Quadriceps Function in elderly patients after Proximal Femoral Fracture.

Research exercise submitted by
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Abstract

The aims of this thesis were twofold. The first was to investigate the practicability, reproducibility and the validity of measurement of leg extensor power (LEP) in Osteoporotic and frail elderly people, in order to determine the changes associated with repeated measurements, and the ability of LEP to discriminate between different patient groups (an Osteoporotic group, frail elderly and patients who have sustained a fractured neck of femur). This was an observational study, using a convenience sample.

Twenty-five Osteoporotic subjects (mean age 68.8 S.E 1.0) attending an out-patient physiotherapy exercise class, 58 proximal femoral fracture (PFF) patients (mean age 78.7 S.E 1.1) and 31 frail elderly patients (mean age 82.8 S.E 1.6) awaiting residential or nursing home care consented to be tested. A series of 10 measurements of LEP (using the Nottingham power rig) were made, with a 30 second rest between measurements. Ten repeated series of measurements were made at 3-day intervals in the Osteoporotic and in the PFF groups. All measurements were made by a single observer. There was a progressive increase in measured LEP over the first 5 attempts at a single visit in all the patient groups, after which performance stabilised and was relatively constant. There were also significant increases in LEP in the Osteoporotic and PFF groups when measured on a second occasion 3 days later, with a mean change of 3.8 Watts (SE 1.6, P=0.02) and 2.1 Watts (SE 0.5, P=0.02) respectively. There was no further significant improvement between a second and third series of measurements in the Osteoporotic group (mean change of -0.5, SE 2.8, P= 0.87).

This study found significant increases in LEP with repeated measures at a single visit. This may have been due to a learning effect or a warming up effect of the muscle groups. We have taken the mean of the 6th to 10th measurements at a single visit as the summary measure of LEP.

There were also significant increases in LEP when measurements were repeated after a 3-day interval. This was likely to be due to a learning effect.

The second, and main aim of the work presented in this thesis was to determine whether systematic progressive high intensity quadriceps training increases leg extensor power and reduces disability in patients rehabilitating after proximal femoral fracture.

This study was an open parallel group randomised controlled trial comparing 6 weeks of quadriceps training (40 patients) plus standard rehabilitation versus standard rehabilitation alone (40 patients). The training group exercised twice weekly, with 6 sets of 12 repetitions of knee extension (both legs), progressing up to 80% of their one-repetition maximum.

The main outcome measures were leg extensor power (Nottingham Power Rig), functional mobility (Elderly Mobility Scale, which includes Functional Reach and a measure of gait speed), disability (Barthel Index) and perceived health status (Nottingham Health Profile). These were made at baseline, after 6 weeks (at the end of the intervention) and at 16 weeks.

Leg extensor power increased significantly in the quadriceps-training group (fractured leg mean improvement at 6 weeks 157% (standard error 16), non-fractured leg 80% (12)) compared to the control group (63% (11) and 26% (8) respectively, unpaired Student t-test P=0.001 and P=0.001 for between group comparisons). Significant improvements in LEP in the quadriceps-training group were maintained at 16 weeks. Quadriceps training resulted in a greater increase in Elderly Mobility Scale score compared to standard rehabilitation (between-group difference of 2.5 (95% CI 1.1,3.8) at week 6 and 1.9 (0.4,3.4) at week 16). Barthel Index score increased significantly from week 0 to 6 in the quadriceps-training group compared to controls (Mann-Whitney U test p=0.05).

Functional Reach improved significantly in the quadriceps-training group compared to controls (unpaired Student t-test $p \leq 0.001$). Patients in the quadriceps-training group scored significantly better in the energy sub-score of the Nottingham health profile at the end of follow-up (Mann-Whitney U test $p=0.019$).

The data from the intervention study was also used to examine the relationship between LEP/Kg and functional capacity. Correlations between LEP/Kg (fractured leg alone, and combined LEP, (fractured leg plus non-fractured leg)) and disability (Barthel) and functional scores (Elderly Mobility Scale, Sit to Stand, Timed Up and Go, Functional Reach and Gait Speed) and grip strength were determined by calculating Spearman's rank correlation.

There were statistically significant correlations for LEP/Kg of the fractured leg and all functional scores with r values ranging between 0.39 and 0.65 for the quadriceps trained group at week 6. The strongest correlations were seen between LEP/Kg and the Elderly Mobility Scale ($r=0.65$). Similar results were seen for combined LEP/Kg at week 6 for the quadriceps trained group. When training induced changes in LEP/Kg and functional measures were analysed there was a significant correlation between change in LEP/Kg and change in gait speed ($r=0.69$). This was not the case for combined LEP/Kg.

Therefore progressive high-intensity quadriceps training in elderly proximal femoral fracture patients increased leg extensor power and reduced disability. This was accompanied by an increase in energy as measured by the Nottingham Health Profile. This intervention may provide a simple practical way of improving outcome in these patients.

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Declaration

This thesis is my own work. I designed both studies, sought ethical approval and obtained part funding for the work through the Mary Miller bequest fund of the Glasgow Royal Infirmary. I recruited all the patients, carried out the assessments and intervention.

Title: Quadriceps Function in elderly patients after a Proximal Femoral Fracture.

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Chapter 1

Proximal Femoral Fractures

1. Background

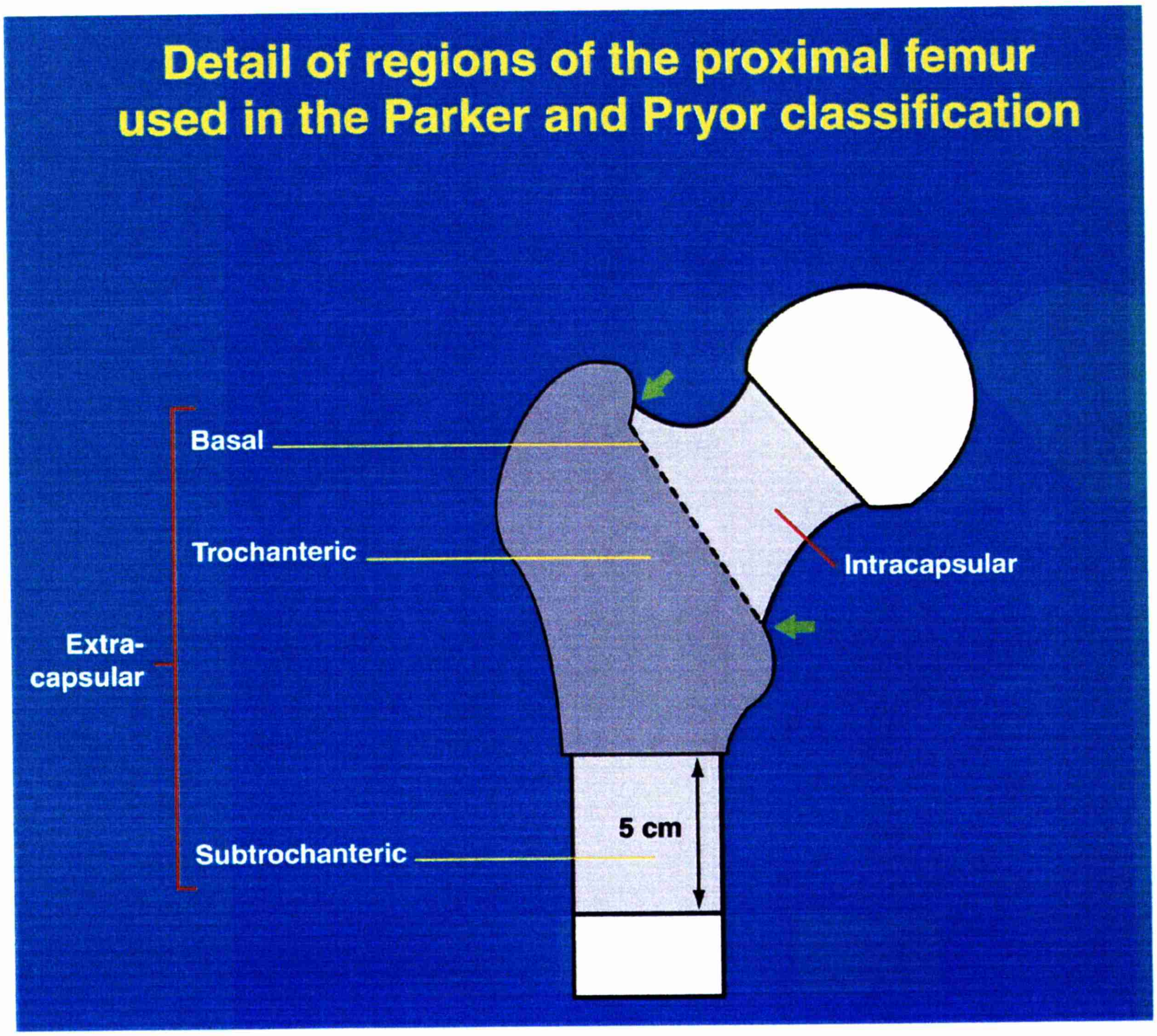
The aim of this section of the thesis is to introduce the problem of proximal femoral fractures. Even today with all the technology of modern medicine and rehabilitation, management of proximal femoral fractures is still a major problem for the rehabilitation team, the patients and their carers. I carried out a randomised controlled trial (RCT) into training of the quadriceps muscle after a proximal femoral fracture (1). This piece of work is one of the first structured strength training interventions in this clinical population and the results indicate that this type of programme can have beneficial effects on both impairment and disability. The following chapters will outline why this work was needed and will describe how the study was carried out.

1.1 Classification – What is a Proximal Femoral Fracture?

A proximal femoral fracture is generally defined as any fracture of the proximal third of the femur. Fractures proximal to the line of insertion of the hip joint capsule are termed intracapsular, and those distal to this line and up to 5 cm distal to the lesser trochanter are termed extracapsular. Figure 1.1 gives details of intracapsular and extracapsular fractures. Intracapsular fractures can be further divided into subcapital and transcervical fractures, and are best subdivided into undisplaced or displaced.

Extracapsular fractures can be further divided into per-, inter- and sub-trochanteric, and are best subdivided by their degree of communication.

Figure 1.1: Proximal Femoral Fracture classification as outlined by Parker and Pryor (2)



It is outwith the scope of this thesis to discuss the types of surgical intervention, however the majority of proximal femoral fractures are managed through surgical intervention by means of some form of internal fixation or arthroplasty. Sometimes full hip replacements are also indicated for intracapsular fractures.

1.2 Type of Proximal Femoral Fractures

Extracapsular fractures tend to occur in older patients (3),(4), (5). The theory behind this difference in age and type of fracture sustained is still unclear, however it is thought that extracapsular fractures are the result of a severe injury, often a fall directly on to the hip. An intracapsular fracture is more often caused by torsional strain. These torsional strains on the axially loaded femur breaking at the weakest point usually the femoral neck.

A study by Keene et al (3) investigated the mortality and morbidity associated with proximal femoral fractures with reference to fracture type (intracapsular and extracapsular). The study was carried out in two similar British trauma receiving centres. In 1,000 cases of proximal femoral fractures there were 490 extracapsular fractures and 510 intracapsular fractures. Mean age at time of fracture was slightly higher in patients with extracapsular fractures (80 years) than in patients with intracapsular fractures (78 years). In both groups about 81% of patients were women. Intracapsular fractures included subcapital and transcervical fractures; extracapsular fractures included basal, trochanteric, per-trochanteric, and sub-trochanteric fractures. Morbidity was measured using a four factor mobility score. Other measures included dependency on walking aids, residential status and degree of residual pain. These factors were recorded for all patients immediately before their fracture and during the subsequent year. Significantly higher mortality at one year was seen in patients with extracapsular fractures (188/490; 38%) than in those with intracapsular fractures (147/510; 29%; $P < 0.01$). Greater morbidity was experienced during the study period by patients with extracapsular fractures, who also were already less mobile and less independent at the time of their injury. The reasoning behind this finding is that patients with extracapsular fractures tend to be older and less mobile than those sustaining an intracapsular fracture (6).

1.3 The Problem

Regardless of fracture type, sustaining a proximal femoral fracture is one of the commonest reasons for an elderly person to be admitted to hospital, with an estimated annual incidence of 54000 cases each year in England alone (4). Between 1982 and 1998 (the last year for which complete data are available) the number of proximal femoral fractures sustained annually in Scotland by people over 55 rose from just over 4000 to 5700, with 80% occurring in women. It is estimated that the number of people alive in Scotland in 1998 who had experienced a proximal femoral fracture was around 27000 (7). In addition the rise in proximal femoral fracture numbers does not appear to be simply a reflection of the growing number of older people. In Scotland for both men and women the age-standardised risk is rising. Between 1982 and 1988 in those over the age of 55 it rose for men from 165 to 205 per 100,000 and for women from 500 to 593 per 100, 000 (7). It was estimated in 1990 that the number of proximal femoral fracture occurring in the world was 1.3 million and then it was estimated that this would increase more than 250% by the middle of this century (8). In terms of financial cost to the Health Service in Scotland alone the annual cost in 1999 was estimated at £30 million (9).

In general the outlook for these patients has been poor with a high incidence of mortality, morbidity and loss of physical function (10), (11), (12), (13), (14).

1.4 Epidemiology

Within the next 20 years the predicted age structure of the population will change considerably. For the elderly, the numbers under 75 years will decline, while those over 75 years will increase by almost 25%. The over 85-age group is set to increase particularly rapidly (15).

The implications of this change in the population structure are considerable both for society and the health service. There could be a disproportionate demand for health care by the elderly. Within the orthopaedic service there is already an increasing demand for joint replacement and an increasing number of proximal femoral fractures (9). The over 65 age group already present two of the main problems to the orthopaedic and trauma service: fractures through osteoporotic bone and also osteoarthritic joints.

It has been estimated that one in 20 women who reach age 65 years will suffer at least one proximal femoral fracture in their remaining years. Of those 85 and older, the fastest growing elderly sub group, 2% of women and 0.6% of men will fracture a hip each year (13).

The lifetime risk for sustaining a fracture is 9% for a female-aged 50, but rises to 12% by 70 and 18% by age 90. The figures for men are 2, 4, and 8% respectively. Once admitted to hospital the average length of stay is often in excess of one month (16), (17).

1.5 Factors Influencing The Incidence Of Proximal Femoral Fracture

There are many factors that influence the incidence of proximal femoral fracture, below are listed the main ones:

1.5.1 Age- Early epidemiological studies have shown sharp increases in proximal femoral fracture after the 6th decade especially in females (18). The bodily changes associated with ageing are responsible both for increasing the chances of an individual falling and for weakening the bone to such an extent that even a minor trauma will result in a fracture.

1.5.2 Sex- All studies have shown a preponderance of female proximal femoral fracture patients. Compared to men, women older than 70 have a nearly doubled risk of sustaining a proximal femoral fracture (19).

1.5.3 Sedentary life style - Studies in Sweden report that the incidence of proximal femoral fracture has increased more in the urban than the rural population (19). Similar findings were also noted in Norway (20), where within the rural population there was no change in the age specific incidences of fractures, whilst there was a progressive increase in the urban areas.

It has been suggested that a more sedentary life style in the urban areas leads to a more rapid rate of age related bone loss. A sedentary lifestyle may also increase the risk of falling, particularly in the elderly by exacerbating the muscular weakness. This in turn may impair mobility and balance, so increasing the risk of falls.

The most elderly and infirm group of the population are often encouraged to become more immobile (21), particularly those in nursing homes and other institutions. Far from protecting them from injury, these patients may be at an even greater risk. Compromised walking, reduced gait speed or lower limb dysfunction and a low level of physical activity are associated with increased risk of proximal femoral fracture (22). A previous period of immobilisation for more than three months is also said to increase risk (23). Conversely studies have suggested that higher levels of leisure time physical activity reduce the risk of proximal femoral fractures (24),(25), and RCT's suggested certain exercise programmes might reduce risk of falls (26), (27), (28). Future research is still needed to evaluate the types and quantity of physical activity needed for optimal protection from falls and identify which populations will benefit most from exercise.

