem, well-being and morale. These are dependent in part upon objective components i.e. functional ability, general health and socio-economic status. It is therefore difficult to find an instrument which encompasses all these components. However, although there is no perfect instrument, there are many tools available which can be used to measure components or combinations of components of QOL.

CHOOSING AN INSTRUMENT

In choosing a suitable instrument a number of issues have to be addressed. It must perform well in terms of reliability, validity and sensitivity to change. It must also be suitable for its intended use for example, in this case, for use in the monitoring of responses to exercise training in very elderly people. These requirements are outlined below. In preparing this part of the chapter four key sources were used (Bowling, 1991; McDowell & Newell, 1996; Ware et al. 1997; George, 1980).

Reliability

The reliability of an instrument is concerned with error in measurement (McDowell & Newell, 1996), that is the extent to which a measure gives consistent or accurate results. It is also important that an instrument can distinguish between true change and random error. Reliability measures can be split into three main components:-

Multiple form reliability

This is rarely used (Ware et al. 1997) but can be calculated when 2 instruments have been developed in parallel and measure the same attribute. They are administered at the same time and to the same individual and scores on each correlated (Bowling, 1991).
Split-half reliability

This is a way of estimating internal consistency. It determines if items on a scale are inter-related. One way to test this is to divide the instrument into 2 equivalent parts and work out the correlations between their scores (Bowling, 1991). Cronbach’s coefficient alpha (the average of all possible split half reliabilities adjusted to the number of items) is the most frequently used indicator of internal consistency (McDowell & Newell, 1996).

Test-retest reproducibility and within observer reproducibility

Does the instrument give the same answer when used by different observers or when the same group of subject’s is re-tested?

Between observer reproducibility can be tested by examining the differences when the same instrument is given to the same set of subject’s by different operators. Test-retest reproducibility is measured by administering the test to the same set of subjects at more than one occasion. However, this should be interpreted with caution as (a) subjects may recall the responses they gave on the previous test visit and (b) subjects responses may vary as the result of genuine change, although this would be likely to underestimate, not overestimate, reliability.

Validity

The validity of an instrument is the extent to which it measures what it is supposed to measure, whilst at the same time not measuring other different but related concepts. The most common types of validity are:

Criterion validity (includes concurrent and predictive validity)

This is concerned with the accuracy of the instrument i.e. its sensitivity and
specificity. It can be assessed by comparing the results of the instrument under examination with those obtained using a 'gold standard'.

Content validity (or face validity)

This is concerned with the relevance of the instrument i.e. is it relevant for the intended use and does it cover all aspects of the attribute to be measured.

Construct validity

This includes convergent and discriminant validity. Convergent validity examines the correlation between the instrument under assessment and other instruments which measure the same phenomenon. Discriminant validity looks at the ability of the instrument to discriminate between the phenomenon it is intended to measure and different but related phenomena (George, 1980).

Sensitivity to change

One of the most important requirements of a instrument which is being used to monitor an 'outcome' is that it is sensitive to change. It is important that any chosen instrument has the ability to detect an improvement or deterioration. For example, an instrument which offers only a choice of 'Yes' or 'No' in response to a question may be less sensitive to change than one which offers a number of graded responses, providing the number of questions is the same. Also, a healthy person will score highly on some physical function scales, therefore there will be little room to detect improvement; this is known as a ceiling effect. It is also important to note that if a scale has low reproducibility it will be capable of detecting only large changes, as it will not be able to distinguish between small changes in the variable being measured and error of measurement.
Additional requirements

An instrument must be reliable, valid and sensitive to change but it is also important that it is suitable for its intended purpose. For our purpose the intended use was to see if 24 weeks of aerobic training had any effect on the quality of life of relatively healthy (Greig et al. 1994) men and women over 80 years of age. It was therefore important that the instrument chosen was suitable for use in this age group. We believed that subjects would feel less inhibited about revealing their feelings if the forms were coded and self-completed. This together with time constraints meant that one requirement of any instrument we chose was that it could be self completed. Therefore, in examining potential instruments the following questions were addressed:

- How does the instrument perform in terms of reliability?
- How does the instrument perform in terms of validity?
- Is the instrument sensitive to change?
- Has the instrument been used with older people?
- Is the instrument suitable for self completion?
- Is the instrument easy to score?
- Is the instrument comprehensive without being too long?

IDENTIFICATION OF POTENTIAL INSTRUMENTS

Thirty eight potential questionnaires which measured components or combinations of components of quality of life were identified from the literature. All were examined in terms of their suitability for use in the intended study. Twenty nine were excluded on the basis of this preliminary analysis, these together with reasons for their exclusion are displayed in Appendix 4. The remaining nine were examined in more detail and are outlined below:
1. The General Health Questionnaire (GHQ)

There are four different versions of the GHQ; the GHQ 12, GHQ 28, GHQ 30 and GHQ 60. The version chosen for consideration here is the GHQ 28, designed for research purposes. This has four different subscales which assess depression, anxiety, social functioning and physical symptoms (Goldberg & Williams, 1991).

Data for reliability, validity and sensitivity to change (outlined below) are mostly derived from the GHQ 30 and the GHQ 60.

Reliability - The GHQ has good reliability with values for internal consistency varying from 0.77 to 0.93 and test-retest values from 0.51 to 0.90 (Goldberg & Williams, 1991).

Validity - There have been over 50 validity studies on versions of the GHQ, with good content and construct validity reported (Goldberg & Williams, 1991). Criterion validity is also reported to be good; when compared with standard psychiatric interviews the GHQ was found to have a sensitivity of 0.55-0.92 and a specificity of 0.80-0.99 (Goldberg & Williams, 1991).

Sensitivity to change - Subjects can give one of four responses in answer to each question ‘less than usual’; ‘no more than usual’; ‘rather more than usual’ or ‘much more than usual’. The GHQ detects disorders of less than two weeks duration and is therefore sensitive to transient change. It has shown improvements in patients after a myocardial infarction (Laerum et al. 1991).

Has the instrument been used with older people? - The GHQ 28 was used among 662 people aged 85 and over living in London; most found it acceptable although it was suggested that some older people may need help to complete it if they have poor eyesight or stiff finger joints (Bowling, 1990).

Is the instrument suitable for self-administration? - The GHQ was designed to be self
administered.

Is scoring easy? - There are different ways to score the GHQ all of which are quick and simple. The most commonly used is the GHQ scoring system where the four responses ‘less than usual’; ‘no more than usual’; ‘rather more than usual’ and ‘much more than usual’ are scored 0-0-1-1. For research purposes the Likert scoring system is used this scores responses 0-1-2-3. This is reported to give a less skewed distribution (Goldberg & Williams, 1991).

Scores can be calculated for each of the four sections or can be added together to give an overall score.

Is the instrument comprehensive but not too long? - The GHQ takes around 5 minutes to complete but is comprehensive giving an assessment of depression, anxiety, social functioning and physical symptoms. However, other quality of life dimensions would need to be determined using other questionnaires.

Conclusion:- The GHQ has good reliability and validity and is sensitive to transient change. It has been used with older people and is easy to complete and score. However, although comprehensive it does not cover all the components of quality of life, therefore if chosen it would need to be used in conjunction with other questionnaires.

2. Profile of Mood States [POMS]

The POMS is a 65 point adjective rating scale which asks questions relating to feelings over the past week. It can be scored to give responses for 6 mood factors (tension/ anxiety; depression/dejection; anger/ hostility; vigour/activity; fatigue/inertia and confusion/ bewilderment) or scores can be summed to give a total mood disturbance (with vigour/activity being negatively weighted).

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Reliability - The POMS has been reported to be highly reliable (McNair et al. 1992). Internal consistency for POMS factors varies from 0.87 for confusion/bewilderment to 0.95 for depression/dejection (measured in a group of 350 male psychiatric outpatients) and 0.84 for confusion/bewilderment to 0.95 for depression/dejection (measured in 650 female psychiatric outpatients) (McNair et al. 1992). Test-retest coefficients vary from 0.65 for vigour/activity to 0.74 for depression/dejection (McNair et al. 1992).

Validity - The overall validity of POMS is good (McNair et al. 1992). Content or face validity is good and several areas of research, including controlled outpatient drug trials and studies of sport and athletes have provided evidence of construct validity (McNair et al. 1992). The POMS has also been compared with similar types of instrument to obtain measures of concurrent validity. Overall this appears to be satisfactory, although concurrent validity varies enormously depending on the instrument the POMS has been compared with (reviewed in detail in McNair et al. 1992).

Sensitivity to change - POMS gives a choice of 5 weighted responses in answer to each question [0 = not at all; 1 = a little; 2 = moderately; 3 = quite a bit; 4 = extremely]. The sensitivity to change of the POMS is excellent. Because it asks for feelings over the past week it can pick up persistent mood reactions whilst also picking up treatment effects. It has been used to show improvements in mood state after exercise training, with changes being seen in those subjects in whom fitness improved (Kowal et al. 1978).

Has the instrument been used with older people? - POMS has been used in some studies with older people (Oldridge et al. 1995; Casten et al. 1995).

Is the instrument suitable for self-administration? - POMS was designed to be self-administered. The only problem when being used in the UK is that some words are Americanised, for example ‘bushed’, and may not be easily understood, particularly by older people. It is therefore important that subjects can come back and ask what
certain words mean, although it may be difficult to explain without using other terms which are listed on the sheet.

*Is it easy to score?* - Scoring can be done by hand by the use of overlay sheets.

*Is the instrument comprehensive but not too long?* - Although there are 65 questions it is easy to complete with completion time estimated at 3-5 minutes. It is comprehensive giving information on 6 factors which affect mood (see above) as well as a total ‘mood’ score.

*Conclusion:* A good instrument with the advantages of good reliability and validity and excellent sensitivity to change. Its main disadvantage is its use of Americanised words.

3. **SF-36 [short form of health survey questionnaire]**

The SF-36 is a 36 item questionnaire which measures 8 aspects of health status: Physical functioning (10 items); role limitation through physical problems (4 items); role limitation through mental problems (3 items); social functioning (2 items); mental health (5 items); bodily pain (2 items); vitality (4 items) and general health perception (5 items). It also includes a question covering change, over the past year, in health status but this is not counted in scoring the 8 dimensions (McDowell & Newell, 1996).

It was developed from the medical outcomes study (MOS) (Tarlov *et al.* 1989) which was based on a multidimensional model of health. The MOS assessed 40 physical and mental health concepts, the SF-36 was constructed to represent 8 of the most important of those included in the MOS and other widely used health surveys (Ware *et al.* 1997).

*Reliability* - The reliability of the SF-36 was reported to be good in a group of General Practitioner (GP) patients aged 16 to 74 years (Brazier *et al.* 1992) with an
internal consistency reported for the eight scales ranging from 0.73 to 0.96. In a random sample of the UK population Cronbach alpha was >0.8 for all items (excluding social functioning where it was 0.76) (Jenkinson et al. 1993). Test-retest reliability has been reported to be between 0.60 to 0.81 (Brazier et al. 1992), although it has been suggested that these values may well be attributable to the fact that the scales are sensitive to short term change i.e may pick up true differences over a 2 week period (Ware et al. 1997).

Validity - Brazier et al. (Brazier et al. 1992) reported good validity in a group of GP patients aged 16 to 74 years. They found that it was able to detect low levels of ill health in those who had scored 0 (good health) on the Nottingham Health Profile. The different items of the SF-36 also correlate fairly well when compared with other instruments measuring the same thing, for example a correlation of 0.78 (for global dimension) with the Sickness Impact Profile was found when used in 106 hip surgery patients (Katz et al. 1992).

Sensitivity to change - The format of the SF 36 means that it gives a choice of weighted responses in answer to each question. It has been reported to be sensitive to change (Beaton et al. 1994).

Has the instrument been used with older people? - The SF-36 has been tested in older people and found to have a good response rate and good internal consistency (Lyons et al. 1994)

Is the instrument suitable for self-administration? - The SF-36 has been used in postal surveys with good response rates (McDowell & Newell, 1996). It takes approximately 5-10 minutes to complete.

Is it easy to score? - Scoring is fairly simple. Scores are coded, summed and transformed from 0 to 100, with higher scores indicating better health.

Is the instrument comprehensive but not too long? - The SF-36 is comprehensive,
measuring 8 aspects of health yet not too lengthy, taking only around 5-10 minutes to complete.

Conclusion: The SF-36 is comprehensive, easy to complete, with good reliability and validity. It has been tested for use with older people and can be self administered.

4. The Sickness Impact Profile (SIP)/Functional limitations profile (FLP)

The SIP is a behaviourly based measure of health status (Bergner et al. 1981), concentrating on assessing the impact of sickness on an individual's behaviour and daily activities (Bowling, 1991; McDowell & Newell, 1996). It comprises 136 items which can be divided into 12 categories, which can be split into those concerned with physical function and those to do with psychological functioning. The FLP is the British version of the SIP, with the main difference being that some of the wording has been altered.

Reliability - Both internal consistency and test-retest reliability are reported to be high with values of 0.81-0.97 (Bowling, 1991) and 0.88-0.92 respectively (Bowling, 1991; McDowell & Newell, 1996). However results are reported to be better for interviewer completed as opposed to self completed forms (Bowling, 1991; McDowell & Newell, 1996).

Validity - The SIP has been reported to have good concurrent and discriminant validity (McDowell & Newell, 1996; Bowling, 1991). Correlations with clinical assessments (large random sample) are moderate to good (0.40 to 0.65) whilst correlations with self ratings are higher (McDowell & Newell, 1996; Bergner et al. 1981).

Sensitivity to change - Because there is not a range of responses the instrument may be less sensitive to change than those giving graded responses. However, some studies have reported sensitivity to change (Sullivan et al. 1990; Liang et al. 1990) although it has been suggested that the SIP/FLP is less sensitive to improvement than deterioration (Fitzpatrick et al. 1988) and may be less sensitive to change than other
instruments including the SF-36. In addition in a group of GP patients Hall et al. (1987) suggested that the instrument showed skewed distribution towards healthy end of the scale, which may make improvements difficult to see.

Has the instrument been used with older people? - The SIP has been used with older people (Fletcher et al. 1992).

Is the instrument suitable for self-administration? - The SIP can be self or interviewer administered although reliability is better if interviewer administered.

Is it easy to score? - The SIP takes around 5-10 minutes to score. The format of the questionnaire is such that respondents are asked questions to which they answer ‘Yes’ if applicable or leave the space blank. There is therefore no way to know if columns left blank represent ‘No’ replies or whether these questions have been omitted deliberately or by mistake (Bowling, 1991). The single score ranges from 1-100 with the lower the score the better. It can also be scored to give scores for each of the 12 sections or for physical and psychological functioning.

Is the instrument comprehensive but not too long? - The major disadvantage of the SIP/FLP is that it is too long - 136 items taking around 20-30 minutes to complete.

Conclusion:- The SIP has been widely used and is reliable and valid. It has also been used in older people. However it is long and may be less sensitive to change than other available instruments. In addition reliability is reported to be reduced when it is self administered. The SF-36 is reported to be more sensitive to change and is much shorter.

5. The Geriatric Depression Scale (GDS)

The Geriatric Depression Scale was designed by Yesavage et al. (1983) specifically as a screening instrument for depression in older people. It was designed to be easily administered and consists of 30 items with a YES/NO answer format. The ‘No’
answer scores are added up with the higher the score the more likely is the individual to be depressed. It is recommended by the Royal College of Physicians of London as a screening instrument for depression in older people (Royal College of Physicians of London et al. 1992).

**Reliability** - The reliability of the GDS is good with an internal consistency (alpha coefficient) of 0.8 to 0.99 (McDowell & Newell, 1996) and test-retest values of 0.85 (Yesavage et al. 1983).

**Validity** - The GDS has been compared to other depression scales. Correlations of 0.78, 0.82, 0.62, 0.81 have been found with the Hamilton rating scale for depression (McDowell & Newell, 1996), and 0.85 with the Beck depression scale 0.85 (Applegate, 1987). There is also a good agreement between the GDS and structured psychiatric interview. It is reported to have good sensitivity and specificity (Brink et al. 1982).

**Sensitivity to change** - The questions ask for feelings over the last week. However healthy non-depressed older people will have low scores to start with therefore it may be difficult to demonstrate an improvement after an intervention - i.e. there may be a ‘floor’ effect.

**Has the instrument been used with older people?** - Designed specifically for use in screening for depression in older people.

**Is the instrument suitable for self-administration?** - The GDS was designed to be self administered, although it can be interviewer administered. It takes about 8-10 minutes to complete.

**Is it easy to score?** - Scoring is simple. The ‘No’ responses are added up, the higher the score the more likely that the individual is depressed.

**Is the instrument comprehensive but not too long?** - Good screening instrument, quick.
and easy to administer.

**Conclusion:** The GDS is a good screening instrument which was designed specifically for use with older people. It has good reliability and validity but because it will give low scores in healthy non depressed people there is the problem of a ‘floor’ effect.

### 6. The Philadelphia Geriatric Centre Morale Scale (PGCMS)

The PGCMS has been described as the instrument of choice for measuring life satisfaction and morale (Bowling, 1995) and is also recommended by the Royal College of Physicians of London as the Quality of Life measure to use with older people (Royal College of Physicians of London *et al.* 1992). Developed by Lawton (1972) it is designed to measure dimensions of emotional adjustment in persons aged 70 to 90 and is applicable to community residents and to people in institutions. It originally consisted of 22 items, revised to 17 (Lawton, 1975). It can be analyzed to give an overall score or to give scores for three subscales, Agitation (6 items); Attitude towards one’s own ageing (5 items) and Lonely Dissatisfaction (6 items).

**Reliability** - Internal consistency is good for all 3 subscales with Cronbach’s alpha of 0.85 for agitation, 0.81 for attitude towards one’s own ageing and 0.85 for lonely dissatisfaction (Lawton, 1975). It has good test-retest reliability with a coefficient value of 0.91 after 5 weeks (Lawton, 1972).

**Validity** - The PGCMS has shown reasonable correlation with the Life Satisfaction Index. It has been suggested that more data are needed on predictive and convergent validity (McDowell & Newell, 1996)

**Sensitivity to change** - Some evidence for responsiveness to health care interventions has been reported (Rubenstein *et al.* 1984; Challis *et al.* 1990)
Has the instrument been used with older people? - The PGCMS was designed for use with older people. It has been used in several UK community studies (Davies & Challis, 1986; Challis et al. 1990).

Is the instrument suitable for self-administration? - The PGCMS is easily administered. It can be self or interviewer administered.

Is it easy to score? - The PGCMS is easy to score. One point is given for each response indicating high morale, range of overall score 0 to 17 with higher scores indicating higher morale. Additionally it can be scored to give results for the 3 sub scales mentioned.

Is the instrument comprehensive but not too long? - The PGCMS is comprehensive, giving information on agitation, dissatisfaction, attitude towards one's own ageing and global life satisfaction, yet takes only a few minutes to complete.

Conclusion:- The PGCMS is a reliable instrument which was developed specifically for use with older people. However, it has been suggested that further validation studies are needed.

7. McMaster health index questionnaire (MHIQ)

The MHIQ was developed as a measure of physical, social and emotional functioning for use in health services evaluation and in clinical research (Chambers 1993). It contains 59-items covering physical (mobility, self care, communication, global physical function), mental/emotional (self-esteem, attitude towards personal relationships, future etc) and social (general well being, work/social role performance/family support etc) health.

Reliability - Values for internal consistency are reported to be 0.76 for the physical scale, 0.67 for the emotional scale and 0.51 for the social (Chambers, 1993).
Test-retest reliability coefficients, measured in a group of psychiatric patients, have been reported to be 0.95, 0.77 and 0.66 for the physical, emotional and social scales respectively. When measured in a group of physiotherapy patients test-retest reliability coefficients were reported to be 0.53, 0.70 and 0.48 for the physical, emotional and social scales, respectively (Chambers, 1993).

**Validity** - It has been reported that the MHIQ can distinguish between different patient groups e.g psychiatry and physiotherapy patients (Chambers, 1993). It appears to correlate reasonably well with ratings for physical function (Chambers, 1993) but there is not much information for emotional and social scales. It has been suggested that more studies on validity are needed including comparisons with more recent scales (Bowling, 1991; McDowell & Newell, 1996)

**Sensitivity to change** - The MHIQ has been shown to demonstrate a change in physical function scores in physiotherapy patients after treatment although it is reported to be less sensitive than other instruments (McDowell & Newell, 1996). There is not much information regarding sensitivity to change for the emotional and social scales.

**Has the instrument been used with older people?** - The suitability for use with older people has been queried as it includes questions relating to sports participation (McDowell & Newell, 1996)

**Is the instrument suitable for self-administration?** - The MHIQ can be self completed or can be administered via personal or telephone interview.

**Is it easy to score?** - The MHIQ if fairly easy to score. Each item is scored by awarding 1 point to 'good' function, scores are added to provide three scale scores.

**Is the instrument comprehensive but not too long?** - The MHIQ is fairly long and takes around 20 mins to complete.
Conclusion: The MHIQ needs more validation especially for emotional and social scales. It may not be as sensitive as other available instruments to changes in physical function and there is little information regarding its sensitivity to change for emotional and social scores. Additionally its use in older people has been queried and it takes 20 minutes to complete.

8. Affect balance scale

The Affect Balance Scale was developed as a measure of happiness or general psychological well-being (McDowell & Newell, 1996). It consists of 10 items, 5 positive responses and 5 negative.

Reliability - Internal consistency is reasonable with values of 0.55 to 0.73 reported for the positive scale and 0.61 to 0.73 for the negative scale. Test-retest coefficients after 3 days are reported to be high, exceeding 0.9 for 9 of the items and 0.86 for 1 question (Bradburn, 1969).

Validity - Bradburn (1969) showed agreement between the questions and other indices of reported well-being and also reported good discriminant validity, for example the instrument can distinguish between employed and unemployed and between rich and poor.

Sensitivity and sensitivity to change - Some evidence of sensitivity to change has been reported (Bradburn, 1969).

Has it been used with older people? - The Affect Balance Scale has been used in large numbers of surveys of elderly people (Fletcher et al. 1992).

Is the instrument suitable for self-administration? - The Affect Balance Scale is self administered with completion time taking less than 5 minutes.

Is it easy to score? - The instrument can be scored in two ways. First it can be used
simply with a ‘Yes’ or ‘No’ reply or second it can be used with a scale of responses
(3, 4 or 5 points) which represent the frequency of experiencing the feeling e.g. when
using the 3 point scale the respondent can choose from three responses, "often"
"sometimes" or "never" in answer to each question.

Is the instrument comprehensive but not too long? - The Affect Balance Scale is brief
but broad in scale. Because of this it may suffer some resulting psychometric
weaknesses (McDowell & Newell, 1996).

Conclusion: - The Affect Balance Scale has been widely used and therefore results can
be compared to other studies. However it has been criticised as some of the items
appear to measure accomplishments (Bowling, 1991; Fletcher et al. 1992) and because
the positive items may measure transient change whilst the negative items have a more
stable state.

9. Nottingham health profile (NHP)

The NHP was designed to give a brief indication of perceived physical, social and
emotional health problems. It is composed of two parts, although part I can be used
on its own. Part I consists of 38 items, each item referring to departures from
"normal" functioning. It splits into 6 sections (physical ability, pain, sleep, social
isolation, emotional reactions and energy levels). Part II gives a brief indication of
handicap and is composed of 7 items which record the effect of health problems on
occupation, jobs around the house, personal relationships, social life, sex life, hobbies
and holidays. The following information concerns part I only.

Reliability - The NHP does not meet the requirements for carrying out tests for split-
half reliability as it is too short and the items are not homogeneous (Bowling, 1991).
Test-retest reliability is reported to be good for part I with coefficients for the 6
sections ranging from 0.75 to 0.88 (McDowell & Newell, 1996).

Validity - The NHP is reported to have good content validity and also is able to
discriminate between different types of patient. It also has shown good correlation with other instruments and reasonable correlation with physiotherapy ratings (McDowell & Newell, 1996)

*Sensitivity to change* - Although some studies have shown changes in response to interventions the NHP is designed to pick up rather severe problems therefore many healthy people may give scores with little room for improvement i.e. ceiling effect.

*Has it been used with older people?* - The NHP has been used in studies with older people (Borgquist et al. 1992; Ebrahim & Williams, 1992; Johansson et al. 1993; Grimby et al. 1992; Rowland et al. 1994)

*Is the instrument suitable for self-administration?* - The NHP is self administered and takes around 10 to 15 minutes to complete

*Is it easy to score?* - The NHP can be scored in different ways, the simplest of which is to count the number of positive responses in each section.

*Is the instrument comprehensive but not too long?* - Comprehensive instrument which is quick and simple to complete.

*Conclusion:*- The NHP is a well used questionnaire. It’s major disadvantage, for it’s proposed use in our study, is that it is designed to identify rather severe problems. This makes responses to interventions in ‘healthy’ individuals difficult to see.

**FINAL SELECTION**

The final selection of instruments was the Profile of Mood States, the General Health Questionnaire, the SF-36 and the Philadelphia Geriatric Centre Morale Scale. These were considered to be best in terms of performance and covered a wide range of components which make up Quality of Life. The Geriatric Depression Scale was also
chosen because it has been recommended by the Royal College of Physicians of London and we wished to gain further information on its use.

Testing of chosen questionnaires on a group of elderly volunteers

To gain further information on the ease of completion of the chosen questionnaires by older people, and to identify any problems we might encounter when using them in the training study, the questionnaires were administered to a group of 7 men and women aged 65 and over who attended fitness classes at the London Central YMCA.

Results

No problems were encountered in the completion of the forms. Feedback from the volunteers highlighted two potential problem areas:

1. The subjects reported that the writing on the forms for the GDS, PGCMS, SF-36 and the POMS was too small and might therefore prove difficult for some elderly people to read. The solution to this problem was to enlarge the forms to make them easier to read. This was possible with all the questionnaires except for the POMS, in which overlay cards are used to score it. Help with completion would therefore be offered if any subject found the wording difficult to read.

2. As expected several terms on the POMS form were not understood, these were ‘Blue’; ‘Bushed’ and ‘Full of pep’. As these were only 3 items out of 65 it was decided to provide explanations of these phrases to subjects where necessary, without using any of the terms also used on the sheet.
CHAPTER FIVE
DESIGN OF MAIN STUDY

- INTRODUCTION

- OVERALL DESIGN OF STUDY
  - Variables measured
    - Physiological
    - Quality of life

- SUBJECT RECRUITMENT
  - Old group
  - Young group

- METHODS
  - Estimation of initial fitness levels
  - Physiological variables
    1. Height, weight and skinfold measurements
    2. \( \text{VO}_2 \text{ max} \)
      - \( \text{Old group} \)
      - \( \text{Young group} \)
    3. Resting heart rate and heart rate
      at an oxygen consumption of 10ml.kg\(^{-1}\).min\(^{-1}\)
    4. Isometric knee extensor strength
    5. Isometric elbow flexor strength
    6. Explosive leg power
    7. Muscle biopsies
      - \textit{technique}
      - \textit{enzyme analysis}
  - Quality of life variables
INTRODUCTION

The aims of the main study have already been outlined in detail chapter one (pg 51). Basically, the study had two main aims. The first of these was to determine the effects of aerobic training on maximal aerobic power, submaximal indicators of aerobic fitness, specific muscle enzyme activities and their corresponding mRNA levels, muscular strength and power, body composition and quality of life of the ‘oldest old’. The second was to compare the physiological adaptations seen in the ‘oldest old’ in response to training, with those seen in a younger group (aged 18-45) trained using the same relative intensity.

OVERALL DESIGN

The overall time plan for the main study is outlined in figure 10. Each subject underwent a 12 week control period followed by 24 weeks (chosen because of questions raised by previous pilot work (Greig et al. 1993) (chapter 1, page 46)) of predominantly aerobic training. Because increasing activity levels over the summer months could conceivably alter any of the variables we were to measure (Cress et al. 1991), we allowed for time of year effects by splitting both the older, and the younger groups into two parts, with half of each group starting to train after the first half had finished.

Physiological measurements (excluding biopsies) were taken before and after the control period and following 12 and 24 weeks of training. At each testing point all subjects were tested within a 16 day period. In the subjects in whom biopsies were performed, samples were taken (all within a 21 day period) before and after the control period and after 24 weeks of training.

Questionnaires for the analysis of quality of life variables were administered, for self completion at home, before and after the control period and following 12 and 24 weeks of training.
GROUP ONE

CONTROL PERIOD

TRAINING PERIOD

Time point (weeks)

0 12 weeks 24 weeks 36 weeks 48 weeks 60 weeks

GROUP TWO

CONTROL PERIOD

TRAINING PERIOD

Figure 10: Design of main study - time plan
Variables measured

Physiological variables :-

- Height, weight and skinfold measurements.
- Resting heart rate and blood pressure.
- $\dot{V}O_2$ max
- Heart rate at an oxygen consumption of 10ml.kg$^{-1}$.min$^{-1}$.
- Isometric knee extensor strength (IKES), isometric elbow flexor strength (IEFS) and lower limb extensor power (LEP).
- Muscle biopsies for analysis of enzyme activities and their corresponding mRNA levels

Quality of life variables:-

To measure components of quality of life the questionnaires identified in chapter 3 were used viz. The Profile of Mood States, General Health Questionnaire, Geriatric Depression Scale, SF-36 and Philadelphia Geriatric Centre Morale Scale.

SUBJECT RECRUITMENT

Old group

For purposes of the present study strict health criteria were used i.e. only those fulfilling "healthy" or "medically stable" criteria (Greig et al.1994) were included in the study, in order that any effect of disease on the response to endurance training could be avoided. The feasibility study described in chapter 2 had identified 29 subjects who fulfilled these criteria and experienced no problem in using the cycle ergometer. Of these, 26 subjects took part in the training study.
Young group

Subjects for the younger group (ages 18-45) were recruited from hospital and medical school staff in response to a poster advertising the study (Appendix 5A) and by word of mouth. Only those subjects who met previously defined criteria (Greig et al. 1994) for 'healthy' or 'medically stable' established from health questionnaires, a resting electrocardiogram (ECG) and a measurement of resting blood pressure (BP) were included. Any subjects aged 35 or over accepted into the study then went on to have a medically supervised exercise ECG.

Twenty nine subjects expressed an interest in taking part in the study, all of whom proved suitable for inclusion.

METHODS

Estimation of initial fitness levels

In order to get some indication of the initial fitness and activity levels of the older subjects we asked each person to complete a Human Activity Profile (HAP Fix & Daughton, 1988). This questionnaire comprises 94 self-report items, each of which represents "a common activity requiring a known amount of average energy expenditure". There are three possible responses to each question "still doing this activity"; "Have stopped doing this activity"; "Never did this activity". From the analysis of these data it is possible to get an estimate of an individual's daily activities, and to give some indication of fitness and activity levels.
Physiological variables

1. Height, body weight and skinfold measurements

Height (wall mounted stadiometer), body mass (heavy clothing and shoes removed) and skinfold measurements were taken by the same operator at all visits. Skinfold measurements were taken at four sites viz. biceps, triceps, subscapular and suprailliac using Harpenden callipers (John Bull).

Body fat was estimated using linear regression equations developed by Durnin and Wormersley 1974. The sum of all four skinfolds was used.

2. VO$_2$ max.

Old subjects

VO$_2$ max was measured as previously described in chapter 2 (pg 55-56). For each individual subject tests were performed at the same time of day on each occasion and at the same laboratory temperature (Shephard, 1984). Because many of the subjects who took part in the feasibility/reproducibility study outlined in chapter 2 also took part in the training study, the same criteria for determination of a maximal test were used i.e a test was considered to be maximal if RER $\geq$ 1.0 (Sidney & Shephard, 1977b), and the subject was judged subjectively to have made a maximal effort.

Young group

VO$_2$ max was measured as previously described for the older subjects with some minor variations as follows. Each of the younger subjects performed 2 maximal effort tests on 2 separate occasions. At the first of these work rates were increased by 25W every 2.5 minutes. The second test was tailored to try to get each subjects to maximum within 10 to 12.5 minutes i.e. 50W increments were used instead of 25W where appropriate.

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In the younger subjects a test was considered maximal if 2/3 of the following criteria were satisfied:- a plateau in oxygen consumption was demonstrated (defined as an increase in VO2 with an increase in work rate, less than the mean -1SD increase at submaximal work rates); RER ≥ 1.1 and HRmax within 10 beats of age predicted maximum (220-age).

Where samples for analysis of lactate levels were available a test was considered maximal if 3/4 of the following criteria were met:- a plateau in oxygen consumption as described above; RER ≥ 1.1; HRmax within 10 beats of age predicted maximum (220-age) and LAmax ≥ 8mmol.l^-1.

3. Resting heart rate and heart rate at an oxygen consumption of 10ml.kg^-1.min^-1

In order to obtain a measurement of resting heart rate and blood pressure, prior to the cycle ergometry test each subject rested on a couch (supine) for ten minutes before the measurements were taken.

The heart rate at a VO2 of 10ml.kg^-1.min^-1 was calculated by using an equation derived by linear regression (for each individual subject) from the relationship between oxygen consumption and heart rate with increasing work rates.

4. Isometric Knee Extensor Strength (IKES)

Isometric knee extensor strength measured using a isometric dynamometer as described by Edwards et al. (1977) (figure 11). In brief, the subject sits in a chair whose back can be adjusted (i.e. moved forwards or backwards) to ensure that the subject sits with a 90 degree angle at hip and knee. To limit movement a strap is placed around the hips of the subject. A strap attached to a inextensible cord is placed around the ankle, just above the malleoli, of the leg to be tested. The inextensible cord is in turn attached to a strain gauge which is connected to a UV recorder.

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Figure 11: Isometric dynanometer
Each subject was asked to perform at least 3 maximal contractions, of several seconds in length, (in each leg), with a rest period between each push. IKES was taken as the best of the 3 recorded efforts (taken as strength held for at least 1 second) for the stronger and for the weaker leg.

5. Isometric Elbow Flexor Strength

Voluntary isometric elbow flexor strength (IEFS) was measured using an isometric dynamometer as described by Höök and Tornvall (1969). The subject is strapped in the chair and a horizontal padded board is placed in front of their chest. Its height is adjusted so that the upper arm (resting on the board) is in a parasagittal plane and at a 90 degree angle to the trunk. A strap is placed around the subjects wrist. This strap in turn is attached to a strain gauge which is connected to a UV recorder.

The subject was asked to make at least 3 maximal contractions, of several seconds duration (per arm), with a rest period in between each contraction. IEFS was taken as the highest value recorded for at least one second, for the stronger and the weaker arm.

6. Explosive Leg Power

Lower limb extensor power (LEP) was measured using the Nottingham Power Rig (Bassey et al. 1990; Bassey & Short, 1990) (figure 12). In brief, the seat of the rig is adjusted for the leg length of the subject, so that the knee remains slightly flexed when the leg is extended. The subject is asked to sit with their arms crossed over their chest to ensure that the movement comes from the lower limb of the subject. Each lower limb is tested separately. The subject is asked to push down on the pedal as hard and as fast as they can. The push on the pedal accelerates a fixed weight flywheel with the final angular velocity of the flywheel measured by an optoswitch and explosive power (average power during the push) calculated by a BBC microcomputer. The subject is given several attempts at the test, with a short rest.
period between pushes, until power values plateau (at least 5 pushes). However, one limitation of the apparatus is that it does not record the time of the push but calculates it on the assumption that the acceleration of the flywheel is constant. Recent work (personal communication with Dr S.Harridge and S.Pearson) suggests that this is not so. The implications of this finding are still being investigated.

7. Muscle Biopsies

*Technique:* Prior to the biopsies being taken blood samples were taken from all subjects who consented to a muscle biopsy. This was so that a full blood count could be taken, to check haemoglobin levels and so that a coagulation study could be performed to check prothrombin time i.e. to eliminate any clotting abnormalities.

In all subjects, on each occasion, biopsies were taken from the lateral part of the Quadriceps Femoris of the left leg using a UCH skeletal muscle biopsy needle (Young et al. 1978). All biopsies were taken by the same operator i.e. Professor Young. Two biopsy samples were taken from each subject, through the same incision, one for analysis of actual enzyme levels and one for analysis of mRNA levels for the enzymes selected. The former were frozen in liquid nitrogen, wrapped in tin foil and stored in capped cryotubes in liquid nitrogen. Samples for later analysis of mRNA were mounted on a cork block, frozen in melting isopentane pre-cooled in liquid nitrogen and stored in liquid nitrogen until analysis.
Figure 12:- An elderly subject using the Nottingham power rig
Enzyme analysis:- Enzymes were chosen to represent different energy pathways. Initially these were cytochrome c oxidase (a respiratory chain marker, carries electrons originating from various dehydrogenase systems towards molecular oxygen), citrate synthase, succinate dehydrogenase (a marker of the TCA cycle) and 3 hydroacyl Co A dehydrogenase (a measure of fatty acid oxidation), and lactate dehydrogenase and phosphofructokinase (as measure of anaerobic capacity). However choice was limited as it was not possible to measure mRNA levels for each of these enzymes either because they had not been sequenced (citrate synthase and succinate dehydrogenase) or because there were too many isoforms of the enzyme (lactate dehydrogenase).

The final choice was therefore 3 hydroacyl Co A dehydrogenase, cytochrome c oxidase and phosphofructokinase. Actual enzyme activity for lactate dehydrogenase was also analysed.

Enzyme assays were performed for the author by Professor Mike Gleeson and colleagues at the University of Birmingham. The author is grateful to Professor Gleeson for details of the methods (Appendix 5B).

Analysis of mRNA levels was performed by Dr Steve Ennion using techniques with which the author is familiar (Appendix 5C - methodology courtesy of Dr Ennion).

Quality of life variables

The questionnaires identified in chapter three were used to measure components of quality of life viz. Geriatric Depression Scale (GDS); Philadelphia Geriatric Centre Morale Scale (PGCMS); Profile of Mood States (POMS); SF-36 and the General Health Questionnaire (GHQ).

The SF-36, GDS and PGCMS questionnaires were enlarged to make them easier to read. Each subject was given a code so that they could complete the questionnaires

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anonymously, as we felt subjects would feel less inhibited about reporting their true feelings this way. For this reason and because of time limits (each ‘assessment’ visit already lasted 1–1.5 hours) questionnaires which could be self completed, at home, had been chosen.

At the first visit to the laboratory each old subject was given the first set of questionnaires to complete. An investigator went through each questionnaire, with each individual subject and explained how to complete it. The subjects were then asked to self-complete the questionnaires within 2-3 days, and bring them back at the next visit. In this way, if they had encountered any problems in completing any of the forms, they could be given help at the next pre control visit.

Subjects were also given questionnaires to complete, at home, at the post control visit and after 12 and 24 weeks of training. They were asked to fill these in within 2 to 3 days and return them in a pre-paid envelope. Help with completion, if required, was always available.
CHAPTER SIX

DESIGN OF THE EXERCISE PROGRAMME

- INTRODUCTION
- EXERCISE SESSION STRUCTURE
  - Old group
    - Warm up
    - Aerobic component
    - Warm down
    - Strength training, flexibility and relaxation.
  - Young group
- EXERCISE INTENSITY
INTRODUCTION

It is generally accepted that, at any age, the benefits of safe exercise substantially outweigh the risks (Report of Royal College of Physicians, 1991). However, in order to minimise the risk of injury, standard teaching practice suggests that an exercise programme should start gently and progress gradually (Shephard, 1991; Elia, 1991). In any exercise programme it is important that, within the programme itself, the exercises can be adapted to suit different individuals. This is particularly important in older groups (Elia, 1991) where there is likely to be a wide range of fitness levels and pathologies.

For purposes of the present study we required:-
A) an exercise programme that would provide a safe and effective aerobic training stimulus, and which was suitable for use with very elderly people and
B) an exercise programme that would provide a safe and effective aerobic training stimulus for a group of young subjects who were to train at the same relative training intensity as the old group.

Both programmes were designed by the author, in conjunction with an exercise practitioner (Ms Susie Dinan), with vast experience in designing exercise programmes for use with older people. Classes for the old group were run either by the exercise practitioner or the author, who had attended an appropriate YMCA course for teaching exercise to over 50’s. In order to match teaching styles as closely as possible, all the routines to be used were practised by the teachers together, several times before the start of the exercise programme.

The exercise specialist taught all classes for the young group of subjects. However, the author attended at least 3 of these classes per week to ensure that training intensity was kept at the required level.

Each subject (old and young) was asked to attend three exercise sessions per week out
of a choice of six (to encourage adherence) over a 24 week period.

Providing a choice of classes ensured that no class was too large. It also allowed the teachers to give individual attention to each subject. It was hoped that both these factors would encourage adherence.

EXECISE SESSION STRUCTURE

Old group

The total length of each session for the older group was approximately one hour and comprised warm up, aerobic, warm down, and strength training, flexibility & relaxation components. The various components were adapted from those commonly used for younger people (see below) according to accepted best practice, and were as follows:-

Warm up

Using a longer warm up for older people has been suggested (Shephard, 1990; Elia, 1991) to minimize the risk of inducing cardiac arrhythmias (Barnard et al. 1973) and to allow sufficient time to mobilize joints which may be stiffer in many elderly people (Johns & Wright, 1962; Long et al.1968). The warm - up component of the session was therefore designed to last 13-15 minutes.

Aerobic component

Routines traditionally used in aerobic training classes with younger people may not be suitable for use with older people. Poor vision, disturbed balance (Iverson et al.1990; Era & Heikkinen, 1985; Overstall et al.1977; Balogun et al.1994), unstable hip and knee joints, reduced foot lift and postural hypotension may all increase the likelihood of trips and falls (Shephard, 1991). In the design of the programme, some movements routinely included into aerobic routines for younger people were omitted. For

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example, sudden changes of speed or direction, crossing steps in front or behind or full turns were avoided. Emphasis was placed on providing clear instructions which were repeated for those hard of hearing. In addition each move was demonstrated and practised, and warning was given of any directional or step changes (Frändin et al. 1992; Young & Dinan, 1994).

For reasons outlined below (pg 117) the aerobic training stimulus was set using the ratings of perceived exertion scale (RPE) (Borg, 1970), with a training intensity set at an RPE of 13-15. The aerobic component was built up gradually over the first 6 weeks, lasting 13 minutes at week two, 17 minutes at week four and 20 minutes by week six. After week six the intensity of the aerobic exercise was increased progressively by increasing the intensity of the routines, to ensure that subjects continued to work at an RPE of 13-15.

To allow for a range of fitness levels, alternatives were given for each exercise to ensure that all subjects were working at the desired intensity. For example, arm movements were increased in those finding the exercise too easy, or taken out altogether if the exercise was too hard (figure 13). After the correct technique had been taught, and in those in whom it was appropriate, intensity could be increased by introducing a degree of spring to the exercise (figure 14).

Warm down

A longer warm down than is normally used with younger people has been suggested to allow the opportunity for central venous return, thereby reducing the likelihood that fainting or arrhythmias will develop (Elia, 1991). The warm down component was designed to last for 10 minutes.

Strength training, flexibility and relaxation

Resistance for strength training was provided initially by body weight e.g. squats (achieved by getting up and down from a chair) and wall press ups and by the use of

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different grades of therabands (Nottingham Rehab) (figure 15) while later in the programme the use of therabands was replaced (in all but one subject) by the use of body bars (Forza Fitness International) which provided more resistance. This component lasted for 10 to 15 minutes.

**Young group**

The exercise session for the younger group lasted approximately 45 minutes. Each session comprised 5 to 10 minutes warm up, 20 minutes of aerobic exercise (REP 13-15), a 5 minute warm down component and 10 minutes of strength training and flexibility exercises. The aerobic component was built up as described for the older group. For the strength training exercises resistance was provided by body weight (lunges, squats, compound movements with spring) and by the use of body bars.

**EXERCISE INTENSITY**

The most commonly used method of setting and monitoring exercise intensity is by setting a training heart rate and by asking subjects to monitor their heart rate during the exercise sessions. The training heart rate is set by either using maximal heart rate and asking subjects to work at a percentage of this, or more usually by asking the subject to work at a percentage of their heart rate reserve (maximal heart rate - resting heart rate). However these methods have several disadvantages. First, unless a true measure of maximal heart rate has been obtained this must be estimated. Estimating maximal heart rate has already been shown to be particularly unreliable in older people. Second, it necessitates the subject slowing down or stopping exercise in order to take the heart rate. Third, heart rates measured by individuals (by palpation) have been shown to be inaccurate, with values reported lower than those measured at the same time by telemetry (Bell & Bassey, 1996). Fourth, although using a percentage of HRmax is reported to be appropriate in prescribing exercise in older people, there is evidence to suggest that %HRR represents a higher than expected percentage of VO$_2$ max (Scharff-Olsen et al. 1992; Kohrt et al. 1998) and that using a %HRR to prescribe exercise intensity may result in older individuals working at a higher than desired
intensity (Kohrt et al. 1998; Panton et al. 1996). Last, using heart rates to prescribe exercise intensity assumes that during the exercise the heart rate increases linearly with increasing VO$_2$. Although this relationship has been shown to be linear during cycling and running in young people, it has suggested that this may not be so in older people (Sidney & Shephard, 1977b).

One alternative to using target heart rates to obtain the desired training intensity is to use the RPE. This is a self perception effort scale which takes into account both central and local sensations (Pandolf, 1982) i.e. it is not just reliant on cardiovascular sensations. It also does not necessitate an individual having to slow down or stop exercising for a value to be obtained. Using RPE has been shown to be effective in prescribing exercise intensity in both young and older adults (Koltyn & Morgan, 1992; Hassmen et al. 1992; Ceci & Hassmen, 1991) with a training intensity of RPE between 13 and 15 approximated to working at 70-80% of VO$_2$max (Pollock et al. 1984; American College of Sports Medicine, 1990). The relationship between RPE and %VO$_2$max has also been reported to be independent of age (Sidney & Shephard, 1977a).

For the purpose of the present study we therefore set the training intensity using the RPE scale. At the first of the pre control visits each subject was thoroughly familiarised with the RPE scale, and asked to rate how hard they were working at each work load during the exercise test. Explanations of the use of the scale were repeated regularly throughout the training period.

Training intensity was set using an RPE between 13 and 15. During the aerobic component of each session subjects were shown the RPE scale and asked to rate how hard they were working. If necessary the intensity of the exercise was adjusted, as described above to ensure that all subjects were working at the desired intensity.

To gain information on the relationship between RPE and %HRmax or %HRR in older people heart rates were monitored (polar sports tester), in each older subject in at least one session per week.

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Figure 13a and b: Increasing or decreasing arm movements to modify the intensity of exercise for individuals to ensure all subjects were working at the same relative intensity.
Figure 14: Increasing the intensity of the exercise by the use of spring, in those subjects in whom it was appropriate (after the correct technique had been taught).
Fig 15: Eighty one year old subject using a median grade theraband to provide resistance.
CHAPTER SEVEN

EFFECT OF TRAINING ON PHYSIOLOGICAL VARIABLES
- OLD SUBJECTS

- STATISTICAL ANALYSIS
  - Data for $\dot{V}O_2$ max, HR at $\dot{V}O_2$ of 10mls.kg$^{-1}$.min$^{-1}$, IKES, IEFS, LEP, body mass and percent body fat.
  - Enzyme and mRNA levels

- RESULTS
  - Adherence
  - Compliance
  - Exercise intensity
  - Aerobic power
    - $\dot{V}O_2$ max
    - Heart rate at an oxygen consumption of 10 ml.kg$^{-1}$.min$^{-1}$
    - Resting heart rate
    - Muscle enzyme levels
      - Biopsy samples
      - Enzyme activities
      - mRNA levels
  - Muscular strength and power
    - Isometric Knee Extensor Strength
    - Isometric Elbow Flexor Strength
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  - Body composition
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- DISCUSSION
  - Adherence
  - Compliance
  - Adaptations to training
- Aerobic power
  - Women
  - Men
  - Training intensity
- Muscular strength and power
  - Women
  - Men
- Body composition
  - Women
  - Men

- CONCLUSION
STATISTICAL ANALYSIS

Data for $\dot{V}O_2$ max, HR at $\dot{V}O_2$ of 10ml.kg.$^{-1}$.min$^{-1}$, IKES, IEFS, LEP, body mass and percent body fat.

The data for these variables at each time point were examined using two-way analysis of variance (ANOVA), with time and subject as the two factors, for the presence of a treatment effect (Appendix 6A). If a treatment effect was identified then the % change over the control period was calculated for each subject and analyzed using non parametric Wilcoxon signed rank test (chosen because most of the data were skewed). If there was no significant change over the control period the pre and post control data were averaged. The change (%), from the mean of pre and post control, over the 12 and 24 week training periods was then calculated for each subject and analyzed using Wilcoxon signed rank test. If a significant change was found over the control period then post control data (i.e. not the average of pre and post control) were used as the starting point for calculating the changes (%) over the 12 and 24 week training periods (Sokal & Rohlf, 1969).

Enzyme and mRNA levels

Because of low subject numbers it was not possible to do statistical analysis for these data.

RESULTS

Adherence

Twenty six subjects entered the training phase of the study, of these 5 failed to complete training. The reasons for this were as follows:- two subjects "dropped out" due to illness unrelated to the study, one was diagnosed with Alzheimer's disease during the study, one
found the time commitment too great and one whose previous knee problem may have been aggravated by the exercises.

The characteristics of the 12 women and 9 men who completed the study are displayed in table 9.

Pre training fitness and activity classifications, as obtained using the Human Activity Profile (HAP, (Fix & Daughton, 1988)) are displayed in tables 10a and b. The HAP uses a comparison with fitness levels and activity levels of peers of the same age and gender. However, normative data are available only for subjects up to 70 years of age, therefore our subjects were classified according to comparisons made with 60-69 year old men and women. For activity levels, our subjects were classified according to comparisons made with 70+ men and women (Fix & Daughton, 1988).

Attendance

There was no significant difference between the average number of sessions attended of the men and women (un-paired T test) (table 11).
<table>
<thead>
<tr>
<th>Age (years)</th>
<th>Height (m)</th>
<th>Weight (kg)</th>
</tr>
</thead>
</table>

**Men (n=9)**

- Range: 80-87 1.6-1.8 58.5-85.5
- Median: 80 1.69 68
- Mean (SD): 81 (2.28) 1.69 (0.06) 68 (8.3)

**Women (n=12)**

- Range: 79-91 1.5-1.65 44-65.5
- Median: 82 1.56 55.9
- Mean (SD): 84 (4.09) 1.58 (0.05) 56.5 (6.01)

**Table 9:- Pre-control characteristics of the subjects who completed 24 weeks of training**
### Table 10a: Pre training fitness levels of the older men and women as determined using Human Activity Profiles.

<table>
<thead>
<tr>
<th></th>
<th>Average and above</th>
<th>Fair</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Men</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(n=9)</td>
<td>100%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td><strong>Women</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(n=12)</td>
<td>84%</td>
<td>8%</td>
<td>8%</td>
</tr>
</tbody>
</table>

### Table 10b: Pre training activity levels of the older men and women as determined by Human Activity Profiles.

<table>
<thead>
<tr>
<th></th>
<th>Active</th>
<th>Moderately active</th>
<th>Impaired</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Men</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(n=9)</td>
<td>67%</td>
<td>33%</td>
<td>0%</td>
</tr>
<tr>
<td><strong>Women</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(n=12)</td>
<td>42%</td>
<td>50%</td>
<td>8%</td>
</tr>
</tbody>
</table>

*Chapter seven*
<table>
<thead>
<tr>
<th></th>
<th>12 weeks</th>
<th>24 weeks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Women</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- mean (SD)</td>
<td>69% (20.9)</td>
<td>67% (13.4)</td>
</tr>
<tr>
<td>Men</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- mean (SD)</td>
<td>78% (23.4)</td>
<td>75% (19.3)</td>
</tr>
</tbody>
</table>

Table 11: Average number of sessions attended after 12 and 24 weeks of training - for those who completed training. Calculated as percentage of possible (i.e. 36 at week 12 and 72 at week 24) classes attended.
Exercise intensity

The mean RPE for men and women for each week of training are displayed in figure 16. The desired training intensity was an RPE between 13 and 15. The older women achieved this by week 2, whilst it was not until week 4 that the older men were working within the desired training range. Although from week 4 onwards the mean RPE of both the men and women men was within the desired training zone, overall the women were found to have worked at a slightly higher intensity than the men ($P < 0.01$).

Heart rate monitoring was not possible in one of the women. In those subjects who had performed a maximal test, and in whom heart rate monitoring was possible (8 men and 8 women) the percentage of maximal heart rate, and the percentage of heart rate reserve achieved during the aerobic component were compared with corresponding RPE values. The mean $\%HR_{max}$ and $\%HRR$ of the men and women at different RPE values are displayed in figures 17 and 18.

All data displayed in graphical form are plotted as mean value plus 1 standard error.
Figure 16: Mean RPE for the men and women for each week of training
Figure 17: Mean RPE and its corresponding percentage of HRmax in (A) the women and (B) the men.
Figure 18: RPE and its corresponding percentage of HRR in (A) the women and (B) the men.
Aerobic power

Collection of gas for analysis was not possible in one subject after 12 weeks of training because resting diastolic blood pressure was > 100mmHg (Greig et al. 1994). In addition exercise data were not available after 12 or after 24 weeks of training in one subject because of increasing intolerance of the mask.

\( \dot{\text{V}}\text{O}_2 \) max

\( \dot{\text{V}}\text{O}_2 \) max data were obtained in nine women and eight men (table 12). ANOVA failed to demonstrate a 'treatment' effect in the \( \dot{\text{V}}\text{O}_2 \) max of the men (figures 19 and 20). In the women there was no significant change in \( \dot{\text{V}}\text{O}_2 \) max over the control period or following 12 weeks of training but there was a 15% mean increase in \( \dot{\text{V}}\text{O}_2 \) max, when expressed corrected for body weight (ml.kg\(^{-1}\).min\(^{-1}\)) (P < 0.01) and a 13% mean increase when expressed as L.min\(^{-1}\) (P < 0.02) following 24 weeks of training (figures 19 and 20).

ANOVA failed to demonstrate a 'treatment' effect in the HRmax, RERmax or LAmax in the men or in the women (table 13).
<table>
<thead>
<tr>
<th></th>
<th>Pre control</th>
<th>Post control</th>
<th>Post 12 weeks training</th>
<th>Post 24 weeks training</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>VO₂ max (ml.kg⁻¹.min⁻¹)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Men (n=8)</td>
<td>22.16 (5.77)</td>
<td>21.84 (5.38)</td>
<td>20.45 (5.01)</td>
<td>22.24 (6.22)</td>
</tr>
<tr>
<td>Women (n=8)</td>
<td>14.02 (2.38)</td>
<td>14.31 (3.49)</td>
<td>13.93 (3.05)</td>
<td></td>
</tr>
<tr>
<td>(n=9)</td>
<td>14.47 (2.45)</td>
<td>13.75 (3.67)</td>
<td></td>
<td>16.2 (3.1)</td>
</tr>
<tr>
<td><strong>VO₂ max (L.min⁻¹)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Men (n=8)</td>
<td>1.512 (0.289)</td>
<td>1.489 (0.302)</td>
<td>1.356 (0.251)</td>
<td>1.465 (0.283)</td>
</tr>
<tr>
<td>Women (n=8)</td>
<td>0.833 (0.158)</td>
<td>0.854 (0.167)</td>
<td>0.768 (0.194)</td>
<td></td>
</tr>
<tr>
<td>(n=9)</td>
<td>0.827 (0.141)</td>
<td>0.786 (0.198)</td>
<td></td>
<td>0.909 (0.172)</td>
</tr>
</tbody>
</table>

*Table 12:* VO₂ max values at each time point, expressed as mean (standard deviation).
Figure 19: $\text{VO}_2 \text{ max}$ of the men ($n=8$) and women ($n=9$) - ml.kg$^{-1}$.min$^{-1}$
Figure 20: $\bar{V}O_2$ max of the men ($n=8$) and women ($n=9$) - L.min$^{-1}$
<table>
<thead>
<tr>
<th></th>
<th>Pre control</th>
<th>Post control</th>
<th>Post 12 weeks training</th>
<th>Post 24 weeks training</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>RERmax</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Men (n=8)</strong></td>
<td>1.08 (0.05)</td>
<td>1.1 (0.10)</td>
<td>1.05 (0.07)</td>
<td>1.07 (0.07)</td>
</tr>
<tr>
<td><strong>Women (n=8)</strong></td>
<td>1.04 (0.05)</td>
<td>1.04 (0.07)</td>
<td>1.02 (0.08)</td>
<td></td>
</tr>
<tr>
<td>(n=9)</td>
<td>1.06 (0.05)</td>
<td>1.05 (0.07)</td>
<td></td>
<td>1.03 (0.11)</td>
</tr>
<tr>
<td><strong>HRmax (bpm)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Men (n=8)</strong></td>
<td>143 (20)</td>
<td>138 (17)</td>
<td>138 (18)</td>
<td>137 (20)</td>
</tr>
<tr>
<td><strong>Women (n=8)</strong></td>
<td>133 (14)</td>
<td>129 (10)</td>
<td>131 (11)</td>
<td></td>
</tr>
<tr>
<td>(n=9)</td>
<td>130 (16)</td>
<td>126 (14)</td>
<td></td>
<td>129 (17)</td>
</tr>
<tr>
<td><strong>LAmax (mmol.l⁻¹)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Men (n=7)</strong></td>
<td>4.3 (0.7)</td>
<td>4.6 (1.4)</td>
<td>4.3 (1.6)</td>
<td>4.9 (1.5)</td>
</tr>
<tr>
<td><strong>Women (n=5)</strong></td>
<td>3.9 (1.0)</td>
<td>3.4 (0.8)</td>
<td>3.7 (1.3)</td>
<td></td>
</tr>
<tr>
<td>(n=6)</td>
<td>3.5 (1.3)</td>
<td>3.3 (0.7)</td>
<td></td>
<td>3.3 (1.4)</td>
</tr>
</tbody>
</table>

Table 13:- RERmax, HRmax and LAmax at each time point, expressed as mean (standard deviation).
Heart rate at an oxygen consumption of 10 ml.kg$^{-1}$.min$^{-1}$.

Because of problems with equipment, measurements of heart rate during the exercise tests were not obtained in 7 of the women following 12 weeks of training. In addition, in two of the women, tests were too short to perform linear regression, and therefore to develop an equation to work out the HR at $\bar{VO}_2$ of 10 mls.kg$^{-1}$.min$^{-1}$ after 24 weeks of training.

In the men there was a 7% mean increase (P < 0.05) in the HR at $\bar{VO}_2$ of 10 ml.kg$^{-1}$.min$^{-1}$ following the control period. Post training data were therefore compared with post control data and not with the mean of the pre and post control data. There was no significant change following 12 weeks of training but after 24 weeks of training there was a 9% mean decrease from post control values (P < 0.05) (table 14, figure 21).

In the women there was no significant change in HR at $\bar{VO}_2$ of 10 ml.kg$^{-1}$.min$^{-1}$ following the control period or after 12 weeks of training but after 24 weeks of training there was a 14% mean decrease (P < 0.01) (table 14, figure 21).

Resting heart rate

ANOVA failed to demonstrate a 'treatment' effect in the resting heart rate of the men (table 14, figure 22).

There was no significant change in resting heart rate following the control period or after 12 weeks of training in the women but after 24 weeks of training there was a 13% decrease (P < 0.01) (table 14, figure 22).
<table>
<thead>
<tr>
<th></th>
<th>Pre control</th>
<th>Post control</th>
<th>Post 12 weeks training</th>
<th>Post 24 weeks training</th>
</tr>
</thead>
</table>
| **HR at \(\dot{V}O_2\)**
| 10ml.kg\(^{-1}\).min\(^{-1}\) |             |              |                        |                        |
| **Men (n=9)** | 91 (9.5)   | 97 (11.3)    | 93 (11.6)             | 89 (10.0)             |
| **Women (n=5)** | 99 (27)   | 112 (27.7)   | 100 (7.8)            |                        |
|           | 107 (12.0) | 108 (20.9)   | 92 (14.5)            |                        |
| **Resting heart rate (bpm)** |             |              |                        |                        |
| **Men (n=9)** | 74 (9.5)   | 75 (11.8)    | 70 (10.3)            | 71 (12.6)             |
| **Women (n=8)** | \(\approx 75\) (\approx 8.5) | \(\approx 73\) (\approx 7.4) | \(\approx 71\) (5.5) | \(\approx 61\) (19.8) |
|           | 75 (8)     | 73 (7.4)     |                        |                        |

**Table 14:** Heart rate at \(\dot{V}O_2\) of 10mls.kg\(^{-1}\).min\(^{-1}\) and resting heart rates at each time point.

Expressed as mean (standard deviation).
Figure 21: Heart rate at VO$_2$ of 10 mls.kg$^{-1}$.min$^{-1}$ at each time point.

$n=5$

* $P<0.05$
** $P<0.01$

Chapter seven
Figure 22: Resting heart rate at each time point

# n=8 (women)

Chapter Seven
Muscle enzyme levels

Biopsy samples

At the commencement of the study all subjects were asked if they would be willing to have 3 muscle biopsy samples taken before and after the control period and after 24 weeks of training. Only 6 of the men and 3 of the women agreed to this part of the study. After the pre control biopsy one of the women declined to have any further samples taken. In addition, 3 subjects (2 men and 1 woman) agreed to have only one further sample taken, at the end of the training period.

In total 21 biopsies were taken for the older group. One subject developed a haematoma (left lateral thigh) immediately post biopsy. The subject rested with the thigh elevated for one hour, after which he was allowed home but advised to rest and to keep the thigh elevated as much as possible. The subject was visited at home on the following day where on examination the thigh was found to be soft with no tenderness. No other problems were experienced.

Enzyme activities

There was no clear trend toward either an increase or decrease for any of the enzymes measured in the men (figure 23). Both of the women showed a slight increase in HAD levels following training, but no other trend was seen (figure 23).

mRNA levels

There was no clear trend in the responses of the men in terms of mRNA levels for any of the enzymes measured (figure 24). In the two women a trend towards increasing levels of COX mRNA and PFK mRNA was seen (figure 24).
Figure 23: Enzyme activities each time point.
(open symbols women; closed symbols men).

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Figure 24: mRNA levels at each time point (open symbols women; closed symbols men).
There was no correlation between the changes in enzyme activities and the changes of the corresponding mRNA levels for COX, HAD or PFK in either the men or the women (figure 25).

**Muscular strength and power**

Data for strength measurements are presented for the stronger and weaker (as measured at the pre control point) legs and arms and for the more and least powerful (as measured at the pre control time point) lower limb.

Isometric knee extensor strength (IKES).

Anova failed to demonstrate a ‘treatment’ effect the IKES of the stronger leg of both the men and the women (table 15).

Anova failed to demonstrate a ‘treatment’ effect in the IKES of the weaker leg of the men (table 15). In the women there was a 14% mean increase in IKES (P < 0.02) over the control period. Comparing post control data with the post training data, there was no significant change after either 12 or 24 weeks of training (table 15).

Isometric elbow flexor strength (IEFS)

Anova failed to demonstrate a ‘treatment’ effect in the IEFS of the stronger arm of both the men and the women (table 16).

In the weaker arm there was no significant change in the men or the women over the control period or after 12 weeks of training. After 24 weeks of training there was a 10% mean increase (P < 0.05) in the IEFS of the men and a 13% mean increase (P < 0.05) in the IEFS of the women (table 16, figure 26).
Figure 25:- Comparison of changes, after training, in enzyme activities and in their corresponding mRNA levels.
<table>
<thead>
<tr>
<th></th>
<th>Pre control</th>
<th>Post control</th>
<th>Post 12 weeks training</th>
<th>Post 24 weeks training</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>IKES (N)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Weaker leg (at pre control time point)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Men (n=9)</td>
<td>313 (92)</td>
<td>329 (114)</td>
<td>317 (116)</td>
<td>320 (98)</td>
</tr>
<tr>
<td>Women (n=10)</td>
<td>207 (50)</td>
<td>247 (70)</td>
<td>218 (68)</td>
<td></td>
</tr>
<tr>
<td>Women (n=12)</td>
<td>210 (57)</td>
<td>238 (68)</td>
<td></td>
<td>241 (62)</td>
</tr>
<tr>
<td><strong>Stronger leg (at pre control time point)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Men (n=9)</td>
<td>356 (115)</td>
<td>359 (135)</td>
<td>344 (111)</td>
<td>340 (74)</td>
</tr>
<tr>
<td>Women (n=10)</td>
<td>232 (49)</td>
<td>249 (77)</td>
<td>230 (68)</td>
<td></td>
</tr>
<tr>
<td>Women (n=11)</td>
<td>239 (54)</td>
<td>250 (74)</td>
<td></td>
<td>264 (60)</td>
</tr>
</tbody>
</table>

**Table 15:** Isometric Knee extensor (IKES) at each time point.  
Expressed as mean (standard deviation)
<table>
<thead>
<tr>
<th></th>
<th>Pre control</th>
<th>Post control</th>
<th>Post 12 weeks training</th>
<th>Post 24 weeks training</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>IEFS (N)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Stronger arm (at pre control time point)</strong></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Men (n=9)</td>
<td>194 (35)</td>
<td>179 (51)</td>
<td>183 (45)</td>
<td>209 (62)</td>
</tr>
<tr>
<td>Women (n=8)</td>
<td>140 (24)</td>
<td>133 (31)</td>
<td>144 (26)</td>
<td></td>
</tr>
<tr>
<td>Women (n=10)</td>
<td>138 (29)</td>
<td>134 (29)</td>
<td></td>
<td>136 (21)</td>
</tr>
<tr>
<td><strong>Weaker arm (at pre control time point)</strong></td>
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<tr>
<td>Men (n=9)</td>
<td>175 (30)</td>
<td>171 (34)</td>
<td>178 (32)</td>
<td>199 (58)</td>
</tr>
<tr>
<td>Women (n=8)</td>
<td>125 (18)</td>
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<td>132 (17)</td>
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<tr>
<td>Women (n=10)</td>
<td>123 (24)</td>
<td>125 (19)</td>
<td></td>
<td>134 (20)</td>
</tr>
</tbody>
</table>

**Table 16:** Isometric Elbow Flexor (IEFS) strength at each time point.
Expressed as mean (Standard deviation)
Figure 26: Isometric elbow flexor strength of the weakest arm at each time point.
Explosive leg power

ANOVA failed to demonstrate a 'treatment' effect in the lower limb extensor power (LEP) of the more powerful leg in both the men and the women (table 17).

ANOVA failed to demonstrate a 'treatment' effect in the LEP of the less powerful leg of the men (table 17, figure 27). In the women there was no significant change in the LEP of the less powerful leg over the control period or following 12 weeks of training, but there was a 29% mean increase (P < 0.01) in LEP following 24 weeks of training (table 17, figure 27).

Body composition

Body weight:- Anova failed to demonstrate a 'treatment' effect in the weight of the men (table 18, figure 28a). In the women there was no significant change in weight over the control period but there was a small 3% decrease after 12 weeks (p < 0.05) and a 2% decrease after 24 weeks of training (p < 0.01) (table 18, figure 28a).

Body fat:- Anova failed to demonstrate a 'treatment' effect in the body fat, as estimated from the skinfold data, of the men (table 18, figure 28b). There was no significant change in body fat following the control period or after 12 weeks of training in the women, but there was a 7% decrease (P < 0.05) in body fat after 24 weeks of training (table 19, figure 28b).
<table>
<thead>
<tr>
<th></th>
<th>Pre control</th>
<th>Post control</th>
<th>Post 12 weeks training</th>
<th>Post 24 weeks training</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LEP (W)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>More powerful leg (at pre control time point)</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Men (n=9)</td>
<td>139 (46)</td>
<td>138 (46)</td>
<td>141 (55)</td>
<td>144 (48)</td>
</tr>
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<td>Women (n=8)</td>
<td>75 (24)</td>
<td>71 (33)</td>
<td>73 (26)</td>
<td></td>
</tr>
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<td>Women (n=11)</td>
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<td>65 (34)</td>
<td>73 (25)</td>
<td></td>
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<td>Less powerful leg (at pre control time point)</td>
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</tr>
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<td>Men (n=9)</td>
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<td>128 (59)</td>
<td>127 (63)</td>
<td>126 (52)</td>
</tr>
<tr>
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<td>59 (19)</td>
<td>60 (24)</td>
<td>62 (21)</td>
<td></td>
</tr>
<tr>
<td>Women (n=12)</td>
<td>56 (18)</td>
<td>53 (24)</td>
<td>59 (21)</td>
<td></td>
</tr>
</tbody>
</table>

**Table 17**: Explosive leg power (LEP) each time point.
Expressed as mean (standard deviation).
Figure 27: Explosive leg power of the less powerful limb at each time point

** P<0.01

# n=8

Chapter seven
<table>
<thead>
<tr>
<th></th>
<th>Pre control</th>
<th>Post control</th>
<th>Post 12 weeks training</th>
<th>Post 24 weeks training</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Body weight (kg)</strong></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Men (n=9)</td>
<td>68.4 (8.34)</td>
<td>69.4 (8.24)</td>
<td>68.8 (8.1)</td>
<td>67.9 (8.68)</td>
</tr>
<tr>
<td>Women (n=12)</td>
<td>56.5 (6.01)</td>
<td>56.3 (6.66)</td>
<td>54.7 (6.09)</td>
<td>55.1 (6.46)</td>
</tr>
<tr>
<td><strong>Body fat (%)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Men (n=9)</td>
<td>21 (3.4)</td>
<td>22 (4.5)</td>
<td>24 (2.3)</td>
<td>21 (4.7)</td>
</tr>
<tr>
<td>Women (n=12)</td>
<td>31 (5.58)</td>
<td>32 (7.25)</td>
<td>32 (3.04)</td>
<td>29.5 (5.17)</td>
</tr>
</tbody>
</table>

**Table 18:-** Body weight and percent body fat at each time point.
Expressed as mean (standard deviation).
Figure 28: Body weight (A) and % body fat (B) at each time point
DISCUSSION

Adherence

Five subject's (20%) 'dropped out' of the study. Of these four 'dropped out' because of illness. Skelton et al (1995) also reported that the reason's for 'drop out' in a group of subjects aged 75 to 93 years (taking part in a resistance training study) did so because of illness. It would seem that not only is the recruitment of suitable older subjects difficult (as discussed in chapter 2, pg 64), but that subject numbers are likely to be further diminished because of illness.

The aerobic exercise programme used to train the older subjects had been designed specifically to start gently and progress slowly, whilst still providing an effective aerobic training stimulus (chapter 6, pg 114). This was in order to minimise the risk of injury to the subjects. However, even though the programme had been so carefully designed the exercise exacerbated an existing knee problem in one subject (details see Appendix 6b). Other studies have also reported injuries in older people who have taken part in exercise programmes; Warren et al. (1993) reported that 2 women taking part in a walk programme 'dropped out' of the study because the exercise aggravated previous foot injuries, whilst Pollock et al. (1991) reported that out of 21 subjects taking part in a walk programme, one sustained an injury (to lower extremity). Pollock also reported that when 14 of these subjects went on to participate in jogging, 8 of them sustained an injury. These findings stress the importance of both the choice and the intensity of exercise when undertaking exercise programmes with older people.

Compliance

To encourage compliance we had provided a choice of 6 classes per week, of which we asked subjects to attend 3. The programme had been designed so that the subjects trained in groups, thereby allowing them to socialise, which it was hoped would also encourage adherence. Verbal feedback from the subjects indicated that this was so.
Additionally, because of the age of the subjects and because many found using public transport difficult, we also provided transport to the classes. The attendance levels of 95% in the older men and 65% in the older women after 24 weeks of training are slightly lower than those reported by Pollock et al. (1991) who reported 81% attendance in a walk/jog programme in 70-79 year old men and women. They are also much lower than those reported by Foster et al. (1989) who reported over 90% attendance in a group of women aged 67-89 years undertaking an exercise programme, however, the subjects taking part in Foster's study were all living in a retirement complex (where the classes were held). In contrast, all our subjects were independent people who led busy lives. Although enthusiastic as a group they reported that it was hard to find the time to attend 3 classes per week.

Adaptations to training

Aerobic power

Women

The results of the present study demonstrate that VO$_2$ max can be increased with training even in women in their 80th year and over, using the ratings of perceived exertion scale to set training intensity. The decrease in the HR at VO$_2$ of 10 ml.kg$^{-1}$.min$^{-1}$, suggests an improved ability to sustain exercise at submaximal levels.

The increase in VO$_2$ max of 15%, when expressed for body weight (which is the functionally important measurement) is within the range of improvements reported by other authors in younger old subjects viz. Cress et al. (1991) in a group of women aged 65-86 years (mean 72 years) in response to a 50 week training programme and Warren et al. (1993) in a group of women aged 67-85 years (mean 74 years) in response to a 12 week training programme. It is also similar to that seen in the only study which investigated women of a similar age to our own (Foster et al. 1989) who reported a 15% increase in VO$_2$ max in response to a 10 week training programme of moderate intensity. However this study was not adequately controlled. The increase is
also similar to the relative increase in VO₂ max which was seen after 24 weeks of training in the younger group of women viz. 12% (figure 32, pg 177). That there was no increase in either HRmax or RERmax following training supports the supposition that the pre control data were taken from truly maximal tests, and that the changes in VO₂ max were true changes.

No significant changes in VO₂ max, HR at VO₂ of 10 ml.kg⁻¹.min⁻¹ or resting heart rate were seen following 12 weeks of training. This raises the possibility that adaptations may take longer to occur in the ‘oldest old’ than they do in younger people. This possibility is discussed in depth in chapter 8 (pg 195).

The implications of the improvement in VO₂ max are great; everyday tasks will require a lower proportion of VO₂ max and can therefore be performed for much longer and with greater ease thus alleviating functional limitations, and perhaps helping in the maintenance of independence.

VO₂ max is dependent on the ability of the heart and lungs to supply the working tissues with oxygen and on the ability of these tissues to utilise the oxygen provided. In young people, one of the adaptations which is seen in response to aerobic training is a change in activity of those muscle enzymes which are concerned with metabolism. These changes are characterised by a slight decrease in glycolytic enzymes; for example LDH, (Sjödin et al.1976) and a marked increase in mitochondrial respiratory enzymes (Anderson & Henriksson, 1977; Gollnick et al.1973; Varnauskas et al.1970). Studies with older people report conflicting findings. Coggan et al. (1992a) reported a decrease in LDH activity, and an increase in HAD activity in a group of 23 men and women aged 60-70 years undergoing a 9 to 12 month training programme. PFK activity was reported to be unchanged. Berthon et al. (1995) reported a small (but non significant) increase in HAD activity, and significant increases in hexokinase and citrate synthase activities in 14 men aged 55-73 year in response to a 6 week programme. Örlander et al. (1980) reported an increase in CCO, PFK and LDH activities, but a decrease in HAD activity in 5 men aged 70-75 years undergoing a 12 week training programme whilst Suominen et al. (1977a) also reported an increase in

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LDH levels in 31 men aged 56-70 years undergoing an 8 week predominantly aerobic training programme, whilst also reporting increases in malate dehydrogenase and succinate dehydrogenase activities. No study has examined the effects of aerobic training on mRNA levels for those enzymes involved in metabolism. Puntschart et al. (1995) compared levels of mRNA for enzymes involved in metabolism in young sedentary men and endurance athletes and reported increased levels of both mithochondrionally encoded RNA and nuclear encoded RNA in the endurance athletes when compared to the sedentary men.

As part of the present study we wished to take muscle biopsy samples for analysis of both enzyme activities, and where possible, their corresponding mRNA levels. In the women the biopsy data were disappointing. Only 2 women agreed to this part of the study. Difficulties in obtaining consent to take biopsies from very elderly women had been foreseen. Indeed, a new technique had been developed which we hoped would allow us to use a much less invasive method of obtaining muscle samples viz. syringe needle aspiration (Ennion et al. 1994). However, although it was found that samples of muscle could be obtained using this technique, it was not possible to quantify the mRNA in such small samples.

In the two women in whom biopsy data was obtained there was a tendency towards an increase in HAD activity following training with no trend seen in PFK, CCO or LDH activities. In mRNA levels there was a tendency towards increased levels of mRNA for CCO and PFK. There was no relationship between the changes in enzyme activities and in their corresponding mRNA levels.