1.5.4 Race- Genetic factors – Incidence rates seem highest in white women, lowest in black men, and intermediate in white men and black women (23).

1.5.5 Seasonal variation- Some authors have found a seasonal variation in the rate of proximal femoral fractures, with the highest number in the winter quarter. This is not however evident in all studies. Most of the studies that have found a seasonal variation have also noted that the fall has occurred within the home, suggesting that the climate may not have a direct influence on the injury. It may support the hypothesis that lowered body temperature results in a lack of co-ordination and the subsequent fall (29).

A European multi-centre study on hip fracture Epidemiology (30), found that the majority (66.5%) of people fell and fractured their hip indoors.

A recent prospective, population based cohort study was performed on people aged 65 years and older followed up from 1990 to 1997 (31). Cases were identified through a prospective registration system. The aim of the study was to investigate seasonal variations in the incidence of fall related fractures among people 65 years and older. There were 10,992 fall related fractures. The risk was higher in the colder seasons (October through March) among people aged 65-79 years (relative risk (RR) = 1.39, 95% confidence interval

(CI) 1.32 to 1.47) and in people aged 80 years and older (RR = 1.17, 95% CI 1.09 to 1.22). The relative risk for proximal femoral fractures was 1.27 (95% CI 1.15 to 1.37) among people aged 65-79 years and 1.08 (95% CI 1.00 to 1.15) for people aged 80 years and older. Slipping on ice and snow seemed to explain the excessive incidence of hip and arm fractures during winter months. The authors suggested preventive measures, targeting this causal mechanism stating that this could reduce the risk of fracture. This study was carried out in Norway and therefore may not directly relate to the figures from Britain.

1.5.6 Nutrition- Poor nutritional state has been linked to proximal femoral fracture and also fatality from the fracture (32). Patients sustaining proximal femoral fractures have been reported to have a reduced skin fold thickness compared with age-matched controls, and to be of lower weight indicating poor nutritional status (33). Maffuli et al (34) measured 119 consecutive proximal femoral fracture patients over the age 65 years and measured their body mass index. From their data they found that 31% of the patients admitted were classified as malnourished and 11% were severely malnourished.

Conversely it has also been suggested that an increase in subcutaneous tissues will absorb some of the force of a fall and thereby have a protective element against a hip fracture (33). However another suggestion is that thinner patients are more likely to develop hypothermia in cold weather and this could result in impaired co-ordination and an increased tendency to fall (29). A third explanation may be that bone strength is preserved in those with a larger body weight.

1.5.7 Smoking/Alcohol - Both smoking and excess alcohol intake have been identified as risk factors for proximal femoral fractures (35).

1.5.8 Prescribed medication - The greater use of prescribed medication by the elderly may be of significance in the rising incidence of fractures. One study involving patients under 50 years found that subcapital fractures were most frequent in patients with concurrent illness and 77 per cent were taking drugs, which could affect bone density (36). There are a number of drugs that have been implicated in the aetiology of proximal femoral fracture. These include: corticosteroids, thyroxine, hypnotics, antidepressants, antipsychotic drugs, anticonvulsants, antihypertensive drugs and laxatives (37). However these show only an association between proximal femoral fracture and a certain drug, it does not prove a cause and effect relationship.

1.5.9 Medical conditions – Patients with a previous proximal femoral fracture have a 2-10 times increased risk of a second hip fracture (19). Impaired mobility and a history of stroke will double the risk of hip fracture (35). Other medical conditions which have been associated with an increased risk of falls, bone weakness and proximal femoral fractures include cardiovascular disease, pneumonia, dementia, visual disorders, Parkinson's disease, dehydration, arthritis to name a few (37).

1.5.10 Bone fragility – Bone strength and mass reduces with age, which partly accounts for the increased risk of proximal femoral fracture in elderly people (38). However, there is evidence that women with proximal femoral fractures have BMD values in the same range as controls, when the measurements are adjusted for age (39). Others have found that there is a reduction of BMD in proximal femoral fractures compared to controls and that during the first year after a fracture; bone loss is accelerated (40), (41). Greenspan et al (42) reported that BMD of the femoral neck was a significant risk factor but was not as important as the direction and energy of the fall. The tendency to fracture could reflect reduced bone strength or increased risk of falling due to diminished neuromuscular response (8).

1.5.11 Falls – The exponential increase in the number of proximal femoral fractures with aging cannot be explained solely on the basis of the decay in bone density, but must be also influenced by the risk of falls. Almost all proximal femoral fracture occur after a fall. Parrkari et al (43) found that in 98% of hip fracture patients, the fracture was a result of a fall. The majority of the patients (76%) reported that they had fallen directly to the side. In 56% of the patients, a fresh subcutaneous haematoma was seen on the greater trochanter of the proximal femur. Most of the elderly fallers who fractured a hip did not manage to break the fall, e.g., with an outstretched arm. They concluded that a typical proximal femoral fracture is the result of a fall and a subsequent impact on the greater trochanter of the proximal femur. The authors suggested the use of external hip protectors to absorb the impact of the fall onto the greater trochanter. Nyberg et al (44) studied a consecutive series of 123 lucid patients, 65 years of age or more, who were admitted for femoral neck fractures. It was ascertained that 95% of all the fractures were caused by falls and <2% were spontaneous. 68% of the falls took place indoors, 47% were classified as extrinsic, 24% as intrinsic, 7% as non-bipedal, and 22% remained unclassified. From a preventative view it was concluded that studies of the nature of falls that lead to proximal femoral fractures are essential.

Lauritsen (19) carried out a review based on epidemiological, experimental, and controlled studies. From all these studies it was noted that Nursing home residents had a high risk of proximal femoral fracture (annual rate of 5-6%), because the incidence of falls in nursing home residents is about 290 falls/1,000 persons/year and about 24% of these impacts lead to proximal femoral fracture.

In conclusion there are many causes of falls in the elderly such as medications, confusion, increased postural sway, concurrent illness, disorders of gait and balance, osteoarthritis, alcohol, visual disorders.

1.5.12 Physical habitus, body weight and height - As stated already proximal femoral fracture patients do appear to have a significantly lower body mass index when compared to controls (19),(33). Body weight in women with proximal femoral fracture is on average 5Kg lower compared to controls. In thin women, risk of hip fracture is several times elevated as compared to obese women. Lean mass after proximal femoral fracture has also been shown to decrease by 10% during the first year, suggesting that focus on muscle strength exercises may facilitate the rehabilitation process. (8).

Lauritsen (19) stated that the effective load acting on the hip is 35% of the body weight in unprotected falls on the hip, therefore women with hip fractures have a lower body weight compared with controls, and they may also have less soft tissue covering the hip even when adjusted for body mass index, indicating a more android body habitus

A recent population-based case-control study (45) investigated the independent association between height and weight at different ages and adult weight change on hip fracture risk, and the combined effects of these factors. The study base comprised postmenopausal women 50-81 years of age who resided in six counties in Sweden during the period October 1993 to February 1995. The study included 1,327 cases with an incident of hip fracture and 3,262 randomly selected controls. They obtained information on body measures and other factors possibly related to hip fracture through mailed questionnaires and telephone interviews. Height and weight change were found to be dominant risk factors. Tall women (> or = 169 cm) had an odds ratio of 3.16 (95% confidence interval = 2.47-4.05) compared with women shorter than 159 cm. Weight gain during adult life was strongly protective: compared with those with moderate weight change (-3 to 3 kg), those with substantial weight gain (> or =12 kg) had a markedly decreased risk of hip fracture (odds ratio = 0.35; 95% confidence interval 0.27-0.45), whereas weight loss was associated with an increased risk. Weight change retained important effects among all subjects, even after controlling for current weight and weight at age 18. In contrast, among women who gained weight, the separate effects of current weight and weight at age 18 were small or absent. Among women who lost weight, both current weight and weight at age 18 had effects that remained after controlling for weight change. The authors concluded that adult weight change and height were dominant body size risk factors for hip fracture.

1.6 Mortality and Morbidity Outcomes after Proximal Femoral Fracture

The outcomes following proximal femoral fracture have been described using many different measures. Outcome in the 1960's and 1970's was reported in terms of mortality, fracture malunion, aseptic necrosis and later segmental collapse, but more recently the emphasis has shifted to measuring the levels of dependence in the home environment (46). The reported mortality associated with proximal femoral fracture still ranges from 2% to 63% depending on such factors as length of the follow up, country studied, type of care, and age distribution of the sample (46). It has been stated that about 20% of people who fracture their hips are dead within a year (47),(48), and many of those who recover from hip fracture require additional assistance in daily living (48),(49). Recent figures from Scotland found that 7% die on acute admission, 10% within the first month and about 25% at four months (9). The most recent statistic from a study carried out in the USA found that at 1 year the mortality rate is 24% (50). It is difficult however to assess the true mortality from a proximal femoral fracture, as it is impossible to determine to what extent the fracture contributed to the eventual death of the patient. Many studies have tried to establish mortality in this group compared to age matched controls and some results have shown that compared to persons of a similar age, race and gender, persons who have a hip fracture show greater mortality post-fracture with a death rate 15 times higher during the first month and 7 times higher during the second month after fracture compared to controls (51). In one study designed to specifically determine the true mortality from a proximal femoral fracture, the degree to which the hip fracture contributed to the death was evaluated. The fracture was judged either directly related, possibly related are totally unrelated to the death of the patient. For 9% of these patients the proximal femoral fracture was thought to have directly contributed to the death, such as occurred in those patients dying of pulmonary embolism following treatment. For 16% the death was possibly related to the proximal femoral fracture and for 12% the death was totally unrelated to the fracture. From these results they estimated the true mortality from the proximal femoral fracture to be 15%. A further 22% of patients died within the first year of injury due to a variety of other conditions associated with ageing (52). Studies of this nature highlight the complex nature of these patients, however mortality rate information only provides information related to the success of medical management. It is an inadequate outcome measure for examining the health status and functional status in the survivors of proximal femoral fracture.

As already mentioned, recently measures of the level of dependence following proximal femoral fracture have received more attention. In the USA it has been observed that between 15-25% of patients who were previously living at home before the fracture spend at least one year after the fracture in institutionalised care (53), (49). In Britain it is estimated that of proximal femoral fracture survivors, 14% remain in the nursing home one year after fracture (54).

Some work has focused on those patients with dementia or who are in Nursing or Residential homes; however most of the data reflects the poor outcome for these patients. A recent prospective audit carried out in Australia described the 4-month outcome of patients from the community and residential care settings (55). Information was collected on pre-fracture health, types of surgical and rehabilitation treatments and dependency. Of the 215 older adults who were admitted during this time, 183 agreed to participate (119 from community and 64 from residential care). Surgical management of the fracture was not affected by admission accommodation. Those from residential care had short hospital stays, less rehabilitation and access to physiotherapy. Although 61% of those from residential care were classified as independently mobile pre-fracture, by 4 months this had declined to 32% of survivors. This is not necessarily common to Australia as other researchers have found that patients with cognitive problems may receive less rehabilitation and more conservative interventions than patients who are cognitively intact (2), (56). This could therefore contribute to the poorer outcomes.

In terms of age and outcome a recent prospective study (5) investigated outcomes after proximal femoral fracture in patients ninety years of age and older, as compared with a population of the same age and sex in the United States and younger patients with hip fractures. Eight hundred and fifty community-dwelling elderly people who sustained an operatively treated proximal femoral fracture were prospectively followed up. Seventy-six of these patients were $\geq$ 90 years, the rest were between 65-89 years. At baseline the groups did not differ in the number of co-morbidities or pre-fracture living situation. The older group were however more dependent in activities of daily living. The outcomes examined in this study were the patients' in-hospital mortality and postoperative complication rates, hospital length of stay, discharge status, mortality rate, place of residence, ambulatory ability, and independence in basic and instrumental activities of daily living twelve months after surgery. Patients who were ninety years of age and older had significantly longer mean hospital lengths of stay than younger individuals ($p = 0.01$), were more likely to die during the hospital stay ($p = 0.001$) and within one year of surgery ($p = 0.001$). Patients who were ninety years of age and older were also more likely to have a decrease in their basic activities of daily living status ($p = 0.03$) and ambulation level ($p = 0.01$). However when standard mortality ratio was measured the authors found that the younger individuals had a higher standard mortality ratio (1.48) than did patients who were ninety years of age and older (1.24). Despite these other factors the authors found that being ninety years of age and older was not predictive of being placed in a skilled nursing facility at discharge or at one-year follow-up, or recovering of pre-fracture independence in instrumental activities of daily living.

In terms of recovery rates a recent cohort study suggested that any further functional improvement after 4 months of a proximal femoral fracture is unlikely (57). Two hundred and fifteen patients aged 55-102 years (median 82) who presented with a fractured hip were interviewed shortly after the injury and 4 and 12 months later. Mobility and functional recovery were monitored. For mobility the results showed that by 4 months 38 patients had died, at which time 36% had also regained the level of mobility that they had before the injury. At 12 months the figure was 39%. The corresponding figures for functional recovery were 29% and 24%. The authors concluded that after 4 months only minimal recovery might be expected.

1.7 Prediction of Outcome after Proximal Femoral Fracture

Numerous investigators have examined predictors of functional recovery in patients who have sustained a hip fracture (58), (50), (53), (4), (10), (59), (13). There still seems however, to be no absolute predictor for persons who were previously community dwelling, as many of the studies have found conflicting results. Reasons for this may include differing rehabilitation interventions, differing hospital systems i.e. USA, GB and Scandinavia, which makes comparisons difficult. There is evidence, however that previously institutionalised patients and patients with significant cognitive dysfunction have a very poor prognosis with respect to post-fracture physical function and survival (60), (61).

A number of studies have also outlined certain factors that predict good functional outcome such as: pre-operative functional status, reduced age, mental status, and continued contact with those who provide social support. (60), (4), (58), (62). These predictors may help define rehabilitation strategies for an individual patient.

There have been several large studies investigating prediction of outcome following proximal femoral fracture. These studies have often found differing independent predictors, highlighting again the complex nature of the proximal femoral fracture patient.

The first by Koval et al (58) investigated which patient characteristics on admission were predictors of failure to recover the functional status that existed before fracture as evaluated within 3 months, 6 months and 1 year after fracture in previously ambulatory, home dwelling elderly patients. Three hundred and thirty eight patients consecutively admitted to the hospital were recruited into the study. Inclusion was restricted to those over 65 with an acute femoral neck or intertrochanteric fracture of non-pathologic origin who were without severe dementia and who were ambulatory and home dwelling before sustaining a fracture. Assessment of Activities of Daily Living (ADL) was done using the Katz method (63), whereby patients are classified as independent or dependent on each of four basic ADL activities: bathing, eating, toileting and dressing. The number of pre-existing significant co-morbidities defined general health status. To assess the role of severity of health problems the American Society of Anaesthesiology (ASA) classification system was used. The results from this study found that 27% of patients admitted were age 85 or older on admission. 50% of patients were classified using ASA rating as having an operative risk of 3 or 4 (3= severe systemic disease, not incapacitating; 4= severe incapacitating systemic condition, constant threat to life). Following statistical analysis Koval et al found that at 3 months patients age 85 and older, an ASA rating of 3or 4 and independence before fracture were associated with failure to have recovered basic ADL.

By 12 months however, only age >85 was a significant predictor of failure to have recovered basic ADL. When they controlled for baseline basic ADL, age 85 and having lived alone prior to fracture were significant predictors of failure to recover basic ADL. The authors hypothesised that the older patient may be frailer, despite controlling for co-morbidities and function before fracture, and therefore less able to resume the tasks and physical activities of rehabilitation and daily life when compared to the younger patient.

Basic activities of daily living function were also strong predictors of recovery at every interval. Patients dependent in basic activities of daily living before fracture were more likely to recover function, reflecting the fact that it is probably easier to recover to a low level of function than to a high one. In the multivariate analysis, controlling for age and basic activities of daily living status before fracture, the presence of one or more co-morbid conditions was a predictor of failure to recover basic ADL at 3 and 6 months but not at 12 months. This might suggest that functional recovery is delayed in the presence of co-morbidities. Living alone before sustaining a fracture was also a significant predictor of failure to recover basic ADL at 3 months.