Men

Training had no effect on the \( \dot{V}O_{2} \) max of the old men. Similarly, there was no effect of training on resting heart rate and, although there was a decrease in the heart rate at a \( \dot{V}O_{2} \) of 10mls.kg\(^{-1}\).min\(^{-1}\) after 24 weeks of training (\( P < 0.05 \)) there had been a significant increase after the control period (\( P < 0.05 \)). There was also no obvious
trend towards increasing enzyme levels (in those measured) or in their corresponding mRNA levels.

There is nothing in the literature regarding changes in $\dot{V}O_2$ max in response to aerobic training in men aged 80 or over.

Increases in $\dot{V}O_2$ max have been reported in response to training in younger old men viz. Cunningham et al. (1986) in 60-65 year old men; Tonino and Driscoll (1988) in 62-79 year old men and women (5 men and 4 women); Seals et al. (1984) in 24 men and women aged 61-67 years and Hagberg et al. (1989) in 70-79 year old men and women (mean age of subject 72 years but percentage of the subjects who were men not reported).

The reasons why there was no increase in the $\dot{V}O_2$ max of the older men is unclear. It seems unlikely that older women but not older men are able to adapt to training. There are several possible explanations for our findings:-

1. The men were nor worked hard enough. The mean RPE for the men over 24 weeks of training was 13.6. Although the men worked within the desired training zone consistently after week 3, when the older men and women were compared the women were found to have been working at a slightly higher intensity overall ($p < 0.01$). However, as outlined below (pg 161) an RPE of 13 in the men (in those performing a maximal test) equated to 59% of HRR and 77% of HRmax, whilst an RPE of 14 equated to 66% of HRR and 79% of HRmax. It would be expected that working at this intensity would be sufficient to elicit a training response.

2. The men may not have trained at the desired intensity for long enough. In contrast to both the younger men and women, and the older women it was not until week 4 that the older men were working at the desired training intensity (figure 16), most likely because they took longer to master the routines. As with the older women it is possible that older men take longer to respond to training therefore, although unlikely, it is possible that an increase may have been seen if we had continued the exercise.
programme and measured the VO\textsubscript{2} max of the men three weeks later.

3. The men in our study may already have been highly trained, and therefore not able to increase their VO\textsubscript{2} max further. At the pre control time point 100\% of the men reported fitness levels of average and above (compared to 84\% of women) whilst 67\% of the men (compared to 42\% of women) reported activity levels as active (tables 10a and b). The pre training VO\textsubscript{2} max of the men viz. 22.2 mls.kg\textsuperscript{-1}.min\textsuperscript{-1} was significantly higher than that of the women. Data from the English National Fitness Survey (Skelton et al.1999) suggest that on average, at each equivalent age, a womans VO\textsubscript{2} max (expressed as mls.kg\textsuperscript{-1}.min\textsuperscript{-1}) will be approximately 77\% of a mans. In the present study the VO\textsubscript{2} max of the women was 64\% of the men's. It is possible that the men were already relatively highly trained compared with the women.

There are few data regarding the VO\textsubscript{2} max of the oldest old men. Harridge et al.(1997) reported a VO\textsubscript{2} max of 27mls.kg\textsuperscript{-1}.min\textsuperscript{-1}. measured in four men aged 80 and over who were all still participating in sport, whilst de Wild et al. (1995) reported a VO\textsubscript{2} max of 26.8 ml.kg\textsuperscript{-1}.min\textsuperscript{-1}. measured in active men (mean age 77 years) participating in the Nijmegen 4-day march. It therefore seems unlikely that our men were very highly trained.

4. One other possible explanation is that some of the men who were already active at the start of the study may have dropped some of their regular physical activities to accommodate the training classes. Although all subjects were asked to maintain current activities throughout the study, no written record of activity levels was made. However, verbal feedback throughout the training programme from subjects indicated that those who participated in regular activities, (mainly golf and swimming), continued to do so throughout the training period.

The reasons why the men showed no adaptation merits further investigation.

\hspace{1cm} 

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Training intensity

We used the RPE scale, in preference to a percentage of HRmax or HRR, to achieve the desired training intensity, for reasons already specified (chapter 6, pg 117). However, to gain further information on relationships between RPE and %HRmax and %HRR, we also measured heart rates where possible. In young people an RPE of 14-16 is reported to be equivalent to 80-89% of HRmax and 75-85% of HRR (American College of Sports Medicine, 1990). In the present study, an RPE of 14 equated to a mean HRmax of 81% and a mean HRR of 63% in the women, and a mean HRmax of 79% and mean HRR of 66% in the men. These data suggest that if we had used a % of HRR to set the training intensity in the present study this may well have resulted in the subjects working at a higher than expected intensity. Recently Kohrt et al. (1998) reported that RPE levels at a given level of VO$_2$ max, or HRmax, may be lower in old subjects (112 women aged 60-72 years), reporting that when subjects worked at a HRmax of 70% the RPE was only 11. Our findings do not support this, as the mean %HR max of 81% in the women and 79% in the men at an RPE of 14 is similar to that reported for young people (American College of Sports Medicine, 1990).

Muscular strength and explosive power

Women

Although the exercise programme was predominantly aerobic, a small strength training component had been included. Previous studies which have included subjects over 80 years have demonstrated improvements in muscular strength and power in response to resistance training in older women viz. Skelton et al. (1995) in healthy women aged 76-93 years and Fiatarone et al. (1994) in frail men and women aged 72-98 years. Previous work had suggested that even including 10 minutes of resistance training within an exercise programme might be enough to elicit improvements in strength and explosive power in frail, very elderly women (Malbut et al. 1993)
In the present study the only adaptations which were seen in response to training were a mean increase of 29% (p<0.01) in the explosive power of the less powerful leg and a 13% increase in the IEFS of the weaker arm (p<0.05) following 24 weeks of training.

Skelton et al. (1994) examined the strength and power of women aged 65 to 89 years, in healthy older people. Their findings as regards individuals aged 80 and over are compared with the results from the subjects in the present study in table 19. The mean scores for IKES (stronger leg), LEP (more powerful leg) and IEFS (more powerful arm) from the subjects in the present study were slightly higher than reported for the subjects in Skelton's study. They were also much higher than reported for the subjects in the pilot study (Malbut et al. 1993) (in 7 women aged 78 to 85 years living in sheltered accommodation). When corrected for body weight (N/kg) the mean value for IKES in the present study was also higher than the mean value reported by Rantanen et al. (in dominant side) in a group of 75 year old women.

It is possible that the subjects in the present study were amongst the 'elite' of their age group, and that including just 10 minutes of resistance exercise within a predominantly aerobic training programme is not enough to stimulate improvements in the stronger/more powerful limbs of healthy older women.

*Men*

Previous studies have also reported improvement in strength and power in response to resistance training in older men viz. Fiatarone et al. (1994) in frail men and women aged 72-98 years, Frontera et al. (1988) in healthy men aged 60-72 years.

In the present study the only significant change seen in response to training was an increase of 13% in the IEFS of the weaker arm (p<0.05).
Skelton et al. (1994) also examined the strength and power of men aged 65 to 89 years, in healthy older people. Their findings as regards individuals aged 80 and over are compared with the results from the men in the present study in table 20. The mean scores for IKES (stronger leg) and LEP (more powerful leg) from the subjects in the present study were slightly higher than those reported for the subjects in Skelton's study, although mean IEFS slightly lower than reported for men aged 80-84 years). When corrected for body weight (N/kg) the mean value for IKES for the men in the present study was also higher than reported by Rantanen et al. (1994) for a group of 75 year old men (although IEFS was lower).

It is possible that as with the women, including 10 minutes of resistance training in a predominantly aerobic training programme is not sufficient to elicit change in the isometric knee extensor strength or explosive leg power of healthy older men.
<table>
<thead>
<tr>
<th>Source</th>
<th>Age (years)</th>
<th>n</th>
<th>IKES (N)</th>
<th>LEP (W)</th>
<th>IEFS (N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skelton et al. (1994)</td>
<td>80-84</td>
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<td>226 (46)</td>
<td>70 (29)</td>
<td>131 (25)**</td>
</tr>
<tr>
<td></td>
<td>85-89</td>
<td>10</td>
<td>194 (43)</td>
<td>64 (56)</td>
<td>102 (21)</td>
</tr>
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<td>Malbut et al. (1993)</td>
<td>78-85</td>
<td>7</td>
<td>203 (35)</td>
<td>54 (20)</td>
<td></td>
</tr>
<tr>
<td>Present study</td>
<td>79-91</td>
<td>11</td>
<td>239 (54)</td>
<td>75 (24)</td>
<td>138 (29)*****</td>
</tr>
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<td></td>
<td></td>
<td></td>
<td>IKES (N/kg)</td>
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<td>IEFS (N/kg)</td>
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<tr>
<td>Rantanen et al. (1994)</td>
<td>75</td>
<td>191</td>
<td>3.6 (1.1)</td>
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<td>2.4 (0.6)</td>
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<tr>
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<td>79-91</td>
<td>11</td>
<td>4.3 (1.2)</td>
<td></td>
<td>2.5 (0.8)*****</td>
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</tbody>
</table>

Table 19:- Comparison of data from the present study with data taken from the literature. Expressed as mean (SD).

* n=9, *** n=10
<table>
<thead>
<tr>
<th>Source</th>
<th>Age (years)</th>
<th>n</th>
<th>IKES (N)</th>
<th>LEP (W)</th>
<th>IEFS (N)</th>
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<td>338 (61)</td>
<td>130 (30)</td>
<td>231 (25)*</td>
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<tr>
<td></td>
<td>85-89</td>
<td>10</td>
<td>305 (63)</td>
<td>80 (49)</td>
<td>171 (40)</td>
</tr>
<tr>
<td>Present study</td>
<td>80-87</td>
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<td>356 (115)</td>
<td>139 (46)</td>
<td>194 (35)</td>
</tr>
<tr>
<td>Rantanen et al. (1994)</td>
<td>75</td>
<td>191</td>
<td>4.9 (1.4)</td>
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<td>3.5 (0.7)</td>
</tr>
<tr>
<td>Present study</td>
<td>80-87</td>
<td>9</td>
<td>5.4 (2.06)</td>
<td></td>
<td>2.9 (0.71)</td>
</tr>
</tbody>
</table>

Table 20:- Comparison of data (men) from the present study with data taken from the literature, expressed as mean (SD).

* n=9

Chapter seven
Body composition

Women

Body fat was estimated using linear regression equations developed by Durnin and
Wormersley (1974), using the sum of all four skinfolds. Actual data obtained using
these equations must be viewed with caution as the equations were developed from
subjects aged 16 to 72 years, and have not been validated in older people. However,
the mean % body fat of the older women in the present study, at the pre control
point, compared well to that reported by Suominen et al. (1997) viz. 30.5 (SD 6.9)
measured in a group of 80 year old women using bioelectrical impedance.

Previous studies have demonstrated reductions in body fat in response to physical
training viz. Sidney et al. (1977) at weeks 14 and 52 in 65 year old subjects enrolled
in a walk programme; Wilmore et al. (1999) in 557 men and women aged 16-65
years in response to 20 weeks of endurance training (body composition measured by
hydrostatic weighing).

In the present study a small but significant 3% decrease in body weight was seen
following 12 weeks of training (p<0.05) whilst a 2% decrease was seen following
24 weeks of training (p<0.01). We also saw a 7% decrease the percent body fat of
the women following 24 weeks of training.

Although a reduction in body weight is not desirable in the ‘oldest old’, as it may
increase the risk of hip fracture (Cummings et al. 1995), the increase in maximal and submaximal aerobic power also seen as a result of the exercise programme may help to reduce the likelihood of falling (Skelton & Dinan 1999).

Men

No change was demonstrated in either body weight or in % body fat in response to training. As with the data from the women absolute values must be viewed with caution. The mean value for % body fat in the men of the present study was slightly lower than that reported by Suominen et al. (1997) (measured by bioelectrical impedance) in a group of 80 year old men \textit{viz.} 21\% (SD 3.4) compared to 23.1 (SD 5.8) and also lower than reported for 80+ men in the National Fitness Survey (calculated in the same way as our data) (Skelton et al 1999) \textit{viz.} 21\% compared to 25.1\%.

Pollock et al. (1997) reported that body fat was lower in older athletes than in older sedentary men. Again it is possible that the men in the present study may have already been highly trained.
CONCLUSION

In conclusion, the main finding from the present study is that 24 weeks of predominantly aerobic training, using the RPE scale to set and monitor intensity, can increase the maximal aerobic power of the ‘oldest old’ women. The relative increases seen in VO$_2$ max after 24 weeks of training are similar to those reported for younger subjects. This finding could have major implications for older women, increasing VO$_2$ max may well prevent many older women from crossing functionally important thresholds thereby helping them to maintain their independence and avoid fatigue in everyday activities.
CHAPTER EIGHT

COMPARISON OF PHYSIOLOGICAL ADAPTATIONS OF THE OLD AND YOUNG GROUPS

- STATISTICAL ANALYSIS
- COMPARISON OF RESULTS
  - Attendance
  - Exercise intensity
    - Women
    - Men
  - VO\textsubscript{2} max
    - Women
    - Men
  - Submaximal oxygen consumption
    - Women
    - Men
  - Resting heart rate
    - Women
    - Men
  - Isometric Knee Extensor Strength
    - Women
    - Men
  - Isometric Elbow Flexor Strength
    - Women
    - Men
  - Explosive Leg Power
    - Women
    - Men

DISCUSSION
  - Adherence and compliance
  - Adaptations to training
- Aerobic power
  - Women
  - Men
- Muscular strength and power
  - Women
  - Men

CONCLUSION
STATISTICAL ANALYSIS

1. The data for the young group with regard to VO\textsubscript{2} max, HR at VO\textsubscript{2} of 10 ml.kg\textsuperscript{-1}.min\textsuperscript{-1}, resting heart rate, IKES, IEFS and LEP were analyzed in the same way as the old group (pg 124)

2. The changes (%) of the two groups over the control and training periods were compared using unpaired t tests.

Subject characteristics and results for the younger group in respect of attendance, VO\textsubscript{2} max, HR at VO\textsubscript{2} of 10 ml.kg\textsuperscript{-1}.min\textsuperscript{-1}, resting heart rate, muscular strength and explosive power are displayed in Appendix 7. In brief the young women showed significant improvements in all variables measured following 24 weeks of training. In addition, apart from LEP (less powerful leg) significant improvements were also seen after 12 weeks of training. Data for VO\textsubscript{2} max were only obtained in 4 young men, although improvements were seen after both 12 and 24 weeks of training these did not reach significance. Significant improvements were seen however, in both HR at VO\textsubscript{2} of 10 ml.kg\textsuperscript{-1}.min\textsuperscript{-1} and resting heart rate after both 12 and 24 weeks of training. No significant improvements were seen in muscular strength and power.

Too few young subjects consented to have a biopsy taken to make comparisons possible.

COMPARISON OF RESULTS

Attendance

Eight of the younger subjects dropped out of the study, 5 because they found the time commitment too great, 2 because of job moves and 1 because of personal reasons. In those who completed training, there was no significant difference between the number of sessions attended by the young and old women or the young and old men either following 12 or 24 weeks of training (figure 29).
Figure 29: Comparison of the average attendance of (A) the old and young women, and (B) the old and young men.
Exercise Intensity

Women

By week two both groups of women were working within the desired training intensity (figure 30). When the mean RPE of the two groups over the 24 weeks were compared, the young group were found to have been working at a slightly higher intensity than the old ones (P < 0.05) (14.4 (SD 0.9) for the old and 14.9 (SD 0.6) for the young women).

Men

The training intensity had been set at an RPE of 13-14. It was not until week 4 that the mean RPE of the old men was within this range (figure 31). The mean RPE over the 24 weeks of training was 13.6 (SD 1.1) in the old men and 15 (SD 0.8) in the young men. Comparing the two group the younger men were found to have been working at a higher intensity than the old ones (P < 0.01)

Although heart rate monitors were also used in the young subjects so that %HRmax and %HRR could be compared with RPE levels, the quality of the data obtained was not of sufficient quality to be of use. Although each subjects skin had been well prepared prior to the application of electrodes (cleaned with alcohol and abraded with gauze) and each electrode was taped securely to the skin, the degree of movement involved in the aerobic component of the session (e.g. jumping, arm stretching, jogging) meant that the electrodes failed to stay in place.
Figure 30: Mean RPE at each week for the old and the young women
Figure 31: Mean RPE at each week for the older and the younger men
Maximal oxygen uptake

Women

\( \dot{V}O_2 \text{ max (ml.kg}^{-1}.\text{min}^{-1}) \):- There were no significant differences detected between the changes of the two groups of women over the control period or following 24 weeks of training. After 12 weeks of training the changes of the 2 groups were significantly different \( (P<0.05) \) (figure 32).

\( \dot{V}O_2 \text{ max (L.min}^{-1}) \):- There were no significant differences detected between the responses of the old and the young women over the control period or following 12 or 24 weeks of training (figure 33).

Men

\( \dot{V}O_2 \text{ max (ml.kg}^{-1}.\text{min}^{-1}) \):- There was no significant difference between the changes \( (\%) \) of the old and young men over the control period or following 24 weeks of training \( (P>0.1) \). Following 12 weeks of training changes between the 2 groups approached significance \( (P<0.1 \text{ CI 1.24 to 27}) \) (figure 34).

\( \dot{V}O_2 \text{ max (L.min}^{-1}) \):- There was no significant difference between the changes \( (\%) \) of the two groups over the control period. There was a significant difference between the responses to 12 weeks of training \( (P<0.05 \text{ CI 5.08 to 30.9}) \) whilst responses of the two groups to 24 weeks of training approached significance \( (P<0.1 \text{ CI 1.3 to 27.7}) \) (figure 35).
Figure 32: Comparison of changes in VO\textsubscript{2} max (ml.kg\textsuperscript{-1}.min\textsuperscript{-1}) between the older and younger women.
Figure 33: Comparison of changes in $\dot{V}O_2$ max (L.min$^{-1}$) between the older and younger women.
Figure 34: Comparison of changes in VO$_2$ max (ml.kg$^{-1}$.min$^{-1}$) between the old and young men.
Figure 35: Comparison of changes in VO₂ max (L.min⁻¹) between the old and young men.
Heart rate at an oxygen consumption of 10 ml.kg\(^{-1}\).min\(^{-1}\).

Women

There was no significant difference between the changes (%) of the two groups of women with respect to HR at \(\dot{V}O_2\) of 10 ml.kg\(^{-1}\).min\(^{-1}\) either following the control period or after 12 (\(P > 0.1\), CI -7.6 to 22) or 24 weeks of training (figure 36).

Men

There was no significant difference between the changes (%) of the two groups of men after the control period. There was, however a significant difference between the changes of the two groups following 12 and 24 weeks of training (\(P < 0.05\) and \(P < 0.01\) respectively) (figure 37).

Resting heart rate

Women

There was no significant difference between the changes (%) in the resting heart rate of the two groups of women over the control period or after 24 weeks of training. After 12 weeks of training the responses between the two groups approached significance (\(P < 0.1\), CI .149 to 14.7) (figure 38).

Men

There was no significant difference in the changes (%) in resting heart rate of the two groups of men either following the control period or after 12 (\(P > 0.1\), CI -17.4 to 1.45) or 24 (\(P > 0.1\), CI -24.3 to 2.13) weeks of training (figure 39).
Figure 36: Comparison of changes in HR at $\dot{V}O_2$ of 10 ml.kg$^{-1}$.min$^{-1}$ between the old and young women.
Figure 37: Comparison of changes in $\text{VO}_2$ of 10 ml.kg$^{-1}$.min$^{-1}$ between the old and young men.
Figure 38: Comparison of changes in the resting heart rate of the old and young women.
Figure 39: Comparison of changes in the resting heart rate of the old and young men.
Isometric knee extensor strength

Women

There was no significant difference between the responses of the two groups with respect to the IKES of the stronger leg either after the control period or after 24 weeks of training. There was, however, a significant difference in the changes seen after 12 weeks of training ($P < 0.05$) (figure 40).

In the weaker leg there was no significant difference in the changes (%) of the two groups after the control period. A significant difference ($P < 0.01$) was seen between the changes of the two groups after 12 weeks of training (figure 40), whilst after 24 weeks of training differences in the responses of the two groups approached significance ($P < 0.1$, CI -28.2 to -2.07).

Men

There was no significant difference between the changes (%) of the older and younger men with respect to the IKES (stronger and the weaker leg) after the control period or following 12 and 24 weeks of training (figure 41).

Isometric elbow flexor strength

Women

There was no significant difference between the changes (%) of the stronger arm of the two groups over the control period. There were significant differences seen between the responses of the two groups after 12 ($P < 0.05$) and 24 ($P < 0.01$) weeks of training (figure 42).
In the weaker arm there was no significant difference between the changes of the two groups over the control period or following 12 or 24 weeks of training (figure 42).

Men
There was no significant difference between the changes (%) of the two groups of men over the control period or following 12 and 24 weeks of training in either the stronger or the weaker arm (figure 43).

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Chapter eight
Figure 40: Comparison of changes in IKES in (A) the stronger and (B) the weaker limbs of the old and young women.

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Chapter eight
Figure 41:- Comparison of changes in IKES in (A) the stronger and (B) the weaker limbs of the old and young men.
Figure 42:- Comparison of changes in IEFs in (A) the stronger and (B) the weaker limbs of the old and young women.
Figure 43:- Comparison of changes in IEFS in (A) the stronger and (B) the weaker limbs of the old and young men.
Explosive leg power (LEP)

Women

There was no significant difference between the changes (%) of the older and younger women over the control period or following 12 and 24 weeks of training, for either the more powerful or least powerful limb (figure 44).

Men

There was no significant difference between the responses of the older and younger men over the control period or following 12 and 24 weeks of training, for either the more powerful or least powerful limb (figure 45).
Figure 44:- Comparison of changes LEP in (A) the more powerful and (B) the least powerful leg of the old and young women.
Figure 45: Comparison of changes LEP in (A) the more powerful and (B) the least powerful leg of the old and young men.
DISCUSSION

Adherence and Compliance

The 'drop out' rate for the younger group was slightly higher than for the older subjects *viz.* 28% compared to 20%. The reasons for dropping out differed between the groups. It would seen that whilst illness was the major reason why older subjects 'dropped out' of the programme, factors such as job moves and time commitment were the reasons given by the young subjects.

In the subjects who completed the study there was no statistical difference between the attendance levels of the old and young groups or between the old men and women. For both groups of subject we had provided a choice of 6 classes to encourage attendance. Verbal feedback indicated that this was so, particularly with the young subjects.

Adaptations to training

Aerobic power

Women

Although relative changes of the old and young women were similar after 24 weeks of training the changes appear to have taken longer to occur in the old group. Although the responses of the two groups were not significantly different (except where $\dot{V}O_{2\text{max}}$ was expressed as ml.kg$^1$.min$^{-1}$), the young women showed significant increases in $\dot{V}O_{2\text{max}}$ (ml.kg$^1$.min$^{-1}$), HR at $\dot{V}O_2$ of 10 ml.kg$^1$.min$^{-1}$ and resting heart rate after 12 weeks of training. The old women showed no such changes. It is widely reported that 12 weeks of aerobic training is sufficient to increase $\dot{V}O_2$ max in younger old subjects. Warren et al. (1993) reported a 12.5% increase after 12 weeks of training in a group of 67 to 85 year (mean age 74yrs) old women and Tonino and Driscoll (1988) a 8% increase in a group of nine 62-79 year old (mean age 70 years)
men and women after 12 weeks of training. Foster et al. (1989) also reported an improvement in VO$_2$ max of 15.4% in a group of 67-89 (mean age 78) year old women after 10 weeks of training, however this study was not adequately controlled.

It is unclear why adaptations took longer to occur in the old group. We aimed to match the relative training intensity between the old and the young women so that adaptations between the groups could be compared. Only two other studies have attempted to do this. Both of these were in men (Makrides et al. 1990; Stratton et al. 1994). Stratton et al. (1994) used an increasing percentage of HRR to achieve a training intensity in a group of 13 old (60-82 years, mean age 68) and 11 young (24-32 years, mean age 28) men. After 6 months the old group increased VO$_2$ max by 21% and the young by 17%, however no data was given after 12 weeks of training. In addition, as already discussed (chapter 7, pg 161) it is possible that working at the same %HRR resulted in the old subjects working at a higher intensity than the young ones. Makrides et al. (1990) used a heart rate corresponding to a percentage of VO$_2$ max as a training stimulus in a group of 12 old (60-70 years, mean age 65) and 10 young (20-30 years, mean age 27yrs) men. They found that both groups increased VO$_2$ max in response to 12 weeks of training, by 38% in the old and by 29% in the young group. However, peak heart rates also increased following training (in both the old and the young groups) suggesting that the initial tests may not have been truly maximal.

In the present study, after the first week, both the old and young women worked consistently within the desired training zone (RPE 13-15). Although the mean RPE of the two groups were similar viz. 14.4 in the old and 14.9 in the young group, the younger group were found to have been working at a slightly higher (p<0.05) intensity. However, even if the young women were working at a slightly higher intensity an RPE of 14 (corresponding to 81% of HRmax% and 63% of HRR) would be expected to induce a training response in older women. Training studies which have used a similar percentage of HRR as the training intensity, have reported increases in VO$_2$ max in slightly younger women. Warren et al. (1993) used 60% of
HRR to prescribe training intensity in a group of women aged 67-85 (mean age 73.6 years) and showed a 12% increase in \( \text{VO}_2 \) max in response to 12 weeks of training whilst Foster et al. (1989) set training intensities using 40% HRR and 60% HRR in group of 67-89 women (mean age 78) and reported increases in \( \text{VO}_2 \) max of 12.6% and 15.4% respectively, in response to 10 weeks of training. However, as already mentioned this study was not adequately controlled.

It therefore seems unlikely that an inadequate training stimulus can explain why no changes were seen after 12 weeks of training.

Improvements in aerobic power in both old and young adults in response to aerobic training are reported to occur as a result of both central and peripheral adaptations (Stratton et al. 1994; Seals et al. 1984; Örlander et al. 1980; Suominen et al. 1977b; Coggan et al. 1992a; Meredith et al. 1989). Perhaps adaptations take longer to occur in very elderly women, or are different to those seen in younger people. Perhaps there is an age threshold above which some systems are less efficient in adapting to training, perhaps because of changes at the cellular level.

Spina et al. (1996) reported that both resting and peak stroke volume were unchanged in response to 9-12 months of endurance training in women aged 60-70 years (mean age 63). This was a despite an increase in \( \text{VO}_2 \) max of 21%. However, in the present study, we saw a 13% decrease in resting heart rate, which would suggest an increase in stroke volume at rest.

Perhaps changes in muscle enzyme activities do not occur with training in the 'oldest' old women. Rooyackers et al. (1996) reported a decrease in mitochondrial protein synthesis with ageing. However, this decline was reported to occur in middle age. It well documented that women older than this can increase \( \text{VO}_2 \) max in response to 12 weeks of training.

The time span of changes in response to endurance training in older women merits further investigation.
Men

Comparison of the data with the young men of the present study was difficult, because of the small number of young men who completed the study, and because the mean RPE over the 24 weeks of training was significantly higher in the young mens viz.15 compared to 13.6. There was a significant difference in the responses of the two groups after both 12 (P < 0.05) and 24 (P < 0.01) weeks of training with respect to the heart rate at a VO$_2$ of 10mls.kg$^{-1}$.min$^{-1}$ with the young men showing a significant improvement. However, although the young men also demonstrated significant improvements in resting heart rate after both 12 and 24 weeks of training, there was no significant differences between the responses of the old and young men (figure 39).

Muscular strength and explosive power

Women

In the young women we saw changes in strength and power in all the variables measured. In addition, in common with the pattern of cardiovascular changes in all but the LEP of the most powerful leg these changes were significant after 12 weeks of training. This was in contrast to the old women, where the only significant improvements seen were an increase in the explosive power of the less powerful leg and increase in the IEFS of the weaker arm following 24 weeks of training.

When the responses of the two groups to training were compared, few significant differences were found viz. IKES (both legs) and IEFS (stronger arm) over 12 weeks of training and IEFS (stronger arm) following 24 weeks of training. However, in all other measures of strength and power the old women had shown a tendency towards improvement after both 12 an 24 weeks of training. Although these did not reach significance in most cases, it could help to explain why so few differences were seen between the responses of the two groups of women.
Comparisons of both the changes and the time span of the changes between the two groups of women should be viewed with caution. Although 10 minutes of resistance exercise was included in the programmes for both groups of women, because no exact measurements were made in the classes it was not possible to ascertain exactly what percentage of each subject's strength the resistance provided equated to. In addition, whilst the routines in the two classes contained the same moves, the aerobic training stimulus in the old group was achieved by low to moderate impact aerobics whilst in the young group it was achieved by moderate to high impact aerobics e.g. running instead of walking, more jumping. It is possible that this could have contributed to the significant changes in strength and power which were seen.

Men

No differences in the responses of the old and young men were detected. Apart from increase in IEFS (weaker arm) in the old men (in which the young men also showed a tendency towards improvement), neither group showed any changes in muscular strength and power in response to training.

It seems that in both healthy old and young men including 10 minutes of resistance exercise within a predominantly aerobic training programme may not be enough to elicit improvements in strength and power.

CONCLUSION

Although it appears that the ability to respond to endurance training is maintained in even the 'oldest old' women, with similar % improvements in VO₂ max to those seen in young women, the adaptations may take longer to occur. The reasons for this finding remain unclear.
CHAPTER NINE

EFFECT OF TRAINING ON THE QUALITY OF LIFE OF
THE OLD SUBJECTS

- METHOD
- RESULTS
  - Completion rate
  - Pre-control data
  - Comparison of pre-control data with data available in the literature
    - The Geriatric Depression Scale
    - The Profile of Mood States
    - SF-36
    - The General Health Questionnaire
  - Effects of training
    - Data handling
    - The Geriatric Depression Scale
    - The Philadelphia Geriatric Centre Morale Scale
    - The Profile of Mood States
    - The SF-36
    - The General Health Questionnaire

- DISCUSSION
  - Completion rate
  - Pre control data
  - Response to training
METHOD

The questionnaires identified in Chapter three were used to assess the quality of life of the subjects, both before and after the control period, and after training. These questionnaires were the General Health Questionnaire (GHQ), the Short Form of the Health Survey Questionnaire (SF-36), the Profile of Mood States (POMS), the Philadelphia Geriatric Centre Morale Scale (PGCMS) and the Geriatric Depression Scale (GDS).

The SF-36, GDS and PGCMS questionnaires were enlarged to make them easier to read. Each subject was given a code so that they could complete the questionnaires anonymously, as we felt subjects would feel less inhibited about reporting their true feelings this way. For this reason and because of time limits (each 'assessment' visit already lasted 1→1.5 hours) questionnaires which could be self completed, at home, had been chosen.

The GHQ was scored using the Likert method of scoring (see chapter 4, pg 86).

All subjects had at least 4 pre-control visits, for measurement of the physiological variables. At the first of these, each subject was given the first set of questionnaires to complete. An investigator went through each questionnaire, with each individual subject and explained how to complete it. The subjects were then asked to self-complete the questionnaires within 2-3 days, and bring them back at the next visit. In this way, if they had encountered any problems in completing any of the forms, they could be given help at the next pre control visit.

Subjects were also given questionnaires to complete, at home, at the post control visit and after 12 and 24 weeks of training. They were asked to fill these in within 2 to 3 days and return them in a pre-paid envelope. It was stressed to each subject that help with completion, if required, was always available.

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RESULTS

Completion rates

Only one subject asked for help in completing the questionnaires, and this only at the pre control visit. The reason for this was poor eyesight. The subject completed subsequent forms using a magnifying glass which she routinely used for reading. As foreseen (chapter 4, pg 99) some of subjects did not understand some of the americanised words used in the POMS viz. 'bushed', 'blue' and 'full of pep'. When explaining what the words meant, care was taken not to use any of the other words listed on the sheet.

Completion rate was disappointing. Potentially data were obtainable for 21 subjects at the pre control and post control time points and after 12 weeks of training, and for 20 subjects after 24 weeks of training. Table 21 shows the number of data sets that were complete i.e. had no missing data at all, at these time points. At the pre-control visit the investigator went through each of the questionnaires, and explained how to complete it. Completion rate was excellent at the pre control visit for all the questionnaires used. At the post control visit completion rates were still good, with an approximate 80% completion rate for all questionnaires. However, this dropped off dramatically after 12 and 24 weeks of training, indeed full data sets for all five questionnaires, at each time point, were obtained in only 6 subjects (two men and 4 women). There was no difference in the number of missing data sets between the older men and women and no effect of age. Reasons for missing data fell into two categories. First, those who did not return any forms at all at one of the testing times. This happened on 6 occasions (5 subjects). Second, the set of forms would either be returned with one form missing or not completed or, more usually, the forms would be returned with some unanswered questions on one or more of the forms. Unfortunately there was no way to collect the missing data. Subjects filled in the forms at home and returned them by post. Without breaking subject anonymity there was no way of knowing who had not completed the forms.

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<table>
<thead>
<tr>
<th>Questionnaire</th>
<th>Pre control (n=21)</th>
<th>Post control (n=21)</th>
<th>12 weeks post training (n=21)</th>
<th>24 weeks post training (n=20)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GDS</td>
<td>21</td>
<td>17</td>
<td>13</td>
<td>14</td>
</tr>
<tr>
<td>PGCMS</td>
<td>21</td>
<td>18</td>
<td>13</td>
<td>15</td>
</tr>
<tr>
<td>POMS</td>
<td>20</td>
<td>17</td>
<td>12</td>
<td>14</td>
</tr>
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<td>SF-36</td>
<td>21</td>
<td>17</td>
<td>14</td>
<td>13</td>
</tr>
<tr>
<td>GHQ</td>
<td>21</td>
<td>17</td>
<td>10</td>
<td>14</td>
</tr>
</tbody>
</table>

Table 21. Number of complete data sets for each of the chosen questionnaires, at each time point.
Because of low numbers, data from the men and the women were combined for analysis in all cases. Data for the POMS were also analysed separately as some studies have suggested that responses may differ between males and females (Ware et al. 1997).

Pre control data

Pre control data for those subjects who completed the study, and had post control data available for comparison are displayed in tables 22 to 25.

As a group the subjects achieved good scores on all the questionnaires used at the pre-control visit. Tables 26 and 27 look at the number of subjects achieving ‘perfect scores’ and the number achieving the ‘worst possible score’ for each of the questionnaires. For only one variable (Physical Role Limitation of the SF-36) did any of the subjects achieve the ‘worst possible score’, whereas many achieved the ‘best possible score’ in other variables. Of particular note are the percentage of subjects achieving perfect scores in the Mental Role Limitation (64%), Physical Role Limitation (63%) and Social Functioning (80%) sections of the SF-36 and in the Severe Depression unit of the GHQ (64%). In only the Total Mood Disturbance and Vigour/Activity units of the POMS, and in the overall score and Social Dysfunction unit of the GHQ did none of the subjects achieve a ‘perfect score’.
<table>
<thead>
<tr>
<th>Scale</th>
<th>Mean</th>
<th>Median</th>
<th>Range</th>
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</thead>
<tbody>
<tr>
<td>Geriatric Depression Scale (GDS)</td>
<td>6.2</td>
<td>7</td>
<td>0-16</td>
</tr>
<tr>
<td>Philadelphia Geriatric Centre Morale Scale (PGCMS)</td>
<td>12.5</td>
<td>14</td>
<td>6-17</td>
</tr>
</tbody>
</table>

Table 22: Pre control data for the Geriatric Depression Scale and the Philadelphia Geriatric Centre Morale Scale (n=15).

Possible range for the GDS is 0 to 30 (with high scores indicating depression). Possible range for the PGCMS is 0 to 17 (with high scores indicating high morale).
Table 23:- Pre control data for the Profile of Mood States (POMS) (n=14)

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Median</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total mood disturbance</td>
<td>1.4</td>
<td>0</td>
<td>-29 - 57</td>
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<tr>
<td>Individual units</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tension/Anxiety</td>
<td>4.5</td>
<td>3</td>
<td>0 - 19</td>
</tr>
<tr>
<td>Depression/Dejection</td>
<td>4.1</td>
<td>0.5</td>
<td>0 - 18</td>
</tr>
<tr>
<td>Anger/Hostility</td>
<td>3.4</td>
<td>2.5</td>
<td>0 - 14</td>
</tr>
<tr>
<td>Vigour/Activity</td>
<td>18.1</td>
<td>16</td>
<td>8 - 29</td>
</tr>
<tr>
<td>Fatigue/Inertia</td>
<td>3.9</td>
<td>2</td>
<td>0 - 17</td>
</tr>
<tr>
<td>Confusion/Bewilderment</td>
<td>3.6</td>
<td>4</td>
<td>0 - 10</td>
</tr>
</tbody>
</table>

Possible scores range from -32 to +200 for TMD, 0 to 36 for tension/anxiety, 0 to 60 for depression/dejection, 0 to 48 for anger/hostility, 0 to 28 for confusion/bewilderment and 0 to 28 for fatigue/inertia (in all cases the lower the score the better). Possible scores for vigour/activity range from 0 to 32, in this case the higher the score the better.
<table>
<thead>
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<th>Subscale</th>
<th>Mean</th>
<th>Median</th>
<th>Range</th>
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</thead>
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<tr>
<td>Physical functioning</td>
<td>70.3</td>
<td>77.5</td>
<td>5 - 100</td>
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<tr>
<td>Role Limitation (physical)</td>
<td>75</td>
<td>100</td>
<td>0 - 100</td>
</tr>
<tr>
<td>Role Limitation** (mental)</td>
<td>85.8</td>
<td>100</td>
<td>33 - 100</td>
</tr>
<tr>
<td>Social Functioning*</td>
<td>93.3</td>
<td>100</td>
<td>44 - 100</td>
</tr>
<tr>
<td>Mental Health*</td>
<td>84.3</td>
<td>92</td>
<td>60 - 100</td>
</tr>
<tr>
<td>Energy/Vitality*</td>
<td>73.6</td>
<td>70</td>
<td>30 - 100</td>
</tr>
<tr>
<td>Pain</td>
<td>77.2</td>
<td>89</td>
<td>22 - 100</td>
</tr>
<tr>
<td>Health Perception*</td>
<td>78.6</td>
<td>72</td>
<td>20 - 100</td>
</tr>
<tr>
<td>Change in Health</td>
<td>48.4</td>
<td>50</td>
<td>25 - 100</td>
</tr>
</tbody>
</table>

Table 24: Pre control data for the SF-36 (n=16, except where indicated)

Possible scores range from 0 to 100 for each section, with the higher the score the better.

* n=15  ** n=14
<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Median</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total Score</strong></td>
<td>11.8</td>
<td>11</td>
<td>6 - 24</td>
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<tr>
<td><strong>Sub-units</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Severe Depression</td>
<td>0.9</td>
<td>0</td>
<td>0 - 5</td>
</tr>
<tr>
<td>Social Dysfunction</td>
<td>6.7</td>
<td>7</td>
<td>5 - 7</td>
</tr>
<tr>
<td>Anxiety/Insomnia</td>
<td>2</td>
<td>1</td>
<td>0 - 7</td>
</tr>
<tr>
<td>Somatic Symptoms</td>
<td>1.9</td>
<td>1</td>
<td>0 - 7</td>
</tr>
</tbody>
</table>

**Table 25:** Pre control data for the General Health Questionnaire (n=16)

Possible values range from 0 to 84 for the total score and from 0 to 21 for each of the sub units, with the lower the score the better.
Table 26:- Percentage of subjects at the pre control time point achieving the best or the worst possible score for the GDS or PGCMS.
(n=15).

<table>
<thead>
<tr>
<th>Scale</th>
<th>% of subjects with the best possible score</th>
<th>% of subjects with the worst possible score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geriatric Depression Scale (GDS)</td>
<td>13</td>
<td>0</td>
</tr>
<tr>
<td>Philadelphia Geriatric Center Morale Scale (PGCMS)</td>
<td>7</td>
<td>0</td>
</tr>
</tbody>
</table>
Table 27:- Percentage of subjects at the pre control time point achieving the best or the worst possible score for each section of POMS (n=14).

<table>
<thead>
<tr>
<th></th>
<th>% of subjects with the best possible score</th>
<th>% of subjects with the worst possible score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Mood Disturbance</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Individual units</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tension/Anxiety</td>
<td>36</td>
<td>0</td>
</tr>
<tr>
<td>Depression/Dejection</td>
<td>50</td>
<td>0</td>
</tr>
<tr>
<td>Anger/Hostility</td>
<td>21</td>
<td>0</td>
</tr>
<tr>
<td>Vigour/Activity</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Fatigue/Inertia</td>
<td>36</td>
<td>0</td>
</tr>
<tr>
<td>Confusion/Bewilderment</td>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>% of subjects with the best possible score</td>
<td>% of subjects with the worst possible score</td>
</tr>
<tr>
<td>--------------------------</td>
<td>------------------------------------------</td>
<td>-------------------------------------------</td>
</tr>
<tr>
<td>Physical Functioning</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>Role Limitation (physical)</td>
<td>62.5</td>
<td>12.5</td>
</tr>
<tr>
<td>Role Limitation** (Mental)</td>
<td>64</td>
<td>0</td>
</tr>
<tr>
<td>Social Functioning*</td>
<td>80</td>
<td>0</td>
</tr>
<tr>
<td>Mental Health*</td>
<td>20</td>
<td>0</td>
</tr>
<tr>
<td>Energy/Vitality*</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>Pain</td>
<td>25</td>
<td>0</td>
</tr>
<tr>
<td>Health Perception*</td>
<td>13</td>
<td>0</td>
</tr>
<tr>
<td>Change in Health</td>
<td>6</td>
<td>0</td>
</tr>
</tbody>
</table>

**Table 28:** Percentage of subjects at the pre control time point achieving the best or the worst possible score for each section of the SF-36. (n=16 except where indicated)

* n=15  ** n=14
<table>
<thead>
<tr>
<th>Sub-units</th>
<th>% of subjects with the best possible score</th>
<th>% of subjects with the worst possible score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total score</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Severe Depression</td>
<td>64</td>
<td>0</td>
</tr>
<tr>
<td>Social Dysfunction</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Anxiety/Insomnia</td>
<td>33</td>
<td>0</td>
</tr>
<tr>
<td>Somatic Symptoms</td>
<td>7</td>
<td>0</td>
</tr>
</tbody>
</table>

**Table 29:** Percentage of subjects at the pre control time point achieving the best or the worst possible score for each section of the GHQ.

(n=16)
Comparison of pre control data with data in the literature

Data for comparison with our subjects were not available for the PGCMS.

Geriatric depression scale

Scores from our subjects for the GDS were compared to those from normal, mildly depressed and severely depressed "geriatric" (aged 55 and over) subjects (Yesavage et al. 1983) (table 30). The mean scores for our subjects were similar to those reported for the normal subjects.

Profile of mood states

Normative data for POMS scores, specifically for older people, are not available, therefore pre control data were compared to those obtained from a group of 2,360 adults aged 16-65 years who participated in a 'self help' smoking cessation programme (Killen et al. 1988) (table 31). Our subjects achieved much better scores for all sections of the POMS. Indeed scores for tension/anxiety, depression/dejection, anger/hostility, fatigue/inertia and confusion/bewilderment were approximately half those of the 'normative' sample.
Table 30. Comparison of GDS pre control data with data taken from the literature.
(mean scores expressed as mean (SD)).
Score from pre-control data of present study | Adult normative sample of 2,360 adults aged 18-65 years (McNair et al. 1992)*
---|---
Mean score | 50th Centile | Mean scores | Mean scores
| | | Women | Men
Total Mood Disturbance | 1.4 (22.8) | 0 | 48.4 (33.6) | 43.5 (28.8)

**Individual units**

- Tension/Anxiety | 4.5 (5.7) | 3 | 12.8 (7.9) | 12.3 (7.0)
- Depression/Dejection | 4.1 (6.2) | 0.5 | 10.2 (10.4) | 8.3 (8.7)
- Anger/Hostility | 3.4 (3.8) | 2.5 | 9.7 (9.3) | 9.2 (8.3)
- Vigour/Activity | 18.1 (7.0) | 16 | 14.9 (6.7) | 9.2 (8.3)
- Fatigue/Inertia | 3.9 (5.1) | 2 | 8.4 (6.8) | 7.0 (5.7)
- Confusion/Bewilderment | 3.6 (2.7) | 4 | 7.3 (5.4) | 6.7 (4.6)

**Table 31.** Comparison of POMS pre control data from the present study with data from the literature, (mean scores expressed as mean (SD))

* Data taken from subjects taking part in a ‘self help’ smoking cessation program.
Table 32 compares the pre control scores from the present study with scores obtained from a sample of the general US population aged 75+. The median scores for our group were greater for all subsections excluding that for Role Limitation (Mental) in which both had a median of 100 (i.e. best possible). Of particular note is the difference in the median score for Role Limitation (Physical) i.e 100 in our group compared to 25 in the US sample. This emphasises that the majority of our subjects were among the physical ‘elite’ for their age. When our results were compared with data available from UK populations, derived from a group of Outpatients and a group of General Practice patients aged 65+; our subjects had much higher scores for all sections, with scores for Physical Functioning and Role Limitation (Physical) being over twice those reported for the two UK groups.

General Health Questionnaire

Bowling (1990) investigated the prevalence of psychiatric morbidity among people aged 85 and over (living at home) using the GHQ. She reported findings from 662 individuals. The GHQ had been scored using the GHQ method of scoring (chapter four, pg 86). Therefore in order to compare their findings with the pre-control data of our subjects we also calculated the total score from our subjects in this way. The range of total scores when calculated in this way is 0-28. Bowling used a threshold score of 5 i.e. individuals who scored higher than this were rated as probably having psychiatric morbidity. She reported that 27% of the subjects had a total score of 6 and over. In the present study no subjects had a score of 6 or over and only 1 subject had a score of 5.
<table>
<thead>
<tr>
<th>Sub scale</th>
<th>Score from pre-control data of present study</th>
<th>Scores taken from general US population for age 75+ (n=264) (Ware et al. 1997)</th>
<th>Mean scores for GP patients (n=48) or Outpatients (n=74) (UK) (Hayes et al. 1995)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean score</td>
<td>50th Centile</td>
<td>Mean scores</td>
</tr>
<tr>
<td>Physical Functioning</td>
<td>70.3</td>
<td>77.5</td>
<td>53.2</td>
</tr>
<tr>
<td>Role Limitation (physical)</td>
<td>75.0</td>
<td>100</td>
<td>45.28</td>
</tr>
<tr>
<td>Role Limitation (mental)</td>
<td>85.8</td>
<td>100</td>
<td>63.18</td>
</tr>
<tr>
<td>Social Functioning</td>
<td>93.3</td>
<td>100</td>
<td>73.89</td>
</tr>
<tr>
<td>Mental Health</td>
<td>84.3</td>
<td>92</td>
<td>73.99</td>
</tr>
<tr>
<td>Energy/Vitality</td>
<td>73.6</td>
<td>70</td>
<td>50.41</td>
</tr>
<tr>
<td>Pain</td>
<td>77.2</td>
<td>89</td>
<td>60.88</td>
</tr>
<tr>
<td>Health Perception</td>
<td>78.6</td>
<td>72</td>
<td>56.66</td>
</tr>
<tr>
<td>Change in Health</td>
<td>48.4</td>
<td>50</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 32. Comparison of SF-36 pre control data taken from the present study with data from the literature.
Effects of training

Data handling

Because the high pre control values left little room for improvement in some cases, the data were analyzed in two ways. Actual changes were calculated but, in addition, the percentage of possible change was also calculated. For example, if the pre control score was 90 and the maximum possible score 100 then a post control score of 95 would represent a 50% improvement. However, if the post control score was 80 this would represent an 11% decrease.

Actual changes and percentage of possible change over the control period were calculated for each subject and analyzed using non-parametric Wilcoxon signed rank test. If there was no significant change over the control period then pre and post control data were averaged. The actual change and the percentage of possible change, from the mean of pre and post control, over the 12 and 24 week training periods were then calculated for each subject and analyzed using non-parametric Wilcoxon signed rank test. If a significant change was found over the control period then post control data (i.e. not the average of pre and post control) were used as the starting point for calculating the changes over the 12 and 24 week training periods (Sokal & Rohlf, 1969).

Geriatric Depression Scale

The total scores from the group at each time point are displayed in Appendix 8A.

1. Actual change - There was no significant difference in the GDS score after the control period or after 12 or 24 weeks of training (table 33).

2. Percentage of possible change - There was a 19% median decrease (P<0.05) in the GDS score over the control period. Comparing the post training with post
control values, there was no change after either 12 or 24 weeks of training (table 33).

Philadelphia Geriatric Centre Morale Scale

The total scores from the group at each time point are displayed in Appendix 8A.

1. Actual change - There was no significant change in the PGCMS score either following the control period or after 12 or 24 weeks of training (table 33).

2. % of possible change - There was a median increase of 29% (P < 0.01) in the PGCMS score over the control period. Comparing the post training with post control values there was no change with either 12 or 24 weeks of training (table 34).

Profile of Mood States

Pre control data from the men and the women were compared using non-parametric unpaired analysis. No significant difference was seen either for Total Mood Disturbance or for any of the subsections figure 46. The data are reported for the men and women combined.

The scores from the group at each time point (for Total Mood Disturbance and for each sub section) are displayed in Appendix 8B.

1. Actual change - There was a decrease in the score for depression over the control period (P < 0.05). There was a significant increase in the score for vigour/activity after both 12 weeks (P < 0.02) and 24 weeks (P < 0.05) of training. No other changes were seen (table 35).
## Table 33. Actual changes in scores for the GDS and PGCMS following the control period and after training, expressed as median (range)

<table>
<thead>
<tr>
<th></th>
<th>Control Period</th>
<th>Post 12 weeks training</th>
<th>Post 24 weeks training</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geriatric Depression Scale (GDS)</td>
<td>-1 (-7 - 5)</td>
<td>-1 (-9 - 5.5)</td>
<td>-0.75 (-7.5 - 3.5)</td>
</tr>
<tr>
<td></td>
<td>NS (n=15)</td>
<td>NS (n=13)</td>
<td>NS (n=14)</td>
</tr>
<tr>
<td>Philadelphia Geriatric Center Morale Scale (PGCMS)</td>
<td>+1 (-2 - 6)</td>
<td>+0.5 (-5 - 5.5)</td>
<td>+1 (-4 - 3)</td>
</tr>
<tr>
<td></td>
<td>NS (n=15)</td>
<td>NS (n=13)</td>
<td>NS (n=15)</td>
</tr>
</tbody>
</table>

*Chapter nine*
### Table 34

Percentage of possible change achieved after the control period and after training. Expressed as median (range).

* post (12 weeks) training values compared to post control values.

<table>
<thead>
<tr>
<th>Scale</th>
<th>Control Period</th>
<th>Post 12 weeks training</th>
<th>Post 24 weeks training</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geriatric Depression Scale (GDS)</td>
<td>-15 (-75 - 32)</td>
<td>0 (-100 - 10)*</td>
<td>-10 (-100 - 17)*</td>
</tr>
<tr>
<td>p &lt; 0.05 (n=15)</td>
<td></td>
<td>NS (n=13)</td>
<td>NS (n=14)</td>
</tr>
<tr>
<td>Philadelphia Geriatric Center Morale Scale (PGCMS)</td>
<td>+29 (-17 - 100)</td>
<td>0 (-31 - 100)*</td>
<td>0 (-44 - 100)*</td>
</tr>
<tr>
<td>p &lt; 0.01 (n=15)</td>
<td></td>
<td>NS (n=13)</td>
<td>NS (n=15)</td>
</tr>
</tbody>
</table>
Figure 46: Comparison of the pre control scores for POMS variables

Possible scores range from -32 to +200 for TMD, 0 to 36 for tension/anxiety, 0 to 60 for depression/dejection, 0 to 48 for anger/hostility, 0 to 28 for confusion/bewilderment and 0 to 28 for fatigue/inertia (in all cases the lower the score the better). Possible scores for vigour/activity range from 0 to 32, in this case the higher the score the better.
<table>
<thead>
<tr>
<th></th>
<th>Control period (n=14)</th>
<th>Post 12 weeks training (n=12)</th>
<th>Post 24 weeks training (n=14)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total mood disturbance</strong></td>
<td>-2 (-34 - 117) NS</td>
<td>-2.5 (-30.5 - 26.5) NS</td>
<td>-6.5 (-20 - 20) NS</td>
</tr>
<tr>
<td><strong>Individual units</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Tension/Anxiety</td>
<td>0 (-9 - 1) NS</td>
<td>0 (-6.5 - 9.5) NS</td>
<td>-0.5 (-11.5 - 13.5) NS</td>
</tr>
<tr>
<td>- Depression/Dejection</td>
<td>-0.5 (-10 - 1) *p&lt;0.05</td>
<td>0 (-4.5 - 12) NS</td>
<td>0 (-9 - 16.5) NS</td>
</tr>
<tr>
<td>- Anger/Hostility</td>
<td>-0.5 (-12 - 10) NS</td>
<td>-0.5 (-3.5 - 4) NS</td>
<td>-0.5 (-8 - 2.5) NS</td>
</tr>
<tr>
<td>- Vigour/Activity</td>
<td>-0.5 (-6 - 24) NS</td>
<td>+2.75 (-5 - 12) *p&lt;0.02</td>
<td>+3.5 (-3 - 5.5) p&lt;0.05</td>
</tr>
<tr>
<td>- Fatigue/Inertia</td>
<td>0 (-4 - 7) NS</td>
<td>0 (-6.5 - 5) NS</td>
<td>+0.5 (-2 - 9) NS</td>
</tr>
<tr>
<td>- Confusion/Bewilderment</td>
<td>-1 (-7 - 3) NS</td>
<td>+1.5 (-2.5 - 5.5) NS</td>
<td>-0.5 (-4.5 - 2.5) NS</td>
</tr>
</tbody>
</table>

Table 35. Actual changes in POMS scores following the control period and after training.
Scores expressed as median change (range).

*Post training compared with post control data
2. % of possible change - Over the control period there were decreases in the scores for Tension/Anxiety (P < 0.05), Depression/Dejection (P < 0.02) and Confusion/Bewilderment (P < 0.05). After 12 weeks of training there was a decrease in the score for Anger/Hostility (P < 0.05) and an increase in the score for Vigour/Activity (P < 0.02). After 24 weeks of training there was a decrease in the score for Anger/Hostility (P < 0.05), an increase in the score for Vigour/Activity (P < 0.05) and a decrease in the score for Total Mood Disturbance (P < 0.05) (table 36).

SF-36

The scores from the group at each time point for each section of the SF-36 are displayed in Appendix 8C.

1. Actual changes - There were no significant changes in any of the sections over the control period, or after 12 weeks of training. After 24 weeks of training there was an improvement in the score for ‘Pain’ (P < 0.02) and an improvement in the score for ‘Change in Health’ which approached significance (P < 0.1) (table 37).

2. Percentage of possible change - There was a significant improvement in the ‘Health Perception’ score following the control period (P < 0.05). No significant changes were seen after 12 weeks of training. After 24 weeks of training there was an improvement in the score for the ‘Pain’ sub section (P < 0.01). The score for ‘Change in Health’ also showed an increase which approached significance (P < 0.1) (table 38).
<table>
<thead>
<tr>
<th></th>
<th>Control period</th>
<th>Post 12 weeks training</th>
<th>Post 24 weeks training</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(n=14)</td>
<td>(n=12)</td>
<td>(n=14)</td>
</tr>
<tr>
<td>Total mood disturbance</td>
<td>-4 (-88 - 5.5)</td>
<td>-9 (-94 - 14)</td>
<td>-29 (-100 - 29)</td>
</tr>
<tr>
<td></td>
<td>NS</td>
<td>NS</td>
<td>p&lt;0.05</td>
</tr>
<tr>
<td>Individual units</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Tension/Anxiety</td>
<td>0 (-75 - 3)</td>
<td>0 (-100 - 38)*</td>
<td>0 (-100 - 69)*</td>
</tr>
<tr>
<td></td>
<td>p&lt;0.05</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>- Depression/Dejection</td>
<td>-3 (-100 - 0)</td>
<td>0 (-100 - 12)*</td>
<td>0 (-100 - 40)*</td>
</tr>
<tr>
<td></td>
<td>p&lt;0.02</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>- Anger/Hostility</td>
<td>-12.5 (-100 - 34)</td>
<td>-13.25 (-100 - 8)</td>
<td>-100 (-100 - 5)</td>
</tr>
<tr>
<td></td>
<td>NS</td>
<td>p&lt;0.05</td>
<td>p&lt;0.05</td>
</tr>
<tr>
<td>- Vigour/Activity</td>
<td>0 (-23.5 - 100)</td>
<td>+20.5 (-31 - 100)</td>
<td>+26.5 (-18 - 100)</td>
</tr>
<tr>
<td></td>
<td>NS</td>
<td>p&lt;0.02</td>
<td>p&lt;0.05</td>
</tr>
<tr>
<td>- Fatigue/Inertia</td>
<td>0 (-100 - 39)</td>
<td>0 (-40 - 25)</td>
<td>+1 (-100 - 14)</td>
</tr>
<tr>
<td></td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>- Confusion/Bewilderment</td>
<td>-14.5 (-100 - 12.5)</td>
<td>+2 (-100 - 20)*</td>
<td>0 (-100 - 12)*</td>
</tr>
<tr>
<td></td>
<td>p&lt;0.05</td>
<td>NS</td>
<td>NS</td>
</tr>
</tbody>
</table>

Table 36: Percentage of possible change achieved after the control and training periods. Expressed as median change (range).

* post training compared with post control data.
<table>
<thead>
<tr>
<th></th>
<th>Control Period</th>
<th>Post 12 weeks training</th>
<th>Post 24 weeks training</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical Functioning</td>
<td>0 (-15 - 70) NS (n=16)</td>
<td>0 (-22.5 - 7.5) NS (n=14)</td>
<td>+1.25 (-22.5 - 60) NS (n=13)</td>
</tr>
<tr>
<td>Role Limitation (physical)</td>
<td>0 (-75 - 25) NS (n=16)</td>
<td>0 (-50 - 62.5) NS (n=14)</td>
<td>0 (-75 - 37.5) NS (n=13)</td>
</tr>
<tr>
<td>Role Limitation (mental)</td>
<td>0 (-33 - 77) NS (n=16)</td>
<td>0 (-67 - 33) NS (n=14)</td>
<td>0 (-34 - 33) NS (n=14)</td>
</tr>
<tr>
<td>Social Functioning</td>
<td>0 (-78 - 12) NS (n=15)</td>
<td>0 (-56 - 39) NS (n=13)</td>
<td>0 (-61.5 - 28) NS (n=14)</td>
</tr>
<tr>
<td>Mental Health</td>
<td>0 (-16 - 46) NS (n=15)</td>
<td>0 (-30 - 20) NS (n=13)</td>
<td>0 (-30 - 28) NS (n=14)</td>
</tr>
<tr>
<td>Energy/Vitality</td>
<td>0 (-30 - 70) NS (n=15)</td>
<td>+1.25 (-5 - 10) NS (n=12)</td>
<td>0 (-60 - 20) NS (n=14)</td>
</tr>
<tr>
<td>Pain</td>
<td>0 (-56 - 22) NS (n=16)</td>
<td>0 (-45 - 23) NS (n=14)</td>
<td>+11 (-6 - 11) P&lt;0.02 (n=14)</td>
</tr>
<tr>
<td>Health Perception</td>
<td>0 (-5 - 10) NS (n=14)</td>
<td>0 (-12.5 - 7.5) NS (n=12)</td>
<td>0 (-15 - 12.5) NS (n=14)</td>
</tr>
<tr>
<td>Change in Health</td>
<td>0 (-50 - 50) NS (n=16)</td>
<td>0 (-25 - 25) NS (n=14)</td>
<td>0 (-25 - 50) P&lt;0.1 (n=14)</td>
</tr>
</tbody>
</table>

Table 37:- Actual changes in SF-36 scores following the control and training periods, expressed as median (range).
<table>
<thead>
<tr>
<th></th>
<th>Control Period</th>
<th>Post 12 weeks training</th>
<th>Post 24 weeks training</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical Functioning</td>
<td>0 (-25 - 74) NS (n=16)</td>
<td>0 (-67 - 17) NS (n=14)</td>
<td>0 (-36.5 - 100) NS (n=13)</td>
</tr>
<tr>
<td>Role Limitation (physical)</td>
<td>0 (-100 - 100) NS (n=16)</td>
<td>0 (-100 - 100) NS (n=14)</td>
<td>0 (-100 - 100) NS (n=13)</td>
</tr>
<tr>
<td>Role Limitation (mental)</td>
<td>0 (-51 - 100) NS (n=16)</td>
<td>0 (-100 - 100) NS (n=14)</td>
<td>0 (-51 - 100) NS (n=14)</td>
</tr>
<tr>
<td>Social Functioning</td>
<td>0 (-88 - 100) NS (n=15)</td>
<td>0 (-72 - 100) NS (n=13)</td>
<td>0 (-74 - 100) NS (n=14)</td>
</tr>
<tr>
<td>Mental Health</td>
<td>0 (-47 - 60) NS (n=15)</td>
<td>0 (-32 - 100) NS (n=13)</td>
<td>0 (-65 - 100) NS (n=14)</td>
</tr>
<tr>
<td>Energy/Vitality</td>
<td>0 (-38 - 100) NS (n=15)</td>
<td>+7 (-14 - 67) NS (n=12)</td>
<td>0 (-92 - 100) NS (n=14)</td>
</tr>
<tr>
<td>Pain</td>
<td>0 (-56 - 100) NS (n=16)</td>
<td>0 (-60 - 100) NS (n=14)</td>
<td>+35.5 (-12 - 100) P &lt; 0.02 (n=14)</td>
</tr>
<tr>
<td>Health Perception</td>
<td>0 (-7 - 62.5) (P &lt; 0.05, n=14)</td>
<td>0 (-12 - 100) NS (n=12)</td>
<td>0 (-40 - 100) NS (n=14)</td>
</tr>
<tr>
<td>Change in Health</td>
<td>0 (-50 - 100) NS (n=16)</td>
<td>0 (-50 - 50) NS (n=14)</td>
<td>0 (-33 - 100) P &lt; 0.1 (n=14)</td>
</tr>
</tbody>
</table>

Table 38. Percentage of possible change in SF-36 scores achieved following the control and training periods. Expressed as median (range).

* Post training compared with post control data
General Health Questionnaire

The scores from the group at each time point for each section of the GHQ are displayed in Appendix 8D.

1. Actual change - There were no significant changes in either the total score or the scores for any of the sub-units over the control period or following 24 weeks of training. There was a decrease in the total score (P < 0.02) after 12 weeks of training (table 39).

2. % of possible change - There were no significant changes in any of the sections over the control period. There was a 16% improvement in the total score after 12 weeks of training (P < 0.05) and of 12% after 24 weeks of training (P < 0.05). After 24 weeks of training there was also a 24% decrease in the score for Anxiety/Insomnia sub-section (P < 0.05) (table 40).
<table>
<thead>
<tr>
<th></th>
<th>Control period</th>
<th>Post 12 weeks training</th>
<th>Post 24 weeks training</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total Score</strong></td>
<td>0 (-4 - 7)</td>
<td>-2.5 (-6 - 2)</td>
<td>-1 (-8 - 16.5)</td>
</tr>
<tr>
<td></td>
<td>NS (n=14)</td>
<td>P&lt;0.02 (n=10)</td>
<td>NS (n=14)</td>
</tr>
<tr>
<td><strong>Sub-units</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Severe depression</td>
<td>0 (-2 - 3)</td>
<td>0 (-2 - 0)</td>
<td>0 (-3 - 5)</td>
</tr>
<tr>
<td></td>
<td>NS (n=14)</td>
<td>NS (n=10)</td>
<td>NS (n=14)</td>
</tr>
<tr>
<td>- Social dysfunction</td>
<td>0 (-1 - 2)</td>
<td>0 (-4.5 - 0.5)</td>
<td>0 (-4.5 - 2)</td>
</tr>
<tr>
<td></td>
<td>NS (n=14)</td>
<td>NS (n=10)</td>
<td>NS (n=14)</td>
</tr>
<tr>
<td>- Anxiety/Insomnia</td>
<td>0 (-5 - 1)</td>
<td>0 (-2.5 - 2.5)</td>
<td>0 (-1.5 - 0.5)</td>
</tr>
<tr>
<td></td>
<td>NS (n=15)</td>
<td>NS (n=12)</td>
<td>NS (n=15)</td>
</tr>
<tr>
<td>- Somatic symptoms</td>
<td>0 (-4 - 7)</td>
<td>0 (-1.5 - 1.5)</td>
<td>0 (-1 - 3.5)</td>
</tr>
<tr>
<td></td>
<td>NS (n=15)</td>
<td>NS (n=12)</td>
<td>NS (n=15)</td>
</tr>
</tbody>
</table>

**Table 39:** Actual changes in scores of GHQ following the control and training periods. Expressed as median change (range).
Control period | Post 12 weeks training | Post 24 weeks training
--- | --- | ---
Total Score 0 (-18 - 10) | -5.5 (-50 - 3) | -11 (-33 - 25)
NS (n=14) | P<0.05 (n=10) | P<0.05 (n=14)

Sub-units

- Severe depression 0 (-100 - 14) | 0 (-100 - 0) | 0 (-100 - 24)
NS (n=14) | NS (n=10) | NS (n=14)

- Social dysfunction 0 (-14 - 14) | 0 (-69 - 3) | 0 (-69 - 14)
NS (n=14) | NS (n=10) | NS (n=14)

- Anxiety/Insomnia 0 (-100 - 15) | 0 (-100 - 12) | 0 (-100 - 35)
NS (n=15) | NS (n=12) | P<0.05 (n=15)

- Somatic symptoms 0 (-57 - 39) | 0 (-100 - 8) | 0 (-60 - 24)
NS (n=15) | NS (n=12) | NS (n=15)

Table 40:- Percentage of possible change in GHQ scores achieved following the control and training periods. Expressed as median change (range).
DISCUSSION

Completion rate

In the present study the questionnaires were given for self-completion, anonymously, at home. This was for two reasons. First, because of time constraints, each testing visit already took at least 1.5 hours. Second, because it was felt that subjects would perhaps be more likely to report their true feelings if they completed the forms anonymously. It has been reported that older people may be less likely to admit to psychiatric morbidity than younger people (Blacker & Clare, 1987).

The completion rate was disappointing. Only 6 subjects had complete data sets, at all time points, for all of the questionnaires used. Completion rates were similar for all of the questionnaires, regardless of length and ease of completion. In pilot work (chapter 4, pg 99) older people had reported no problems in completing the questionnaires. However, on the advice of these subjects some of the questionnaires were enlarged to make them easier to read. Completion rate was excellent at the pre control and 80% at the post control time point, which would suggest that the subjects in the present study also experienced few problem in completing the forms. It is unclear why the completion rate was much worse after 12 and 24 weeks of training.

Hayes et al. (1995) reported that when the SF-36 was self-completed by older people (age 75+), 61% of the respondents omitted one or more of the questions; this was compared to 12% when the questionnaire was interviewer administered. Reasons given were problems of visual impairment, writing difficulty, or difficulties with questions relating to work or vigorous activity. Failure to answer some of the questions did explain some of the missing data in the present study. However, at the pre control visit completion rate was excellent, suggesting that the subjects in this study experienced few problems in completing the questionnaires.

One other possibility is that too many questionnaires were used. Quality of life is made up of different components, and there is no single questionnaire which covers all

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of them. The questionnaires had been chosen to ensure that we covered as many components as possible. Subjects did complain that they felt there were too many to fill in. It is possible that while at the start of the study they took time and care in filling in the forms, they became less careful at later stages.

It is likely completion rate would have been higher if the forms had not been filled in anonymously or if they had been interviewer administered. However, Bowling (1990) suggested that where questionnaires have been designed to be self completed, it is possible that interviewers may bias the responses when assisting elderly people in their completion.

Pre control data

In selecting the questionnaires we chose only those which, in addition to meeting other set criteria, also had proven ability to change in response to an intervention (see chapter 4).

The pre-control data of the subjects showed a skewed distribution towards the better end of the scale, for most of the variables, in all of the questionnaires used. We compared the pre control data from our subjects with available data in the literature, for the GDS, the POMS, the SF-36 and the GHQ. Apart from the GDS, where our subjects scores were similar to those reported from a group of "normal" people aged over 55 (Yesavage et al. 1983), our subjects achieved much better scores, when compared to individuals of a similar age (SF-36 (Ware et al. 1997) and GHQ (Bowling, 1990)) and when compared to younger subjects (POMS (Killen et al. 1988)).

A possible explanation for these findings is that we compared our subjects to samples of the general population for the SF-36 and GHQ, and to younger subjects taking part in a stop smoking self help programme for POMS. It is likely that in the case of the SF-36 and the GHQ in particular these samples would include some individuals with either physical or psychological disorders. In contrast, our subjects were all highly
selected and relatively healthy. In addition, they all volunteered to take part in the study, which perhaps suggests that they had a positive attitude.

Response to training

The good scores achieved at the pre-control time point by the subjects meant that changes as a result of the aerobic training might be difficult to demonstrate, as in some cases there was little room for improvement. For this reason the data were analysed in two ways; the actual changes were calculated but the percentage of possible changes achieved were also calculated.

There is conflicting evidence as whether or not aspects of quality of life can be improved through physical exercise in older people. Some studies have demonstrated an effect of training on psychological variables viz. Hill et al. (1993) in 87 sedentary adults older adults in response to a year long endurance programme and Lavie & Milani (1995) in 199 people aged 65 and over undergoing cardiac rehabilitation. None of these studies included a non exercising ‘attention’ control group. Other studies which have included older people have reported no effect of training on psychological variables viz. Sheldahl et al. (1993) in 60-71 year old men in response to a 6 months training programme; Stanton & Arroll (1996) in mildly hypertensive people aged 26-71 (mean age 55 years) in response to 6 months of training and Stewart et al. (1993) in 194 subjects aged 50-65 (no control group) in response to a 12 month exercise programme.

In the present study actual improvements were seen in the Vigour/Activity subunit of the POMS and the total score of the GHQ following 12 weeks of training, whilst after 24 weeks of training improvements were seen in the pain subunit of the SF-36 and in the Vigour/Activity subunit of the POMS.

At the pre control time point 25% of the older subjects had already achieved the
highest possible score for the Pain subunit of the SF-36. When compared to data in
the literature the scores for pain levels were much better than reported for subjects of
a similar age viz mean of 77 compared to a mean of 61 from a sample of the US
population. Even so, after 24 weeks of training the median score for Pain rose from
81.5 (post control value) to 100 (i.e. best possible score), with 65% of subjects now
achieving a perfect score. Previous studies have also reported improvements in self
perceived pain levels in response to increased exercise levels. Sharpe et al. (1997)
reported improved pain levels in older adults who had attended twice weekly sessions
of low intensity movements for one year whilst Ettinger et al. (1997) reported
improved pain levels in response to an exercise programme in 439 people aged 60 or
over with knee osteoarthritis.

At the pre control time point the mean score for Vigour/Activity subunit of the POMS
was higher than that reported in the literature for a group of adults aged 18-65 years
(i.e. a mean score of 18 compared to a mean of 15 (women) and 9 (men)). In
response to training the median score increased by 3.5 bringing median score to 20.5.
Engels et al. (1998) also reported an increase in self reported vigour in response to
exercise training in older adults (mean age 68.6 years).

We also looked the data in terms of achievement of percentage of possible change.
Looked at in this way some additional improvements were seen following training viz.
improvements in Anger/Hostility (POMS) (after 12 and 24 weeks), Total Mood
Disturbance (POMS) (after 24 weeks), Anxiety/Insomnia (GHQ) (after 24 weeks) and
Total Score (GHQ) (after both 12 and 24 weeks). At the pre control time point there
had been only 4 variables in which no subject achieved a perfect score viz. Total score
and Social Dysfunction (GHQ) and Total Mood Disturbance and Vigour/Activity
(POMS). It is interesting to note that improvements were seen in three of these
variables following training.

However, changes which were seen must be viewed with a degree of caution.
Although there was a control period, because of time and cost restraints there was no
control group during the training part of the study. There is evidence to suggest that it
may not be the exercise per se, but the social contact which increases mood and well-being. Hassmén & Koivula (1997) compared an exercise group with a control group, who instead of physical training did mental tasks and found that the improvement in mood was uniform in both groups. Brown et al. (1995) split a group of 135 men and women in their 50s into 6 groups viz. control; a moderate intensity walking group; a low intensity walking group; a low intensity walking plus relaxation group; a Tai chi group and a ‘mindful’ exercise group. They found improved scores for physical attributes in the moderate intensity walking group after training but the only other changes reported were in the ‘mindful’ exercise group. Here they reported a decrease in tension, depression, anger and confusion and total mood disturbance. Blumenthal (1989) reported improvements in psychological variables in exercisers in comparison with a control group, but they saw the same changes in a group who took part in Yoga and Flexibility group.

We saw a significant improvement in the actual score for the Depression/Depression subunit of the POMS over the control period. In addition when looked at in terms of % of possible change we also saw improvements in Tension/Anxiety (POMS), Depression/Depression (POMS), Confusion/Bewilderment (POMS), GDS score, PGCMS score, and Health Perception (SF-36). These changes would suggest that it is the taking part not the exercise per se which improves psychological functioning. Perhaps even the limited attention the subjects had already received at the pre control visit, or the anticipation of the subsequent exercise programme was enough to improve some aspects of mood as well as to increase morale.

CONCLUSION

In conclusion, although the results must be viewed with a certain degree of caution because of the lack of a attention control group, it seems that training can improve some self perceived psychological variables in the ‘oldest old’. Of particular note is the improvement in pain levels which could have a favourable impact on the quality of life of older individuals. Whether it is the exercise per se. or the social contact which is responsible for the changes seen remains unclear.
CHAPTER TEN

DISCUSSION AND FUTURE WORK

- MEASURING VO$_2$ MAX IN VERY ELDERLY PEOPLE

- CRITERIA FOR THE DETERMINATION OF A MAXIMAL TEST

- MEASURING QUALITY OF LIFE IN OLD AGE

- ENDURANCE TRAINING IN VERY ELDERLY PEOPLE
  - Compliance
  - Physiological adaptations to endurance training in
    the ‘oldest old’ women
  - Comparison of adaptations of the old and young women
  - Physiological adaptations to endurance training in
    the ‘oldest old’ men
  - Effect of endurance training the quality of life of
    the ‘oldest old’

- CONCLUSIONS
MEASURING VO$_2$ MAX IN VERY ELDERLY PEOPLE

Few studies have attempted to obtain true measures of maximal oxygen uptake in very elderly people. Work presented in this thesis has demonstrated that, at least in health, it is possible to obtain a measure of VO$_2$ max in the most individuals in their 80th year and above. It has also confirmed the reproducibility of such tests. The values of VO$_2$ max obtained in the women viz. 14.1 ml.kg$^{-1}$.min$^{-1}$ are similar to those reported by the only other study which has measured VO$_2$ max in women of a similar age viz. 13.6 ml.kg$^{-1}$.min$^{-1}$ in 8 women aged 73 to 86 years (Foster et al. 1986). The subjects in the present study conformed to strict health criteria, and probably represented the most healthy of their age group. The low values of VO$_2$ max which were seen in the women are striking. It seems that even in health, many very elderly women will be using a high percentage of their VO$_2$ max in the performance of everyday tasks. A small, further decrease, such as seen after illness, may render some everyday activities either difficult or impossible to perform, thereby threatening the independence and quality of life of the individual. The importance of aerobic training as a means to increase VO$_2$ max in very elderly women is clear.

CRITERIA FOR THE DETERMINATION OF A MAXIMAL TEST

A variety of criteria to determine if VO$_2$ max has been reached have been used in studies with elderly people (table 5, chapter 3 pg 69). Only Sidney and Shephard (1977b) have attempted to examine criteria for use with older people but the mean age of their subjects was only 63 years. Studies since 1993 (when the present study was designed) which have included very elderly people have continued to use a variety of criteria (Binder et al. 1996; Inbar et al. 1994) to determine if VO$_2$ max has been reached, or have not given the criteria that were used (Harridge et al. 1997). Only de Wild et al. (1995) have justified their choice of criteria. Using the data from those subjects who were judged (subjectively) to have performed a maximal test, we examined available criteria. From this examination it was concluded that there is no clear choice of criteria for determining if a test is truly maximal in old age. It is clear that criteria used when testing younger people are not suitable for use with the 'oldest
old’. Demonstrating a plateau is difficult, predicted maximal heart rate is unreliable, whilst if maximal lactate or respiratory exchange ratio values are to be used as secondary criteria there needs to be some age-adjustment.