Another study carried out by Parker et al (4) investigated 894 consecutive proximal femoral fracture admissions to the hospital. Two hundred and twenty were excluded because they were admitted from residential homes, and another 31 who had a pathological fracture were rejected. A total of 643 were eligible for the study. At year 1 65% of patients were living at home, 10% had died during hospital stay and a further 12% had died after discharge. Fourteen percent had required residential or nursing home care. Fifty seven percent of the fractures were intracapsular. These patients were more likely to achieve successful rehabilitation than those with an extracapsular fracture (Of patients living alone

61% achieved successful rehabilitation compared with 71% who did not live alone). Seventy four percent of all patients were women with a mean age of 78 years. Using logistic regression they found that having a mental test score of >6, and subjects who were able to do shopping prior to fall led to a 90% chance of successful rehabilitation. This study demonstrated that pre-fracture mobility is the most useful predictor of return to home.

Another study by Koval (60) investigated predictions of outcome made at discharge and found that patients who were independent in ambulation at hospital discharge were more likely to regain their pre-fracture independent living status at 12month follow-up. Another study has also found that ambulatory capacity at discharge and also balance is predictive of good outcome and return to home after hip fracture (64).

Koval concluded his paper with an interesting question, one that is relevant to the randomised controlled trial (RCT) to be described: How can information on predictors of outcome be used to improve our treatment of geriatric hip fracture patients? Patient age, pre-fracture activity of daily living dependency, and the number of associated medical co-morbidities are all factors that are independent of treatment. Regardless of the treatment approach utilized, these factors cannot be altered and therefore how much emphasis should be placed on these factors? Koval suggested that more emphasis should be placed on the patients' ambulatory status at hospital discharge. He concluded that this could only be achieved through more intensive rehabilitation programmes.

The most recent study (10) investigating outcomes after hip fracture in 571 adults aged 50 and over admitted to 4 New York hospitals found that lower levels of function prior to the fracture and age were predictive of post-fracture functioning, and the presence of compromised vital signs, low levels of pre-fracture function are predictive of post-fracture mortality. 'Function' both pre and post-fracture was measured using a modified version of the Functional Independence Measure (locomotion subscale). The modified acute Physiology and Chronic Health Evaluation Score (APACHE) was used to measure vital signs.

Table 1.1 Summary of the factors that have been listed as predictive of mortality post Proximal Femoral Fracture

Factors listed as being predictive of increased mortality Post-Proximal Femoral Fracture
Age of patient at the time of injury
Impaired mental state or a reduced mental test score
Number of associated medical illnesses
Active medical problem at time of admission
Presence of cardiac disease
Chronic pulmonary disease
Undernutrition
Bedsores present at time of admission
A greater degree of dependency on others prior to admission
Placement in residential accommodation prior to fall
Fall whilst a hospital in patient
Poor mobility prior to the fracture
Reduced activity of the patient prior to the fracture
Inability to go shopping
Fall within the home
Fracture caused by moderate trauma as opposed to severe trauma
Reduced body weight
Low American Society of Anaesthesiologists (ASA) grade
Increased degree of osteoporosis

It is evident from all the studies carried out that predicting outcome, although aimed at structuring rehabilitation has not been very conclusive. Koval has already suggested that improving the rehabilitation strategies should be the emphasis of future research.

1.8 Rehabilitation after a Proximal Femoral Fracture

The aim of this part of the chapter is to outline those studies that have investigated outcome in relation to rehabilitation of patients following proximal femoral fracture. This will highlight the fact that more research is required to find the optimal rehabilitation strategies as few studies have investigated the specific components of rehabilitation and why therefore I felt it necessary to undertake this RCT (described in chapter 6).

The most recent Cochrane review (65), which was updated in April 2000, highlighted the need for good randomised trials in physiotherapy after proximal femoral fracture. The review was carried out on all randomised or quasi-randomised trials comparing different mobilisation strategies/programmes after hip fracture surgery. It included strategies for mobilisation, such as early weight bearing, gait retraining, electrical stimulation and other physical therapy interventions. The aim was to evaluate the effects of different mobilisation strategies and programmes after hip fracture surgery. Four trials were selected each evaluating a different intervention. One trial of 87 patients compared twice daily with once daily physiotherapy (66). Only limited outcome data were available for checking the claims in the trial report that there was no demonstrable difference in recovery of the two patient groups at nine weeks follow-up. A treadmill gait-retraining programme was compared with a conventional gait- retraining programme in one trial of 40 patients (67).

More patients in the treadmill group had recovered their pre-fracture level of mobility by the time of hospital discharge, which tended to happen earlier than for the control group. Neither of these differences was statistically significant. This trial will be discussed more in section 7.10. One trial of 24 patients compared neuromuscular stimulation of the quadriceps muscle with placebo stimulation (68). No data were available to test the claims that neuromuscular stimulation improved the recovery of mobility, assessed up to 13 weeks. One trial involving 273 patients with a displaced intracapsular fracture treated by internal fixation compared weight bearing at two weeks after surgery with delayed weight bearing at 12 weeks after surgery (69). The results suggested that there were no statistically significant differences between the two methods of treatment for the outcomes of non-union, mortality and overall unfavourable outcome at one year (42/141 versus 50/132; relative risk = 0.79, 95%confidence interval = 0.56 to 1.10). This study was carried out over 30 years ago. Since then operative techniques have changed considerably and much more is known about the dangers of immobilisation. Patients are no longer on bed rest for such a long period of time and common practice is now to start mobilising on the first post-operative day. It therefore has no real relevance to current practice. The review however highlights the necessity for good trials with good methodologies to determine the impact of specific physiotherapy interventions on the outcomes of patients after proximal femoral fractures.

1.8.1 Ambulation after Proximal Femoral Fracture

There have been many studies investigating ambulatory status post fracture (70), (71), (10), (72), (73), (11), (74), (60), (75), (12), (57). Recovery of independence post hip fracture at 1 year ranges from 41% to 97% (46), (71). There are reasons for such variability, these include: different definitions of recovery, differences in the length of follow up, differences in methodology. In some studies pre-fracture ambulatory status was used to assess post fracture performance, whereas in other studies post fracture ambulation was described without regard to pre fracture ability. Koval et al (71) stated that the reporting in most studies of ambulation has been very broad i.e. functional versus non-functional ambulators and therefore only give a very crude assessment of recovery.

Regardless of whether investigators use pre-fracture or post fracture criterion, results across studies indicate that long-term residual disability is common. In the review carried out by Craik (46) it was stated that patients walked more slowly, perceived their balance to be more impaired than it was prior to fracture, and demonstrated more postural sway than did a group of non-disabled age matched controls. This was carried out in a small sample of patients between the ages of 50-64. However it does highlight the fact that even in younger patients factors such as fear of falling and perception of reduced balance are major concerns for the individuals.

Barnes (74) investigated ambulation outcomes after hip fracture. This study was a descriptive study carried out in the USA and the purpose was to determine what percentages of hip fracture patients undergoing rehabilitation were able to reach pre- injury ambulatory status at time of discharge from Physiotherapy. The association of 11 factors with the ability to achieve pre injury walking ability was measured using chi-squared analysis. These factors were age, sex, number of visits to physiotherapy, presence of pain in affected leg, leg length difference, side of fracture, motivation, orientation, alertness, previous leg fracture, surgical repair, i.e. prosthesis or fracture site pinning. Only previous leg fracture and number of visits to physiotherapy showed a significant association with the patient's ability to return to pre walking ability. Forty percent of the patients returned to their pre fracture walking ability.

1.8.2 Models of Care for Proximal Femoral Fracture Patients

This section will be divided into studies, which investigate post surgical care as whole and specific interventions for patients following proximal femoral fracture. It is important to take account of where studies have been carried out, as different models of care exist between UK, USA and Scandinavia where most of the studies have been carried out. A vast number of studies exist in this area, but as has already been suggested from the Cochrane review (65), not many have been of high quality in terms of defining the specific physiotherapy intervention. Having said that the importance of rehabilitation post proximal femoral fracture is now well recognised. Bonar and colleagues (76) reported that the likelihood of a patient's returning home after a hip fracture was influenced by the intensity of nursing care and therapy provided. This point was also stressed by Guccione et al (77) who reported that an increase in the frequency of physical therapy increased the probability of improved physical function and likelihood of a patient's return home after hip fracture. Egol et al (12) also concluded that aggressive physical therapy is essential to optimise the patient's short and long-term functional outcome. Many of the papers published however, have not given details about the type of physical therapy or rehabilitation intervention, but discussed more the process of rehabilitation. The papers that have discussed the actual interventions will be discussed later in this chapter.

In the UK many of the studies have investigated the benefits of Geriatric Orthopaedic Units (GORU's). There has now been a Cochrane database created on all the evidence designed to examine the effectiveness of such co-ordinated inpatient rehabilitation, supervised by a Geriatrician, compared with usual orthopaedic care, for older patients with proximal femoral fracture (78). In this database only good quality randomised controlled trials of post-surgical care of proximal femoral fracture have been included. Table 1.2 highlights all the studies included and the main outcomes. The conclusions to date drawn from the evidence suggest that there is a trend to effectiveness of GORU's when combined outcome variables (death and institutional care, death and deterioration in function) are considered. However the studies reviewed had different aims, interventions and outcomes so conclusive evidence is still not available.

It is interesting to note from the studies included in the Cochrane database that none of them actually detailed what actually happened in rehabilitation.

1. Cameron et al (79) did not detail physiotherapy intervention. The patients were mobilised once the post-operative X-ray showed adequate fixation. The patient received 2 sessions of physiotherapy on weekdays. No other information regarding physiotherapy input was recorded.

2. Fordham et al (80) did not detail any physiotherapy intervention. The only mention of physiotherapy input was in terms of hours input. The GORU group received more physiotherapy (total hours 258 compared to 198 for the control group) .
3. Galvard et al (81) did not detail any physiotherapy intervention. The trial was purely investigating the differences between a Geriatric and orthopaedic led service.
4. Gilchrist et al (82) did not mention any physiotherapy intervention.
5. Swanson et al (83) did not detail any specific intervention, just stated that the standard group received daily physiotherapy by the physiotherapist rostered to the orthopaedic ward. In the intervention group the physiotherapy involved early mobilisation and twice daily intense sessions by the physiotherapist. No information was given as to what the intense sessions included.
6. Kennie et al (84) did not detail any specific intervention, just stated that both groups of patients received both Physiotherapy and Occupational Therapy. The measure of functional independence used was the Katz Index (63).

As an addition to the study by Kennie et al (84) however, the Occupational Therapist and Physiotherapist carried out a study investigating the role of each profession in this service (85). The role of the Physiotherapist was assessment of patients with regard to function, joint range of movement, muscle power, swelling, pain and leg length, and the planning of a course of treatment on assessment findings tailored to the requirements of the individual patient. The forms of therapy included: graded exercises, flowpulse therapy, neuromuscular strapping, progression of mobility, increasing endurance with recording walking distances, gait re-education, joint home visits. No further mention was made of muscle power assessment or training.

In the USA the systems tend to be different with Acute Inpatient Rehabilitation being new. Due to the prospective payment system often in place in the USA many patients have a very short stay in an acute hospital with little rehabilitation. Many are sent to skilled nursing facilities for their rehabilitation. However, Fitzgerald et al (86) reviewed records of elderly patients admitted with proximal femoral fracture to a large community hospital from 1981 to 1986. They found that after the implementation of the prospective payment system patients received less physical therapy (3.5 versus 7.1 sessions; $P < 0.0001$), walked shorter distances at discharge (3 versus 13 metres; $P < 0.01$), and were more frequently transferred to nursing homes (83 versus 55 percent; $P < 0.01$). They concluded that since the implementation of the prospective payment system, hospitals have reduced the amount of care given to patients with hip fracture and have shifted much of the rehabilitation burden to nursing homes. The increase in the number of such patients remaining in nursing homes one year after the fracture suggests that the overall quality of care for these patients may have deteriorated.

Most of the recent studies from the USA are investigating the effects of acute inpatient rehabilitation on outcomes for proximal femoral fracture patients. Some studies have assessed the rehabilitation intervention in depth, however many of these have not been randomised controlled trials.

1.8.3 Specific Physiotherapy Interventions after Proximal Femoral Fracture

Baker (67) was one of the first investigators to attempt a randomised controlled trial into the rehabilitation outcomes of two different types of intervention on ambulatory outcome post proximal femoral fracture. One intervention was a standard gait re-education programme using a frame and progressing onto other walking aids. The other intervention was gait re-training on a treadmill. The idea behind this was that there is a difference in the walking pattern when using an aid compared to walking unaided. It was hypothesised that gait retraining would therefore be more effective if factors considered essential for motor skill acquisition were followed. These are: elimination of unnecessary muscle activity, feedback and accurate practice. They suggested that this might be more readily achieved using a treadmill than conventional gait re-training methods. The authors' conclusions to this study were that the mobility of the treadmill group compared to the control group was significantly better following the different rehabilitation interventions. The results from this study have since been criticised as the conclusions drawn were based on a sub-group analysis. This will be discussed in more depth in chapter 7.

Sherrington et al (87) also carried out an RCT to determine the effect of a home exercise programme on strength, postural control, and mobility following hip fracture. Forty-two people 64-94 years of age were recruited into the study 7 months after sustaining a fall related hip fracture. Thirty-five were living independently in the community and 7 were living in institutional care. The main outcome measures in this study were quadriceps strength; postural sway, Functional Reach, weight-bearing ability, walking velocity and self rated fall risk. Isometric measurements of strength were made of the affected and non-fractured leg at 90 degrees of knee flexion. The intervention consisted of a "home-based" programme of a specific weight-bearing exercise established at a visit by a physiotherapist. The exercise, which was also used as an outcome measure involved standing on a block and attempting to lift the contra-lateral leg off the ground by extending the hip and knee of the leg on the block. In the testing procedure a 5.5cm and 10.5cm block was used and both legs assessed. At home the patients were given telephone books 5cm, 23cm and 27cm thick to use as the stepping box. An assessment of pre-test performance was carried out to establish the maximum number of repetitions the patient could safely execute and the height of the stepping box. The patients were asked to perform the exercises every day for 1 month. There was no significant difference between the groups at the study entry. At the end of the trial, the intervention group showed significantly greater quadriceps strength in the fractured leg and increased walking velocity. The intervention subjects also improved their weight-bearing ability and reported reduced subjective falls risk. In contrast, there were no significant improvements in any of the test measures in the controls. Within the intervention group, improvements in quadriceps strength were significantly associated with improved performances in the weight-bearing test measures and with increased walking velocity. The authors concluded that the weight bearing exercise programme improved strength and mobility following hip fracture. They called for further research to ascertain whether the extent of this improvement in the fall risk factors were sufficient to prevent falls

Jette (13) found negative results from a controlled trial of an intensive rehabilitation programme after a hip fracture. Patients were assigned to one of two orthopaedic services. One was the standard post surgical rehabilitation programme. The other service was an intensive rehabilitation in addition to the standard service. There were 40 subjects in the standard group and 35 in the intensive rehabilitation group.

Standard post surgical treatment consisted of breathing exercises and sets of quadriceps exercises on the first day post operation, progressing to daily active assisted exercises. On day 2 the subjects were allowed out of bed and ambulated as their pain allowed. The intensive programme included standard treatment as above and 1-2 hours of individualised patient and family education by the physiotherapist. A geriatric assessment examined medical needs and discharge planning. A home visit was carried out by the physiotherapist 2 days post discharge. Follow up phone calls were made up to one-month post discharge by the physiotherapist.

The assessment tools used were Functional Status Index, which reports on patients self reported physical and social function, before the fracture, at discharge and 3,6,12 months post discharge.

Tinetti et al (88) investigated a home-based multi-component rehabilitation programme for hip fracture patients. The purpose of this randomised controlled trial was to determine whether a comprehensive rehabilitation strategy, addressing both modifiable physical impairments and activities of daily living (ADL) disabilities, would result in enhanced recovery in physical and social functioning after a hip fracture. This intervention was compared to patients receiving 'usual home care service'. The specific aim was to investigate whether the multi-component intervention strategy lead to better recovery when compared to the usual care among non demented persons who returned to the community post hip fracture. The physiotherapy interventions comprised gait and transfer practice, training in the use of assistive devices. Participants were also instructed in the performance of progressive, competency based exercises for balance, for upper and lower extremity conditioning (using four levels of colour coded resistive bands) and, if indicated by the baseline assessment, for specific muscle and joint groups. Participants carried out their exercise programmes daily with no supervision. To enhance and monitor adherence to the daily exercise programmes, participants completed an exercise checklist each day. The functional component of the intervention based on the principles of Occupational Therapy, was designed to identify and improve inefficient and/or unsafe performance of tasks of daily life. The number of visits for both the Physiotherapist and Occupational Therapist were tapered over time but the intervention lasted for up to 6 months. The usual care group consisted of standard physiotherapy. Only a few of the participants received Occupational Therapy. The specific content and duration of the therapy-training programme was left to the discretion of the physiotherapists. The usual physiotherapy intervention for this group consisted of gait and transfer training, strengthening and range of motion exercises usually without resistive bands or weights. The outcome of this study was that there was no significant differences between the two groups, however it was noted that the participants randomised to the usual care received more rehabilitation and home care services and experienced a higher rate of recovery compared to previous cohorts. The conclusions drawn from this paper were that the challenge is to determine more accurately the composition and duration of rehabilitation and home services that will ensure optimal functional recovery most efficiently in older persons after hip fracture.

These studies have been the main randomised controlled trials investigating actual physiotherapy intervention and it is evident that still little is known regarding the optimum methods of treatment.

1.9 Long-Term Declines in physical function following Proximal Femoral Fracture

A recent case control study investigated decline in physical functioning, directly attributable to the effects of hip fracture (89). They found that proximal femoral fractures are associated with a dramatic decline in physical functioning at two years, independent of the effects of increasing age, pre-existing medical conditions and disabilities. Nine hundred and eleven people with a proximal femoral fracture at the time of the initial interview were randomly selected and 910 randomly selected older people, without proximal femoral fracture (controls), were invited to participate in the study. At two years changes in physical functioning, defined in terms of self-reported mobility, functional dependence and physical activity were examined. Data from the survivors (572 cases and 756 controls) showed that, after controlling for pre-existing chronic medical conditions and disabilities, proximal femoral fracture patients were 4.2 times more likely than controls to be immobile within the community (95% confidence interval (CI) 2.8-6.2, $p < 0.001$) and 2.6 times more likely to be functionally dependent (95% CI 1.7-4.1, $p < 0.001$). Proximal femoral fracture patients were also spending less hours per day on their feet compared with controls.

Another prospective study (72) investigated the changes in physical function following proximal femoral fracture in a community-living elderly population. The outcome measures included; self-reported performance of dressing, transferring, walking across a room, climbing stairs, and walking one-half mile before the fracture occurred and 6 weeks and 6 months post-fracture. Baseline factors were assessed before the proximal femoral fracture occurred. Of the 120 subjects who sustained a proximal femoral fracture, 22 died within 6 months of the fracture. Among survivors there was a sustained decline in function at 6 weeks after the fracture with little improvement by 6 months. At baseline, 86% could dress independently versus 49% at 6 months; 90% could transfer independently versus 32% at 6 months; 75% could walk across a room independently versus 15% at 6 months; 63% could climb a flight of stairs versus 8% at 6 months; and 41% could walk one-half mile versus 6% at 6 months.

1.10 Conclusion to Chapter

Egol 1997 (12) 'Attainment of a successful functional outcome is the goal of fracture treatment. However, despite improvements in implant technology, operative technique, and rehabilitation protocols, outcomes for elderly hip fracture patients often fall short of expectations.'

The past 40 years have seen the development of many effective techniques for internal fixation and femoral head replacement; hence the move from investigating mortality rates following proximal femoral fracture to investigating disability following proximal femoral fracture. It is now fully recognised that rapid and effective fracture treatment is a prerequisite for successful rehabilitation. It will not alone produce successful outcome, but unsuccessful surgery does carry a much higher risk of poor outcome. Certain factors such as patient age, gender, associated co-morbid conditions and pre-fracture ambulatory and functional ability are independent of all the efforts of the rehabilitation team. Other factors, however, such as surgical timing, avoidance of iatrogenic complications, collaborative practice, and establishment of proper support networks can be affected by our rehabilitation interventions. The most recent Cochrane report has shown that rehabilitation in a specific rehabilitation setting (GORU) for elderly proximal femoral fracture patients shows a trend to more favourable outcome in terms of death and institutional care and death and deterioration in function. Many of the studies included in the Cochrane report however have not detailed the actual sub-components of rehabilitation such as specific physiotherapy interventions. In fact in a review by Craik 1994 (46) it was stated that physical therapy intervention following proximal femoral fracture had not changed since the 1970's, and the challenge was for new research to reduce the residual disability after proximal femoral fracture. Another study stated that lack of adequate physical therapy was a factor in patients remaining in a long-term skilled nursing facility. (12). It has also been stated that proximal femoral fracture patients discharged to American nursing homes with active physical rehabilitation were less likely to remain institutionalised (90). Most of the studies on post surgical care of the proximal femoral fracture patient have stated that the patients had daily physical therapy but most have not described in detail what was involved in this part of the rehabilitation process (79), (80), (81), (82), (83). The other Cochrane review (65), which was updated in April 2000, highlighted the need for good randomised trials in physiotherapy after proximal femoral fracture.

It is therefore, essential to study the components of this rehabilitation process. It may be that if more structured approach to the components of rehabilitation were investigated then functional outcomes for proximal femoral fracture patients could be maximised. The aim of the randomised controlled trial, which will be discussed in chapter 6, is to investigate a specific high intensity strength training intervention on both physical function and lower limb power for patients admitted to a GORU after a proximal femoral fracture.

Table 1.2 Studies Comparing Standard Care to Geriatric Orthopaedic Rehabilitation Units

Author	Year/ Trial type	Patient number	Interventions	Outcomes	Results
Cameron (79) UK	1993 RCT	252	Early mobilisation Comprehensive rehabilitation Early discharge	Mortality, Functional status, Length of stay, Place of residence Readmission, carer burden, cost effectiveness	Reduction in length of stay, a modest short term improvement in level of physical independence and accommodation status after discharge
Fordham (80) (UK)	1986 RCT	108	GORU	Mortality, Functional status, Length of stay, Place of residence, cost effectiveness	No significant differences were found in length of stay, functional score or discharge outcome.

Table 1.2 Studies Comparing Standard Care to Geriatric Orthopaedic Rehabilitation Units

Author	Year/ Trial type	Patient number	Interventions	Outcomes	Results
Galvard (81) Scandinavia	1995 RCT	378	Geriatric rehabilitation, transfer to Geriatric hospital + weekly visit by Orthopaedic surgeon	Mortality, gait speed, length of stay, place of residence, readmissions, cost	No significant difference between the two groups in walking speed or absence/presence of pain at 1 year follows up. More re-admissions for 'orthopaedic group' for orthopaedic related problems
Gilchrist (82) (UK)	1988 RCT	222	GORU	Laboratory tests, length of stay, discharge placement of patients	No detectable difference between the mortality, length of stay or placement between GORU and control group.

Chapter 2

Skeletal Muscle Function in the Elderly

2.1 Introduction

This chapter will focus on the effects of ageing on skeletal muscle and how strength training may enhance physical function in elderly subjects. This will provide the background for my RCT, which was a structured quadriceps strength-training programme, aimed at improving leg extensor power and functional ability.

A common problem in the elderly is loss of mobility, which ultimately leads to a loss of independence. An important component that contributes to loss of mobility in many elderly people is the atrophy and weakness of skeletal muscle. Weakness makes everyday activities more difficult and the sense of effort may lead to a voluntary reduction in physical activity which itself leads to further muscle atrophy. Muscular forces are needed to retain the structural integrity of the skeletal system, to maintain posture, for locomotion, for breathing and in almost all aspects of daily living. Reductions of muscle strength in the elderly have been associated with falls and fractures, especially of the neck of femur (91), (92), (93). The marked decrease in muscle strength and size with ageing is a multifactorial syndrome, which may be attributable in part to: biological changes of ageing itself, the accumulation of acute and chronic diseases, the assumption of a sedentary lifestyle and selective or generalised nutritional inadequacies. Inactivity and under nourishment are potentially at least partially reversible with appropriate interventions (94).

It has been suggested that identification of appropriate modalities of physical activity, which have positive effects on muscle physiology in the aged, should be the focus of research. (58). This chapter will focus on muscle assessment and the changes that occur in muscle with ageing and the studies that have been carried out which show that with training some of these age-related changes can be reversed in terms of muscle strength, muscle power and function.

2.2 Skeletal Muscle Characteristics

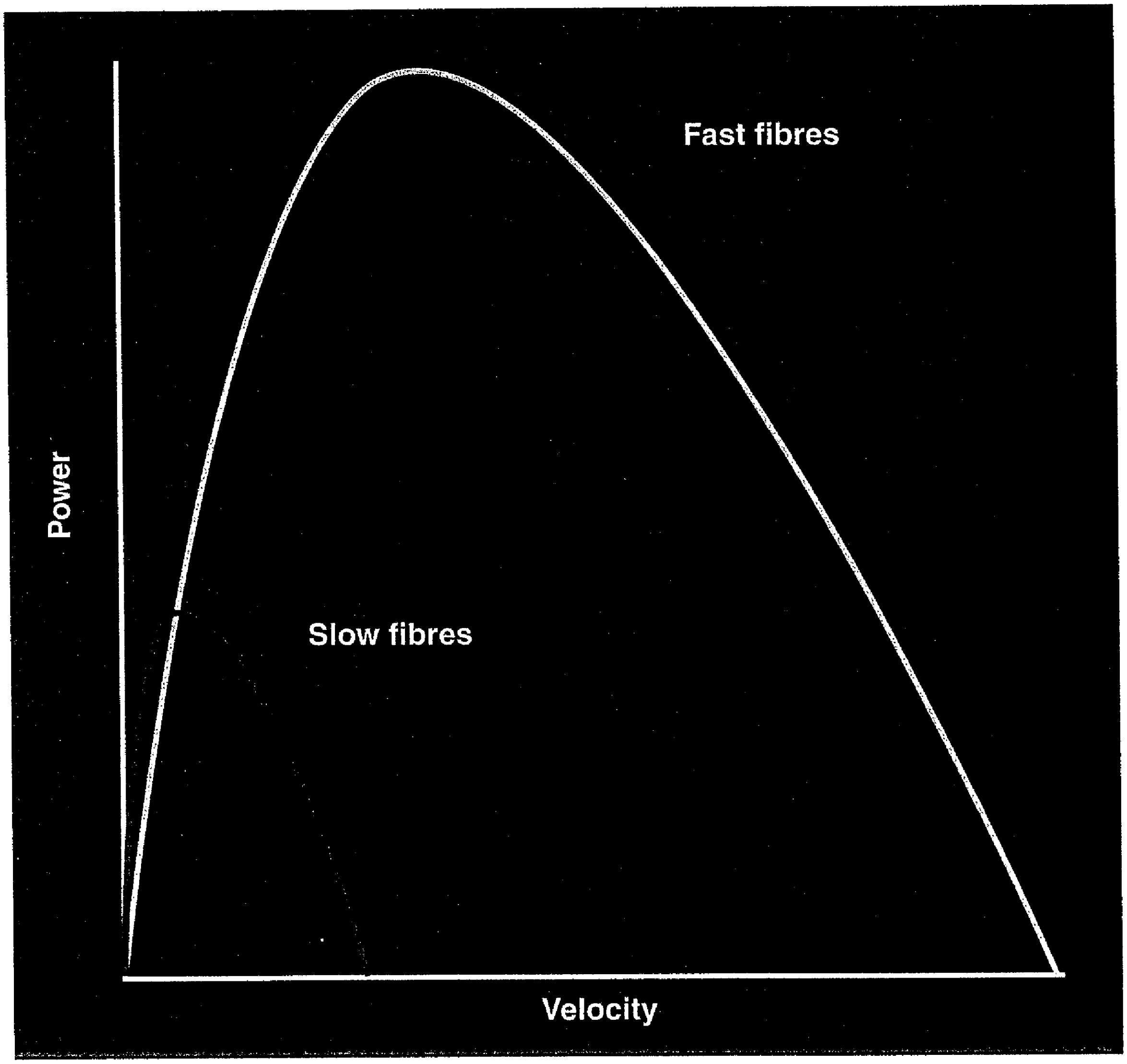
Skeletal muscles are composed of various fibres that have markedly different morphological and physiological characteristics. These differences have led to several different systems of classification. Fibres can be classified as fast twitch or slow twitch. A fast twitch motor unit is one that develops force rapidly. It also relaxes rapidly and therefore has a short twitch time. Slow twitch motor units, in contrast, develop force and relax slowly and have a long twitch time. A common classification based on histochemical characteristics refers to slow-twitch and fast-twitch motor units as Type I and Type II, respectively. The differences in mechanical characteristics of the muscle fibres is accompanied by a distinct difference in their ability to demand and supply energy for contraction, and to withstand fatigue. Type I fibres are generally fatigue resistant and have a high capacity for aerobic energy supply, but they have limited potential for rapid force development, as characterised by low actomyosin myofibrillar ATPase activity and low anaerobic power (95).

Type II are essentially the opposite, characterised by fatigability, low aerobic power, rapid force development, high actomyosin myofibrillar ATPase activity and high anaerobic power (95). With a higher speed of shortening, fast fibres have the potential to generate higher power outputs and to generate greater forces during fast movements than slow fibres (96). Type II muscle fibres can be further classified into subdivisions. Type IIA and type IIX.

These are important aspects of muscle physiology as training has been shown to affect the recruitment, size and proportion of the different muscle fibre types and this is seen even in old age.

Generally the greater the speed with which a muscle contracts, the smaller the force it can exert. This relationship between force (torque) and speed of contraction is described by the classical power-velocity curve. (Fig 2.1)

Figure 2.1 The Power Velocity Curve (96)



2.3 Definitions of Strength and Power

The terms muscle strength and muscle power are often used interchangeably, however there are distinct differences between them and they should not be confused.

- Strength - Muscle 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 maximal effort (96).
- Power – Muscle power is a combination of force of contraction and speed of movement, and is the rate of performing work (expressed in watts) (97). In physics power is precisely defined as 'the time rate of doing work'. (Force*Distance / Time).

In order to train the muscle at the appropriate intensity for the desired result accurate assessment of the ability of the muscle to generate force must be established. There are various methods for assessing muscle function and these shall be outlined below.

2.4 Skeletal Muscle Assessment

Accurate assessment of human muscle performance is essential to evaluate the efficacy of training studies. This applies to both young and older subjects. The capacity of muscle to generate force can be assessed through either static or dynamic contraction. Isometric (static) assessment reveals the amount of tension a muscle can generate against a resistance permitting no observable joint movement. Isotonic (dynamic) strength, the application of force through all or part of a joint's range of motion, can be assessed via a concentric (shortening) or eccentric (lengthening) mode of contraction. In many studies impairment is measured by assessing various aspects of muscle function. (98), (99), (100), (101), (102).

2.4.1 Isometric Assessment

The ability of a muscle to produce static force can be measured using hand held dynamometry and cable tensiometry. Accurate measurement by this method depends on a number of factors, including body position; correct joint angle (that capable of generating the greatest force), and correct location of the pulling strap on the body part serving as the lever. Isometric testing is limited because the measurement of strength is isolated to the specific point of application within a joint's range of movement. Despite this many studies in the elderly have used hand held isometric dynamometry. (103), (104), (105), (100). Isometric measurement of hand grip strength can also be measured using a hand grip dynamometer (106), (107), (108), (109), (110), (111).