Ideally the best way to determine if \( \dot{V}O_2 \) max has been reached is to demonstrate a plateau in oxygen consumption. It is possible that by performing intermittent, instead of continuous tests, a plateau in oxygen consumption may be more easily demonstrated in very elderly people. Possible future work would be to compare the results from continuous and intermittent tests in people aged 80 and over, to determine if a plateau in oxygen consumption is more easily demonstrated when an intermittent test is used.

MEASURING QUALITY OF LIFE IN VERY ELDERLY PEOPLE

There is no single questionnaire which measures all components of quality of life. Thirty six questionnaires were identified for possible use in the training study. Those chosen were those which conformed most closely to requirements viz. performed well in terms of reliability, validity, sensitivity to change, had previously been used with older people, could be self completed, were easy to score and were comprehensive without being too long. A selection of questionnaires were chosen to cover different components of quality of life.

Because the questionnaires were to be used to examine changes in response to training, it was important that the chosen questionnaires had been shown to be sensitive to change. The questionnaires chosen had all demonstrated this ability. However, when the pre control data of the subjects were examined, it was found that as a group our subjects had achieved good scores on all questionnaires, for almost all of the variables. Indeed, compared to samples of the general population of a similar, or younger, age the scores of our subjects were much better. One explanation for this finding is that whilst samples from the population will most likely include those with both physical and psychological problems, the subjects in the present study were all
highly selected, physically healthy people, who by virtue of the fact that they had volunteered to take part in the study could be said to have a positive attitude towards life. It seems that not only were the subjects used physically healthy but they were also mentally healthy. This poses the problem of which questionnaires to use in studies of healthy older people, if changes in response to an intervention are to be demonstrated.

ENDURANCE TRAINING IN VERY ELDERLY PEOPLE

Compliance

The old and young subjects gave differing reasons for dropping out of the study. In the young subjects, job moves, time commitment and personal reasons were the reasons subjects dropped out, while in the old group most 'dropped out' because of illness. This emphasises one of the difficulties in working with such elderly people, not only are suitable subjects difficult to recruit, but subject numbers are likely to be depleted because of illness.

Physiological adaptations to endurance training in very elderly women

The training study reported in this thesis has demonstrated that 24 weeks of progressive aerobic training, using the ratings of perceived exertion scale to prescribe and monitor exercise intensity, can increase the maximal aerobic power of even very elderly women.

The mean pre control value of \( \dot{V}O_2 \) max of the older women was only 14 ml.kg\(^{-1}\).min\(^{-1}\). The improvements seen in \( \dot{V}O_2 \) max and in submaximal indicators of aerobic fitness are clear, everyday tasks will require a lower proportion of \( \dot{V}O_2 \) max and can therefore be performed for longer and with greater ease. In those elderly women who are still independent, such an increase may well provide a safety margin, perhaps preventing \( V_{O_2} \) max levels falling to such a point that independence is put at risk. In those who have already lost an aspect of their independence, such an increase may
improve their everyday functioning and perhaps increase the quality of their everyday lives.

The biopsy data obtained from the older women were disappointing. As part of the training study we wished to obtain muscle biopsy samples for the analysis of enzyme activities (involved in metabolism) and where possible their corresponding mRNA levels. This was to see if the training stimulus had stimulated an increase in mRNA levels and, if so, whether this increase was translated into protein. However, only two women agreed to have biopsies taken before and after training. Difficulties with obtaining biopsies in very elderly women had been foreseen. Indeed, a new technique had been developed which we had hoped would allow us to use a much less invasive method of obtaining muscle samples viz. syringe needle aspiration (Ennion et al. 1994). However, although it was found that samples of muscle obtained with this technique were suitable for PCR, it was not possible to quantify the mRNA in such small samples.

In a recent review Spina (1999) suggested that older men and women (between the ages of 60-75) may adapt to training in different ways and that while in older women an increase in \( \dot{V}O_2 \text{ max} \) is probably due solely as a result of peripheral adaptations, the increase in \( \dot{V}O_2 \text{ max} \) which is seen in older men is largely due to an augmented cardiac output, with only 1/3 of the increase due to a wider a-v difference.

This suggestion makes it all the more disappointing that we did not obtain biopsies in from the older women. Although in the present study a decrease in resting heart (13%) was seen suggesting an increased resting stroke volume (which does not support Spina’s findings) it would have been interesting to determine the extent to which changes in enzyme activities contributed to the improvement seen in \( \dot{V}O_2 \text{ max} \).

Possible future work would be to recruit and train women aged 80 and over, who have specifically agreed to have biopsies taken. However, finding enough suitable subjects to take part in such a study may pose a problem.
Comparison of adaptations of older and younger women.

Although the relative changes of the older and younger women were similar after 24 weeks of training the changes appear to have taken longer to occur in the older women. Whilst the younger women showed a significant average increase of 12% in VO₂ max (ml.kg⁻¹.min⁻¹) after 12 weeks of training, the older women showed no such change. The reasons for this are unclear. Both groups worked within the desired training zone, and although the younger women were shown to have worked at a slightly higher intensity over the 24 weeks, the training intensity used to train the older women would be expected to elicit a change after 12 weeks of training. It seems that whilst even the ‘oldest old’ women can increase their VO₂ max in response to endurance training, with relative increases similar to those reported in younger women, the adaptations may take longer to occur.

The time span of adaptations to endurance training of older women merits further investigation. Possible future work would be to train a group of women aged 80 and over (perhaps using a treadmill or cycle ergometer to determine the precise % of VO₂ max that each individual worked at) and to re-measure VO₂ max at 2 week intervals.

Physiological adaptations to endurance training in very elderly men.

Training had no effect on the VO₂ max of the older men. Similarly, there was no effect of training on resting heart rate and, although there was a decrease in the heart rate at a VO₂ of 10ml.kg⁻¹.min⁻¹ after 24 weeks of training (P<0.05) there had been a significant increase after the control period (P<0.05). There was also no obvious trend towards increasing muscle enzyme activities (in those measured) or in their corresponding mRNA levels.

The reasons why no increase was seen in the VO₂ max of the older men are unclear. Possible explanations for our findings have already been discussed. Although it seems unlikely that older women but not older men are able to adapt to training, as already mentioned Spina (1999) has suggested that older men and women adapt to endurance
training in different ways. No previous study has examined the effect of endurance training on such old men. Although it seems unlikely, it is possible that men of such an age can not adapt to endurance training. This needs further investigation.

It would be interesting to take a group of men aged 80 and over, strictly controlled for activity levels, and train them using a cycle ergometer or treadmill (in order to determine the precise percentage of \( \text{VO}_2 \text{ max} \) they were trained at) to examine the changes in enzyme activities and in resting and peak exercise stroke volume and cardiac output (using doppler echocardiography).

**Effect of endurance training on the quality of life of very elderly people.**

The completion rates of the questionnaires were disappointing in the present study. It is likely completion rate would have been higher if the forms had not been filled in anonymously or if they had been interviewer administered. However, the degree to which the interviewer would have biased the answers remains unclear. The completion rates for the older group at the pre control time were good, suggesting that the subjects experienced few problem in completing the forms. Possibly if the length of the testing visit had been extended with the subjects completing the forms before they left we would have attained more data. This would however, have taken away subject anonymity.

The good scores achieved at the pre-control time point meant that changes as a result of the endurance training would be difficult to demonstrate, as in some cases there was little room for improvement. For this reason the data were analysed in two ways; the actual changes were calculated but the percentage of possible changes achieved were also calculated.

In response to training actual improvements in the Pain subunit of the SF-36 and in the Vigour/Activity subunit of the POMS were demonstrated. The improvement in self-perceived pain was of particular interest. At the pre control time point 25% of the
older subjects had already achieved the highest possible score for this variable. Even so, after 24 weeks of training the median score for Pain rose from 81.5 (post control value) to 100 (i.e. best possible score), with 65% of subjects now achieving a perfect score. Such an improvement in self perceived pain would be expected to have a significant effect on the quality of life of an individual.

When looked at in terms of 'percentage of possible change' after training we also saw improvements in Anger/Hostility and Total Mood Disturbance (POMS); Anxiety/Insomnia and Total Score (GHQ) which would suggest that training may have had a beneficial effect on mood.

However, the results should be viewed with caution as there was no control group and it has been suggested that it is the social contact, not the exercise, which has a positive impact on mood. Over the control period we saw a significant actual improvement in the Depression/Dejection subunit of the POMS and, when looked at in terms of 'percentage of possible change', improvements in Tension/Anxiety, Depression/Dejection and Confusion/Bewilderment subunits of POMS as well as improvements in the Health Perception subunit of the SF-36 and scores of the Geriatric Depression Scale and the Philadelphia Geriatric Morale Scale. This is interesting in that it suggests that even in these mentally healthy older people, the limited attention they had received through the 4 pre control visits, together with the anticipation of taking part in the training classes may have been enough to improve mood and morale. Verbal information from the subjects suggested that many were lonely, indeed, many reported that they volunteered for the study in order to meet new people, as well as to improve their fitness.

However, if taking part in an exercise class can improve psychological functioning whilst at the same time improving physical functioning, so much the better.

Future possible work would be to take a group of mentally less healthy individuals and (using a control group) examine the effects of a physical training programme on components of quality of life.
CONCLUSION

In conclusion the main finding from the work presented in this thesis is that although even in health very elderly women have very low values of \( \dot{V}O_2 \max \), this can be improved in response to 24 weeks of aerobic training. Improvements seen are similar to those reported for younger women, although adaptations may take longer to occur. The implications of this finding are clear; everyday tasks will require a lower proportion of an individual's \( \dot{V}O_2 \max \), and can therefore be performed for longer and with greater ease. The increase may also help to prevent levels of \( \dot{V}O_2 \max \) dropping to such levels that independence is put at risk. In less healthy women such an increase may well improve everyday functioning, thereby improving quality of life.
REFERENCES


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APPENDIX ONE A

Texts of publications arising from thesis
ENDURANCE TRAINING IN THE "OLDEST OLD": THE EFFECT OF 24 WEEKS OF TRAINING

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This work was funded by the Sir Halley Stewart Trust, Research into Aging and Forza Fitness International

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Aerobic training in old age

ABSTRACT

OBJECTIVE: To determine the effects of aerobic training on the maximal aerobic power of healthy, very elderly people. 
DESIGN: The study consisted of a 12 week control period followed by 24 weeks of progressive aerobic training. 
SUBJECTS: 26 men and women aged 79 to 91 years conforming to pre determined health criteria. 
MEASUREMENTS: Measurements taken were maximal aerobic power (VO\textsubscript{2} max), heart rate at an oxygen consumption of 10ml.kg\textsuperscript{-1}.min\textsuperscript{-1} (HR at VO\textsubscript{2} 10), resting heart rate, muscle biopsies for the analysis of enzyme activities and their corresponding mRNA levels, isometric knee extensor strength (IKES), isometric elbow flexor strength (IEFS) and lower limb extensor power (LEP). 
MAIN RESULTS: Pre control values of VO\textsubscript{2} max for the women and men were 14.1 (SD 2.79) and 22.0 (5.12) ml.kg\textsuperscript{-1}.min\textsuperscript{-1} respectively. No significant change was seen in the VO\textsubscript{2} max of either group over the control period. After training there was a 15% increase in the VO\textsubscript{2} max of the women (P < 0.01), no change was seen in the men. In the women, there was no significant change in HR at VO\textsubscript{2} 10 over the control period but a 14% decrease (P < 0.01) was seen after training. In the men there was a 7% (P < 0.05) increase in HR at VO\textsubscript{2} 10 over the control period and a 5% (P < 0.05) decrease after training. No effect of training was seen on IKES, IEFS or LEP of either group. 
CONCLUSION: Progressive aerobic training can increase the maximal aerobic power of very elderly women. A 15% increase in VO\textsubscript{2} max may prevent many elderly women from crossing functionally important thresholds, thereby helping to maintain independence.

Keywords: Maximal aerobic power; Aged, 80 and over; perceived exertion; endurance training, muscle enzymes

Running Head: Aerobic training in old age
INTRODUCTION

The percentage of the population who are elderly (i.e. over 65), is rising worldwide. In most developed countries the fastest growing age segment of the elderly population is those aged 80 and over. Although people are tending to live longer, the quality of these 'extra' years may be poor. Whilst in youth most physiological functions have a generous spare capacity, increasing age is characterized by a progressive erosion of these 'safety margins'. Maximal aerobic power or maximal oxygen uptake (VO$_2$ max) is an important component of fitness. It depends upon the capacity of the lungs and the cardiovascular system to provide the working muscles with oxygen and on the ability of those muscles to extract and utilize the oxygen provided. Both cross-sectional and longitudinal studies have demonstrated a decline in VO$_2$ max with advancing age. Many elderly people, in particular women, have such low values of VO$_2$ max that it would need only a small, further reduction to render some everyday activities either unpleasant or impossible to perform.

VO$_2$ max can be increased in younger adults in response to endurance training. Studies in younger old subjects (mean ages 70-74 years) have also reported that VO$_2$ max can be improved with training. No controlled study has looked at the effects of training in subjects over 80 years of age, who are arguably those who would benefit most from an improvement in VO$_2$ max. Pilot work (unpublished) had suggested that older women may not respond to endurance training in the same way as younger people. The purpose of the present study was to examine the effects of 24 weeks of endurance training on VO$_2$ max, and submaximal indicators of aerobic fitness in very elderly men and women.

METHOD

Subjects and Study design

The study had received approval from the Royal Free Hospital ethical practices subcommittee and all subjects gave written informed consent. Potential subjects (i.e. those in their 80th year and above), were recruited from a volunteer data base, through an article in a local newspaper and by word of mouth. All subjects underwent an initial assessment which included the completion of health questionnaires, measurement of resting blood pressure and a resting electrocardiogram (ECG). Only those subjects who met previously defined criteria for 'healthy' or 'medically stable' were included. Of the 80 subjects who volunteered only 34 proved suitable for inclusion. These subjects went on to have a medically supervised exercise ECG. On the basis of this test 5 further subjects were excluded. A further 3 subjects 'dropped out' before the training began. Of the 26 subjects who commenced training 5 failed to complete training; two subjects "dropped out" due to illness unrelated to the study, one was diagnosed with Alzheimer's disease during the study, one found the time commitment too great and one whose previous knee problem may have been aggravated by the exercises. Subject characteristics...
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for those completing the study are displayed in \textit{table 1}

All subjects were familiarised with the procedures on two visits to the laboratory (during which the assessment and exercise ECG took place) prior to definitive measurements being made. Each subject then performed a progressive maximal effort test on each of three separate occasions, separated by at least 3 days. The best of these tests was taken as the pre control value. Measurements were taken before and after the 12 week control period and after 24 weeks of training. At each testing point all subjects were assessed within a 16 day testing period for all variables except muscle biopsies; all subjects agreeing to this part of the study had biopsies taken within a 21 day period. Subjects were asked to maintain current activity levels over the control period and throughout training. In addition, because a spontaneous increase in activity over the summer months could conceivably improve any of the variables we were to measure, we allowed for time of year effects by splitting the group into two parts, with half of the group starting to train after the first half had finished.

\textit{Variables measured}

\textbf{Aerobic power}

Preliminary work had confirmed the feasibility, and reproducibility of maximal tests in very old age. 

Subjects were asked to abstain from any caffeine intake (i.e. coffee, tea or chocolate) for at least 2 hours prior to the test. For each individual subject, tests were performed at the same time of day on each occasion and at the same laboratory temperature. Each test was supervised by the same two testing staff, both of whom had been trained in cardiopulmonary resuscitation. Resting heart rate was taken after each subject had rested on a couch for 10 minutes. An electrically braked cycle ergometer (Cybex) was chosen for the study as it provided stability for the more frail subjects and allowed ancillary measurements to be easily taken.

Tests for each subject had been tailored from preliminary tests to try to get each subject to maximum within 10-12.5 minutes. Tests started at a work rate of 25W and progressed in either 15W or 25W increments every 2.5 minutes until the subject could no longer continue, despite urging from testing staff.

Expired gas was collected via a nasal and mouthbreathing face mask (Hans Rudolph type 7930 or 7940). Expired gas passed into a mixing chamber from which samples were drawn through gas analyzers. Heart rate (Hewlett Packard), \( CO_2 \) concentration (infra red; PK Morgan), \( O_2 \) concentration (paramagnetic; PK Morgan) and inspired volume (Harvard dry gas meter) were measured during the last minute of a 2.5 minute rest period, every 30 seconds during exercise and at peak exercise. ECG was
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monitored continuously (Datascope) for safety reasons. The CO$_2$ and O$_2$ analyzers were calibrated using room air and two different gas mixtures of known concentrations. The dry gas meter was calibrated by pumping through known gas volumes using a 1 litre syringe (PK Morgan).

Fingertip samples (intact whole blood) were taken (where possible) in the last 30 seconds of each stage, at peak exercise and 5-7 mins post exercise. These were analyzed for lactate concentration (LM5 Analox Instruments). The analyzer was calibrated using two samples of known lactate concentration; a lactate/pyruvate quality control serum and a lactate standard (both Analox Instruments).

Traditional criteria used for determining if VO$_2$ has been reached in young people may not be suitable for use with older people. Many older people are unable to demonstrate a plateau in oxygen consumption, predicting maximal heart rate, unreliable at all ages, may become more so with age and maximal RER and Lactate values decrease with age. For purposes of this study a test was considered to be maximal if RER $\geq 1$ and the subject was judged to have performed a 'maximal effort' test.

The heart rate at a VO$_2$ of 10mls.kg$^{-1}$.min$^{-1}$ was calculated by using an equation derived by linear regression (for each individual subject) from the relationship between oxygen consumption and heart rate with increasing work rates.

Muscle Biopsies

Biopsies were taken from the lateral part of the Quadriceps Femoris using a UCH skeletal muscle biopsy needle. Two biopsy samples were taken from each subject, through the same incision, one for analysis of enzyme activities and one for analysis of mRNA levels for the enzymes selected. The former were frozen in liquid nitrogen, wrapped in tin foil and stored in capped cryotubes in liquid nitrogen. Samples for later analysis of mRNA were mounted on a cork block, frozen in melting isopentane pre-cooled in liquid nitrogen and stored in liquid nitrogen until analysis.

Enzyme analysis: Cytochrome C oxidase (CCO), 3-Hydroxyacyl CoA dehydrogenase (HAD) and Phosphofructokinase (PFK) were chosen to represent different energy pathways and because it was possible to measure corresponding mRNA levels. Lactate dehydrogenase (LDH) was also measured, although it was not possible to measure mRNA levels for this enzyme as too many isoforms of this enzyme exist.

Enzyme assays

Samples were weighed, transferred to Potter-Elvehjem homogenisers containing a 100-fold volume of ice-cold 50% glycerol containing 20 mM sodium phosphate buffer, pH 7.4, 5mM $\beta$-mercaptoethanol, 0.5mM ethylenediaminetetraacetic acid (Na$_2$ EDTA) and 0.02% bovine serum albumin (BSA) and homogenised for 30 seconds.

Phosphofructokinase (PFK) and Lactate dehydrogenase (LDH) were measured on the
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fresh homogenates without further storage. Aliquots of homogenate were kept on ice and assayed for PFK and LDH activity within 30 minutes. For the other enzymes, aliquots of the homogenates were stored at -70°C prior to analysis. All of the homogenate assays for a given enzyme were carried out in duplicate on the same day at 30°C.

Homogenate PFK activity was determined as described by Opie and Newsholme 16. For LDH, a Sigma Diagnostics kit (Procedure No. 228-UV, Sigma-Aldrich Co Ltd, Poole, Dorset, UK) was used.

The activity of 3-Hydroxyacyl-CoA dehydrogenase (HAD) was determined by a spectrophotometric modification of the fluorometric method described by Chi et al. 17 whilst Cytochrome C oxidase (CCO) was determined using the polarographic method as described by Henriksson et al. 18.

Measurement of mRNA

RNA was isolated from cryosections by a scaled down version of the method described by Choczynski and Sacchi 19. Sixty 10μm cryosections yielded approximately 30-50μg of total RNA. A 1μl aliquot of each sample was run on a RNA gel to check no degradation of RNA had occurred during storage or preparation. Three dilutions of each RNA sample were prepared in 10mM NaOH, 1mM EDTA to give final volumes of 500μl containing 16,8 and 0.8μg of RNA. Samples were loaded via slot blot apparatus onto Zeta probe nylon membrane (BioRad) according to the manufacturer's instructions.

Preparation of cDNA probes:- Polymerase chain reactions (PCR) using gene specific primers for 1. Cytochrome C oxidase subunit VIIa (COX7a); 2. Phosphofructokinase (PFK), 3. 3-Hydroxyacyl-CoA dehydrogenase alpha sub-unit (COA),4. ribosomal protein (S26) were performed on oligo dT primed human muscle cDNA essential by the methods described in Ennion et al. 20. The PCR primers used and the regions of the respective genes they amplify are given in table 2. PCR products were then cloned into pCR 2.1 plasmid (Invitrogen) and sequenced to verify that they contained the correct gene sequence.

Hybridisation:- Plasmid constructs were linearized with the appropriate restriction enzyme and labelled with [Ö-32P] dCTP (Amersham) by specifically priming with either Sp6 or T7 primer to facilitate labelling of only the full length antisense strand. Slot blots were hybridised with labelled probe according to the method of Church and Gilbert 21. Hybridisation and washing was performed at 10°C below the calculated melting temperature of the probe (75,70,70,and 72°C for COX7a, S26, PFK and COA respectively). After washing, membranes were exposed to a phosphorimaging screen (Molecular Dynamics) for 18 hours.

Quantification of message:- Phoetoimages of the slot blots were analysed using ImageQuant software (Molecular Dynamics) to give a value of the number of counts
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per slot in arbitrary units. Value for COX7a, PFK and COA were normalised against the value for S26. This ribosomal subunit has been shown to act as a good invariant control for gene expression studies and is a better standard than the 18S of 28S subunits which are known to vary under some conditions 22.

Isometric Knee Extensor Strength

Voluntary isometric knee extensor strength (IKES) was measured as described by Edwards et al. 23. Each subject was asked to perform at least 3 maximal contractions, of several seconds duration, (in each leg), with a rest period between each contraction. IKES was taken as the best of the 3 recorded efforts (taken as the maximal force held for at least 1 second) for each leg.

Isometric Elbow Flexor Strength

Voluntary isometric elbow flexor strength (IEFS) was measured as described by Höök and Tornvall 24. The subject was asked to make at least 3 maximal contractions, of several seconds duration (per arm), with a rest period in between each contraction. IEFS was taken as the highest value recorded (taken as the maximal force held for at least one second) for each arm.

Explosive Lower Limb Power

Lower limb extensor power (LEP) was measured using the Nottingham Power Rig 25,26. The subject was asked to push down on the pedal as hard and as fast as they could. Each subject was given several attempts (minimum of 5 per leg), with a rest period between pushes, until a plateau was reached. LEP was taken as the highest value recorded for each lower limb.

Exercise training

Each subject was asked to attend three of six exercise sessions per week over a 24 week period. The exercise sessions consisted of a consistently formatted progressive exercise to music programme. The total length of each session was approximately one hour and comprised warm up, aerobic training, warm down, and strength training, flexibility and relaxation components. The various components were adapted from those commonly used for younger people according to accepted best practice, as described below:-

Warm up:- Using a longer warm up for older people has been suggested 27,28 to minimize the risk of inducing cardiac arrhythmias 29 and to allow sufficient time to mobilize joints which may be stiffer in many elderly people 30,31. The warm - up component of the session was designed to last 13-15 minutes.

Aerobic component:- At week one a great deal of the session was spent in teaching routines. The aerobic component was built up gradually over the first 6 weeks, lasting 13 minutes at week two, 17 minutes at week four and 20 minutes by week six. After
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week six the intensity of the aerobic exercise was increased progressively by increasing the intensity of the routines to ensure that subjects continued to work at the required training intensity.

Training intensity:- For the purpose of the present study training intensity was set using the Ratings of Perceived Exertion (RPE) Scale \(^{32}\), using an RPE between 13 and 15. The RPE has been shown to be effective in prescribing exercise in both younger and older individuals \(^{33-35}\). All subjects had been thoroughly familiarised with its use during their pre control tests. In addition, the use of the scale was explained at regular intervals throughout the training programme. During the aerobic component of each session subjects were shown the RPE scale and asked to rate how hard they were working. If necessary the intensity of the exercise was adjusted, by giving alternatives, for individual subjects to increase or decrease the intensity of the exercise.

Heart rates were also monitored (Polar Sportstester) in each subject in at least one session per week, in order to compare RPE levels with \(\%\) of HRmax and \(\%\) HRR in those subjects who had performed a maximal effort test.

Warm down:- A longer warm down than is normally used with younger people has been suggested to maintain central venous return, thus reducing the likelihood that fainting or arrhythmias will develop \(^{28}\). The warm down component lasted for 10 minutes.

Strength training, flexibility and relaxation :- This component lasted for 10 to 15 minutes. Resistance for strength training was provided initially by body weight e.g. squats (achieved by getting up and down from chair) and wall press ups and by the use of different grades of theraband (Nottingham Rehab) while later in the programme the use of therabands was supplemented (in all but one subject) by the use of body bars (Forza Fitness International) which provided more resistance.

STATISTICAL ANALYSIS

Data for \(\dot{V}O_2\) max, HR at \(\dot{V}O_2\) of 10mls.kg\(^{-1}\).min\(^{-1}\), IKES, IEFS and LEP.

The data for these variables at each time point were examined using analysis of variance (ANOVA) for the presence of a treatment effect. If a treatment effect was identified then the \(\%\) change over the control period was calculated for each subject and analysed using non parametric Wilcoxon signed rank test \(^{36}\). If there was no significant change over the control period then pre and post control data were averaged. The change (\(\%\)), from the mean of pre and post control, over the training period was then calculated for each subject and analysed using non parametric Wilcoxon signed rank test. If a significant change was found over the control period then post control data (i.e. not the average of pre and post control) were used as the starting point for calculating the changes (\(\%\)) over the training period \(^{37}\).
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Enzyme and mRNA levels
Because of the small number of subjects who agreed to biopsies it was not possible to do statistical analysis for these data.

RESULTS

Attendance

There was no significant difference (P > 0.1; CIA -20.5 to 5.11) between the average number of sessions attended by the men (median 71% range 44-100) and the number attended by the women (median 65% range 46-88)(un-paired T test )36.

Exercise intensity

The mean RPE for men and women for each week of training are displayed in figure 1. Whilst the mean RPE for the older women was within the desired training zone by week 2, this was not achieved by the men until week 4. Although after week 4 the mean RPE of both the men and women was within the desired training zone, overall the women were found to have worked at a slightly higher intensity than the men (P < 0.01; CIA -1.58 to -.00379).

Heart rate monitoring during training was not possible in one of the women. In those subjects who had performed a maximal test, and in whom heart rate monitoring during training was possible (8 men and 8 women) the percentage of HRmax, and the percentage of HRR achieved during the aerobic component at an RPE of 14 were calculated. In the women an RPE of 14 corresponded with 81% of HRmax and 63% of HRR, whilst in the men it corresponded to 79% of HRmax and 66% of HRR.

Maximal oxygen uptake

Collection of expired gas for analysis was not possible in one subject after either 12 or 24 weeks of training because of increasing intolerance of the face mask.

\( \dot{V}O_2 \) max data were obtained in nine women and eight men table 3. Analysis of variance (ANOVA) confirmed a ‘treatment’ effect in the \( \dot{V}O_2 \) max of the women (P < 0.05) but not the men (P > 0.75). In the women there was no significant change in \( \dot{V}O_2 \) max over the control period (P > 0.1), but there was a 15% mean increase, when expressed as mls.kg\(^{-1}\).min\(^{-1}\), (P < 0.01), and a 13% mean increase when expressed as l.min\(^{-1}\) (P < 0.02) in \( \dot{V}O_2 \) max following training.

ANOVA failed to demonstrate a ‘treatment’ effect in either the men or women in terms of HRmax (P > 0.25 and P > 0.5), RERmax (P > 0.5 and P > 0.5) or lactate max
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(LAmax) (P > 0.25 and P > 0.75) table 3.

**Heart rate at an oxygen consumption of 10 mls.kg⁻¹.min⁻¹**

In two of the women it was not possible to measure the HR at \( \dot{V}O_2 \) of 10mls.kg⁻¹.min⁻¹ as tests were too short to perform linear regression.

ANOVA confirmed a ‘treatment’ effect in both the men (P < 0.01) and the women (P < 0.005) table 4. In the women there was no significant change in the HR at \( \dot{V}O_2 \) of 10mls.kg⁻¹.min⁻¹ over the control period (P > 0.1), but there was a 14% mean decrease (p < 0.01) following training. In the men there was a 7% mean increase (p < 0.05) in the HR at \( \dot{V}O_2 \) of 10mls.kg⁻¹.min⁻¹ over the control period. Post training data were therefore compared with post control data. Following training there was a 9% mean decrease (P < 0.05) in HR at \( \dot{V}O_2 \) of 10mls.kg⁻¹.min⁻¹.

**Resting heart rate**

ANOVA confirmed a ‘treatment’ effect in the resting heart rate of the women (P < 0.001) but not of the men (P > 0.5). In the women there was no significant change in resting heart rate over the control period (P > 0.1) but there was a 13% decrease (P < 0.01) after training table 4.

**Muscle enzyme levels**

**Biopsy samples**

At the commencement of the study all subjects were asked if they would be willing to have muscle biopsy samples taken before and after the control period and after 24 weeks of training. Only 6 of the men and 3 of the women agreed to this part of the study. After the pre control biopsy one of the women declined to have any further samples taken. In addition, 3 subjects (2 men and 1 woman) agreed to have only one further sample taken, at the end of the training period.

**Enzyme activity and mRNA levels**

Low subject numbers meant that it was not possible to perform statistical analysis. Figures 2 and 3 depict results for each individual subject, for each enzyme (figure 2) and, where possible, its corresponding mRNA (figure 3).

Enzyme activities

There was no clear trend towards either an increase or decrease for any of the
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enzymes measured in the men. Both of the women showed a slight increase in HAD levels following training, but no other trend was seen.

mRNA levels
There was no clear trend in the responses of the men in terms of mRNA levels for any of the enzymes measured. In the two women all that was seen was a trend towards increasing levels of COX mRNA.

There was no correlation between the changes of enzyme activities and the changes of the corresponding mRNA levels.

Muscular strength and power

Data are presented for the stronger (as measured at the pre control point) legs and arms and for the most powerful (as measured at the pre control time point) lower limb.

ANOVA failed to demonstrate a 'treatment' effect in either the men or the women in terms of IKES (P > 0.50 and P > 0.10) or the LEP (P > 0.50 and P > 0.10) (table 5). ANOVA also failed to demonstrate a 'treatment' effect in the LEFS of the women (P > 0.50) but a 'treatment' effect was demonstrated in the men (P < 0.05). There was no significant change in IEFS of the men over the control period (P > 0.1), but there was a 22.5% increase in IEFS following training which approached significance (P = 0.1).

DISCUSSION

The 15% increase in the $\bar{VO}_2$ max of the women indicates that the ability to respond to a progressive aerobic training programme is maintained even in women in their 80s.

Training intensity was set using the RPE scale. However, heart rates were also monitored so that comparisons of RPE and its corresponding %HRmax and %HRR could be made. Analysis of data showed that the subjects worked at a mean RPE of 14 throughout the training period. American College of Sports Medicine guidelines equate an RPE of 14-15 to 80-89% HRmax and to 75-84% HRR or $\bar{VO}_2$ max in younger people, with the assumption that exercise intensities using a %HRR are numerically equivalent to those using a %$\bar{VO}_2$ max. However, there is evidence to suggest that %HRR represents a higher than expected percentage of %$\bar{VO}_2$ max
and that using %HRR to prescribe exercise intensity may result in older individuals working at a higher than intended intensity. In the present study (in those subjects who had performed a maximal test), an RPE of 14 equated to 81% of HRmax but to only 63% of HRR.
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The women’s mean pre training value of VO\textsubscript{2} max of 14.0 ml.kg\textsuperscript{-1}.min\textsuperscript{-1} is similar to that to that reported by Foster et al.\textsuperscript{14} in a group of 8 women aged 73-86 years viz. 13.6 ml.kg\textsuperscript{-1}.min\textsuperscript{-1}. The subjects in the present study were all relatively healthy and were all still living independently; such a low VO\textsubscript{2} max would suggest that even in health the majority of women aged over 80 will experience difficulties in the performance of everyday tasks. For example the oxygen cost of walking at 2mph is reported to be approximately 9ml.kg\textsuperscript{-1}.min\textsuperscript{-1}.\textsuperscript{41} For prolonged walking to remain comfortable, the oxygen cost probably needs to be less than 50% of the weight specific maximal aerobic power.\textsuperscript{42} That is, one would need a VO\textsubscript{2} max of 18ml.kg\textsuperscript{-1}.min\textsuperscript{-1} to walk comfortably at this speed. From the data in this study it seems likely that walking comfortably at even 2mph is impossible even for healthy 80-year-old women.

The mean increase in VO\textsubscript{2} max of 15% seen in the women of the present study is similar to that reported in studies of ‘younger’ old women. Warren et al. (1993) reported an increase in VO\textsubscript{2} max of 12.6% in response to a 12 week exercise programme,\textsuperscript{7} Cress et al. (1991) an increase of 16% in response to 50 weeks of training,\textsuperscript{6} Foster et al. (1989) reported a 15% increase in response to a moderate exercise programme lasting 10 weeks in women aged 67-89 years (mean age 78 yrs), however, this study was not adequately controlled\textsuperscript{43}.

The decrease in the resting heart rate and heart rate at a VO\textsubscript{2} of 10 ml.kg\textsuperscript{-1}.min\textsuperscript{-1} which were also seen in response to training would indicate that the ability to maintain a submaximal task had improved.

In younger people, one of the adaptations which is seen in response to aerobic training is a change in muscle enzyme activities, which are concerned with metabolism. These changes are characterised by a slight decrease in glycolytic enzymes; for example LDH\textsuperscript{44}, and a marked increase in mitochondrial respiratory enzymes.\textsuperscript{45-47} Studies with older people report conflicting findings. Coggan et al.\textsuperscript{48} reported a decrease in LDH activity, and an increase in HAD activity in a group of 23 men and women aged 60-70 years undergoing a 9 to 12 month training programme. PFK activity was reported to be unchanged. Berthon et al.\textsuperscript{49} reported a small (but non significant) increase in HAD activity, and significant increases in hexokinase and citrate synthase activities in 14 men aged 55-73 year in response to a 6 week programme. Örlander et al.\textsuperscript{50} reported an increase in CCO, PFK and LDH activities, but a decrease in HAD activity in 5 men aged 70-75 years undergoing a 12 week training programme whilst Suominen et al.\textsuperscript{51} also reported an increase in LDH levels in 31 men aged 56-70 years undergoing an 8 week predominantly aerobic training programme, whilst also reporting an increase in malate dehydrogenase activity. No study has examined the effects of aerobic training on mRNA levels for those enzymes involved in metabolism. Puntschart et al.\textsuperscript{52} compared levels of mRNA for enzymes involved in metabolism in sedentary men and endurance athletes and reported increased levels of both mitochondrially encoded RNA and nuclear encoded RNA in the endurance athletes when compared to the sedentary men.
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As part of the present study we wished to take muscle biopsy samples for analysis of both enzyme activities, and where possible, their corresponding mRNA levels. In the women the biopsy data were disappointing. Only 2 women agreed to this part of the study.

In those women there was a tendency towards an increase in HAD activity following training with no trend seen in PFK, CCO or LDH activities. In mRNA levels there was a tendency towards increased levels of mRNA for CCO and PFK. There was no relationship between the changes in enzyme activities and in their corresponding mRNA levels.

In the present study no changes were seen in response to training in the men with respect to $\dot{V}O_2max$, submaximal indicators of aerobic fitness or in enzyme or mRNA levels. The reasons for this are unclear. There was no significant difference between the older men and women in attendance levels. It seems unlikely that older women, but not men are able to respond to training.

There is nothing in the literature regarding changes in $\dot{V}O_2max$ in response to training in men aged 80 or over. In ‘younger’ old age groups increases in $\dot{V}O_2max$ have been reported in response to training in men and in mixed groups viz. Cunningham et al. (1986) in 60-65 year old men (mean age 63 years) 53; Tonino and Driscoll (1988) in 62-79 year old men and women (5 men and 4 women, mean age 70 years) 4; Seals et al. (1984) in 24 men and women aged 61-67 years (mean age 63 years) 52 and Hagberg et al. (1989) in 70-79 year old men and women 5 (mean age of subject 72 years but percentage of the subjects who were men not reported).

The pre training $\dot{V}O_2max$ of the men viz. 22.2 ml.kg$^{-1}$.min$^{-1}$ was significantly higher than that of the women. Data from the English National Fitness Survey 42 suggest that on average, at each equivalent age, a woman’s $\dot{V}O_2max$ (expressed as mls.kg$^{-1}$.min$^{-1}$) will be approximately 77% of a man’s. In the present study the $\dot{V}O_2max$ of the women was 64% of the man’s. It is possible that the men were already more highly trained than the women.

There are few data regarding the $\dot{V}O_2max$ of the oldest old men. Harridge et al. (1997) report a $\dot{V}O_2max$ of 27mls.kg$^{-1}$.min$^{-1}$. in four men aged 80 and over who were all still participating in sport 55, whilst de Wild et al. (1995) 56 reported a $\dot{V}O_2max$ of 26.8 ml.kg$^{-1}$.min$^{-1}$. in active men (mean age 77 years) participating in the Nijmegen 4-day march. It therefore seems unlikely that our men were very highly trained.