2.4.2 Isotonic Assessment

Isotonic strength is measured dynamically with dumbbells, ankle weights and barbells. The strength of a particular muscle group is determined by testing the maximum amount of weight that can be lifted through a joint's range of motion for either 1 repetition (1RM) or 10 (10 RM). There are limitations to this form of testing such as the inability to control test velocity, the amount of contribution from accessory muscles and the fact that strength is measured at the weakest joint angle. Despite this it has been used in most of the strength training studies involving elderly populations as it is inexpensive, safe to use and includes a natural component of concentric and eccentric resistance. (112), (113), (114), (115), (116).

2.4.3 Isokinetic Assessment

The most novel form of muscle function testing is Isokinetic testing. Isokinetic devices allow individuals to exert as much force and angular movement as they can generate at a pre-determined velocity. This form of measurement has one main advantage over isotonic assessment and that is that a muscle group can be assessed to its maximal potential throughout a joint's entire range of motion. Some studies in the elderly have used Isokinetic assessments (117), (118), (119), (102), (120) however these have been with healthy elderly groups and not the frail populations. This is probably due to the complex nature of the testing equipment, which is not suitable for the frailer individual.

2.5 Measurement of Muscle Power

Much of the early work into the mechanical characteristics of the motor units and their respective muscle fibres was carried out in the late 1970's (121), (122), (123), (124). Bosco et al (122) studied the influence of skeletal muscle fibre composition on the mechanical performance of human skeletal muscle under dynamic conditions. A young healthy population with differing muscle fibre composition of the vastus lateralis was used as subjects to perform maximal vertical jumps on a force-platform. Two kinds of jumps were performed: one from a static starting position, the other with a preliminary counter-movement. The calculated mechanical parameters included height of rise of centre of gravity, average force, net impulse and average mechanical power (W). It was observed that the percentage of fast twitch fibres was significantly related ($p<0.05$) to these variables in the starting jump condition and also to height rise and net impulse of the positive work phase in counter-movement jump. It was concluded that skeletal muscle fibre composition also determines performance in a multi-joint movement. Bosco suggested that the result was explainable through the differences in the fibre characteristics of the motor units and their respective muscle fibres.

Bosco et al (125) also developed an anaerobic test for muscle power. The study was undertaken to assess the relationship between the mechanical power developed during an anaerobic power test and muscular fibre distribution. Ten track and field male athletes were used as subjects, whose muscle fibre composition (taken from the vastus lateralis) varied from 25% to 58% fast twitch fibres. The test consisted of measuring the flight time with a special timer during 60 seconds of continuous jumping. A formula was derived to allow the calculation of mechanical power during a certain period of time (every 15 seconds during 60 seconds of jumping performance). The relationship between the mechanical power for the first 15-second period correlated best with fast twitch fibre distribution ($r = 0.86$, p less than 0.005). However, the power output during the successive 15 second periods demonstrated lower correlation with twitch fibres, and this relationship became statistically non-significant after 30 seconds of work. The sensitivity to fatigue of the test was supported by the relationship observed between the decrease of power during 60 seconds jumping performance and the percentage of twitch fibres (r = 0.73, p less than 0.01). These early studies were some of the first to show that human muscular performance is influenced by skeletal muscle fibre composition.

Muscle power is now regularly assessed using the vertical jump using a Kistler force plate (126). Other measures of muscle power also include pneumatic leg press machines (127), isokinetic dynamometers (128) and cycle ergometers (129). More recently the Nottingham Power Rig has been used in both young and elderly populations to determine leg extensor muscle power (127),(130).

2.6 Definition of Types of Training

Resistance training refers to training where an overload resistance is applied. The resistance can be low, which is usually referred to as muscular endurance training, or moderate to high, which can be called strength training. Endurance training has met with mixed outcomes in elderly training programmes with some studies reporting benefits (131), (132) while others found that generally endurance training resulted in relatively small physiologic and functional benefits (133), (134). It may be the magnitude of change with endurance training is low because the intensity of the training is also low. It is now widely recognised that strength training can improve muscle function in elderly subjects. It is not as clear however which type of strength training can produce gains in power because up until recently most of the studies investigated purely strength changes (135). The following section will focus on the changes that occur in muscle with ageing, the causes and how this affects both strength and power output in the elderly. The mechanisms by which strength and power can be improved will also be discussed.

2.7 Effects of Ageing on Skeletal Muscle

It has been well established that significant losses in maximal force production (muscle strength) take place with aging (136), (137), (138). This decline in strength is most closely related to a loss of muscle mass.

Cross sectional studies have shown that muscle strength remains similar from 20-45 years (136), thereafter significant losses in muscle strength begin after 45-50 years. This loss of strength is said to proceed at about 1.5% per year so that by age 70 the major muscle groups of the lower limb are only able to generate approximately 60% of the force generated by younger adults (20-30 years of age) (139), (140).

One particular cross sectional study of carefully screened healthy subjects suggested that between 65-89 years of age the knee extensor muscles 'lose' isometric strength at an annual rate of 1-2% (of the value at age77) (141). Another study (142) confirmed these findings and found that there was approximately a 2% reduction in muscle strength in patients over 65 years annually. Data from longitudinal studies however have found both greater increases in this amount of loss (137) and lesser rates of loss (143).

The percentage of this decline is similar for both men and women, although men are stronger than women as determined by absolute strength, throughout life by approximately 50%. Aniansson (100) demonstrated that isometric muscle strength in women was on average 56 percent of that in men at the age of 70. Isokinetic peak torque values were also about 56 percent of that in men.

There is now more evidence regarding the rate of strength loss after the age of 70, a study by Aniansson et al (137) demonstrated that the knee extensor muscle strength was approximately 30% lower in a group of 78-81 year old subjects compared to 70-year-olds. A more recent longitudinal study (144) investigating changes in isokinetic muscle strength in older healthy men found that there was a significant reduction in the isokinetic strength of the knee extensors, knee flexors and elbow flexors. The mean age at baseline of the subjects was 65.4 (S.D $\pm$ 4.2) and at test 2 was 77.6 (S.D $\pm$ 4.0). This loss of strength was apparent at both slow and fast angular velocities. The mean percentage change over the 12-year period in the knee extensors was –23.7 $\pm$ 14.6% at the slower velocity and at the faster velocities the mean percentage change was –29.8$\pm$22.9%. Another recent longitudinal study (145) of 120 men and women who were re-measured after approximately 10 years found that the rates of average decline per decade for the knee extensors was 14%. Greig et al (143) on the other hand found very little change in knee extensor strength in a group of 14 healthy men and women after an 8 year period when isometric strength was the main outcome measure. The differences in rate of decline of muscle strength in these studies could be due to the fact that the subjects involved may not necessarily all have been 'healthy' and therefore might not have been homogenous groups. There may also have been variations in the levels of physical activity being carried out by the different groups, which could have affected the rate of loss.

2.8 Possible Explanations for Decreased Skeletal Muscle Function in the Elderly

In order to understand the causes of decreased skeletal muscle function in the elderly, numerous attempts have been made to assess the muscle morphology of ageing muscles mainly using muscle biopsies (136), (146), (147). Whole muscle area has also been assessed using techniques such as computerised tomography (148) and more recently magnetic resonance imaging (149).

It would appear that with advancing age there is a reduction in the number of muscle fibres or a reduction in their size or both. A study by Lexell et al (146) examined cross-sections of autopsied whole vastus lateralis muscle from 43 previously physically healthy men between 15 and 83 years of age in order to study the effects of increasing age on the human skeletal muscle and found that with ageing muscle there was a loss of fibres, with no predominant effect on any fibre type, and to a lesser extent a reduction in fibre size, mostly of type II fibres. Other studies have found that the size of type II fibres are more affected with age than the type I fibres (150), (136), (151). There may also be a shift in the proportions of type I and type II fibres which could contribute to the atrophy seen. Type II fibres tend to be large, while in general type I fibres are small in cross sectional area. A decrease in the number of large type II fibres with an increase in the number of small type I fibres could decrease the total muscle fibre cross sectional area and therefore decrease muscle mass. Type II fibres may also be stronger for their cross sectional area than type I fibres. Therefore any reduction in the relative area of muscle occupied by type II fibres would reduce the specific strength of a muscle (97).

Jansson (152) analysed biopsy data from 42 studies to investigate the relationship between percentage of type I fibres and age. Jansson found that there were changes in the fibre type frequency with age. For example in men with a low physical activity level, there was a significant decrease in percentage of type I fibres from ages 20 to 49, however from age 50 through to 89 the percentage of type I fibres increased. This trend was similar for moderately active men. This was not the case for women where there was no clear cut relationship, although the changes were similar.

As well as the proportion of fibre types changing there may also be the phenomenon of co-expression of fibres, which occurs with ageing (153). Andersen et al (153) took two muscle biopsies from 12 frail elderly subjects (mean age 88+ 1 SE) of the vastus lateralis muscle. The results from these biopsies indicated that up to 50% of the fibres analysed showed coexpression i.e. type I and type IIA, type IIA and IIX and type I and type IIX.

The major contributory cause for the reduction of muscle fibres with ageing is thought to be the loss of alpha motor neurons in the spinal cord, and then the secondary denervation of their muscle fibres. The result leads to the motor unit pool to a given muscle to undergo degeneration and reorganisation (154), (155). The neurodegenerative process has been reported in studies of muscle from older humans (146), (155). This denervation of the muscle fibres is followed by reinnervation by the surviving motor neurons. This has led to the fibre type grouping, fibre atrophy, irregularly shaped fibres and diminished synchronisation of motor unit contractions. It is thought that eventually the reinnervation may fail to keep up with the degeneration and therefore permanently dennervated fibres are lost and replaced with fat and connective tissue. One early study examined the relationship between maximal isometric twitch force and the estimates of motor unit numbers in the extensor digitorum brevis muscle. They found a substantial reduction in twitch force in individuals over 60 years of age that correlated well with reduced numbers of motor units as estimated by an electrophysiological technique (156). A more recent study by Doherty et al (155) using the biceps brachii and brachialis muscles reinforced this correlation between reduced motor unit number and reduced contractile strength in older individuals.

As well as structural changes that occur with ageing muscle there may also be reductions in blood flow and capillarity of the ageing muscle. These changes could cause decreases in metabolic activity within the remaining muscle mass that could account for some of the decreased function. One possible explanation could be a reduction in mitochondrial density and oxidative capacity, which may in turn contribute to reduced exercise capacity in elderly people (157), (158). However there have only been a few studies that have considered the effects of increasing age on the capillary bed of the ageing muscle and the findings are still inconclusive (159).

In addition to this skeletal muscles also undergo significant qualitative changes during the ageing process. Muscle quality has been estimated by normalising strength to muscle cross sectional area (specific force or tension). The results from a recent study by Frontera et al (160) suggested that the intrinsic ability of muscle fibres to generate force is lower in older subjects. The authors suggested a possible reason for this was due to alterations in the contractile elements of the muscle cell.

Other studies have also looked at the contractile properties of fibre types in old and young men and women and have again found reductions in the whole muscle cross sectional area in older populations (144). One explanation for this decrease in strength per unit cross-sectional area is that the cross sectional area occupied by force generating tissue may be overestimated in the elderly muscle, as aged muscle contains increased proportions of fat and connective tissue (96). This increased proportion of fat tissue could lead to a reduction in the force output.

A recent longitudinal study (161) supported this suggestion. They investigated skeletal muscle attenuation coefficient, as determined by computed tomography, which measures muscle density. Lower values reflect increased muscle lipid content. This investigation examined the hypothesis that lower values for muscle attenuation are associated with lower voluntary isokinetic knee extensor strength at 60 degrees/sec in 2,627 men and women aged 70-79 yr participating in baseline studies of the Health ABC Study. Their results showed that strength was higher in men than in women (132.3 $\pm$ 34.5 vs. 81.4 $\pm$ 22.0 N, $P < 0.01$). Men had greater muscle attenuation values (37.3 $\pm$ 6.5 vs. 34.7 $\pm$ 7.0 Hounsfield units) i.e. lower lipid levels and muscle cross-sectional area at the mid-thigh than women (132.7 $\pm$ 22.4 vs. 93.3 $\pm$ 17.5 cm, $P < 0.01$ for both). The strength per muscle cross sectional area (specific force) was also higher in men (1.00 $\pm$0.21 vs. 0.88 $\pm$ 0.21). The attenuation coefficient was significantly lower for hamstrings than for quadriceps (28.7 $\pm$ 8.7 vs. 41.1 $\pm$ 6.9 Hounsfield units, $P < 0.01$). Midthigh muscle attenuation values were lowest ($P < 0.01$) in the eldest men and women and were negatively associated with total body fat ($r = -0.53$, $P < 0.01$). Higher muscle attenuation values were also associated with greater specific force production ($r = 0.26$, $P < 0.01$). Multivariate regression analysis revealed that the attenuation coefficient of muscle was independently associated with muscle strength after adjustment for muscle cross sectional area and mid-thigh adipose tissue in men and women. The authors hypothesised that the results demonstrated that the attenuation values of muscle on computed tomography in older persons could account for differences in muscle strength not attributed to muscle quantity.

Other researchers have reinforced the hypothesis of a reduction in fast twitch type II fibres. Harries et al (119) measured maximal isokinetic knee extensor strength as torque in 17 young (mean age ± SD, 21 ± 3 years) and 16 elderly (68 ± 5 years) women at differing angular velocities. The elderly women were significantly weaker than the young women at all angular velocities. The rate of loss of absolute torque with increasing velocity was similar for both age groups, but when torque was standardised as a percentage of the individual's maximum, the elderly group showed a significantly greater rate of loss than the younger group. The authors hypothesised that the age differences are compatible with lower ratio of type II to type I fibre in the older group. Aniansson et al (93) investigated this by taking muscle biopsy material from vastus lateralis of the quadriceps during surgery from 43 66-100-year-old female and nine 70-89-year-old male patients with fresh hip fractures. They found a reduction in muscle fibre size in the vastus lateralis; especially in the fast twitch fibres compared to a historical control group in the female group. However the proportion of the slow twitch and fast twitch fibres remained the same. They also found that prior to the fracture about 60% of the study group were not 'healthy' and many were dependent in ADL. They concluded that the muscle fibre atrophy and weakness in muscle strength in this population might be partly attributable to low physical activity and maybe partly reversible with exercise.

Another contributory factor to the reduction in specific strength could be that elderly people have insufficient neural drive to be able to fully recruit all the motor units during a maximal voluntary contraction. Voluntary activation of muscles requires activation of motor parts of the cortex, which in turn, activate the motorneuron pool in the ventral grey matter of the spinal cord. A recent study (162) found that elderly subjects had a small but significant failure of activation of their quadriceps muscles. The study involved a maximal voluntary isometric contraction of the quadriceps with and without superimposing electrical stimulation. The central activation ratio was used to quantify the degree of volitional activation of the quadriceps during maximal voluntary isometric contraction. The study indicated that older subjects had a small but significant failure of their quadriceps muscle and the authors hypothesised this could be caused by voluntary activation not reduction in muscle mass alone. This study also found that the older muscle exhibited properties of slower-twitch muscle during force frequency testing. This study was carried out in active older subjects so this activation deficit could potentially be even worse in older subjects with disease.

Another study specifically investigated the muscle strength of hip fracture patients (163). The authors investigated the extent of muscle weakness in older female hip fracture patients compared with healthy older and young women. The aim was to determine the extent to which muscle weakness was caused by a decline of the force produced per unit area of muscle rather than by a decline in muscle bulk; and to investigate the mechanism of the decline in force per unit area. Maximum voluntary force was measured during isometric and pliometric contractions. Muscle cross-sectional area was also measured using an anthropometric technique. The results of this study showed that the isometric maximum voluntary force of the adductor pollicis muscle was lower in both groups of older subjects than in the young women. This was partly explained by a reduction in the cross sectional area of the muscle, but there was also a decrease in the force per unit area of the remaining muscle. There was a greater reduction in these values for the hip fracture patients. The authors suggested that hip fracture patients may be particularly susceptible to muscle weakness. There was also no improvement in the measures on repeat measurement 2 weeks later. They hypothesised that the weakness was probably present before the fracture and may have actually contributed to its occurrence.

In summary the age related changes to the motor unit in terms of the size, characteristics and the functional properties of the motor unit pool may have a profound effect for muscle force production. As well as this the quality of the remaining muscle tissue may be reduced thereby reducing the force production of the aged muscle.

Theoretically, therefore, interventions designed to increase skeletal muscle size and function through increased physical activity levels may result in clinically important consequences in the frail elderly. In particular interventions aimed at increasing quadriceps function are of particular importance as this muscle group is closely associated with locomotion and basic activities of daily living. It might also be the case that under disease conditions these physiological changes could be accelerated. Therefore trials investigating such changes should specifically differentiate between healthy and non-healthy groups and it would also appear that hip fracture patients might be particularly susceptible to reductions in muscle strength.

2.9 Strength Training Programmes for Elderly People

Strength training can be defined as progressively overloading the neuromuscular system using high resistance to increase the ability to perform maximal contractions (164).

Strength training programmes for the elderly and the very old have met with significant success in increasing muscular strength. Table 2.1 shows a summary of results of resistance training for elderly. A review of the literature was carried out to find strength training studies involving elderly subjects. The search included studies carried out up until October 2001. Studies were included into this table if the main outcome measure was lower limb strength, the subjects were over 60 and if the training was of moderate to high intensity. Studies were excluded if a specific strength measurement was not used and the training intensity was very low.

It is evident from table 2.1 that aging does not appear to reduce the ability of the musculoskeletal system to adapt to resistance exercise. It is considered now that if the intensity of the training programme is low than only modest improvements in strength are observed (165), but if the training stimulus is of an appropriate intensity, strength gains in older adults are similar to those in younger adults (166), (135). A recent study however investigating strength changes in older and younger subjects after a nine week strength training intervention found that the younger subjects showed significantly greater improvements in 1RM strength compared to the older subjects. Both older and younger groups however did make substantial gains (167).

Other studies as well as measuring changes in muscle strength have investigated morphological changes in muscle tissue. Hagerman et al (112) in a recent RCT assessed intramuscular and transport factors that may be associated with strength increments, in addition to the determination of strength. Eighteen untrained men ages 60-75 years volunteered for the study; 9 were randomly placed in the resistance-training group, and the other half served as untrained or control subjects. The resistance-training group subjects performed a 16-week high-intensity (85-90%) 1 repetition maximum resistance training programme (twice weekly) consisting of 3 sets each to failure (6-8 repetitions based on 1 RM of 3 exercises): leg press, half squat, and leg extension with 1-2 minutes rest between sets. Pre- and post- training strength was measured for the 3 training exercises using a 1 RM protocol. Body fat was calculated using a 3-site skinfold method. Biopsies from the vastus lateralis muscle were obtained for fibre type composition, cross-sectional area, and capillarization measurements. Resistance training produced significant changes in the following comparisons: percentage fat decreased in the resistance-training group by almost 3%, strength improved for all exercises: leg extension = + 50.4%, leg press = + 72.3%, half squat = + 83.5%; type IIB fibres decreased and IIA fibres increased; cross-sectional areas of all fibre types (I, IIA, IIB) increased significantly, and capillary to fibre ratio increased but not significantly. No significant changes occurred in any pre- to post-tests for the untrained control group. The results showed that skeletal muscle in older, untrained men responded with significant strength gains accompanied by considerable increases in fibre size and capillary density.

Frontera et al (148) carried out a case series study on twelve healthy untrained male volunteers (age range 60-72 yr). The aim of the study was to investigate the strength conditioning on skeletal muscle function and mass in older men after 6 and 12 weeks of training. The men participated in a 12-week strength training programme (8 repetitions/set; 3 sets/day; 3 days/wk) at 80% of the one repetition maximum (1 RM) for extensors and flexors of both knee joints. The effects of weekly measurements of 1 RM showed a progressive increase in strength in extensors and flexors. There were significant increases in strength by week 6 and by 12 wk extensor and flexor strength had increased 107.4 ($P < 0.0001$) and 226.7% ($P < 0.0001$), respectively. This progressive increase in 1RM amounted to an average of 5% improvement in 1RM per training day. Isokinetic peak torque of extensors and flexors measured on a Cybex II dynamometer increased by 10.0 and 18.5% ($P < 0.05$) at 60 degrees/s and 16.7 and 14.7% ($P < 0.05$) at 240 deg.sec^{-1}. The torque-velocity relationship showed an upward displacement of the curve at the end of training, mainly in the slow-velocity high-torque region. Mid-thigh composition from computerized tomographic scans showed an increase ($P < 0.01$) in total thigh area (4.8%), total muscle area (11.4%), and quadriceps area (9.3%). Biopsies of the vastus lateralis muscle revealed similar increases ($P < 0.001$) in type I fibre area (33.5%) and type II fibre area (27.6%). The fact that the strength gains made by 1RM measurement were far greater than that of the isokinetic measurements was possibly due to the specificity of training, in that the training and testing were both isotonic. The fact that the training also had its greatest influence in the slower velocity measurements could also be due to the fact that these speeds mirrored the training speed. This was not measured but it was estimated that the duration of each repetition was between 6-9 seconds through a range of 90 degrees.

2.10 Changes in Muscle Power with Ageing

Although research from the last decade clearly demonstrates that older people can achieve training induced gains in muscle strength that are similar to those of younger adults, only a few investigations have focused on changes in muscle power with age (141), (126), (168), (141), (169). It is evident now that the rate of muscle power decline is faster than that of strength. There is a loss of muscle strength of up to 1.5% per year, however it is now thought that loss of power may be even more at 3.5% per year, but this has only been shown in a cross sectional study of healthy men and women between the ages of 65-89 (141).

Muscle power is essential for functional activities most notably locomotion and ability to rise from a chair. It is essential therefore to establish strategies that will reverse / slow down the rate of decline in elderly people as such declines could prevent basic activities of daily living being carried out.

Bassey (170) demonstrated that in very old adults leg extensor power is more important than strength for performing daily activities such as stair climbing, rising from a chair and walking. Older adults who required some form of walking aid had between 42-54% less leg extensor power than those who could complete the tasks unaided. This has led researchers to believe that there might be a functional threshold of leg power (also strength and aerobic power) below which basic activities can no longer be carried out.

The main findings from the National Survey carried out by the Sports Council and Health Education Authority (171) concluded that leg power of the dominant leg of at least 3 watts per kilogram was needed to climb stairs unaided, and that people who could not generate more than 2 watts per kilogram could not climb stairs without assistance or only extremely slowly. From their cohort of women in the 65-74 age group, who were community dwelling, they found a considerable number below this 'functional threshold'. The fact that these were healthy women with no obvious pathology creates a worrying baseline especially for the frailer population who may be well below this functional threshold. Since the publication of this survey the threshold level, which was sited in the National fitness survey has been re-adjusted in a later publication (172). The results from this survey regarding functional threshold levels will be discussed in chapter 7.5 in relation to my RCT.

2.11 Theories for Loss of Power in the Elderly

One theory for the loss of power is the selective atrophy of type II fibres and the fact that the power output of type II fibres is approximately four times that of type I fibres (173). Other important factors contributing to this loss could be a decrease in the number of motor units, particularly those innervating high-threshold fast twitch fibres (174),(154).

A cohort study carried out by De Vito et al (126) investigated the age-related decline in maximal muscle power in 52 sedentary healthy women aged between 50 and 75 years to determine whether force or velocity is the major determinant. Maximal muscle power was estimated from two types of vertical jumps, squatting and counter-movement, performed on a Kistler force platform. In the squat jump the subject assumed a bent knee position 90 degrees knee flexion and jumped from that position. In the countermovement jump the subject started from an upright position and was preceded by a counter-movement. These measures allowed for calculation of the vertical force applied to the body centre of gravity and the corresponding vertical velocity. An age-related decline in absolute power was statistically significant in all the conditions examined and in both peak power and average power values. The decrease in vertical velocity was also statistically significant. The main finding of the study was the demonstration that vertical velocity was the critical determinant of the age-related decline in power in healthy elderly women .

Kostka et al (129), in a cross sectional study, investigated the relationship between maximal anaerobic power and corresponding optimal velocity and habitual physical activity and with maximal oxygen consumption (VO2max) in twenty-nine community dwelling, healthy women aged 66-82 years. Maximal power was measured using a friction-loaded non-isokinetic cycle ergometer. They found a strong positive correlation between habitual physical activity and maximal power in healthy elderly women.

Bassey et al (170) measured 26 residents of a chronic care hospital (13 men of mean age 88.5 $\pm$ 6 SD years and 13 women of mean age 86.5 $\pm$ 6 SD years) on the Nottingham Power Rig and carried out performance measures such as stair climbing, walking speed, chair rises. Leg extensor power was significantly correlated with all performance measures, but the performance measures were generally not significantly correlated with each other (except for chair rising and walking speed). They also found that women had significantly less leg extensor power than men. They concluded that measurement of leg extensor power in frail elderly people could prove useful in focusing effective rehabilitation programmes

A cross sectional study carried out by Skelton et al (141) examined the effects of healthy ageing on muscle strength, power and potentially related functional ability. Measurements used were isometric knee extensor, elbow flexor and handgrip strength, leg extensor power, timed rise from a low chair, lifting a weighted bag onto a surface and stepping unaided onto boxes of different heights. There were 50 men and 50 women, age 65-89 in the study. The differences in isometric strength and leg extensor power over the age range were equivalent to losses of 1-2% and 3.5% per annum respectively. The decline in explosive strength was faster than the decline in isometric strength for men but not women. Power standardised for body weight was associated with chair rise time and step height. Strength standardised for weight was associated with chair rise time.

Foldvari et al (175) recently tested the hypothesis that peak muscle power is closely associated with self-reported functional status in sedentary elderly community-dwelling women. Muscle power in this study was measured using a specifically designed pneumatic resistance machine. They used baseline data that were collected as part of a 1-year randomised controlled clinical trial of a combined programme of strength, power, and endurance training in 80 elderly women (mean age 74.8 ± 5.0 years) with 3.2 ± 1.9 chronic diseases, selected for baseline functional impairment and/or falls. They found functional status at baseline was related to physiologic capacity, habitual physical activity level, neuropsychological status, and medical diagnoses. Leg power had the strongest correlation to self-reported functional status ($R = -.47$, $p < .0001$) of any of the physiologic factors tested. In a forward stepwise regression model, leg press power and habitual physical activity level were the only two factors that contributed independently to functional status ($r = .64$, $p < .0001$), accounting for 40% of the variance in functional status. They concluded that leg power is a strong predictor of self-reported functional status in elderly women (175). There are limitations with self-reported measures in physical function as they rely on respondents' memories and subjective judgement, however the results do indicate a relationship between power and function in this elderly group.

To date Lamb et al (176) have been the only researchers to quantify lower limb muscle power of hip fracture patients using the Nottingham health rig. They investigated the significance of leg extensor power, postural sway, age, pre-injury mobility and fracture type in recovery walking and stair climbing ability. They found leg extensor power of the fractured leg to be the most important determinant of walking speed and stair climbing ability ($R^2= 0.40$, $P<0.001$ and $R^2=0.33$, $P<0.002$) respectively.

2.12 Changes in Muscle Power through Training Interventions

Table 2.2 details the studies that have shown changes in muscle power through training interventions. A review of the literature was carried out to find training studies involving elderly subjects. The search included studies carried out up until October 2001. Studies were included if muscle power was the primary outcome measure and a specific measure of power was used and subjects were over 60. Studies were excluded if a direct measure of muscle power was not used. From the studies carried out it is evident that muscle power can improve through progressive resistance training.

A recent study (135) investigated changes in muscle power with progressive resistance training. The authors examined the influence of progressive resistance training on muscle power output in 17 men and women aged 56-66 years, and compared their responses to 15 men and women aged 21-30 years. All subjects performed 12 weeks of progressive resistance training at a workload equivalent to 80% of the one repetition maximum (1RM). All training and assessments of 1RM and power were made on Keiser pneumatic resistance machines. Subjects performed five exercises; three sets per exercise, twice weekly. Muscle power was measured (isotonically) at resistances equivalent to 40, 60, and 80% of the 1RM; on the knee extension and arm pull machines. All subjects increased arm pull power similarly at 40 and 60% of 1RM, independent of age or sex. There was not a significant increase in arm pull power at 80% of 1RM. Older and younger subjects also had similar absolute increases in leg extensor power at 40 and 60% of 1RM, but men responded with greater absolute gains than women at these percentages ($p < .05$). The increase in leg extensor power at 80% of 1RM was similar in all groups. Older and younger subjects increased strength similarly in all exercises except the left knee extension. Independent of age, men increased strength more than women in all exercises except the double leg press. They concluded that individuals in their sixth decade could still improve muscle power (and strength); however, men may attain greater absolute gains than women

One cross sectional study by Hakkinen et al (103) examined the effects of high intensity strength training combined with explosive types of exercises for 12 weeks on 18 men and women (50 year age group) and 21 elderly men and women (70 year age group). Measurements included electromyographic activity, muscle cross sectional area of the quadriceps, isometric maximal force and force-time curve of the leg extensor muscles. They found significant increases in the maximum integrated electromyographic activity of the trained muscles in all groups, primarily during the first 8 weeks. Significant enlargement of the cross sectional area of the quadriceps for all groups and significant shifts occurred in all groups in the shape of the absolute force-time curves and the maximal rate of force production. These results suggested that this type of programme could lead not only to changes in strength but also explosive force production (power). These changes were accompanied by adaptations in the nervous system and muscular hypertrophy.

A recent RCT (177) investigated the efficacy of a 12-week high velocity training in healthy older people. The primary outcome was leg press peak power. The training group carried out high velocity leg exercises three times a week with increasing resistance in combination with a 45 minute programme of moderate exercise once a week. The results showed an overall improvement in power of 22%, but also at a resistance of 70% of the body weight leg extensor power increased by 141%.

Some studies have not made direct measurements of muscle power but have assessed power using more functional tests such as time to rise from a chair or stair climbing

These studies have found that these field test assessments of power have increased through strength training interventions (178), (179), (115), (180), (142).

One specific RCT (178) recruited fourteen independent-living elderly adults (mean age 73 years) and randomly assigned them to either a strength training intervention or a control group (stretching). Supervised sessions lasted 20-45 minutes, three times/week for 12-weeks. Strength exercises included hip flexion and extensions, knee extensions, and hamstring curls using elastic tubing resistance and body weight squats. The main outcome measure was rising from a chair as this is considered one of the most demanding functional tasks routinely undertaken during daily activities due to the high level of knee torque. A force transducer, which measured the vertical force applied onto the ground from the subjects' feet, was used and from this vertical time a force graph was produced which represented strength, power and motor control ability in the lower limb. This vertical force-time curve of a fast chair rise was measured pre and post training. The peak slope, which represents muscle power increased significantly in the training group compared to the control group. The authors hypothesised that strength training using a moderately intensive programme can modify the power and force of a chair rise.

An RCT (142) carried out by Chandler et al investigated the effects of a 10 week progressive strength training programme using resistive bands in functionally impaired community dwelling men and women (77.6 $\pm$ 7.6 years). They found that there was a significant impact of strength gain on chair rise performance in participants who were more impaired.

One particular RCT (180) investigated the effect of frequency of resistive training on gain in muscle strength and neuromuscular performance in healthy older adults. They used chair rising as the functional measure of power / neuromuscular performance. Forty-six community-dwelling healthy men (n = 29) and women (n = 17) aged 65 to 79 years were either assigned to high-intensity resistance training 1, 2, or 3 days per week for 24 weeks or to a control group. The intervention was a progressive resistance training consisting of three sets of eight exercises targeting major muscle groups of the upper and lower body, at 80% of one-repetition maximum (1-RM) for eight repetitions, either 1, 2, or 3 days per week. For each of the exercises, muscle strength increased in the exercise groups relative to the control group ($P < .01$), with no difference between the weekly, twice weekly and three thrice-weekly groups. The time to rise successfully from the chair 5 times decreased significantly ($P < .01$) at 24 weeks, Changes in chair rise ability was correlated to percentage changes in quadriceps strength ($r = -0.40$, $P < .01$) and lean mass ($r = -0.40$, $P < .01$). The authors concluded that a programme of once or twice weekly resistance exercise achieves muscle strength gains similar to 3 days per week training in older adults and is associated with improved neuromuscular performance.