Another possible explanation why no changes were seen in the men is that perhaps they were not worked hard enough. The mean RPE for the men over 24 weeks of training was 13.6. Although the men worked within the desired training zone consistently after week 3, when the older men and women were compared the women were found to have been working at a slightly higher intensity overall ($p<0.01$). However, an RPE of 13-14 (in those performing a maximal test) equated to 59%-66% of HRR and 77%-79% of HRmax. It would be expected that working at this intensity
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would be sufficient to elicit a training response.

One other possible explanation is that some of the men may have dropped some of their regular physical activities to accommodate the training classes. Although all subjects were asked to maintain current activities throughout the study, no written record of activity levels was made. However, verbal feedback throughout the training programme from subjects indicated that those who participated in regular activities, (mainly golf and swimming), continued to do so throughout the training period.

The reasons why the men showed no adaptation merits further investigation.

Although the primary aim of the study was to determine the effects of training on VO$_2$ max a small strength training component was also included in the programme. It seems that while including 10 minutes of strengthening exercise into an aerobic programme with frail elderly women is enough to elicit improvements in strength and power $^{57}$, it is not sufficient to induce improvements in healthy very elderly people.

In conclusion, the present study has demonstrated that 24 weeks of predominantly aerobic training can increase the maximal aerobic power of very elderly women. The relative increases seen are similar to those reported for younger subjects. This finding could have major implications for older women, increasing VO$_2$ max may well prevent many older women for crossing functionally important thresholds thereby helping them to maintain their independence and avoid fatigue in everyday activities.

ACKNOWLEDGEMENTS

The authors would like to thank all the subjects who participated in the training programme for their time and commitment to the study

REFERENCES


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42. Skelton DA, Young A, Walker A, Hoinville E, The members of Activity & Health Research: *Physical Activity in Later Life; a Further Analysis of Physical Activity and Fitness Data for Adults aged 50 and Over, Collected in the Allied Dunbar National Fitness Survey and the Health Education Authority National Survey of Activity and Health*, London, Health Education Authority; 1999:

43. Foster VL, Hume GJE, Byrnes WC, Dickinson AL, Chatfield SJ. Endurance training for elderly women - moderate vs low intensity. *J Gerontol* 1989; 44; No 6; M184-M188


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<td><strong>Men (n=9)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Range</td>
<td>80-87</td>
<td>1.6-1.8</td>
<td>58.5-85.5</td>
</tr>
<tr>
<td>- Median</td>
<td>80</td>
<td>1.69</td>
<td>68.0</td>
</tr>
<tr>
<td>- Mean (SD)</td>
<td>81 (0.06)</td>
<td>1.69</td>
<td>68.0 (8.3)</td>
</tr>
<tr>
<td><strong>Women (n=12)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Range</td>
<td>79-91</td>
<td>1.5-1.65</td>
<td>44-65.5</td>
</tr>
<tr>
<td>- Median</td>
<td>82</td>
<td>1.56</td>
<td>55.9</td>
</tr>
<tr>
<td>- Mean (SD)</td>
<td>84 (0.05)</td>
<td>1.58</td>
<td>56.5 (6.0)</td>
</tr>
</tbody>
</table>

**Table 1:** Pre-control characteristics of the subjects who completed training
Aerobic training in old age

<table>
<thead>
<tr>
<th>Gene</th>
<th>Forward PCR primer</th>
<th>Reverse PCR primer</th>
<th>EMBL</th>
<th>Region</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>database</td>
<td>cloned*</td>
<td>(base pairs)</td>
</tr>
<tr>
<td>COX7a</td>
<td>5'actccgccccagggacagg3'</td>
<td>5'gttattgacacttgtagctcagg3'</td>
<td>M83186</td>
<td>16-331</td>
<td>315</td>
</tr>
<tr>
<td>PFK</td>
<td>5'ggcccatctcataaatatcc3'</td>
<td>5'tgcaaggtacagaataaaag3'</td>
<td>M260066</td>
<td>2313-2542</td>
<td>229</td>
</tr>
<tr>
<td>COA</td>
<td>5'tatggcgccacagatgtggac3'</td>
<td>5'gaggggtgcctcaggatggctttag3'</td>
<td>D16480</td>
<td>2197-2604</td>
<td>407</td>
</tr>
<tr>
<td>S26</td>
<td>5'aagcgacgtctcataatagccagtgcctag3'</td>
<td>5'gtctaaatccaaggggtggtcttc3'</td>
<td>X69654</td>
<td>187-330</td>
<td>143</td>
</tr>
</tbody>
</table>

*Region cloned corresponds to the sequence positions in the respective database accession file.*
Aerobic training in old age

<table>
<thead>
<tr>
<th></th>
<th>Pre control</th>
<th>Post control</th>
<th>Post training</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>VO₂ max (mls.kg⁻¹.min⁻¹)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Men</td>
<td>22.2 (5.8)</td>
<td>21.8 (5.4)</td>
<td>22.2 (6.2)</td>
</tr>
<tr>
<td>Women</td>
<td>14.5 (2.5)</td>
<td>13.8 (3.7)</td>
<td>16.2 (3.1)</td>
</tr>
<tr>
<td><strong>VO₂ max (L.min⁻¹)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Men</td>
<td>1.51 (0.29)</td>
<td>1.49 (0.30)</td>
<td>1.47 (0.28)</td>
</tr>
<tr>
<td>Women</td>
<td>0.83 (0.14)</td>
<td>0.79 (0.20)</td>
<td>0.91 (0.17)</td>
</tr>
<tr>
<td><strong>HRmax (bpm)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Men</td>
<td>143 (20)</td>
<td>138 (17)</td>
<td>137 (20)</td>
</tr>
<tr>
<td>Women</td>
<td>130 (16)</td>
<td>126 (14)</td>
<td>129 (17)</td>
</tr>
<tr>
<td><strong>RERmax</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Men</td>
<td>1.08 (0.05)</td>
<td>1.1 (0.10)</td>
<td>1.07 (0.07)</td>
</tr>
<tr>
<td>Women</td>
<td>1.06 (0.05)</td>
<td>1.02 (0.08)</td>
<td>1.03 (0.11)</td>
</tr>
<tr>
<td><strong>LAmax mmol.1⁻¹</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Men*</td>
<td>4.3 (0.7)</td>
<td>4.6 (1.4)</td>
<td>4.9 (1.5)</td>
</tr>
<tr>
<td>Women**</td>
<td>3.5 (1.0)</td>
<td>3.3 (0.7)</td>
<td>(3.3 (1.4)</td>
</tr>
</tbody>
</table>

Table 3:- VO₂ max, HRmax and RERmax values at each time point, for the 8 men and 9 women who performed maximal tests.
Expressed as mean (standard deviation). *n=7 ** n=6
Aerobic training in old age

<table>
<thead>
<tr>
<th></th>
<th>Pre control</th>
<th>Post control</th>
<th>Post 24 weeks training</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>HR at $\dot{V}O_2$</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10mls.kg$^{-1}$.min$^{-1}$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Men</strong> (n=9)</td>
<td>91 (10)</td>
<td>97 (11)</td>
<td>89 (10)</td>
</tr>
<tr>
<td><strong>Women</strong> (n=9)</td>
<td>107 (12)</td>
<td>108 (21)</td>
<td>92 (15)</td>
</tr>
<tr>
<td><strong>Resting heart rate (bpm)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Men</strong> (n=9)</td>
<td>74 (10)</td>
<td>75 (12)</td>
<td>71 (13)</td>
</tr>
<tr>
<td><strong>Women</strong> (n=11)</td>
<td>75 (8)</td>
<td>73 (7)</td>
<td>61 (20)</td>
</tr>
</tbody>
</table>

Table 4: Heart rate at $\dot{V}O_2$ of 10mls.kg$^{-1}$.min$^{-1}$ and resting heart rates, of the group. Expressed as mean (standard deviation).
Aerobic training in old age

<table>
<thead>
<tr>
<th></th>
<th>Pre control</th>
<th>Post control</th>
<th>Post training</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>IKES (N)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stronger leg</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Men (n=9)</strong></td>
<td>356 (115)</td>
<td>359 (135)</td>
<td>340 (74)</td>
</tr>
<tr>
<td><strong>Women (n=11)</strong></td>
<td>239 (54)</td>
<td>250 (74)</td>
<td>264 (60)</td>
</tr>
<tr>
<td><strong>IEFS (N)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stronger arm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Men (n=9)</strong></td>
<td>194 (35)</td>
<td>179 (51)</td>
<td>209 (62)</td>
</tr>
<tr>
<td><strong>Women (n=10)</strong></td>
<td>138 (29)</td>
<td>134 (29)</td>
<td>136 (21)</td>
</tr>
<tr>
<td><strong>LEP (W)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>More powerful leg</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Men (n=9)</strong></td>
<td>139 (46)</td>
<td>138 (46)</td>
<td>144 (48)</td>
</tr>
<tr>
<td><strong>Women (n=11)</strong></td>
<td>75 (24)</td>
<td>71 (33)</td>
<td>79 (25)</td>
</tr>
</tbody>
</table>

**Table 5:**- Isometric knee extensor strength (IKES), Isometric elbow flexor strength (IEFS) and lower limb explosive power (LEP) at each time point.

Expressed as mean (standard deviation).
The physiology of physical performance and training in old age
Katie Malbut-Shennan and Archie Young

Introduction
The benefits of exercise in the prevention of cardiovascular disease and in cardiac rehabilitation are well known. Even in patients with heart failure, in whom rest was previously advocated, training can increase exercise tolerance [1].

However, if we are going to increase the use of physical activity in the rehabilitation of older cardiac patients we must first understand the changes in physical performance which come with increasing age, their implications for everyday life and for physiological testing, and the scope for improvement by physical training. In this review we deal with the changes in strength, explosive power and maximal aerobic power which are seen with healthy ageing and discuss the ways in which performance can be improved through physical training. We also discuss the special problems of studying these areas in older people and of setting appropriate training programmes.

Even healthy ageing sees changes in muscle and the cardiovascular system which can affect exercise tolerance and everyday functional ability. While most physiological functions have a generous spare capacity in youth, increasing age is characterized by a progressive erosion of these safety margins. In elderly women in particular, maximal aerobic power and muscular strength and power may fall to such levels that independence is put at risk. For the older patient there may be an additive effect of age and disease. Rehabilitation-induced increases in exercise performance can therefore offer the potential for great gains in everyday functional ability for older cardiac patients.

Muscle mass
Skeletal muscle mass begins to decline in middle age, even in healthy people (Fig. 1) [2]. The explanation for most of the loss of muscle (also known as sarcopenia or muscle cachexia) is reviewed in detail elsewhere [3–5]. Briefly, there is an apparently obligatory loss of muscle fibres, probably as a result of incompletely compensated denervation. In addition, in older people there may also be impaired regeneration of muscle after damage. Atrophy of surviving muscle fibres is variable, perhaps reflecting individual variations in habitual activity.

Muscular strength and explosive power
One of the consequences of the declining muscle mass is a loss of muscle strength. Additionally, older muscle may be weak for its size [4]. Strength begins to decline in late middle age and cross-sectional data imply that across the age range 65–89 years even healthy men and women lose strength at a rate of 1–2% (of a 77-year-old's value) per year [6].
The loss of muscular power (the combination of force of contraction and speed of movement) is even greater, with cross-sectional data consistent with loss at a rate of 3–4% per year. Not only are frail elderly people weak, but when moving their body weight, their weakness is such that they must use a contraction velocity below the peak of their power/velocity curve. The greater the resistance against which power must be developed the greater the extra loss of explosive power. For example, the maximal plantar flexor power of a 70-year-old man might be only some 20% less than that of a young man when developing a 10-Nm torque, but would be some 90% less than that of the young man when developing a 70-Nm torque (Fig. 2) [4].

A reduction in the intrinsic ‘speed’ of the muscle can also contribute to a reduction in explosive power, such as occurs during cooling (e.g. in those elderly people who are immobile, thin and living in poorly heated accommodation) or as a result of a reduction in the relative amount of fast contracting myosin heavy chain (MHC) isoforms present in older human muscle.

**Functional consequences**

Large numbers of healthy elderly women have power below, or near, functionally important thresholds and so have lost, or are in danger of losing, the ability to perform some important everyday tasks. For example, measurements of lower limb extensor power made in the English National Fitness Survey showed that nearly half the women...
but only 15% of the men) aged 70–74 years had a unilateral power: weight ratio below 1.5 W/kg [7], the least value be confident of being able to mount a 30 cm step without using the hands [8]. The sex difference in power: weight ratio helps explain the greater prevalence of fallibility, of falls and of restricted independent mobility amongst elderly women than amongst elderly men.

Effects of training
It is well documented that young adults can increase their muscular strength and power in response to resistance training. The improvement has been described as having three overlapping components [9]. The first is an increased skill in the action under study. This is why increases in one repetition maximum (the greatest weight that can be lifted once) are greater than those in isometric or isokinetic strength. The second component is an increase in the force produced per unit cross-sectional area of the muscle and the third is growth of the muscle.

Randomized, controlled trials have shown that improvements in strength and power can also be gained by older people [10], even by those who are frail [11]. Because of the weakness of older people, effective strength training can be achieved with very little specialized equipment, even just using body weight may be enough.

Strength training does not halt the underlying loss of muscle fibres but the improvements in strength are equivalent to 15–20 years of ‘rejuvenation’ and may prevent an individual falling beneath functionally important thresholds. Although training may provide an improvement in selected functional abilities, functional gains are more likely if the performance of strengthening exercises is accompanied by the practice of specific functional skills [12].

Aerobic power
Maximal aerobic power or maximal oxygen uptake ($\text{VO}_2\text{max}$) is also an important component of fitness. It depends on the ability of the heart and lungs to supply oxygen to the working muscles and the capacity of those muscles for aerobic metabolism. Both cross-sectional and longitudinal studies have demonstrated a decline in $\text{VO}_2\text{max}$ with age. The rate of decline is approximately 10% per decade, starting from the mid-20s, although when expressed in terms of body weight (ml/kg per min), there appears to be a uniform decrement from the early teens [13]. The relative contributions of the possible underlying mechanisms to the decline remain unclear. A reduced maximal heart rate and the shrinking muscle mass seen with ageing probably both contribute. When $\text{VO}_2\text{max}$ is corrected for muscle mass the decline seen with age is greatly diminished [14]. A diminished ventilatory capacity [15] may also play a role. Whatever the explanation, the decline is seen even with healthy ageing. Although there is limited evidence to suggest that part of the decline can be explained by disuse, and that by maintaining a high level of customary physical activity an individual can slow the rate of decline [16], this remains a controversial issue.

Functional consequences
The decline in $\text{VO}_2\text{max}$ means that a given task will require a higher percentage of $\text{VO}_2\text{max}$ in an older person than in a younger one. For many elderly people, especially women, some daily tasks may require such a large proportion of their $\text{VO}_2\text{max}$ that they become difficult or impossible to perform. The sex difference in body composition means that women are particularly disadvantaged for weight-bearing activities, as their aerobic power: weight ratio is lower than that of men of the same age.

The oxygen cost of walking at 3 miles per hour (mph) is approximately 12.5 ml/kg per min (for argument and references, see [7]) and at 2 mph approximately 9 ml/kg per min [17]. For prolonged walking to remain comfortable, the oxygen cost probably must be less than 50% of the aerobic power: weight ratio [7]. That is, one needs a $\text{VO}_2\text{max}$ of 18 ml/kg per min to walk comfortably at 2 mph, and of 25 ml/kg per min to walk comfortably at 3 mph. In the English National Fitness Survey, 80% of women (but only 35% of men) aged 70–74 years had an aerobic power: weight ratio below 25 ml/kg per min. Data for older people are very scarce but figures from the literature [18] and from our own laboratory (K. Malbut-Shennan et al., unpublished data) suggest an aerobic power: weight ratio of approximately 14 ml/kg per min for 80-year-old women. It seems likely that walking comfortably at 3 mph is impossible for most women in their early 70s and that even just 2 mph (in comfort) is impossible for most 80-year-old women.

Inactivity, whether chosen or enforced (perhaps as a result of illness), may reduce $\text{VO}_2\text{max}$ by a further 10–20%. Just sitting quietly would then require around 35% of an 80-year-old female’s $\text{VO}_2\text{max}$. This is a similar percentage of $\text{VO}_2\text{max}$ to that averaged over an 8 h shift by workers in heavy industry (e.g. coal-face miners) [17]. Small wonder that elderly patients complain of fatigue.

Effects of training
$\text{VO}_2\text{max}$ can be increased in younger adults with endurance training. Training also greatly improves the ability to sustain exercise at a fixed, submaximal, absolute level of energy expenditure. The improvement occurs as a result of the enlargement of cardiorespiratory dimensions (central adaptation) and from an increased content of intramuscular oxidative enzymes and an increased capillarization of muscle (peripheral adaptations). This ability to respond to endurance training appears to be maintained into the 70s with improvements in $\text{VO}_2\text{max}$ of 10–20% (Table 1) [19–24], similar to the improvements seen in response to equivalent training in young adults. However, there are no controlled studies on the effects in people older than this.

The functional implications of improvements in maximal aerobic power are clear; a given everyday task or activity will require a lower proportion of $\text{VO}_2\text{max}$ and may therefore be performed for much longer and with greater ease. A 10–20%
Table 1 Changes in the directly determined maximal oxygen uptake $\text{VO}_2\text{max}$ of healthy elderly subjects undergoing endurance training

<table>
<thead>
<tr>
<th>Age range (years)</th>
<th>$n$</th>
<th>Duration (weeks)</th>
<th>$\Delta \text{VO}_2\text{max}$ (%)</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>61-67</td>
<td>11</td>
<td>52</td>
<td>30</td>
<td>Seals et al. (1984) [19]</td>
</tr>
<tr>
<td>60-65</td>
<td>33</td>
<td>52</td>
<td>10</td>
<td>Cunningham et al. (1986) [20]</td>
</tr>
<tr>
<td>62-79</td>
<td>9</td>
<td>12</td>
<td>8</td>
<td>Tonino and Driscoll (1988) [21]</td>
</tr>
<tr>
<td>70-79</td>
<td>16</td>
<td>26</td>
<td>22</td>
<td>Hagberg et al. (1989) [22]</td>
</tr>
<tr>
<td>65-86</td>
<td>17</td>
<td>50</td>
<td>16</td>
<td>Gross et al. (1991) [23]</td>
</tr>
<tr>
<td>71-76</td>
<td>14</td>
<td>12</td>
<td>12</td>
<td>Warren et al. (1993) [24]</td>
</tr>
</tbody>
</table>

Age range refers to published range or was calculated as means ± 2SD. Studies have been included only if they included an adequate control group, control period, or stable pretraining baseline. Overall, ignoring differences in duration and intensity of training, the mean improvement is 15%.

Special considerations for measuring physiological responses during exercise in old age

Physiological responses during exercise are measured in younger adults to determine baseline fitness levels, to monitor the effects of training and for exercise prescription. When conducting such tests in older people, several considerations need to be made.

Choice of ergometer

Two main types of ergometer are commonly used for studying exercise performance, the treadmill and the cycle ergometer. At first, our group chose to use the treadmill [23] on the grounds that it uses walking, a familiar activity for all ages which is not limited by the strength of the quadriceps. However, it may not always be the appropriate choice, particularly in frail or very elderly people, whose balance may be impaired. It has been our experience that for these subjects the cycle ergometer may be a better choice as it provides greater stability. After similar familiarization, these subjects feel safer on the cycle than on the treadmill. The cycle ergometer has the added advantage that it allows ancillary measurements to be more easily taken (e.g. blood sampling for analysis of lactate levels).

Gas collection

In young adults expired gas for analysis is usually collected through a mouthpiece. Our laboratory has found that the mouthpiece is not well tolerated by a large proportion of elderly people [25], perhaps because of age-related changes in the mouth. An alternative to the mouthpiece is to use a nasal and mouth-breathing mask for gas collection, which seems to be tolerated much better by the older subject. The face-mask also has the advantage that it allows the subject to speak if necessary.

Test procedure

People of all ages need adequate familiarization before undergoing an exercise test. For older subjects the time allowed for familiarization needs to be longer, often involving several visits before an accurate baseline measurement can be taken. Tests traditionally used in younger adults need to be adapted to take into account lower $\text{VO}_2\text{max}$ values (they need to have smaller work increments) and need to be short enough so that the test is not limited by quadriceps weakness. For example, for direct measurement of $\text{VO}_2\text{max}$, in a study in our laboratory, a group of 80 to 93-year-old men and women underwent three maximal effort tests (in addition to a medically supervised preliminary test during which expired gas was not collected). Although two tests would have been sufficient for some of the group, for others, particularly the women, it was only at the third test that they were judged to have performed a truly maximal test. Work rates for the tests started at 25 W and went up in 15 W stages every 2.5 min. Tests were tailored for each individual, from the initial test, to try to get each to a maximum between 10 and 12.5 min. For a few of the men this meant that work rates were increased in 25 W intervals.

A direct measurement of $\text{VO}_2\text{max}$ is the standard for determining an individual’s capability for aerobic exercise. However, directly measuring $\text{VO}_2\text{max}$ involves working the individual to maximal effort and is not appropriate for many older people, particularly patients. Even when it is appropriate, there is the problem that criteria for deciding whether the maximum has been reached have not been adequately validated for use in this age group, and there is evidence that criteria used in younger groups are not suitable [26]. For these reasons $\text{VO}_2\text{max}$ is often estimated, by using a predicted value for maximal heart rate and extrapolating from the submaximal oxygen consumption and heart rate data. It is important to recognize the pitfalls of such an approach. First, it relies on the use of a predicted maximal heart rate. This is unreliable at all ages [27,28] and may become even more unreliable in older people [29]. Second, the extrapolations rely on a linear relationship between heart rate and oxygen consumption and there is some evidence that the relationship may not be linear as a subject approaches $\text{VO}_2\text{max}$ [30].

One other way of monitoring the effect of a training programme is to estimate an individual’s heart rate at a standardized submaximal oxygen consumption. We have found that 10 ml/kg per min is appropriate for use with very elderly subjects. The subjects perform a submaximal test during which oxygen consumption and heart rate are measured. The data are then subjected to linear regression so that the heart rate at a $\text{VO}_2$ of 10 ml/kg per min can be calculated by interpolation.

It is also important to remember that data obtained from laboratory-based treadmill tests, which give a valid indication of the cardiovascular responses in everyday physical
activity in younger people, may not do so in older subjects. Elderly people have a significantly higher heart rate during treadmill walking than during corridor walking at the same speed and the difference is increased when a mouthpiece is worn [31]. This could have implications when prescriptions are based on treadmill data. For some purposes, therefore, it may be advisable to perform other tests, for example based on telemetric recordings of cardiorespiratory variables during free walking [32], which may give a clearer idea of an older person’s cardiorespiratory responses to everyday activity.

Training in old age

Exercise programmes need to be adapted to ensure that they are suitable for older people [33]. As well as including all the elements common to any general fitness programme, a programme for older people must also aim to include exercises which load the bones, target postural and pelvic floor muscles, and develop body awareness and balance skills. The programme must place great emphasis on safety; it needs to include a longer warm-up session to mobilize joints, stretch muscles and gradually increase demands on the cardiovascular system as well as a longer warm-down to preserve venous return. The programme needs to exclude any exercise which puts the participants at unnecessary risk. For example, it should not include exercises which involve sudden changes of direction. Lastly, the programme must be fun, incorporating opportunities for socialization, a factor which may be particularly important for many elderly people.

Annotated references

- of special interest
- of outstanding interest


The authors review the physiological changes associated with strength training in young adults.

This randomized, controlled trial of strength training used inexpensive equipment to train healthy women aged 76–93 years.

A randomized, placebo-controlled trial compared progressive resistance exercise training, multivitamin supplementation, both interventions and neither in 100 frail nursing-home residents.

Increases in strength, balance and functional ability were demonstrated in women aged over 74 years in response to 8 weeks of training. This important study involved the practice of functional tests in the training.

Maximal oxygen intake was measured in 86 healthy men between the ages 40 and 72 years (cross-sectional data). The study also included some longitudinal data for 40 of the men who had been tested 21–33 months previously. Results were compared with cross-sectional and longitudinal data from the literature.


This randomized, controlled study looked at the effects of either endurance or resistance training on VO2 max in men and women aged 70 to 79 years. No increase was found in VO2 max in the resistance-trained group but a 22% increase was found in VO2 max in the endurance-trained group.

This controlled study shows that healthy older women can increase VO2 max, leg strength and type II muscle fibre area in response to a long-duration, combined aerobic-resistance exercise programme.


In a brief article the authors cover the benefits of exercise, the content of exercise classes for older people and safety issues. They also raise the issue of having specialized teachers to teach classes to older people.
SECTION: VOLUNTARY MUSCLE

AEROBIC EXERCISE

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The ability to sustain muscular activity for more than just a minute or two depends upon the ability of the cardiorespiratory system to deliver an adequate supply of oxygen to the working muscles and the capacity of those muscles for aerobic metabolism. This Chapter summarises the changes in endurance-related aerobic muscle function that are associated with increasing age, the impact these changes have on functional capacity and the effects of physical training.

MAXIMAL AEROBIC POWER
Both cross-sectional and longitudinal studies have demonstrated a decline in maximal aerobic power (i.e. maximal oxygen uptake, VO\(_2\) max) with advancing age. When expressed in absolute terms (l/min) the decline is some 10% per decade starting from the mid 20s (Hagberg 1987) although when expressed relative to body weight (ml.kg\(^{-1}\).min\(^{-1}\)) there is a uniform decrement from at least the early teens (Dehn and Bruce 1972). The relative contributions of the underlying mechanisms responsible for the decline remain unclear. Changes in the cardiovascular system (see Lakatta chapter in new version of OTGM) may be partly responsible whilst the decline in ventilatory capacity (Muiesan \textit{et al.} 1971) may also play a role. The declining muscle mass is also important. Indeed when VO\(_2\) max is corrected for muscle mass the decline seen with ageing is greatly diminished (Fleg and Lakatta 1988).

Opinion remains divided as to whether the rate of decline of maximal oxygen uptake with age can be slowed by regular, vigorous physical activity (Heath \textit{et al.} 1981; Rogers \textit{et al.} 1990; Kavanagh \textit{et al.} 1989). Elite, veteran sportsmen are an interesting and highly selected group of people. The top performers are highly motivated, have a very high level of customary physical activity and are probably free of significant exercise-limiting disease. Studies of such individuals could be said to offer a glimpse of the effect of ‘pure ageing’ on maximal exercise performance. Saltin (1986) reports that inactive and still active former élite orienteers differed in their VO\(_2\) max values but not in the rates of decline of VO\(_2\) max. Similar rates of decline in prolonged exercise (about 10 per cent per decade) are also seen in cross-sectional comparisons of the running speeds (e.g. figure 1), swimming speeds (e.g. calculated from Tanaka and Seals 1997) and cycling speeds (e.g. see 1st edition) of older, age-related record holders. Although the individual performances are extraordinary, these data suggest that a high level of physical activity does not slow the decline in VO\(_2\) max with increasing age.

AEROBIC POTENTIAL OF ELDERLY MUSCLE
There is conflicting evidence as to whether the potential for aerobic metabolism (capillary density and oxidative enzyme activity) of the remaining muscle mass is maintained into old age. Coggan (1992b) compared ‘sedentary’ old with ‘sedentary’ young subjects and demonstrated a decreased muscle capillarization and lower oxidative enzyme levels in the older subjects. However, the matching of activity levels was not totally convincing, with sedentary defined very broadly as ‘no activities other
than low intensity recreational sports'. Conversely, Örlander and colleagues (1980) studied a group of men between the ages 22-65 years, defined as sedentary on the basis that all were white collar workers who did no, or only light physical activity in their spare time, and also a group of pensioners defined as 'comparatively active for their age'. Within the sedentary group they found no overall decrease in oxidative enzyme activity with age. Moreover, they found higher levels of some oxidative enzymes in the active group of pensioners. Other studies have compared active older and sedentary younger subjects (Jakobsson et al. 1990) or taken data taken from a group of older people and compared them with data taken from young people in the literature (Grimby et al. 1982) and have found no difference in muscle capillarization. The latter study also compared enzymatic activity in older subjects with data previously gathered from younger subjects and with data from the literature, concluding that ageing had no effect on the oxidative potential of muscle (Grimby et al. 1982).

Coggan and colleagues (1990) also compared master athletes with young runners matched for amount and absolute intensity of training exercise and found a higher capillary to fibre ratio, a higher number of capillaries in contact with each muscle fibre and higher oxidative enzyme activity in biopsies from the master athletes. However, the master athletes were training at a higher percentage of their VO\textsubscript{2} max and were perhaps more highly trained than the younger runners. It seems likely that differences in oxidative enzyme activities and in capillarity owe more to differing physical activity levels than to differing ages.

**LACTATE THRESHOLD**
The lactate threshold can be defined as the highest oxygen consumption that can be achieved before there is a sharp increase in blood lactate concentration. In elderly people it occurs at a higher percentage of VO\textsubscript{2} max than in younger people (Iredale and Nimmo 1997). The most probable explanation for this is a decreased responsiveness to sympathetic stimulation. During the initial stages of exercise, lactic acid is added to the blood by active muscle in proportion to the increasing number of motor fibres recruited and their intensity of contraction. At the same time the removal of blood lactate (predominantly by skeletal muscle) also increases so that there is only a slow rise in overall blood lactate concentration. As exercise intensity increases, circulating adrenaline starts to rise. This increases the release of lactate from the working muscles whilst also decreasing the removal of lactate by other tissues (for review see Stainsby and Brooks 1990). Ageing is associated with a decreased responsiveness to sympathetic stimulation and although circulating levels of adrenaline in older people appear to be higher at the same relative exercise intensity than in younger people (Fleg 1985), a decreased responsiveness could at least partly explain the lower blood lactate levels which are seen at the same percentage of VO\textsubscript{2} max in older people. Nevertheless, because of the low levels of VO\textsubscript{2} max which are seen in many older people, lactate levels at the same absolute level of oxygen consumption may well be higher than in younger people.

**FUNCTIONAL CONSEQUENCES**
The reduction of VO\textsubscript{2} max with advancing age means that a given task or activity will require a greater proportion of maximal aerobic power. Thus, activities with a low absolute oxygen cost may yet demand a high proportion of an old person's VO\textsubscript{2} max. This situation is made worse by the fact that the absolute energy cost of some activities increases with age. The increasing absolute energy cost of walking (Bassey...
and Terry 1986), for example, may be explained by the shortening of stride length as age increases (Himann et al. 1988).

The gender difference in body composition means that women are particularly disadvantaged for weight-bearing activities, as their aerobic power/weight ratio is less than that of men of the same age. Many elderly people, in particular women, have such low values of VO₂ max that it would need only a small, further reduction to render some everyday activities either unpleasant or impossible to perform.

The oxygen cost of walking at 3mph is approximately 12.5 ml.kg⁻¹.min⁻¹ (for argument and references see Skelton et al. 1997) and at 2mph approximately 9ml.kg⁻¹.min⁻¹ (Durnin and Passmore 1967a). For prolonged walking to remain comfortable, the oxygen cost probably needs to be less than 50% of the aerobic power/weight ratio (Skelton et al. 1997). That is, one needs a VO₂ max of 18ml.kg⁻¹.min⁻¹ to walk comfortably at 2mph, and of 25ml.kg⁻¹.min⁻¹ to walk comfortably at 3mph. In the English National Fitness Survey, 80% of women (but only 35% of men) aged 70 to 74 had an aerobic power/weight ratio below 25ml.kg⁻¹.min⁻¹. Data for older people are very scarce but figures from the literature (Foster et al. 1986) and from our own laboratory (Malbut-Shennan et al., unpublished data) suggest an aerobic power/weight ratio of about 14 ml.kg⁻¹.min⁻¹ for 80-year-old women. It seems likely that walking comfortably at 3mph is impossible for most women in their early 70s and that even just 2mph (with comfort) is impossible for a majority of 80-year-old women.

Inactivity whether chosen or enforced (perhaps as a result of illness), may reduce VO₂ max by a further 10-20%. Surgery results in similar reductions in VO₂ max (evidence, mostly from younger age groups, reviewed by Young 1990). Figure 3 illustrates the drastic consequences of a 15% reduction in VO₂ max for an average healthy 80-year-old woman. Just sitting quietly would then require around 35% of her VO₂ max (a similar percentage of VO₂ max to the rate of energy expenditure averaged over an 8 hour shift by workers in heavy industry e.g. coal-face miners (Durnin and Passmore 1967b).

The good news is that even seemingly trivial absolute levels of activity may be expected to make an important contribution to the restoration or maintenance of aerobic fitness in old age. Encouraging patients to wash and to dress in their own clothes each day is important, not only to practice the necessary skills and for self respect, but perhaps also as an aerobic training stimulus as these activities would require approximately 60% of an healthy, or 70% of a deconditioned 80 year old woman’s VO₂ max (Durnin and Passmore 1967c).

Some elderly patients suffer an accelerated decline in functional ability because an outcome of their condition is that the absolute energy cost of everday tasks is increased. A very large proportion of maximal aerobic power must then be used for simple, everyday activities. For example, a stroke may cause spasticity, which, combined with the change in gait and balance will cause unproductive increases in energy expenditure. Osteoarthritis may also cause an increase in the energy cost of walking (Pugh 1973). The oxygen cost of walking (in ml.kg⁻¹.min⁻¹) after an amputation may be elevated by some 30% (Syme’s amputation), 60% (below knee), or 120% (unilateral above knee, or bilateral below knee) (Waters et al. 1976; DuBow
et al. 1983). Those with above knee amputations have a slower cadence and shorter stride length than those with more distal amputations and, despite walking more slowly, they must still use a higher proportion of VO$_2$ max (Waters et al. 1976). The level of amputation is of extreme importance for the preservation of endurance capacity and the subsequent ability to perform everyday activities. The majority of amputations are the result of peripheral vascular disease. Most of these patients are elderly and many also have evidence of coronary vascular disease. For some of them, particularly those who have had an above-knee amputation, walking may not be a realistic goal, due to the prohibitively high, relative energy cost.

**IMPROVING PERFORMANCE**

VO$_2$ max can be increased in younger adults with endurance training. Training also greatly improves the ability to sustain exercise at a fixed, submaximal, absolute level of energy expenditure. The improvement occurs as a result of the enlargement of cardiorespiratory dimensions (central adaptation) and from an increased content of intramuscular oxidative enzymes and an increased capillarization of muscle (peripheral adaptations).

This ability to respond to endurance training appears to be maintained into the 70s with improvements in VO$_2$ max of 10 to 20% (Seals et al. 1984; Cunningham et al. 1986; Tonino and Driscoll 1988; Hagberg et al. 1989; Cress et al. 1991; Warren et al. 1993) (table 2). These changes are similar to the improvements seen in response to equivalent training in young adults with the expected central (Stratton et al. 1994; Seals et al. 1984) and peripheral (Orlander et al. 1980; Suominen et al. 1977; Coggan et al. 1992a; Meredith et al. 1989) adaptations. There are very few controlled studies in which the subjects have been more than 70 years of age and none where they were over 80 years, arguably those whose everyday life would benefit most from such changes.

Although training increases the ability to sustain exercise at a fixed, submaximal, absolute level of energy expenditure there is uncertainty about its effect upon the ability to sustain exercise at a constant relative energy expenditure. The question is not adequately settled for any age group. Some studies have shown no improvement (Saltin et al. 1969; Rumley et al. 1988), but one (Seals et al. 1986) of men and women aged 61-67 years found that after one year of endurance training the plasma lactate at 67% of VO$_2$ max was reduced by a quarter.

The functional implications of improvements in maximal aerobic power are clear; a given everyday task or activity will require a lower proportion of maximal power and may therefore be performed for much longer and with greater ease, thus alleviating functional limitation. If the rate of deterioration of VO$_2$ max can be slowed, so much the better. Even if this is not the case, a 10-20% training-induced improvement in VO$_2$ max may effectively postpone the crossing of functionally important thresholds for some 10-20 years.

For patients, training which involves practice of functional skills may provide additional functional benefits. For example, in hemiparetic stroke patients walking practice has been shown to produce substantial and progressive reductions in the energy expenditure required to walk at 1mph (Macko et al. 1997).
<table>
<thead>
<tr>
<th>Age range* (years)</th>
<th>N</th>
<th>Duration (weeks)</th>
<th>Δ VO₂ max (%)</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>61-67</td>
<td>11</td>
<td>52</td>
<td>30</td>
<td>Seals et al. 1984</td>
</tr>
<tr>
<td>60-65</td>
<td>33</td>
<td>52</td>
<td>10</td>
<td>Cunningham et al. 1986</td>
</tr>
<tr>
<td>62-79</td>
<td>9</td>
<td>12</td>
<td>8</td>
<td>Tonino and Driscoll 1988</td>
</tr>
<tr>
<td>70-79</td>
<td>16</td>
<td>26</td>
<td>22</td>
<td>Hagberg et al. 1989</td>
</tr>
<tr>
<td>65-86</td>
<td>17</td>
<td>50</td>
<td>16</td>
<td>Cress et al. 1991</td>
</tr>
</tbody>
</table>

Table 1: Reported changes in the directly determined maximal oxygen uptake of healthy elderly subjects undergoing endurance training.

* Published range or calculated as mean ± 2SD.

Studies have been included only if they included an adequate control group, control period, or stable pre-training baseline. Overall, ignoring differences in duration and intensity of training, the mean improvement is 14 per cent.
Figure 1: Veteran world records for 3000m indoor run (Autumn 1996). Courtesy of the British Veteran Athletic Federation.
Figure 2:- Implications of a 15% fall in maximal oxygen uptake such as might follow surgery in an otherwise healthy 80yr old woman.
REFERENCES


AEROBIC TRAINING CAN INCREASE MAXIMAL OXYGEN UPTAKE IN WOMEN OVER 80

K.E. Malbut-Shennan, S.M. Dinan, A. Young. University Department of Geriatric Medicine, Royal Free Hospital School of Medicine, London NW3 2PF, UK.

No controlled study has looked exclusively at training effects on maximal oxygen uptake (\( \dot{V}O_2 \) max) in those aged 80 and over. After thorough familiarisation a direct measurement of \( \dot{V}O_2 \) max as well as heart rate at an oxygen consumption of 10mls.kg \(^{-1}\).min\(^{-1}\) (HR at \( \dot{V}O_2 \)10) were made in 26 subjects aged 80 to 93 years. Measurements were repeated after a 12 week control period and after 12 and 24 weeks of progressive aerobic training; 19 subjects completed training. If ANOVA identified a significant time effect, data were compared by Wilcoxon matched pairs rank test. Pre-training \( \dot{V}O_2 \) max values for those fulfilling criteria for attainment of \( \dot{V}O_2 \) max (9/10 women and 8/9 men) were 14.1 (SD 2.79) and 22.0 (5.12) mls.kg\(^{-1}\).min\(^{-1}\) respectively. No significant change was seen in the \( \dot{V}O_2 \) max of these subjects following the control period or after 12 weeks of training. After 24 weeks of training there was no change in the \( \dot{V}O_2 \) max of the men, but a 15% increase (P < 0.01) was seen in the women. In the 10 women who completed training there was no significant change in HR at \( \dot{V}O_2 \)10 after the control period or after 12 weeks of training but a 14% decrease (P < 0.01) was seen after 24 weeks of training. In the 9 men there was a 7% (P < 0.05) increase in HR at \( \dot{V}O_2 \)10 after the control period, no significant change after 12 weeks of training and a 5% (P < 0.05) decrease after 24 weeks of training. Aerobic training can increase \( \dot{V}O_2 \) max even in very elderly women.

Supported by The Sir Halley Stewart Trust and Research into Ageing.
DETERMINING MAXIMAL OXYGEN UPTAKE IN VERY ELDERLY MEN AND WOMEN

KE MALBUT, SM DINAN, H VERHAAR, A YOUNG

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Traditional criteria for the attainment of maximal oxygen uptake (\(\dot{V}O_2\) max), well established in young subjects, become less so in later years. These are: - maximal heart rate (HRmax) within 10 beats of age predicted maximum; Respiratory exchange ratio (RER) \(\geq 1\); peak blood lactate \(\geq 8\) mmol; a plateau in oxygen consumption with increasing work rate.

30 'medically stable' (Age Ageing 1994;23: 185-9) subjects aged 80-93 (mean 83) and 25 young subjects aged 22-44 performed 2-4 maximal effort, progressive, cycle ergometry tests. Data are reported only from the best performance of each subject who was felt subjectively to have worked to their maximum (18 old and 19 young). Demonstrating a plateau in the older group was not practicable because (1) increments in work rate were small and (2) tests were short despite the small increments. 0/15 older and 8/10 young subjects achieved blood lactate levels \(\geq 8\) mmol (group mean = 4.34 and 8.33 respectively). 13/18 older and 17/19 younger subjects fulfilled heart rate criteria (group mean = 140 and 187 respectively). 15/18 older and 19/19 younger subjects achieved an RER \(\geq 1\) (group mean = 1.06 and 1.12 respectively).

There was a wide inter-individual variability in HRmax in the older group (120-180) casting doubt on its reliability as an indicator of \(\dot{V}O_2\) max. At present, RER seems to be the only reliable objective indicator of \(\dot{V}O_2\) max in this age group.
Criteria for the attainment of maximal oxygen uptake (VO$_2$ max) are well established for young subjects but become less clear with increasing age. Neither peak lactate levels (m.mol) or the Respiratory exchange ratio (RER) have been fully evaluated in very elderly people. Predicted maximal heart rate becomes increasingly unreliable in older people because of the wide variation in true maximal heart rate in the elderly and it is not always possible to demonstrate an oxygen plateau, in addition criteria for determining a plateau has been reached appears to vary somewhat from study to study.

10 men (medically stable) aged 79 - 82 (mean 80) had a minimum of 3 progressive cycle ergometry tests to maximal work rate. Data reported is from the last 2 tests (T2 and T3) from the 9 subjects who were felt subjectively to have exercised to their maximal capacity. Mean maximal heart rate achieved was 141bpm (SD 17.1) for T2 and 139bpm (SD 22.1) for T3. Average peak RER value achieved were 1.05 (SD 0.039) for T2 and 1.03 (SD 0.054) for T3. Mean peak lactate values were 3.83 m.mol (SD 0.780) for T2 and 5.14 m.mol (SD 1.96) for T3. Mean peak VO2 was 1.52 L.min$^{-1}$ (SD 0.289) for T2 and 1.4 L.min$^{-1}$ (SD 0.323) for T3. When expressed in terms of body weight mean peak VO2 was 23 ml.kg.min$^{-1}$ (SD 6.13) for T2 and 21.3 mls.kg.min$^{-1}$ (SD 6.54) for T3. There was no significant differences seen for any of the variables measured between T2 and T3 when compared using confidence interval analysis. To determine if a plateau in oxygen consumption had been reached regression lines were calculated for each subject for all work loads, excluding the final one. This allowed the oxygen consumption for the final work load to be predicted. This was then expressed as a ratio of the actual change in oxygen consumption between the last two work loads and the predicted change.

89% of subjects achieved an RER > 1 in T2 and 67% in T3. 78% of subjects achieved a heart rate within 10 beats of maximum predicted (using formula 220-age) in T2 and 67% in T3 although there was wide variability between subjects in terms of the peak heart rate achieved. No subjects achieved a Lactate value > 8m.mol in T2 and only 1 subject achieved it in T3. For both T2 and T3 only 33% (3 subjects) showed an oxygen consumption which rose less than 50% of predicted with an increase in work load. 56% (5 subjects) achieved an increase of <60 % in T3.

We conclude that although it is possible to produce reproducible tests in this age group it is not always clear whether or not VO2 max has been achieved.

This work was supported by the Sir Halley Stewart Trust, Research into Ageing and the Nestor Foundation.
APPENDIX ONE C

Supplementary publications
Effects of Resistance Training on Strength, Power, and Selected Functional Abilities of Women Aged 75 and Older

A. Skelton, PhD, Archie Young, MD, FRCP, Carolyn A. Greig, PhD, and Mie E. Malbut, MSc

OBJECTIVE: To determine the effects of 12 weeks of progressive resistance strength training on the isometric strength, plosive power, and selected functional abilities of healthy women aged 75 and over.

SIGN: Subjects were matched for age and habitual physical activity and then randomly assigned into either a control or an exercise group.

TITLING: The Muscle Function Laboratory, Royal Free Hospital School of Medicine, London.

PARTICIPANTS: Fifty-two healthy women were recruited through local and national newspapers. Five dropped out fore and seven (4 exercisers and 3 controls) during the study. Pre- and posttraining measurements were obtained on 20 exercisers (median age 79.5, range 76 to 93 years) and 20 controls (median age 79.5, range 75 to 90 years).

INTERVENTIONS: Training comprised one supervised session (1 hour) at the Medical School and two unsupervised sessions (supported by an exercise tape and booklet) per week for 12 weeks. The training stimulus was three sets of 12 to 15 repetitions of each exercise, using rice bags (1.5 kg) or elastic tubing for resistance. The exercises were designed specifically to strengthen the muscles considered relevant for the functional tasks, but were not to mimic the functional measurements. No intervention was prescribed for control subjects.

MEASUREMENTS: Pre- and posttraining measurements were made for isometric knee extensor strength (IKES), isometric elbow flexor strength (IEFS), handgrip strength (HGS), leg extensor power (LEP), and anthropometric indices (Body impedance analysis, arm muscle circumference, triceps skinfold thickness).

RESULTS: Improvements in IKES (mean change 27%, P = .03), IEFS (22%, P = .05), HGS (4%, P = .05), LEP/kg (18%, P = .05) were associated with training, but the improvement in LEP (18%, P = .11) did not reach statistical significance. There was an association between training and a reduction in normal pace knee rise time (median change 21%, P = .02) and a small improvement in step up height (median 5%, P = .05). The other functional tests did not improve.


Cross-sectional studies have shown that across the age range of 65 to 89 years, even healthy men and women have differences in isometric knee extensor strength, isometric elbow flexor strength, and handgrip strength, consistent with losses of 1 to 2% per annum. More importantly, the decline of explosive leg extensor power across this age range is about 3.5% per annum. It is important to maintain muscle strength in order to be able to continue to complete daily tasks successfully and to be able to do this with reasonable safety margins.

Women should be the initial target for intervention to help maintain the ability to perform everyday tasks and activities. Not only is disability disproportionately more common in women, but they also have lower strength and power standardized for body weight than do men of the same age.

There have been more than 40 exercise training studies in older subjects that have considered one or more measures of strength as an outcome. Only 11 of these have been randomized and controlled, and until very recently (see below), these studies have considered only the youngest 'old,' those with mean ages between 66 and 75. Even fewer studies have considered functional ability. One recent randomized and controlled study examined older subjects (mean age 82, range 71-90 years) and found that both resistance training and aerobic training improved strength and functional measures in a small group of sedentary older adults.
ping or bag-lifting ability, their data for that test were exclud- 
clined from further analysis.

RESULTS

Seven women, four from the training group and three from the control group, dropped out during the 12 weeks of the study because of ill health (not related to the exercise). Results are reported from the 20 exercisers (median age 79.5 years, range 76-93 years) and 20 controls (median age 79.5 years, range 73-90 years) who completed the study.

Compliance:

Three subjects attended extra class sessions because they were unable to complete home sessions, and nine completed extra home sessions because they were unable to attend the class. Eight of 20 subjects attended all classes and completed all (or more) home sessions. No one attended fewer than nine class sessions (range 9-14, median 10.5 (10 or 11) classes). According to the exercise diaries no one performed fewer than 20 home sessions (range 20-30, median 24 classes). The median total number of sessions completed was 35.5 (range 31-40). Except for the first 2 weeks of the study where a number of people felt stiff after training, the exercises caused no discomfort, and there were no untoward occurrences.

Lifestyle and Anthropometry

The training and control groups did not differ in their pretraining levels of habitual physical activity on any of the three scales used. Both groups had a median score of 3 (range 3-5) on a 6-point scale,11 corresponding to light exercise for 2-4 hours per week. On the HAP scale,12 the training group had a median maximum activity score (MAS) of 76.5 (range 60-85) and a median adjusted activity score (AAS) of 73 (range 48-81), and the control group had a median MAS of 76 (range 71-82) and a median AAS of 71 (53-80). Unfortunately, age-matched normal values for these scores are not available, but a MAS of 76.5 is approximately the 74th percentile, and an AAS of 73 is the 67th percentile of 70 to 79 year women.12 Pre-and posttraining questionnaire answers showed no difference for either group. On these scales, activity score would not be influenced by the training program itself. Subjects scored highly on the TMIG Index (controls: median 13, range 11-13; exercisers: median 13, range 11-13).

The control group was heavier than the training group (mean 61.5 kg vs 54.1 kg; P < .05). Over the study period, neither group varied in its body weight, height, arm muscle circumference, demi-span or phase angle (Table 1).

Table 1. Anthropometric Indices Pre- and Posttraining in the Training and Control Group

<table>
<thead>
<tr>
<th></th>
<th>Training</th>
<th></th>
<th></th>
<th>Control</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre</td>
<td>Post</td>
<td>%Δ</td>
<td>Pre</td>
<td>Post</td>
<td>%Δ</td>
</tr>
<tr>
<td>Body weight (kg)</td>
<td>54.1 (9.1)</td>
<td>54.1 (9.3)</td>
<td>0</td>
<td>61.5 (11.4)</td>
<td>62.2 (11.8)</td>
<td>0</td>
</tr>
<tr>
<td>Body height (m)</td>
<td>1.54 (0.07)</td>
<td>1.54 (0.07)</td>
<td>0</td>
<td>1.57 (0.07)</td>
<td>1.57 (0.06)</td>
<td>0</td>
</tr>
<tr>
<td>Demi-span (cm)</td>
<td>72.1 (2.9)</td>
<td>72.3 (3.0)</td>
<td>0</td>
<td>73.9 (4.2)</td>
<td>73.3 (3.4)</td>
<td>-1</td>
</tr>
<tr>
<td>AMC (cm)*</td>
<td>23.0 (2.9)</td>
<td>22.5 (2.6)</td>
<td>-2</td>
<td>24.8 (3.8)</td>
<td>24.1 (2.8)</td>
<td>-1</td>
</tr>
<tr>
<td>Phase angle†</td>
<td>5.7 (0.7)</td>
<td>6.2 (1.1)</td>
<td>9</td>
<td>6.0 (0.7)</td>
<td>6.3 (0.7)</td>
<td>8</td>
</tr>
</tbody>
</table>

Values expressed as mean (SD). %Δ = mean % change in variable. n = 20 for each group, except † as measured from resistance and reactance (Body Impedance Analyser) (n = 18 for training group, n = 17 for control group). * AMC = Arm muscle circumference. P-values are calculated from the F-ratio as derived from analysis of variance.
Table 2. Strength and Power Measurements

<table>
<thead>
<tr>
<th></th>
<th>Training</th>
<th>Control</th>
<th>F Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre Post %Δ</td>
<td>Pre Post %Δ</td>
<td></td>
</tr>
<tr>
<td>CES (N)</td>
<td>199.9 (55.9) 239.7 (76.3) 27</td>
<td>243.3 (66.7) 242.9 (63.7) 3</td>
<td>0.031* 0.829</td>
</tr>
<tr>
<td>CES/kg (N/kg)</td>
<td>3.8 (1.2) 4.7 (1.8) 27</td>
<td>4.0 (1.0) 4.0 (1.1) 2</td>
<td>0.019* 0.832</td>
</tr>
<tr>
<td>IGS (N)</td>
<td>212.2 (33.6) 218.4 (38.1) 4</td>
<td>209.3 (49.3) 204.0 (44.9) -3</td>
<td>0.050* 0.361</td>
</tr>
<tr>
<td>IFS (N)</td>
<td>106.6 (28.3) 127.0 (35.2) 22</td>
<td>133.8 (28.0) 127.4 (25.0) -3</td>
<td>0.049* 0.278</td>
</tr>
<tr>
<td>EP (W)</td>
<td>61.7 (23.0) 79.3 (18.7) 18</td>
<td>69.8 (31.4) 71.2 (31.4) 4</td>
<td>0.112 0.489</td>
</tr>
<tr>
<td>EP/kg (W/kg)</td>
<td>1.2 (0.5) 1.4 (0.4) 18</td>
<td>1.1 (0.5) 1.2 (0.5) -1</td>
<td>0.049* 0.453</td>
</tr>
</tbody>
</table>

Values expressed as mean (SD). n = 20 for all. P = the P value for the F-ratio. P_w = P value for the co-variate weight. IES = Isometric knee extensor strength; L/kg = Isometric knee extensor strength/body weight; HGS = Handgrip strength; IFS = Isometric elbow flexor strength; LEP = Leg extensor power; LEP/kg = Leg extensor power/body weight. *P ≤ .05 as obtained from analysis of variance using body weight as a co-variate.

\[ \%\Delta \text{ in strength and power} = \frac{100 \times \text{posttraining-pretraining}}{\text{pretraining}} \]

Figure 1: Mean percentage change after training. 
IFS = isometric knee extensor strength, IFS = isometric elbow flexor strength, LEP/kg = leg extensor strength standardized for body weight, HGS = handgrip strength. The error bars denote ± standard error. *P ≤ .05.

Functional Ability

The training group did not differ from the control group on the pretraining functional ability data. Functional ability did not change in the control group during the study. In the training group, functional reach, self-paced stair climbing speed (flights/sec), self-paced walking rate, step rate, heart rate during stair climbing or corridor walk, bag lifting, chair rising, or floor rising did not change with training (Table 3).

Kneel Rise

Two different data sets, normal pace and fast pace, were obtained for kneel rise. There was an association between a reduction in kneeling time (normal pace) (P = 2), but not between training and a change in kneeling time (fast pace) (P = .29) (Table 3).

Step Stepping

Two of the training group and three of the control group were at the 'ceiling' of our stepping-up measurements (55 cm) pretraining, and two of the training group and five of the control group at the 'ceiling' of stepping down. None deceased their stepping-up performance and their data, therefore, have been excluded from analysis. In the training group, of the 18 not at our 'ceiling' improved their stepping up ability (5–15 cm), and four decreased their stepping-up ability (5 cm). Using Fisher's exact test, there was an improvement in stepping-up ability with training, P = .005 (2-sided), corresponding to a median increase of 2.5 cm. The probability of an improvement in stepping-down ability with training was not significant (P = .34).

Discussion

Twelve weeks of progressive resistance strength training significantly increased strength and LEP/kg in very old women. The improvements in muscle strength in our subjects are at least equal to those seen in studies with younger subjects. Cross-sectional data suggest that muscle strength is lost at a rate of 1 to 2% per annum, and muscle power even faster at 3 1/2% per annum, in healthy women older than the age of 65. It is likely that at the end of training, the subjects were stronger than they had been for many years. Although increases of IFS and IES in the training group were large, the increase in HGS was not (4%) and is unlikely to be biologically significant.

Strength may be an important limiting factor in the maintenance of an independent lifestyle. Whipple et al. have documented that nursing home dwellers with a history of falls had only 62% of the quadriceps strength of fellow residents not experiencing falls and only 37% of the strength of community dwellers. An intervention that would increase strength and power may help in the prevention of falls.

The present study did not directly examine mechanisms of strength gains. Nevertheless there was no change in the measured phase angle or arm muscle circumference, implying no increase in lean body mass. An increase in muscle cross-sectional area smaller than the increase in strength is a common finding of strength-training studies. It has been considered that most untrained older subjects can fully activate their muscles in a voluntary contraction. Our twitch interpolation data, although very limited, suggest that this may not be so; we are unable to exclude the possibility that our subjects' strength gains were the result of a change in the completeness of activation achieved.

Although the results for quadriceps relaxation rate are for only a small number of subjects, they do suggest that training can increase relaxation rates. Muscle power is determined by the velocity of shortening and the overall size and strength of the muscle. With an increase in strength and 'speed' of the muscle after training, we would perhaps expect...
Table 3. Functional Ability Data Pre- and Posttraining

<table>
<thead>
<tr>
<th></th>
<th>Training</th>
<th>Control</th>
<th>F-Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>Pre</td>
<td>Post</td>
</tr>
<tr>
<td>Chair rise-normal (sec)</td>
<td>20</td>
<td>1.0 (0.5-3.5)</td>
<td>0.9 (0.5-1.6)</td>
</tr>
<tr>
<td>Chair rise-fast (sec)</td>
<td>20</td>
<td>0.7 (0.3-2.3)</td>
<td>0.6 (0.4-1.2)</td>
</tr>
<tr>
<td>Chair rise X 10 (sec)</td>
<td>20</td>
<td>28.2 (7.8-63)</td>
<td>28.8 (15-62.5)</td>
</tr>
<tr>
<td>Kneel rise-normal (sec)</td>
<td>17</td>
<td>2.8 (1.0-13.8)</td>
<td>2.2 (1.0-4.5)</td>
</tr>
<tr>
<td>Kneel rise-fast (sec)</td>
<td>15</td>
<td>1.8 (0.6-3.0)</td>
<td>1.7 (0.9-2.5)</td>
</tr>
<tr>
<td>Floor rise (sec)</td>
<td>17</td>
<td>4.1 (2.0-17.0)</td>
<td>4.0 (1.9-18.5)</td>
</tr>
<tr>
<td>Functional reach (cm)*</td>
<td>20</td>
<td>94.7 (4.5)</td>
<td>96.0 (5.0)</td>
</tr>
<tr>
<td>SP walking speed (m/s)*</td>
<td>20</td>
<td>1.4 (0.5)</td>
<td>1.2 (0.3)</td>
</tr>
<tr>
<td>SP stair speed (flights/s)*</td>
<td>17</td>
<td>0.10 (0.03)</td>
<td>0.11 (0.04)</td>
</tr>
<tr>
<td>Corridor heart rate (b/m)*</td>
<td>12</td>
<td>94.1 (6.6)</td>
<td>98.7 (11.1)</td>
</tr>
<tr>
<td>Stair heart rate (b/m)*</td>
<td>12</td>
<td>117.0 (11.2)</td>
<td>116.4 (11.0)</td>
</tr>
<tr>
<td>Step up height (cm)</td>
<td>18</td>
<td>40 (20-50)</td>
<td>45 (25-55)</td>
</tr>
<tr>
<td>Step down height (cm)</td>
<td>18</td>
<td>40 (20-50)</td>
<td>45 (25-55)</td>
</tr>
<tr>
<td>Bag raise (kg)</td>
<td>12</td>
<td>6.75 (6-7.5)</td>
<td>8 (6-8)</td>
</tr>
</tbody>
</table>

Values expressed as median (range), except * mean change (SD). SP = self-paced, b/m = beats per minute. \( T = P < .05 \); \( T = P < .01 \) as obtained from analysis of variance using body weight as a covariate. \%Δ = median change (except * mean change).

an increase in muscle power. LEP/kg and LEP both increased by 18% in the training group, but only LEP/kg showed a statistically significant increase. We would suggest that the training subjects have received a significant biological effect.

There have been two other fully randomized, controlled training studies that have considered functional ability and strength in older people. One showed that 12 weeks of a combination of strength and balance training increased both strength and chosen gait velocity. Fiatarone et al., looking at the effect of 10 weeks of training with leg press or wall-mounted pulleys in men and women more than 70 years old, found significant improvements in lower extremity strength, gait velocity, and stair climbing power. The subjects in these studies were either not as healthy as those in this study or were very frail and had functional difficulties. Neither chosen gait velocity nor stair-climbing power was improved in the present study, where the volunteers were functionally more able than in Fiatarone's study. No other strength-training study has considered muscle power and functional ability in older people.

Only two of the functional tasks, stepping up and rising from the kneeling position on the floor (normal pace), improved with strength training. Step-up height is related to LEP/kg, and this is supported by the fact that stepping-up ability did improve, with training, in this study. Kneel rise time is also related to LEP/kg and IKES/kg (unpublished data). Both step height and bag raise involved a cut-off height or weight beyond which the task was no longer considered functional. A number of women were able to step our highest step or lift our heaviest bag. These women were excluded from the analyses because they could not improve (see Statistical Methods). This reduced the statistical power of this analysis. However, of the 11 functional ability tasks that showed no improvement, only two had reduced statistical power. We conclude that task-independent increases in strength and LEP/kg can produce only limited improvements in functional ability in healthy, independent, older women. Perhaps improving functional ability requires training that includes practice of the functional tasks.

Women in the training group also reported subjective benefits. Many suggested that they felt better able to cope with the demands of daily life (shopping, use of public transportation, etc.), five reported that movement in the shoulders had improved, three that their balance was much improved, and one that she could now cut her toe-nails and have a bath rather than a shower.

The enthusiasm of the volunteers for the exercise classes was apparent from their expressed hope that the program could be continued. At follow-up 6 months later, one weekly class had been set up in a subject's front room (3 women attending), two women had joined classes elsewhere, and 12 reported that they continued to practice at home, at least once a week, the exercises used in the study.

We conclude that a simple-to-follow program of progressive resistance exercise can produce substantial increases in muscle strength and power, standardized for body weight, in healthy, independent, older women. Isolated improvements of strength and power standardized for body weight may not be sufficient to improve functional ability in such people.

ACKNOWLEDGMENTS

The authors thank Research Into Ageing, the Violet M. Richards Charity, and the University of London Central...
search Fund (RJL Body Impedance Analyser) for their support. They also wish to thank the volunteers for their enthusiasm and perseverance, Caroline Sabin for statistical analysis, and Helena Rhodes, Susie Dinan, and Tony Lyolat for their help with the exercises.

REFERENCES


Bassey EJ, Ramadale SJ. Leg extensor power improves in women with feasible exercise programmes. J Physiol (Abstact) 1993;467:121P.


There was little overlap between groups positive for different isotypes: between antibody titre and age for any isotype (IgG r=0.248, IgM r=0.026, IgA r=0.007), and the mean ages of positive and negative groups did not differ significantly (unpaired t-test: IgG=66 years, IgG 71 years, p=0.06; IgM=66, IgM=67, p=0.75; IgA=67, IgA=67, p=0.82). 18% were positive for IgG, 11% for IgM, and 22% for IgA. There was little overlap between groups positive for different isotypes: a total of 42% of patients demonstrated significantly elevated titres to one or more isotypes. This contrasted with a control population with 71 years: p=0.06; IgM=66, IgM=67, p=0.75: IgA=67, IgA=67, r=0.026, IgA r=-0.007). and the mean ages of positive and negative no history of cerebrovascular disease, in whom less than 1% had positive IgG levels, 5% positive IgA and 2% positive IgM. We conclude that anticardiolipin antibodies of all isotypes are present in a high proportion of stroke patients. There is no relationship to age. We suggest that anticardiolipin antibodies may not represent a pathogenetic mechanism for stroke and that routine testing for these antibodies is not justified in any age group.

There were mean increases in isometric knee extensor strength, isometric elbow flexor strength and lower limb extensor power of 13-30% in the 20 training group subjects (J. Physiol., abstract in press).

Step height showed a significant improvement with training (p<0.01), corresponding to a median increase of 2.5cm. Time to rise from a low chair also improved (both "as fast as possible", median change 14.3%, p=0.01 and "at a comfortable pace", median change 16.6%, p<0.04).

Tests of time (and ability) to rise from a low chair 10 times, rise from the floor, walk a 118m corridor, stair-climb (max. 6 flights), lift 2-8kg onto a table top and functional reach showed no improvement with training.

These data suggest that task independent increases in strength and power can produce only limited improvements in functional ability.

We thank Research Into Aging, The Violet Richards Charitable Trust and The British Geriatrics Society (Dobie Bursary) for their support.

**The Antioxidant Status of Patients with Psoriasis**

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We have previously reported the high incidence of alcohol misuse in patients with psoriasis. It is postulated that free radical formation during ethanol metabolism is responsible for alcohol-induced tissue damage. Antioxidants (e.g. alpha-tocophorol and certain trace elements) are cytoprotective and may be reduced in alcoholics. It has been suggested that some trace elements may be depleted in psoriasis, but the results are inconsistent. Alpha-tocopherol has not been studied previously in psoriatic patients. This study was designed to investigate the antioxidant status of psoriasis, with special reference to those who were heavy drinkers. 68 patients (42M, 26F) of whom 27 (40%) were alcohol measues were studied. Serum zinc and copper were determined by flameless atomic absorption and alpha-tocopherol by HPLC. Compared with normal controls the mean serum zinc (13.2 ± 3.4 v 17.5 ± 6.5, p<0.001) and alpha-tocopherol (13.8 ± 6.2 v 18.0 ± 3.0, p<0.001), but not copper (14.9 ± 5.5 ± 15.5 ± 6.5, 0.05<p<0.1) were significantly reduced. Subdividing the psorics into drinkers and non-drinkers, there was a greater reduction in all three parameters in alcohol misusers (low zinc 33% v 10%, p<0.05; low copper 30% v 12%, 0.05<p<0.01; low alpha-tocopherol 52% v 20%, p<0.01). Inflammatory responses, particularly neutrophil activation are enhanced by low zinc and free radical production. The exacerbation of psoriasis by alcohol may be explained by such a mechanism.


**Measurement of Antioxidant Activity in Lipoproteins Using Enhanced Chemiluminescence**

SRJ MAXWELL, O WIKLUND*, G BONDJERS*

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Oxidative modification of lipoproteins is now established as an important factor in atherosclerosis. Endogenous antioxidant activity (AOA) in lipoproteins influences their susceptibility to oxidation. We describe a new assay for chain-breaking AOA in lipoprotein solutions based on their potential to quench light emission from a glowing peroxidase-catalyzed enhanced chemiluminescent reaction. By comparison with the quenching produced by a standard antioxidant solution of the water-soluble tocopherol analogue tiroxol AOA can be quantified.

These measurements suggest that all lipoprotein fractions have significant activity and that this is related in a non-linear manner with lipoprotein concentration, increasing significantly on a "per particle" basis at higher concentrations. Mean AOA in very low density, low density and high density lipoprotein fractions from 26 healthy controls were 39.9 ± 5.3, 20.3 ± 4.0 and 5.3 ± 1.0 umol of tiroxol equivalents per litre respectively when measured at 1mg protein/ml. Using known values for the protein content of the lipoprotein fractions these values correspond to 79.3 ± 10.7, 10.3 ± 2.0 and 0.84 ± 0.13 equivalents per particle.

The AOA can be further defined on a "per lipid" basis if the concentrations of cholesterol and triglyceride in the lipoprotein fraction are known. These calculations gave values of 6.6 ± 0.8, 3.9 ± 0.7 and 4.0 ± 0.6 tiroxol Eq/1000 lipid molecules respectively. Parallel measurements of chemiluminescence and conjugated diene formation suggest that the oxidative stress imposed by the reaction causes lipid peroxidation but only after all AOA has been exhausted. AOA could be increased by addition of alpha-tocopherol or probucol (but not beta-carotene) to plasma prior to lipoprotein separation.

This simple assay offers a rapid technique for investigating the effects of diseases, drugs or dietary manipulation on lipoprotein antioxidant status.
Syringe needle aspiration of skeletal muscle. An alternative to muscle biopsy for some applications.


Departments of *Anatomy and Developmental Biology and *Geriatric Medicine, Royal Free Hospital School of Medicine Hampstead, London. *Nuffield Department of Orthopaedic Surgery University of Oxford.

Biopsy of skeletal muscle is used routinely for diagnostic and investigative purposes. There are three main biopsy methods currently in use: the open biopsy, the Bergstrom needle method and the conchotome method. However, the invasive nature of these procedures is limiting in studies requiring multiple repetitive sampling.

In applications where molecular information about the expression patterns of various muscle genes is sought, a muscle biopsy yields amounts of tissue far in excess of that actually required. Therefore, in order to investigate longitudinal patterns of muscle gene expression we have developed a relatively non-invasive technique (syringe needle aspiration) which provides enough material for the analysis, by the polymerase chain reaction (PCR), of the expression of muscle genes. This is far less invasive than even the needle biopsy and thus better suited to studies which require repeated sampling.

Sampling is done with a 19 gauge needle and a 20ml syringe. After needle insertion into the muscle a vacuum is pulled with the syringe plunger and four 1cm excursions into the muscle carried out. The vacuum is then released slowly and the needle withdrawn. RNA is then prepared from the aspirate by a scaled down version of the method published by Chomczynski and Sacchi, (1987). cDNA prepared from the muscle RNA is primed with oligo dT(15) so as to allow analysis of multiple genes from the same aspirate. PCR is then performed using specific primers for the genes of interest.

Using this technique in human biopsies we have investigated the expression of five different isoforms of the myosin heavy chain gene (embryonic, neonatal, slow type I, fast IIX and fast IIA), dystrophin and insulin-like growth factor I, demonstrating that both rare (dystrophin) and abundant (myosin heavy chain gene) transcripts can be successfully amplified.

Reference
TRAINING INCREASES STRENGTH AND POWER IN VERY ELDERLY WOMEN

KE MALBUT†, CA GREIG, E PIPPET†, F BUTLER†, A YOUNG, S DINAN**, C BARKER** and K OLIVER**

Human Performance Laboratory, University Department of Geriatric Medicine, Royal Free Hospital School of Medicine, London and London Central YMCA* ('introduced)

There has been no controlled study of training-induced changes in strength or explosive power beyond 75 years of age. Studies of changes in explosive power are rare even at younger ages. Maximal voluntary isometric quadriceps strength and lower limb extensor power were measured in seven healthy women aged 78 to 85 years (mean 81 years), all living in sheltered housing, before and after a 12 week control period and after 12 weeks of training. Training, for 50 minutes 3 times per week, was designed mainly to increase aerobic endurance but included 10 minutes of stretching and strengthening. Analysis of variance confirmed the presence of a significant 'treatment' effect on the power of each subject's more powerful limb (p < 0.01) and the strength of each subject's stronger quadriceps (p < 0.05). The changes in strength and power over the control and training period were therefore examined further (in non-parametric, Wilcoxon-based tests). Control and Training median changes in strength were +7% (NS) and +17% (95% CI 14% to 42%) respectively. Control and Training median changes in power were -1% (NS) and +23% (95% CI 12% to 43%) respectively.

This work was supported by the Violet M. Richards Charity Trust and the British Geriatrics Society Dhole Bursary.
Muscle strength and power after strength-training by women aged 75 and over: a randomized, controlled study

D.A. Skelton, C.A. Greig, K. Malbut and A. Young

Human Performance Laboratory and University Department of Geriatric Medicine, Royal Free Hospital School of Medicine, Rowland Hill Street, London NW3 2PF

There has been no randomized, controlled study of strength-training by very elderly people.

Forty-seven healthy women, matched for age and habitual physical activity, were randomly assigned to either a control or exercise group. Training comprised one supervised session per week at the Medical School, transport provided, and two unsupervised home sessions, and lasted for 12 weeks. Each session (about 1 h) included (1) warm-up and stretch, (2) progressive resistance strengthening exercises, each with three sets of 4–8 repetitions (using elastic tubing), and (3) a ‘warm-down’ component. No exercise mimicked the measurement procedures. Home sessions were supported by an exercise tape and booklet. Monitoring by diary indicated that participation was good. No intervention was prescribed for the controls.

Seven women did not complete the study, five because of ill-health (three exercisers, two controls), and two because of other commitments (one exerciser, one control). Pre- and post-training data for isometric knee extensor strength (IKES), isometric elbow flexor strength (IEFS), handgrip strength (HGS), and leg extensor power (LEP), were obtained from twenty exercisers, median age 79.5 years (range 76–93 years) and twenty controls, median age 79.5 years (range 75–90 years). All procedures received Local Ethics Committee approval.

In the exercise group, using paired t tests, there were significant increases in IKES, IEFS, and LEP compared with baseline values (Table 1). HGS did not alter significantly in the exercise group, but the small loss of left HGS in the control group did reach statistical significance.

Table 1. Mean changes in strength and power

<table>
<thead>
<tr>
<th>% change</th>
<th>Exercise</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>IKES</td>
<td>Left</td>
<td>+30%</td>
</tr>
<tr>
<td></td>
<td>Right</td>
<td>+26%</td>
</tr>
<tr>
<td>IEFS</td>
<td>Left</td>
<td>+20%</td>
</tr>
<tr>
<td></td>
<td>Right</td>
<td>+24%</td>
</tr>
<tr>
<td>LEP</td>
<td>Left</td>
<td>+23%*</td>
</tr>
<tr>
<td></td>
<td>Right</td>
<td>+13%*</td>
</tr>
<tr>
<td>HGS</td>
<td>Left</td>
<td>+7%</td>
</tr>
<tr>
<td></td>
<td>Right</td>
<td>0%</td>
</tr>
</tbody>
</table>

*= P < 0.05, † = P < 0.01.

We conclude that a ‘simple-to-follow’ programme of progressive resistance exercise can produce substantial increases in muscle strength and power in healthy, very elderly women.

We thank Research into Ageing, The Violet Richards Charitable Trust and The British Geriatrics Society (Dhole Bursary) for their support.
APPENDIX ONE C

IMPROVING PHYSICAL PERFORMANCE AND QUALITY OF LIFE IN

OLDER PEOPLE

CONSENT FORM

The procedures involved in this study have been explained to me by Katie Malbut. I understand that I may withdraw from the study at any time without having to give a reason.

Signature of volunteer subject:-

Signature of witness:-
APPENDIX TWO A

Text of pilot study

A pilot study of the effects of an aerobic training programme on laboratory and functional measures of physical ability in very elderly women

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Katie Malbut
Elizabeth Pippet
Felicity Butler
Archie Young

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Royal Free Hospital School of Medicine
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NW3 2PF
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Correspondence to: Professor Young
Summary. 7 healthy women aged 78 to 85 years, all residents of warden controlled (sheltered housing) accommodation, took part in a pilot study to examine the effect of 12 weeks of endurance training on both laboratory and functional measures of physical ability. Subjects were tested before and after a 12 week control period and after 12 weeks of training. Training sessions were held three times per week. Each lasted 50 minutes and included 20 minutes of exercise aimed at working the subjects at 60-70% of predicted maximal heart rate and 10 minutes of stretching and strengthening exercise. Testing took place at the Royal Free Hospital School of Medicine, training took place in sheltered housing accommodation. Although there was no suggestion of any training effect on heart rate at the same zero gradient walking speed, self-paced walking speed or stair climbing work rate, increases in isometric knee extensor strength and lower limb extensor power suggest that some adaptations have taken place. Control and training median changes in strength were +2%(NS) and +15% (95% Confidence interval +0.2% to +30%) respectively. Control and training median changes in power were -6%(NS) and +21%(95%CI +13% to +28%).

Keywords. aerobic training; aged, 80 and over; strength; power; muscle physiology

Introduction

With ageing maximal oxygen uptake (VO₂ max) decreases at 10% per decade (for review see Greig and Young, 1992). An elderly person therefore performs everyday tasks at a higher percentage of their VO₂ max than a young person. Eventually performance of daily tasks becomes impossible. Endurance training has been shown to increase VO₂ max in subjects up to about 70 years of age (e.g Blumenthal et al. 1989; Cress et al. 1991; Posner et al. 1991; Stratton et al. 1991) but no controlled study has investigated the effects in older subjects, who would be expected to benefit most. The idea of aerobic training by very elderly people is attractive; if VO₂ max can be increased, this may well improve their ability to perform everyday tasks and maintain physical independence for longer.

This report concerns a pilot study of the effects of predominantly ‘aerobic’ training in 7 women aged 78 to 85 yrs on both laboratory and functional measures of physical ability. Some findings have been published as an abstract (Malbut et al. 1993).

Method

Volunteers for the pilot study were recruited from local warden-controlled ('sheltered') housing. Each potential subject was sent a comprehensive health questionnaire to complete, criteria for exclusion were strict (details available on request). Seven healthy females were accepted for the study (table 1). Each underwent a graded exercise treadmill test, under medical supervision (modified Naughton protocol, Patterson et al. 1972) during which a 12 lead electrocardiogram was monitored. No abnormalities were detected. Baseline measurements for each subject were recorded several days later. These were height, weight, left and right isometric knee extensor strength (Edwards et al. 1977) ≥3 maximal voluntary contractions on each side and lower limb extensor power (Bassey and Short, 1990; Greig et al. 1990) ≥5 attempts each side. Best left and best
right strength values were averaged for analysis, as were those for power. Functional ability tests were a timed, self-paced walking test, at each subject’s chosen comfortable walking speed (m.s⁻¹) along a corridor circuit (100 to 200m) and a timed, self-paced stair climb (comprising 6 flights, each of height 1.885m) during which heart rate was monitored using telemetry (‘Polar Sportstester’, Finland. The speed of the treadmill was set to the self-paced walking speed of the individual and the gradient to zero. Heart rate, oxygen consumption, carbon dioxide production and minute ventilation were monitored during the final minute of a three minute period standing on the treadmill and of a three minute walking period. Treadmill tests were supervised by two operators trained in cardio-pulmonary resuscitation.