Other studies, which have not specifically measured muscle power but have taken muscle biopsies, have found morphological changes in the fibre types (99),(181) with strength training interventions. On the other hand some studies have found no change in morphology following resistance training (182), (116) although strength and power gains have been achieved

A recent case series study by O'Neill et al (182) studied ten moderately active participants (8 women, 2 men; mean age 66.3 +/- 1.2 years). The subjects undertook 8 weeks of isotonic knee-extensor resistance training in one limb. The other limb served as the control. Afterwards, peak torque output (180 degree /s) and mean power increased 30.8% and 27.2%, respectively, in the experimental limb. A moderate, non-significant, cross-over training effect was observed in the contra-lateral untrained limb for the same measures. Whereas mean fibre cross-sectional area was unaltered in the contra-lateral untrained limb by training, Fibre Types I and IIb in the experimental limb displayed increased cross sectional area. However, mean cross sectional area's for all fibre types in the trained experimental limb were no larger ($p > .05$) than those observed in the contra-lateral untrained limb before or after training. There were no significant changes in muscle-fibre-type composition, the proportion of Type I myosin heavy chain, or Type IIa cross sectional area. These data suggest that short-term resistance training can significantly increase isokinetic peak torque in the elderly, despite minimal changes in the histochemical and biochemical parameters.

2.13 Conclusion to Chapter

The evidence to date does indicate that there is a reduction in muscle strength and power with ageing. Many of the early studies focused on muscle strength but muscle power is now receiving more attention, as most of the functional activities of daily living require rapid force production. With proximal femoral fractures being so common in the elderly this group require specific attention, as mobility is a major problem for them. Quadriceps muscle function is a major determinant of ambulatory ability. It is therefore important to identify training programmes that will assist in improving ambulation. One such strategy may be to improve lower limb explosive power. My RCT aims to address this issue.

Table 2.1: Strength Training Studies Using Elderly Subjects

Author	Study Type	Age Range or Mean Age of Subjects	Number in Study	Limbs/muscle groups tested	Measurement modality	Strength increases	Resistance level	Length of programme
Baker et al 2001(183)	RCT	69±6(trained group) 68±6 (Controls)	46 men and women	Knee extension (KE), knee flexion (KF) and leg press (LP)	1RM	71% increase 1RM in the affected leg for KE	Moderate	16 weeks
Sclicht et al, 2001 (184)	RCT	61-87	24	Lower limb	1RM	48.3% increase in leg extension between weeks 2-8	Moderate/ High	8 weeks
Hortobagyi et al, 2001 (185)	RCT	66-83	30 men and women	Quadriceps	1RM (also isokinetic dynamometer)	35% increase in 1RM	Moderate	10 weeks
Hagerman et al, (112)	RCT	60-75	18 men	Lower limb Leg extension (LE), Leg press (LP)	1RM	50.4% for LE, 72.3% for LP and 83.5% for half squat	High	16 weeks
Sharman et al, 2000 (186)	Controlled trial	60-75	20 men and women	Lower limb	1RM	33.8% increase in 1RM squat (females) 31.2% for males	High	6 months
Ivey et al, 2000 (187)	Controlled trial	65-75	22 older men and women	Quadriceps	1RM	26.4% increase men, 33% increase women	High	9 weeks

Author	Study Type	Age Range or Mean Age of Subjects	Number in Study	Limbs/muscle groups tested	Measurement modality	Strength increases	Resistance level	Length of programme
Cress et al, 2000 (188)	RCT	76±4	22 older men and women	Upper and lower limbs	Isokinetic dynamometer (Knee flexion/extension at 60 mdeg/sec) and 4RM	9% incease in Isokinetic knee flexion. 33% increase in leg press	High	6 months
Lemmer et al, 1999 (189)	Controlled trial	65-75	23 men and women	Knee extension	1RM	27% increase in knee extension in men and 27% increase in women	Moderate to high	9 weeks
Tracy et al, 1999 (190)	Observati onal study	65-75 (men) 65-73 (women)	23 men and women	Quadriceps	1RM	27% increase for men. 29% increase for women.	High	9 weeks
Skelton et al, 1996 (191)	RCT	74-89	20 women	Lower Limbs	Isometric Knee extension strength	20% mean improvement in isometric Knee extension strength	Moderate	8 weeks
Hartard et al, 1996 (192)	Controlled trial	63.6±6.2 (trained group) 67.4±9.7 (controls)	31 women	11 major muscle groups. Lower limb – leg press	1RM	39.3% increase for leg press	High	6 months

Author	Study Type	Age Range or Mean Age of Subjects	Number in Study	Limbs/muscle groups tested	Measurement modality	Strength increases	Resistance level	Length of programme
Welle et al, 1996 (193)	Controlled trial	72-72	8 men and women	Elbow flexion (EF), knee extension/ flexion, lateral pulldown	3RM	Measured in terms of specific tension (ratio of 3RM to CSA) KE=32±14%, F=64±13% EF=19±5%	High	12 weeks
Taafe et al, 1996 (116)	RCT	65-79	36 women	Knee extension/flexion and leg press	1RM	59.4±7.9%	High	12 weeks
Wolfson et al, 1996 (194)	RCT	Mean age 75± years	110 men and women	Hip extension, abduction. Knee flexion/extension. Ankle plantar flexion	Isokinetic dynamometer	Knee extension 25% Summed lower extremity strength 14%	High	12 weeks
Sipila et al, 1996 (132)	RCT	76-78	42 women	Knee extension and flexion	Isometric dynamometer	Knee extension torque/body mass 19.1%	High	18 weeks
Lexell et al, 1995 (195)	Controlled trial	70-77	35	Elbow flexors and knee extensors (KE)	1RM and isokinetic dynamometer	At 11 weeks 49% elbow flexors and 163% KE	High	1 year

Author	Study Type	Age Range or Mean Age of Subjects	Number in Study	Limbs/muscle groups tested	Measurement modality	Strength increases	Resistance level	Length of programme
Skelton et al, 1995 (196)	RCT	76-93	52 women	Upper and lower limbs	Isometric knee extensor, elbow flexor and handgrip strength	27% increase knee extensor, 22% increase elbow flexors and 4% handgrip strength	Moderate	42 weeks
McCartney et al, 1995 (197)	RCT	60-80	142 men and women	Upper and lower extremities	1RM	+20-65%	High	42 weeks
Fiatarone et al, 1994 (115)	RCT	72-98	100 men and women	Hip and knee muscle groups	1RM	+113% average increase	High	10 weeks
Pyka et al, 1994 (198)	Controlled trial	68.2±1	25 men and women	Upper and lower extremities1rm +30-97%	1RM	+30-97%	Moderate/ high	1 year
Judge et al, 1994 (199)	RCT	Mean age 80	110 men and women	Hip abduction and extension, knee ext/flex and ankle DF	Isokinetic dynamometer and 1RM	1RM (knee extension) =73%	Moderate	13 weeks
McMurdo et al, 1994 (200)	RCT	67-98	36 men and women	Major muscle groups	Isometric	18N increase	Moderate	6 months

Author	Study Type	Age Range or Mean Age of Subjects	Number in Study	Limbs/muscle groups tested	Measurement modality	Strength increases	Resistance level	Length of programme
Dupler et al, 1993 (201)	Observational study	61-81	20 men and women	Major muscle groups	1RM	Leg press male=60.3% female=80.3	High	12 weeks
Nichols et al, 1993 (202)	RCT	67.1±1.5	36 women	Trunk, upper and lower limbs	1RM	18-71% increases	High	24 weeks
Meredith et al, 1992 (203)	RCT	61-72	11 men	Knee extension/ flexion	1RM	104%	High	12 weeks
Grimby et al, 1992 (204)	Observational study	78-84	9 men	Quadriceps	Isokinetic dynamometer 30 and 180 deg/sec	10% increase concentric knee extension at 30 deg/sec. 19% exxentric at 30 deg/sec and 13% at 120 deg/sec	Isokinetic training	Median 62 days
Charette et al, 1991 (99)	RCT	64-86	27 women	Quadriceps, hamstrings, gluteus medius and maximus, iliopsoas	1RM	+28% - 115%	High	12 weeks

Author	Study Type	Age Range or Mean Age of Subjects	Number in Study	Limbs/muscle groups tested	Measurement modality	Strength increases	Resistance level	Length of programme
Brown et al, 1990 (205)	Controlled trial	60-70	14 men	Elbow flexors and lower limbs (bilateral leg press)	1RM and isokinetic dynamometer	23% increase 1RM and 17% isokinetic dynamometer	High	12 weeks
Fiatarone et al, 1990 (114)	Observational study	86-96	10 men and women	Quadriceps	1RM	174% ±31%	High	8 weeks
Frontera et al, 1988 (148)	Observational study	60-72	12 men	Knee flexion and extension	1RM	+107-227%	High	12 weeks
Aniansson et al, 1981 (124)	Observational study	69-74	12 men	Quadriceps	Isometric and isokinetic	9-22%	Moderate	12 weeks

Table 2.2: Changes in directly measured muscle power through training studies

Author	Study Type	Age range Or mean Age	Numbers in study	Test	Power increases	Length and type of programme
Earles et al, 2001 (177)	RCT	78±5	43 men and women	Pneumatic leg press	22% peak torque 150 average power at 70% body weight	12 weeks, 3 times a week of high velocity leg ecercises
O'Neill et al, 2000 (182)	Controlled trial	66.3±1.2	10 men and women	Peak torque 180 deg/sec on isokinetic dynamometer	Experimental limb 172.6±SD21.3 to 219.5±SD27.2 ($Nm.rad.s^{-1}$)	8 weeks knee extensor resistance
Nicholson et al, 2000 (178)	RCT	Mean age 73	14 men and women	Vertical force time of a fast chair raise	Significant improvement in P slope (representing muscle power)	12 weeks, 3x per week for 20-45 minutes for lower limb using elastic bands and body resistance
Joszi et al, 1999 (135)	Controlled trial of elderly men and women and younger men and women	56-66	17 men and women	Arm pull power and leg power	15±SE3.4% at 40% 1RM and 9.5±SE2.3% at 60% 1RM	12 weeks of progressive strength training between 40-80% 1RM
Skelton et al, 1995 (196)	RCT	76-93	52 women	LEP on the Nottingham power rig	18% increase in LEP (P=0.11)	12 weeks 3 x per week (resistance bands and weights (1-1.5Kg)
McCartney et al, 1995 (197)	RCT	60-80 ex group	142 men and women	Max power output on a cycle ergometer	7.1% increase in peak cycling power output	42 weeks of progressive lifting from 50-80% 1RM

Chapter 3

Functional Status Assessment Scales and Perceived Health Status Measures

3.1 Introduction

Measurement of muscle power and strength gain is important but it is also necessary to assess whether gains in these physiological parameters can translate into improvement in functional ability and perceived quality of life. Many studies have found associations between strength gains and functional gains in elderly subjects using selected functional assessment tools (142),(206),(115),(114),(191). Bassey found an association between muscle power and functional ability (170), but few have investigated the association between improvement in leg extensor power and changes in function in a frail elderly population. This section will evaluate some of the major functional tools used in elderly subjects, specifically focusing on the assessment tools chosen for my study.

3.2 Measuring Disability

Many early rehabilitation studies focused primarily on impairment, measuring function in terms of organ systems, such as muscle strength, sensation, and range of movement, balance, and other physical abilities. However, as the field of rehabilitation has grown and moved beyond the acute phase of disability, the concerns have shifted towards longer-term outcome and re-adaptation of patients back into the community. With this shift in focus, measurements have gone beyond just measuring impairment to assess disability as well. Assessments of this type are concerned with activities that individuals perform in their daily life. Most studies now incorporate both measures of impairment and disability to gain a more holistic approach of the patient outcome.

In the 1980 WHO, functional status assessment was classified as the measure of the impact of disability. Recently, WHO, in the International Classification of Functioning and Disability (ICIDH-2), classified level of functioning for the whole person as an activity rather than focusing on disability. That framework serves as the foundation for functional status measures (207).

Functional status assessments are primarily concerned with measuring the ability of an individual to perform activities required in daily life. An individual can be considered disabled when an activity is limited in its nature, duration, or quality of performance. Rehabilitation is the process of alleviating disability. Evaluating the rehabilitation process is accomplished through assessment of an individual's status. Therefore, the measurement of disability is central to the rehabilitation process. Functional status assessment within the realm of rehabilitation occurs across many domains, encompassing the physical, mental, social, occupational, and economic activities of an individual. There are many generic assessment tools that have been used to measure disability in the elderly population (208), (209), (210), (211). There are also some disease specific tools and in particular some for proximal femoral fracture patients (212), (213). It is the aim of this chapter to highlight those that have been widely used and where published evidence of validity, sensitivity and reliability has been published.

3.2.1 Katz Activities of Daily Living Scale

One of the earliest scales developed was the Katz Activities of daily living Scale (63). Most of the published studies using the Katz scale have been used with elderly patients, including many specifically with hip fractures, however there is still little evidence for the validity and reliability of this scale (214), (58).

3.2.2 The Barthel Index

Probably one of the most widely used scales is the Barthel Index (215). The Barthel Index was developed in 1955 to assess change in functional status in individuals with Neurologic or Musculoskeletal disorders who were undergoing rehabilitation. The Barthel is a rating index that assesses an individual through direct observation and review of medical records. The Barthel index assesses 10 ADL's. Eight can be described as self-care activities (feeding, transfer from chair to bed and back, grooming, toileting, bathing, dressing, bowel and bladder continence), and two as mobility-related activities (walking or propelling a wheelchair on a level surface 50yd with or without assistive devices or prostheses, ascending and descending stairs).

The Barthel is among the most widely used measures of functional status, providing for extensive testing of validity, reliability and sensitivity. Because it was the first measure developed to assess the rehabilitation process, it has served as a benchmark by which to judge other measures (211), (216). A number of investigators have modified the Barthel index, either expanding the number of items or changing the scoring procedures to allow for more sensitivity (217), (209).

One particular case study (218) monitored 102 patients admitted to a rehabilitation ward on a weekly basis using the Barthel Index. The three commonest diagnoses were 'stroke', 'fractured neck of femur' and 'dementia recovering from acute illness'. There was a significant rise in Barthel scores between admission to the rehabilitation ward (median Barthel 6) and discharge (median 13) for the group as a whole (median change 6, 95% CI 5-7; $p < 0.001$) and for each of the three main diagnostic groups. Barthel scores and mental test scores (MTS) at discharge were significantly related to destination on discharge, with a characteristic pattern for patients unable to return home and having to be placed in nursing homes (Barthel < 10, MTS < 7). This study outlined that use of the Barthel in a rehabilitation setting was feasible and could pick up clinically important change. The results reinforced the use of the Barthel as a useful tool for outcome measurement, case-mix adjustment and audit of discharge practices

In 1996 a joint working party from the Royal College of Physicians and the British Geriatric Society recommended the use of the Barthel when assessing functional ability post proximal femoral fracture, however they did acknowledge that there was a ceiling effect with this scale (219).

3.2.3 The Get up and Go Scale and the Timed Get up and Go scale

The Get up and Go test, was originally designed by Matthias et al (220). The subject was observed while rising from a chair, walking 3 metres and then returning to the chair. This test standardised most of the basic mobility manoeuvres and was quick and practical. Unfortunately in this original test the scoring system was imprecise. The performance was rated on a scale of 1-5 according to the observer's perception of the patients' risk of falling. The extremes of the scale were easy to score (1 and 5) the intermediate numbers were less clear. This led Podsiadlo et al (208) to develop the timed up and go. The same procedures are carried out but the manoeuvre is timed from initiation of the movement to completion. Podsiadlo et al carried out criterion validity on the scale hypothesising that it should correlate with balance, gait speed and functional capacity. They chose the Berg balance scale (221), gait speed over a 15-metre walkway and the Barthel index (215) to investigate if the scale was a valid tool. They found that the timed up and go test did correlate with these other scales and therefore they stated that this scale had concurrent validity with these more extensive measurement scales.