Tests were repeated on at least two separate occasions, to allow for familiarisation. Measurements taken from the last visit were recorded as the pre-control data. During all treadmill tests the speed was set to the self-paced walking rate recorded at the pre-control visit. The tests were repeated once after a twelve week control period and again after completion of training.

For training, there were two groups, of 3 and 4 subjects. They trained 3 times each week for twelve weeks. Each session comprised 10 mins warm up exercise, 20 mins of aerobic exercise, 10 mins of stretching and strengthening exercise and 10 mins of warm down. Target exercise heart rate for the aerobic component was taken as 60-70% of the maximum predicted heart rate of each subject. The aerobic training exercises were chosen in the expectation that they would benefit both walking and stair climbing but deliberately excluded practice of these specific activities.

Ethical approval. The study was approved by the Ethical Practices Subcommittee of the Royal Free Hospital and School of Medicine and all subjects gave their informed consent.

Data handling. Changes over the control and training periods, were compared by analysis of variance. If these confirmed the presence of a ‘treatment-period’ effect, data were further examined with a paired non-parametric Wilcoxon-based test (Gardner et al. 1989). If there was no significant difference between pre-control and post-control values, the post-training value was compared with the mean of the pre- and post-control values.

Results
There was no suggestion of an effect of training on the heart rate at the same zero gradient walking speed on the self-paced walking speed, or on work rate during the self-paced stair climb, table 2. (Adequate oxygen uptake data for all visits were obtained only in 3 subjects, table 3.) Training resulted in significant increases in both isometric knee extensor strength and lower limb extensor power, table 4.

Discussion
Why was there no suggestion of an aerobic training effect? It may be that it is not possible to increase in this age group; no previous study has concentrated specifically on endurance training at this age. Adaptations to endurance training in this age group may differ from those seen in younger individuals or it may be that the subjects were already highly trained; if everyday activities require a large proportion of an individual’s VO₂ max then would this in itself not provide a training stimulus? Alternatively it is possible that the subjects experimental training was not sufficiently hard. Although they were training at a high percentage (60-70%) of their predicted maximum heart rate, only one subject was working above 50 % of predicted heart rate reserve (HRR). As maximal heart rate decreases with age this alters the
relationship between percentage of maximal heart rate and percentage of heart rate reserve. Perhaps % of HRR is a more appropriate guide to the intensity of training in old age. Although training effects have been observed even when exercising at an low intensity as low as 50% HRR, the exercise period was longer than in this study (Foster et al. 1989).

Finally, it may be that aerobic training effects are seen during walking only if walking itself forms part of the training; less extreme examples of specificity of aerobic training are well described e.g.Clausen et al. 1970. A surprising result was the ease with which strength and power were increased: the training was not primarily intended to do this.

Since some adaptation clearly occurred, it seems all the more surprising that we saw no evidence of aerobic adaptations. In designing the definitive study we must reconsider the training intensity needed to promote aerobic adaptation and must include at least one test which reproduces a training exercise.

This work was supported by the Violet M.Richards Charity Trust, the British Geriatrics Society Dhole Bursary (to Dr.Greig) and the Peter Samuel Royal Free Fund. We would also like to thank Susie Dinan, Carole Barker and Keith Oliver from the London Central YMCA for their help with the exercise classes.

References


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<th>Range</th>
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<td>78-85</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>53</td>
<td>46-57</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>159</td>
<td>153-162</td>
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Table 1. Characteristics of subjects (n=7)
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<tr>
<th></th>
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<th>Post Control</th>
<th>Post Training</th>
</tr>
</thead>
<tbody>
<tr>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>same zero gradient</td>
<td></td>
<td></td>
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</tr>
<tr>
<td><strong>walking speed (bpm)</strong></td>
<td></td>
<td></td>
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<tr>
<td>Median</td>
<td>108</td>
<td>111</td>
<td>112</td>
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<tr>
<td>Range</td>
<td>96 to 121</td>
<td>79 to 138</td>
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<tr>
<td><strong>Self paced</strong></td>
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<td><strong>walking speed (m.s(^{-1}))</strong></td>
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<td>4.3</td>
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<td><strong>Self paced</strong></td>
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<td><strong>stair climbing</strong></td>
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<td><strong>work rate (W)</strong></td>
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<td>88</td>
<td>94</td>
<td>97</td>
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<tr>
<td>Range</td>
<td>32 to 114</td>
<td>30 to 119</td>
<td>42 to 123</td>
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**Table 2:** Self-paced walking rate, self-paced stair climbing work rate and heart rate at same zero gradient walking speed.

bpm = beats per minute
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<tr>
<th>Subject</th>
<th>Pre-Control</th>
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<th>Post-Training</th>
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<tr>
<td>1</td>
<td>15.4</td>
<td>14.6</td>
<td>10.1</td>
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<td>15.0</td>
<td>12.8</td>
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<tr>
<td>3</td>
<td>14.0</td>
<td>15.4</td>
<td>16.8</td>
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Table 3. Oxygen uptake (ml.kg\(^{-1}\).min\(^{-1}\)) at same zero gradient walking speed
<table>
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<tr>
<th></th>
<th>Pre</th>
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<th>Post</th>
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<th>(3→4)</th>
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<tr>
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<td>(1+2)/2</td>
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<tr>
<td>Median</td>
<td>192</td>
<td>192</td>
<td>+2(NS)</td>
<td>192</td>
<td>228</td>
<td>+15 (0.2% to 30%)</td>
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<td>131 to 228</td>
<td>154 to 268</td>
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<td>Power (W)</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>Median</td>
<td>51</td>
<td>53</td>
<td>-6(NS)</td>
<td>52</td>
<td>71</td>
<td>+21 (13% to 28%)</td>
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<tr>
<td>Range</td>
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<td>25 to 72</td>
<td>28 to 69</td>
<td>30 to 84</td>
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**Table 4**: Isometric knee extensor strength and lower limb extensor power (mean of L+R)

NS = not significant
APPENDIX THREE A
Criteria for definition of medically stable and healthy

Exclusion criteria to define MEDICALLY STABLE elderly subjects for exercise studies

- History of myocardial infarction within the previous 2 years.
- Cardiac illness: symptoms of aortic stenosis, acute pericarditis, acute myocarditis, aneurysm, severe angina, clinically significant valvular disease, uncontrolled dysrhythmia, claudication, within the previous 10 years.
- Thrombophlebitis or pulmonary embolus within the previous 2 years.
- History of cerebrovascular disease.
- Acute febrile illness within the previous 3 months.
- Severe airflow obstruction.
- Uncontrolled metabolic disease (e.g. diabetes, thyroid disease).
- Major systemic disease active within the previous 2 years (e.g. cancer, rheumatoid arthritis).
- Significant emotional distress, psychotic illness or depression within the previous 2 years.
- Lower limb arthritis, classified by inability to perform maximal contractions of lower limbs without pain.
- Lower limb fracture sustained within the previous 2 years. Upper limb fracture within the previous 6 months. Non-arthroscopic lower limb joint surgery within the previous 2 years.
- Any reason for a loss of mobility for greater than 1 week in the previous 2 months or greater than 2 weeks in the previous 6 months.
- Resting systolic blood pressure $>200\text{mmHg}$ or resting diastolic blood pressure $>100\text{mmHg}$.
- Taking beta-blockers or digoxin, or not in sinus rhythm, excluded from ergometry because of difficulty interpreting heart rate.
- On daily analgesia.
Exclusion criteria to define 'HEALTHY' elderly subjects for exercise studies

- History of myocardial infarction within the previous 10 years.
- Cardiac illness: e.g. symptoms of aortic stenosis, acute pericarditis, acute myocarditis, aneurysm, severe angina, clinically significant valvular disease, uncontrolled dysrhythmia, claudication, within the previous 10 years.
- Thrombophlebitis or pulmonary embolus within the previous 10 years.
- History of cerebrovascular disease.
- Acute febrile illness within the previous 6 months.
- Moderate or severe airflow obstruction.
- Metabolic disease (e.g. diabetes, thyroid disease), whether controlled or uncontrolled.
- Major systemic disease diagnosed or active within the previous 20 years (e.g. cancer, rheumatoid arthritis).
- Significant emotional distress, psychotic illness and anything worse than mild anxiety or depression within the previous 10 years.
- Osteoarthritis, classified by inability to perform maximal contractions of upper or lower limb muscles without pain.
- Bone fracture sustained within the previous 2 years.
- 'Old person's fracture' after 40 years of age (Colles, hip, vertebral).
- Non-arthroscopic joint surgery, ever, in the relevant limb part.
- Any reason for a loss of mobility for greater than 1 week in the previous six months, or greater than 2 weeks in the previous year.
- On daily medication (including daily simple analgesia). On oestrogen replacement therapy. On medication for hypertension, or with a diuretic for any other reason, even if not daily.
- Obese, i.e. a Body Mass Index (wt.ht²) greater than 29.9.
- Resting systolic blood pressure >200mmHg, or resting diastolic blood pressure >100mmHg.
APPENDIX THREE B

Flyer sent to potential subjects

COPY OF WRITTEN INFORMATION TO BE SENT TO POTENTIAL SUBJECTS

Exercise testing in older subjects - a pilot study

We are looking for volunteers to help with a pilot study to look at exercise testing (to assess stamina or exercise capacity) in older people. This study will prepare the way for a further study which aims to increase exercise capacity or stamina as well as quality of life in older people through exercise training.

If you are interested we would like you to come to the Royal Free Hospital where we will give you a routine health screen. This will include measuring your blood pressure, heart rate, height and weight.

We will then ask you to do some exercise for us on an exercise bike. This will involve you exercising as much as you can, and will last 10-15 minutes depending on how fit you are. If at any time during the test you wish to stop we will terminate the test immediately. During the exercise we will measure your heart rate and the amount of oxygen your body is using (you will need to breath into a mouthpiece for this). Once you have completed the exercise we will monitor your heart rate until it has returned to resting value after which you will be free to return home.

If you wish we will be pleased to arrange your transportation to and from the Royal Free Hospital.

If at any time during the study you wish to withdraw, then you may do so without giving a reason.
Criteria for termination of an exercise test.

1. Subject requests to stop
2. Failure of the monitoring system
3. Progressive angina (chest pain)
4. Two-millimeter horizontal or downsloping ST-depression on the ECG.
5. Sustained supraventricular tachycardia
6. Ventricular tachycardia
7. Exercise induced left or right bundle branch block
8. Any significant drop (10mmHg) in systolic blood pressure
9. Light headedness, confusion, ataxia, pallor, cyanosis, nausea, or any sign of peripheral circulatory insufficiency
10. Inappropriate bradycardia
11. Excessively high blood pressure: systolic >260mmHg, diastolic >120mmHg
12. Presence of dangerous dysrhythmias such as premature ventricular contractions and multifocal PVC's

Change in oxygen consumption with increasing work rate.

(A) No plateau in oxygen consumption demonstrated

(B) Plateau in oxygen consumption demonstrated

* Last 2 readings in each stage used to calculate the oxygen consumption at each work rate.
APPENDIX 3E

THE POWER OF A TEST

The probability that a test will produce a significant difference at a given significance level is called the power of a test. It will depend on the difference between the populations compared, the sample size and the significance level chosen (Bland 2000). A good power is one which is 0.8 (80%) or above.

Power can be calculated as follows

\[
\text{Power} = 1 - P(X)
\]

where \( P \) is the possibility of

\[
X = t - \frac{\text{mean of population 1} - \text{mean of population 2}}{\text{SE difference}}
\]

(for 95% significance level \( t = 1.96 \))

\[
\text{SE difference} = \sqrt{\frac{\text{Standard deviation 1}^2 + \text{Standard deviation 2}^2}{\text{Sample size 1} \cdot \text{Sample size 2}}}
\]

References

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<td>2. Katz index of ADL (3)</td>
<td>X</td>
</tr>
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<td>3. Hamilton rating scale for depression (4,5)</td>
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<td>4. Zung self-rating depression (4)</td>
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<td>5. Life satisfaction index (4,6-8)</td>
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<td>6. Rosser index of disability and distress (7)</td>
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<td>7. Quality of well-being scale (4)</td>
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<td>16. The functional status index (6,8)</td>
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<td>18. The Karnofsky performance index.(5,9)</td>
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<td></td>
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<td>?suitability for use with older subjects or for our purpose</td>
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References


6. George LK: *Quality of Life in Older Persons: meaning and measurement*, New York, Human Sciences Press; 1980:


We are looking for healthy volunteers aged 18 to 45 years to act as a control group for a study of the effects of aerobic training in old age. The study will involve taking part in 3 free aerobics classes per week over a period of 24 weeks. Your fitness level will be measured before and after training. If you are interested please contact Katie on extension 3206 for more details.
APPENDIX FIVE B
Methodology for analysis of enzyme activities

Samples were weighed, transferred to Potter-Elvehjem homogenisers containing a 100-fold volume of ice-cold 50% glycerol containing 20 mM sodium phosphate buffer, pH 7.4, 5mM β-mercaptoethanol, 0.5mM ethylenediaminetetraacetic acid (Na₂ EDTA) and 0.2% bovine serum albumin (BSA) and homogenised for 30 seconds.

Phosphofructokinase (PFK) and Lactate dehydrogenase (LDH) were measured on the fresh homogenates without further storage. Aliquotes of homogenate were kept on ice and assayed for PFK and LDH activity within 30 minutes.

For the other enzymes, aliquots of the homogenates were stored at -70°C prior to analysis. All of the homogenate assays for a given enzyme were carried out in duplicate on the same day at 30°C.

Homogenate PFK activity was determined as described by Opie and Newsholme.

The activity of b-Hydroyacyl-CoA dehydrogenase (HAD) was determined by a spectrophotometric modification of the fluorometric method described by Chi et al whilst Cytochrome c oxidase (CCO) was determined using the polarographic method as described by Henriksson et al.

For LDH, a Sigma Diagnostics kit (Procedure No. 228-UV, Sigma-Aldrich Co Ltd, Poole, Dorste, UK) was used. The reagent contained 50 mM lactate, 7 mM NAD and hydrazine buffer, pH 8.9, and to 1.0ml of this in a semi-micro cuvette was added 10 μl of homogenate. LDH catalyses the oxidation of lactate to pyruvate with the simultaneous reduction of NAD. The increase in absorbence at 340nm due to the formation of NADH was recorded every 30 seconds for 4 minutes.

References


APPENDIX FIVE C
Methodology for analysis of mRNA levels

*Extraction of RNA*
RNA was isolated by a scaled down version of the method described by Choczynski and Sacchi (1987). For each sample 10 μm sections were cut on a cryostat (Bright) and placed in 500 μl of denaturing solution. After phenol extraction and ethanal precipitation the dried pellet of RNA was washed 3 times in 70% ethanol and dissolved in 20 μl of DEPC treated water. Sixty 10 μm cryosections yielded approximately 30-50 μg of total RNA. A 1 μl aliquot of each sample was run on a RNA gel to check no degradation of RNA had occurred during storage or preparation.

*Slot blotting of RNA*
Three dilutions of each RNA sample were prepared in 10 mM NaOH, 1 mM EDTA to give final volumes of 500 μl containing 16, 8 and 0.8 μg of RNA. The samples were loaded via slot blot apparatus onto Zeta probe nylon membrane (BioRad) according to the manufacturer’s instructions. Blots were air dried and baked at 80°C for 30 minutes in a vacuum oven.

*Preparation of cDNA probes*
The polymerase chain reaction (PCR) using gene specific primers for 1. Cytochrome C oxidase subunit VIIa (COX7a)
2. Phosphofructokinase (PFK), 3. 3-hydroxyl-CoA dehydrogenase alpha sub-unti (COA), 4. ribosomal protein S26 (S26) was performed on human muscle cDNA essential by the methods described in Ennion et al. (1995). The PCR primers used and the regions of the respective genes they amplify are given in table 1. PCR products were then cloned into pCR 2.1 plasmid (Invitrogen) by TA cloning as per the manufacturer’s instructions. The inserts of the plasmid clones were than sequenced to verify that they contained the correct gene sequence.
Hybridisation

Plasmid constructs were linearized with the appropriate restriction enzyme and labelled with $^{32}$P $\cdot$ dCTP (Amersham) using a Decaprime kit (Ambion) according to the kit instructions with the exception that the random decamers were replaced with Sp6 or T7 primer to facilitate labelling of the full length antisense strand. Slot blots were hybridised with labelled probe according to the method of Church and Gilbert (\cite{church84}) with a probe concentration of $10^6$ cpm/ml of hybridisation buffer. Hybridisation and washing was performed at 10°C below the calculated melting temperature of the probe (75, 70, 70, and 72°C for COX7a, S26, PFK and COA respectively). After washing, membranes were sealed in plastic bags to prevent drying and exposed to a phosphorimaging screen (Molecular Dynamics) for 18 hours. Membranes were stripped and checked for complete removal of probe by re-exposure with a phosphorimaging screen (Molecular Dynamics) for 36 hours between each successive hybridisation.

Quantification of message

Phosphoimages of the slot blots were analysed using ImageQuant software (Molecular Dynamics) to give a value of the number of counts per slot in arbitrary units. Value for COX7a, PFK and COA were normalised against the value for S26. This ribosomal subunit has been shown to act as a good invariant control for gene expression studies and is a better standard than the 18S of 28S subunits which are known to vary under some conditions \cite{3528}.

References


<table>
<thead>
<tr>
<th>Gene</th>
<th>Forward PCR primer</th>
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<th>EMBL database</th>
<th>Region cloned*</th>
<th>Size (base Pairs)</th>
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<td>PFK</td>
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* Region cloned corresponds to the sequence positions in the respective database accession file
APPENDIX 6A

Example of 2 way ANOVA with time and subject as two factors.

Subject | Pre Control | Post Control | Post 24 wk training | Ex
--- | --- | --- | --- | ---
1 | 97 | 103 | 96 | 2.98
2 | 97 | 101 | 86 | 2.84
3 | 81 | 92 | 80 | 2.53
4 | 98 | 82 | 96 | 2.86
5 | 85 | 91 | 85 | 2.61
6 | 95 | 101 | 102 | 2.98
7 | 76 | 77 | 75 | 2.28
8 | 103 | 118 | 99 | 3.20
9 | 84 | 102 | 78 | 2.64
\[ \begin{array}{c|c|c|c}
\text{Ex} & \text{Ex^2} & \text{Ex^2} \\
818 & 75066 & 7977 & 71367 \\
\end{array} \]

1. Grand total = 818 + 877 + 797 = 2492
2. Sum of Squared observations = 75066 + 86477 + 71367 = 232910
3. Sum of Squared Column totals ÷ Sample size of Column
   \[ \frac{818^2 + 877^2 + 797^2}{9} = \frac{230384.67}{9} \]
4. Sum of Squared Row totals ÷ Sample size of rows
   \[ \frac{298^2 + 303^2 + 264^2}{3} = 232090 \]
5. Grand total squared ÷ total sample size = 2492^2 ÷ 27
   \[ = 2302.37 \]
6. SS total = # 2 - # 5 = 2907.63
7. SS treatments = # 3 - # 5 = 382.3
8. SS rows = # 4 - # 5 = 2087.63
9. SS error = # 6 - # 7 - # 8 = 437.7

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<td>16</td>
<td>437.7</td>
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From table F 0.01 [2, 16] 6.23 . . . P < 0.01
Currently in KTM's learning study.
Also in D.S.'s cross-sectional study.)

M.D. degree this year. Getting more since starting study.
In 5 months, esp. at first. Spec. medically.
She at rest. Even moderate with sleep?

Slight swelling.

Weeks ago went on 12 mile ramble. Pain afterwards.
No better with Ibuprofen ~3 years. Nothing much.

Some discomfort under MCP great joint.
Could include uveoretinal effusions (October 1981)
Dwelling/claustrophobia Lake District & New Jersey. Knee "jiggly" there.

Fybogel
Ibuprofen 400mg/day for ~1/2, ending yesterday. No benefit.
Exam:

- V. slight bilat. varus knees.
- Lips OK.
- Feet OK.
- L leg ~ 1" longer than R. ≠

- Trace fluid L knee.
- Trace bilat. retropat. effusion.
- Tender post. med. L joint line = hip pain.
- Both knees full ROM.

Check Xrays knees, standing — cholesterol in lat. comp. Oliene.
- Slight v. j. space med. comp. @ knee.
- (?) else o. note.

- Plan: omni ex. class this Monday and next Monday.
- Transfer thick residue from ① shoe to ② (to puré double in ②).
- AV review in ② and discuss exercise choice and ESD.

Rx:

- (?) med/surg synj. — although none actually felt.
APPENDIX SEVEN

Physiological results from the young subjects
<table>
<thead>
<tr>
<th></th>
<th>Age (years)</th>
<th>Height (m)</th>
<th>Weight (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Men</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Range</td>
<td>28-44</td>
<td>165-184.5</td>
<td>67.5-93.5</td>
</tr>
<tr>
<td>Median</td>
<td>34</td>
<td>172.5</td>
<td>76</td>
</tr>
<tr>
<td>Mean</td>
<td>35</td>
<td>174</td>
<td>78</td>
</tr>
<tr>
<td>(SD)</td>
<td>(6.7)</td>
<td>(7.49)</td>
<td>(9.7)</td>
</tr>
<tr>
<td><strong>Women</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Range</td>
<td>21-44</td>
<td>153.5-175</td>
<td>54.3-79</td>
</tr>
<tr>
<td>Median</td>
<td>30</td>
<td>161.5</td>
<td>64.2</td>
</tr>
<tr>
<td>Mean</td>
<td>30</td>
<td>162</td>
<td>65.1</td>
</tr>
<tr>
<td>(SD)</td>
<td>(6)</td>
<td>(5.44)</td>
<td>(8.15)</td>
</tr>
</tbody>
</table>

Characteristics of younger group completing 24 weeks of training

Men n=5, Women n=16
<table>
<thead>
<tr>
<th></th>
<th>12 weeks</th>
<th>24 weeks</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Men</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- mean (SD)</td>
<td>62% (12.5)</td>
<td>52% (12.2)</td>
</tr>
<tr>
<td><strong>Women</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- mean (SD)</td>
<td>59% (20)</td>
<td>59% (16.3)</td>
</tr>
</tbody>
</table>

Average attendance of the younger men and women after 12 and 24 weeks of training
<table>
<thead>
<tr>
<th></th>
<th>Pre control</th>
<th>Post control</th>
<th>Post 12 weeks training</th>
<th>Post 24 weeks training</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \dot{VO}_2 ) max (mls.kg(^{-1}).min(^{-1}))</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Men (n=4)</td>
<td>35.54 (10.5)</td>
<td>37.17 (7.65)</td>
<td>39.07 (6.98)</td>
<td>40.82 (4.34)</td>
</tr>
<tr>
<td>Women (n=7)</td>
<td>25.51 (4.2)</td>
<td>26.99 (4.5)</td>
<td>28.96 (5.83)***</td>
<td></td>
</tr>
<tr>
<td>Women (n=10)</td>
<td>28.08 (6.21)</td>
<td>29.39 (6.24)</td>
<td></td>
<td>32.11 (6.25)**</td>
</tr>
<tr>
<td>( \dot{VO}_2 ) max (L.min(^{-1}))</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Men (n=4)</td>
<td>2.742 (0.513)</td>
<td>2.970 (0.734)</td>
<td>3.113 (0.635)</td>
<td>3.179 (0.477)</td>
</tr>
<tr>
<td>Women (n=7)</td>
<td>1.704 (0.269)</td>
<td>1.790 (0.346)</td>
<td>1.888 (0.342)**</td>
<td></td>
</tr>
<tr>
<td>Women (n=10)</td>
<td>1.786 (0.268)</td>
<td>1.837 (0.330)</td>
<td></td>
<td>2.013 (0.330)**</td>
</tr>
</tbody>
</table>

Mean \( \dot{VO}_2 \) max values at each time point for younger subjects, expressed as mean (standard deviation).

** P < 0.01
*** P < 0.02
**VO₂ 18+ GROUP - ACTUAL VALUES**

<table>
<thead>
<tr>
<th>HR at VO₂ 10mls.kg⁻¹.min⁻¹</th>
<th>Pre control</th>
<th>Post control</th>
<th>Post 12 weeks training</th>
<th>Post 24 weeks training</th>
</tr>
</thead>
<tbody>
<tr>
<td>Men (n=5)</td>
<td>104 (7.7)</td>
<td>104 (8)</td>
<td>91 (6)**</td>
<td>88 (7.8)**</td>
</tr>
<tr>
<td>Women (n=10)</td>
<td>120 (10.9)</td>
<td>113 (13.22)</td>
<td>107 (18.5)*</td>
<td></td>
</tr>
<tr>
<td>Women (n=13)</td>
<td>110 (10.5)</td>
<td>109 (12)</td>
<td></td>
<td>100 (13)**</td>
</tr>
</tbody>
</table>

**Resting heart rate (bpm)**

| Men (n=5)                  | 78 (7.76)   | 73 (10.19)   | 64 (2.88)**           | 64 (14)**             |
| Women (n=16)               | 76 (7.84)   | 73 (10.14)   | 62 (20.87)**          | 65 (8.73)**           |

Heart rate at VO₂ of 10mls.kg⁻¹.min⁻¹ and resting heart rate at each measurement point, expressed as mean (standard deviation)

* P < 0.05  
** P < 0.01  
***P < 0.02  

356
### 18+ GROUP - ACTUAL VALUES

<table>
<thead>
<tr>
<th></th>
<th>Pre control</th>
<th>Post control</th>
<th>Post 12 weeks training</th>
<th>Post 24 training</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>IEFS (N)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Weakest arm</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Men (n=5)</td>
<td>232 (58)</td>
<td>263 (39)</td>
<td>248 (40)</td>
<td>271 (51)</td>
</tr>
<tr>
<td>Women (n=15)</td>
<td>152 (43)</td>
<td>154 (39)</td>
<td>167 (41)*</td>
<td>171 (38)**</td>
</tr>
<tr>
<td><strong>Strongest arm</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Men (n=5)</td>
<td>253 (57)</td>
<td>276 (51)</td>
<td>271 (33)</td>
<td>291 (60)</td>
</tr>
<tr>
<td>Women (n=15)</td>
<td>169 (40)</td>
<td>158 (44)</td>
<td>183 (46)**</td>
<td>182 (41)**</td>
</tr>
</tbody>
</table>

Average IEFS for young men and women expressed as mean (standard deviation)

*P < 0.05

**P < 0.01
<table>
<thead>
<tr>
<th></th>
<th>Pre control</th>
<th>Post control</th>
<th>Post 12 weeks training</th>
<th>Post 24 training</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>IKES (N)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Weakest leg</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Men (n=5)</td>
<td>522 (130)</td>
<td>553 (131)</td>
<td>584 (116)</td>
<td>489 (126)</td>
</tr>
<tr>
<td>Women (n=15)</td>
<td>349 (103)</td>
<td>357 (115)</td>
<td>398 (93)*</td>
<td>409 (115)**</td>
</tr>
<tr>
<td><strong>Best leg</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Men (n=5)</td>
<td>550 (131)</td>
<td>548 (88)</td>
<td>549 (124)</td>
<td>522 (126)</td>
</tr>
<tr>
<td>Women (n=15)</td>
<td>379 (110)</td>
<td>362 (106)</td>
<td>417 (96)**</td>
<td>437 (116)**</td>
</tr>
</tbody>
</table>

Isometric Knee extensor (IKES) strength for men and women, expressed as mean (Standard deviation)
18+ GROUP - ACTUAL VALUES

<table>
<thead>
<tr>
<th></th>
<th>Pre control</th>
<th>Post control</th>
<th>Post 12 weeks training</th>
<th>Post 24 training</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LEP (W)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Least powerful leg</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Men (n=5)</td>
<td>269 (80)</td>
<td>321* (60)</td>
<td>318 (35)</td>
<td>337 (49)</td>
</tr>
<tr>
<td>Women (n=16)</td>
<td>148 (50)</td>
<td>156 (48)</td>
<td>176 (7)*</td>
<td>196 (54)**</td>
</tr>
<tr>
<td>Most powerful leg</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Men (n=5)</td>
<td>305 (90)</td>
<td>330 (77)</td>
<td>350 (49)</td>
<td>347 (70)</td>
</tr>
<tr>
<td>Women (n=16)</td>
<td>165 (54)</td>
<td>159 (53)</td>
<td>177 (48)</td>
<td>197 (50)**</td>
</tr>
</tbody>
</table>

Explosive leg power (LEP) of the men and women expressed as mean (standard deviation).

*P < 0.05
**P < 0.01
APPENDIX EIGHT A

Scores for the Geriatric Depression Scale
and Philadelphia Morale Scale at each time point

<table>
<thead>
<tr>
<th></th>
<th>Pre Control</th>
<th>Post control</th>
<th>Post 12 weeks training</th>
<th>Post 24 weeks training</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geriatric Depression</td>
<td>7 (0-16)</td>
<td>4 (0-17)</td>
<td>4 (0-15)</td>
<td>5.0 (0-20)</td>
</tr>
<tr>
<td>Scale (GDS)</td>
<td>(n=15)</td>
<td>(n=15)</td>
<td>(n=13)</td>
<td>(n=14)</td>
</tr>
<tr>
<td>Philadelphia Geriatric</td>
<td>14 (6-17)</td>
<td>14 (8-17)</td>
<td>15 (8-17)</td>
<td>14 (5-17)</td>
</tr>
<tr>
<td>Centre Morale Scale</td>
<td>(n=15)</td>
<td>(n=15)</td>
<td>(n=13)</td>
<td>(n=15)</td>
</tr>
<tr>
<td>(PGCMS)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Scores for the Geriatric Depression Scale (GDS) and the Philadelphia Geriatric Centre Morale Scale (PGCMS) at each testing point. Expressed as median (range). Maximum possible scores are 30 for the GDS (with high scores indicating depression) and 17 for the PGCMS (with high scores indicating high morale).
### APPENDIX EIGHT B - Scores for the Profile of Mood States at each time point.

<table>
<thead>
<tr>
<th></th>
<th>Pre control (n=14)</th>
<th>Post control (n=14)</th>
<th>Post 12 weeks training (n=12)</th>
<th>Post 24 weeks training (n=14)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total mood disturbance (TMD)</strong></td>
<td>0 (-29 - 57)</td>
<td>-4 (-28 - 33)</td>
<td>-6 (-28 - 33)</td>
<td>-10 (-29 - 98)</td>
</tr>
<tr>
<td><strong>Individual units</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Tension/Anxiety</td>
<td>3 (0 - 19)</td>
<td>2 (0 - 10)</td>
<td>1.5 (0 - 15)</td>
<td>1 (0 - 28)</td>
</tr>
<tr>
<td>- Depression/Dejection</td>
<td>0.5 (0 - 18)</td>
<td>0.5 (0 - 17)</td>
<td>1 (0 - 12)</td>
<td>0.5 (0 - 34)</td>
</tr>
<tr>
<td>- Anger/Hostility</td>
<td>2.5 (0 - 14)</td>
<td>2.5 (0 - 16)</td>
<td>3 (0 - 7)</td>
<td>0 (0 - 13)</td>
</tr>
<tr>
<td>- Vigour/Activity</td>
<td>16 (8 - 29)</td>
<td>18.5 (12 - 32)</td>
<td>24.5 (11 - 32)</td>
<td>20.5 (9 - 32)</td>
</tr>
<tr>
<td>- Fatigue/Inertia</td>
<td>2 (0 - 17)</td>
<td>0.5 (0 - 19)</td>
<td>3 (0 - 13)</td>
<td>3 (0 - 27)</td>
</tr>
<tr>
<td>- Confusion/Bewilderment</td>
<td>4 (0 - 10)</td>
<td>3 (0 - 7)</td>
<td>2 (0 - 8)</td>
<td>2.5 (0 - 6)</td>
</tr>
</tbody>
</table>

Scores for Total Mood Disturbance and subunits of POMS, expressed as median (range). Possible scores range from -32 to +200 for TMD, 0 to 36 for tension/anxiety, 0 to 60 for depression/dejection, 0 to 48 for anger/hostility, 0 to 28 for confusion/bewilderment and 0 to 28 for fatigue/inertia (in all cases the lower the score the better). Possible scores for vigour/activity range from 0 to 32, in this case the higher the score the better.
## APPENDIX EIGHT C

Scores for the SF-36 at each time point

<table>
<thead>
<tr>
<th></th>
<th>Pre Control</th>
<th>Post control</th>
<th>Post 12 weeks training</th>
<th>Post 24 weeks training</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical Functioning</td>
<td>77.5 (5-100)</td>
<td>77.5 (30-100)</td>
<td>77.5 (10-100)</td>
<td>90 (40-100)</td>
</tr>
<tr>
<td></td>
<td>(n=16)</td>
<td>(n=16)</td>
<td>(n=14)</td>
<td>(n=13)</td>
</tr>
<tr>
<td>Role Limitation</td>
<td>100 (0-100)</td>
<td>87.5 (0-100)</td>
<td>87.5 (0-100)</td>
<td>100 (0-100)</td>
</tr>
<tr>
<td>(physical)</td>
<td>(n=16)</td>
<td>(n=16)</td>
<td>(n=14)</td>
<td>(n=13)</td>
</tr>
<tr>
<td>Role Limitation</td>
<td>100 (33-100)</td>
<td>100 (33-100)</td>
<td>100 (0-100)</td>
<td>100 (33-100)</td>
</tr>
<tr>
<td>(mental)</td>
<td>(n=14)</td>
<td>(n=14)</td>
<td>(n=13)</td>
<td>(n=12)</td>
</tr>
<tr>
<td>Social Functioning</td>
<td>100 (44-100)</td>
<td>100 (22-100)</td>
<td>100 (22-100)</td>
<td>100 (22-100)</td>
</tr>
<tr>
<td></td>
<td>(n=15)</td>
<td>(n=15)</td>
<td>(n=13)</td>
<td>(n=14)</td>
</tr>
<tr>
<td>Mental Health</td>
<td>92 (60-100)</td>
<td>92 (32-100)</td>
<td>92 (64-100)</td>
<td>92 (16-100)</td>
</tr>
<tr>
<td></td>
<td>(n=15)</td>
<td>(n=15)</td>
<td>(n=13)</td>
<td>(n=14)</td>
</tr>
<tr>
<td>Energy/Vitality</td>
<td>70 (30-100)</td>
<td>75 (40-100)</td>
<td>75 (55-100)</td>
<td>77.5 (5-100)</td>
</tr>
<tr>
<td></td>
<td>(n=15)</td>
<td>(n=15)</td>
<td>(n=12)</td>
<td>(n=14)</td>
</tr>
<tr>
<td>Pain</td>
<td>89 (22-100)</td>
<td>81.5 (33-100)</td>
<td>83.5 (11-100)</td>
<td>100 (44-100)</td>
</tr>
<tr>
<td></td>
<td>(n=16)</td>
<td>(n=16)</td>
<td>(n=14)</td>
<td>(n=14)</td>
</tr>
<tr>
<td>Health Perception</td>
<td>72 (20-100)</td>
<td>82 (25-100)</td>
<td>82 (67-100)</td>
<td>87 (15-100)</td>
</tr>
<tr>
<td></td>
<td>(n=15)</td>
<td>(n=15)</td>
<td>(n=13)</td>
<td>(n=14)</td>
</tr>
<tr>
<td>Change in Health</td>
<td>50 (25-100)</td>
<td>50 (25-100)</td>
<td>50 (25-100)</td>
<td>50 (50-100)</td>
</tr>
<tr>
<td></td>
<td>(n=16)</td>
<td>(n=15)</td>
<td>(n=14)</td>
<td>(n=14)</td>
</tr>
</tbody>
</table>

Scores for each section of the SF-36, expressed as median (range). Possible scores range from 0 to 100 for each section, with the higher the scores the better.
APPENDIX EIGHT D
Scores for the General Health Questionnaire
at each time point.

<table>
<thead>
<tr>
<th></th>
<th>Pre control</th>
<th>Post control</th>
<th>Post 12 weeks training</th>
<th>Post 24 weeks training</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Score</td>
<td>11 (6 - 24)</td>
<td>11.5 (8 - 20)</td>
<td>8.5 (5 - 12)</td>
<td>11 (5 - 34)</td>
</tr>
<tr>
<td></td>
<td>(n=14)</td>
<td>(n=14)</td>
<td>(n=10)</td>
<td>(n=14)</td>
</tr>
<tr>
<td>Sub-units</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Severe depression</td>
<td>0 (0 - 5)</td>
<td>0 (0 - 6)</td>
<td>0 (0 - 3)</td>
<td>0 (0 - 6)</td>
</tr>
<tr>
<td></td>
<td>(n=14)</td>
<td>(n=14)</td>
<td>(n=10)</td>
<td>(n=14)</td>
</tr>
<tr>
<td>- Social dysfunction</td>
<td>7 (5 - 7)</td>
<td>7 (6 - 9)</td>
<td>7 (2 - 7)</td>
<td>7 (2 - 9)</td>
</tr>
<tr>
<td></td>
<td>(n=14)</td>
<td>(n=14)</td>
<td>(n=10)</td>
<td>(n=14)</td>
</tr>
<tr>
<td>- Anxiety/Insomnia</td>
<td>1 (0 - 7)</td>
<td>1 (0 - 5)</td>
<td>1 (0 - 4)</td>
<td>1 (0 - 10)</td>
</tr>
<tr>
<td></td>
<td>(n=15)</td>
<td>(n=15)</td>
<td>(n=12)</td>
<td>(n=15)</td>
</tr>
<tr>
<td>- Somatic symptoms</td>
<td>1 (0 - 7)</td>
<td>1 (1 - 10)</td>
<td>1 (0 - 6)</td>
<td>1 (1 - 10)</td>
</tr>
<tr>
<td></td>
<td>(n=15)</td>
<td>(n=15)</td>
<td>(n=12)</td>
<td>(n=15)</td>
</tr>
</tbody>
</table>

Values for total score and each sub-unit of the GHQ, expressed as median (range).
Possible values range from 0 to 84 for the total score and from 0 to 21 for each of the sub units, with the lower the score the better.