3.2.4 The Functional Reach Score

Duncan et al (222) established Functional Reach as a measure of balance. It has been described as the difference between arm's length and maximal forward reach, using a fixed base of support. Basically it is measuring the limits of stability in an anterior direction. The reliability of the tool was tested against a laboratory measure of balance known as the centre of pressure excursion (223). This measurement was an already accepted measure of dynamic balance. It was designed to mimic simple reach tasks. In the initial development study of Functional Reach, volunteers of differing age categories were recruited. The age range was from 20-87. The results of this study showed that Functional Reach measures were strongly associated with measurements of the centre of pressure excursion. The test was highly reproducible. Age influenced the measurements of reach; with increasing age the measures of reach decreased. Height also influenced the ability to reach. The conclusion drawn from this initial study was that Functional Reach was a portable, reliable precise, and a reasonable approximator of the margin of stability (222).

A further study carried out by the same authors (224) assessed the predictive validity of the tool in identifying elderly subjects at risk for recurrent falls. Two hundred and seventeen elderly, community-dwelling male veterans (aged 70-104) underwent baseline screening and were followed for 6 months to monitor falls. Subjects with two or more falls during the 6-month follow-up were classified as recurrent fallers. Logistic regression revealed that if individuals were unable to reach, the adjusted odds ratio (OR) of having two falls was 8.07 (2.8-23.71); if their reach was less than or equal to 6 inches the OR was 4.02 (1.84-8.77); and if reach was greater than 6 inches but less than 10 inches the OR was 2.00 (1.35-2.98). The association between Functional Reach and recurrent falls was not confounded by age, depression, or cognition. The authors hypothesised that the Functional Reach had predictive validity in identifying recurrent fallers. Since these studies the Functional Reach has been used as a measure of balance in many studies with conflicting views regarding its efficacy as a true measure of dynamic balance (225), (226), (227), (228), (229), (230).

The conflicting views regarding functional reach relate to whether it truly can identify high risk fallers and whether it is a feasible tool for elderly subjects. As a simple measure of balance however it does have face validity as the actual task of reaching forward does mimic many of the functional tasks that are required for everyday activities. It is probable that falls often occur when an individual tries to reach for objects outwith their base of support; therefore a test, which identifies subjects with a poor reach, seems justifiable. It is also simple to carry out and the instructions are minimal and therefore would seem an appropriate tool for elderly subjects.

One study specifically studied the relationship between fall-related efficacy in daily-life activities and function as well as instrumental tests of balance in patients with hip fracture. Fifty-five elderly inpatients (mean age 82.3) with newly operated hip fractures were assessed during the last week in hospital before discharge (225). The scales used were The Falls Efficacy Scale, Swedish version FES (S) and questions on fear of falling. The FES (S) is a translated version of the original falls efficacy scale devised by Tinetti et al (231). Functional Reach and tests on a balance platform were also performed. The results showed a significant relationship between the subjective ability measured with the FES (S) and the objectively measured balance in the Functional Reach test and also between fall-related efficacy measured with FES (S) and fear of falling. Very few significant correlations however were found between the results from balance tests on the force platform and those obtained with FES (S) and Functional Reach. The authors concluded from this study that the Falls Efficacy Scale, Swedish version, and the Functional Reach were useful in analysing balance function in elderly patients following proximal femoral fracture surgery.

Another cross sectional study (230) found that the Functional Reach could discriminate between old and young subjects. The younger subjects were able to reach significantly further than the older subjects.

Another study investigated whether muscle force of the ankle muscles contributed to scores in three different balance measures. Fifty community-dwelling volunteers between 65 and 91 years of age (mean = 74.82, SD = 6.11) were recruited. Based on their histories, 11 subjects were classified as being at risk for falling. Measures were the Berg Balance Scale (BBS), the Functional Reach Test, and the Timed Get Up & Go Test. The force generated by 12 lower-extremity muscle groups was measured using a handheld dynamometer. Ankle dorsiflexors and hip extensor forces were lower in subjects reporting falls, and force of the ankle dorsiflexors predicted fall status. Distal muscle force measures may be able to contribute to the prediction of functional balance scores; however, the muscles involved in the prediction differ depending on the measure of balance (227).

A recent case control study compared mean Functional Reach distance in healthy elders compared to individuals with known balance impairments, in order to analyse the extent to which Functional Reach measures dynamic balance. Thirteen healthy elders and 15 individuals with vestibular hypofunction were tested. There was no difference in Functional Reach distance between healthy elders and individuals with vestibular hypofunction. They also found that Functional Reach distance was not correlated to lateral stability measures, but was related to anterior-posterior postural control measures of Functional Reach (r = .69 to .84) in both groups. These data suggested that Functional Reach did not measure dynamic balance (232). It should be noted that the sample size was small and the patients tested had a specific pathology, so these results may not be generalisable. Another case control study also comparing the Functional Reach in fallers and non-fallers did not find any difference in the mean score between the groups (229).

Another study estimated the feasibility, reliability, and construct validity of both the Timed Get Up & Go Test and Functional Reach in a large heterogeneous sample (n=2305) to establish their importance relative to traditional measures of function. (233). They found both physical performance measures proved infeasible in many subjects (29.3% for the Timed Up and Go, 35.9% for the Functional Reach). Cognitive impairment was the most important determinant of inability to complete the tests. For those able to complete the tests, cognitively unimpaired subjects could reach farther (median 29 cm) and complete the Timed Get Up & Go Test in less time (median 12 seconds) than those cognitively impaired (25 cm for Functional Reach, 15 seconds for the Timed Get Up & Go Test). The test-retest reliability co-efficient between the screening and clinical administrations of the Timed Get Up & Go Test was 0.56 for all participants (intra-class correlations), 0.50 for the cognitively unimpaired, and 0.56 for the cognitively impaired. Construct validity was substantial, and correlation co-efficients between performance measures and self-report activities of daily living (ADL) measures ranged from 0.40 to 0.70. Compared with a global clinical measure of frailty, correlation co-efficients were more modest (0.38 to 0.60). They concluded that the Functional Reach and the Timed Get Up & Go Test were not feasible tools in this study. The Timed Get Up & Go Test also showed poor test-retest reliability.

A recent trial, which considered both the Functional Reach test and the Timed Get Up & Go Test, highlighted the need for standardisation of the tests in terms of footwear. The study was conducted to determine whether footwear affected performance of these tests in older women. They found that subjects performed better on Functional Reach when barefooted or wearing walking shoes compared with wearing dress shoes, regardless of floor surface. Differences were found among all footwear conditions for the Timed Get Up & Go Test performed on a linoleum floor. For this test, the women moved fastest in walking shoes, slower barefooted, and slowest wearing dress shoes. The authors concluded that footwear should be documented and should remain constant from one test occasion to another when both the Functional Reach, Timed Get Up & Go Tests are used in the clinic and in research (226).

3.2.5 The Elderly Mobility Scale

The Elderly Mobility Scale is a 20 point validated assessment scale for assessment of frail elderly subjects. The Elderly Mobility Scale tests the following: lying to sitting, sitting to lying, sitting to standing, standing, gait, walking speed and Functional Reach. As such it covers locomotion, balance and key positional changes, which are prerequisites to more complex activities of daily living (ADL). (211).

3.2.5.i Lying to Sitting, Sitting to lying

These two tests are scored out of 2, which represents independence. Where help is required the score drops to 1 or 0, depending on the level of assistance.

3.2.5.ii Sitting to Standing

The Elderly Mobility Scale scores a maximum of 3 if the patient is able to rise from a 19-inch chair in under 3 seconds (allowing use of upper limbs).

3.2.5.iii Stand

The Elderly Mobility Scale assesses the ability to stand and use the upper limbs without holding on. The maximum score is 3 where the patient is able to stand independently and reach forward and to the side.

3.2.5.iv Gait

The Elderly Mobility Scale scoring is based on the type of assistance required to walk, where a maximum score is achieved if the subject covers 50 metres. The maximum of 3 is scored if an elderly patient walks safely with either a stick or no aid. Where a frame, rollator, two sticks, crutches are used the score is 2.

3.2.5.v Walking Speed

Patients are timed over a 6-metre course, at their normal speed, using their usual walking aid. Maximum score is given for a time of under 15 seconds, corresponding to a walking speed of 0.4 metres per second and faster.

3.2.5.vi Functional Reach

This simple measure of balance is incorporated into the Elderly Mobility Scale but is also a measure in its own right. In terms of measurement for the Elderly Mobility Scale the maximum score is 4 and this is given if the patient can reach 16 cms ad beyond, a score of 2 is given for those who reach between 8-15 cms and a score of 0 for those who are unable or can only reach up to 8 cms.

This scale is now becoming more widely used in rehabilitation settings. It has content validity in that it evaluates a number of well-recognised manoeuvres used in daily life. Inter-rater reliability of the scale has also been established (211). Concurrent validity has also been established with the Barthel score and also the Functional Independence measure (211) and a recent paper (234) has found it to be more sensitive to mobility changes in a group of patients attending a Geriatric day hospital than either the Barthel Index or the Functional Ambulation Category (235).

3.2.6 The Functional Recovery Score (FRS)

Zuckerman et al (213) have developed a new functional assessment tool, specifically for use with hip fracture patients. The eleven-item Functional Recovery Score comprises of three main components: basic activities of daily living instrumental activities of daily living, and mobility. The authors have carried out a further study to assess the predictive and discriminant validity and responsiveness of the Functional Recovery Score. Six hundred and eighty-two elderly patients who sustained a hip fracture were prospectively followed and evaluated by using the Functional Recovery Score at three, six, and twelve months after surgery. It was found to be responsive to change. They also found that the Functional Recovery Score had predictive validity: pre-fracture scores were predictive of death, skilled nursing facility transfer, and re-hospitalisation within one year of fracture. In addition, the Functional Recovery Score had discriminant validity as mean scores for the following groups were significantly different from each other at three and six months: (a) patients who were alive, living in the community, and did not require re-hospitalisation; (b) those who were admitted to a skilled nursing facility; and (c) those who were re-hospitalised. Comparison of the Functional Recovery Score with a sex- and age-matched non-hip-fracture population indicated that hip fracture resulted in a 20 percent loss of function within the first year. Reliability testing using telephone interviews of patients as a means of obtaining information indicated very high reliability. The Functional Recovery Score could now be considered as method of assessing functional outcome for elderly hip fracture patients. As this is such a new scale, with only one validation study, more controlled studies may still be needed to be undertaken to assess its feasibility in hip fracture patients.

Recently another new measure has been designed for hip fracture patients (236). The Lower Extremity Measure and has been modified from the Toronto Extremity Salvage Score (TESS). In order to test its validity and reliability forty-three community-dwelling patients with a hip fracture completed the lower extremity measure, Older Americans' Resources and Services (OARS), and the Short form 36 (SF-36) were assessed in the hospital so that the pre-fracture status could be obtained; they were then followed prospectively at six weeks and at six months. All patients were interviewed twice in the hospital to assess the reliability of the lower extremity measure (intraclass correlation coefficient = 0.85). To establish criterion validity, the measures were compared with the Timed Up and Go test at six weeks. The lower extremity measure scores significantly correlated with the Timed Up and Go test scores ($r = -0.53$, $p = 0.03$) and also significantly correlated with the SF-36 subscale scores and the OARS scores. Both the lower extremity measure and the SF-36 scores changed significantly between all of the time-periods ($p < 0.05$). Measures of responsiveness indicated that the lower extremity measure was the best measure for detecting changes in physical function. The authors concluded that based on the results of the study the lower extremity measure could detect clinically important changes in physical function over time in patients with a hip fracture and would be most useful for clinical trials or cohort studies. They also concluded that the SF-36 physical function subscale is a valid measure for patients with a hip fracture. However validation has only been carried out on the Timed Up and Go test, which in light of the new research may not be the most appropriate comparator; therefore more validation work may be required before this can become a recognised scale.

3.3 Measurement of Perceived Health Status:

The ability to walk and to perform activities of daily living addresses the extent of physical disability but not the psychological disability that occurs following fracture. Perceived Health Status is especially important as a measure of performance or process of health care because it incorporates multiple domains and generally involves the patients' own perspective. It has been suggested that proximal femoral fractures do adversely affect health related quality of life (14) and it is therefore important to evaluate this in order to structure rehabilitation to minimise these adverse affects. Global outcome measures such as the Functional status Index (237) and the Functional Index measure (238), the Nottingham Health Profile (239), the SF36 (210), the Euroqol instrument (240), have all been used to measure perceived health status in elderly patients and include assessment of the person's ability to perform within society. The

Nottingham Health Profile will be discussed in this chapter, as this is the one that was used in my RCT.

Recent years have seen a remarkable explosion of research into quality of life in health care. The reasons for this development are many and complex but must include the growing recognition that the benefits of health and social services cannot be assessed merely by how long recipients survive. Measures are needed that are more meaningful and relevant to patients, citizens, and policy makers alike (241).

A committee concerned with health outcomes for older people agreed to define health related quality of life as 'a personal perception characterising the way an individual feels about his or her health status, including physical, psychological, religious, and social domains of health status'. Institute of Medicine 1996. (241).

Up until recently many of the psychological questionnaires/ scales were defined as measuring quality of life, however this is now thought to be misleading (242). For the purposes of this thesis The Nottingham Health profile will be described as a measure of perceived health status. However, previous research into the psychological well being of proximal femoral fracture patients has defined the impact of the fracture in terms of quality of life.

The Nottingham Health Profile was developed in the UK and is based on lay perceptions of health status. The conceptual basis of the Nottingham Health Profile was that it should reflect lay rather than professional definitions of health. The Nottingham Health Profile is not an index of disease, illness or disability but relates rather to how people feel when they experiencing various states of ill health.

The Nottingham Health Profile includes 38 yes/no items about health symptoms in 6 domains and scales (energy, pain, emotional reactions, sleep, social isolation, physical mobility), which are weighted for severity. It also includes a second part that asks a single question about health-related interface in each of 7 activities. Activities include employment, social relationships and activities, household activities, and sexual activity. The Nottingham Health Profile scores are calculated to represent a continuum of 0 (best health) to100 (worst health). It can be used via interview and self-administration.

Early testing of the tool on elderly people showed that the scores obtained from questionnaire could effectively differentiate between the 'well' groups and the 'ill' groups. The authors took four groups of elderly people over 65. A sample of 41 consisted of people in an exercise study that were classified as 'fit'. Another sample of 19 were taken from a General Practitioners list that had no known illness. Another sample of 49 were taken from a luncheon club with a variety of health and social problems. The final sample was 54 chronically ill patients drawn form the General Practitioners list. Many other studies using different age groups were also carried out in order to validate the tool (239).

The Nottingham Health Profile has now been extensively tested for face, content and criterion validity and has been found to be a highly satisfactory measure of subjective health status, in the physical, social and emotional domains; and to be a useful guide to the extent by which health problems restrict normal physical and social activities (239). In rehabilitation studies it has been used to assess outcome after stroke (243) and also knee surgery (244).

One study recently compared the use of the generic Nottingham Health Profile to a more disease specific tool, the Harris hip score to assess quality of life before and after a total hip replacement (212). They followed the patients for five years and compared the results with the information obtained from a specific scoring system for hip replacement patients (Harris hip score) with the generic Nottingham Health Profile. They hypothesised that the generic tool would be more sensitive than a conventional hip score in determining the outcome of hip replacement. The results found that both scoring systems correlated highly with each other and were each heavily influenced by the system of functional classification defined by Charnley. After five years both reflected the function of the implant and the general state of the patient.

Recently there have been studies investigating the quality of life of hip fracture patients after being discharged from the hospital and its relation to functional ability. A recent case control study (245) investigated quality of life and functional independence 6 to 12 months post-hip fracture. Ninety-two subjects and 92 controls were recruited. The Short Form-36 (SF-36) was utilised to measure quality of life. The Modified Barthel Index, the Frenchay Activities of Daily Living Index, the Timed Up and Go, and the Berg Balance Scale were used to measure functional ability. Despite being age and gender matched, the hip fracture subjects scored significantly ($p<0.05$) worse than the controls in all measures of function. The fracture group was slower on the Timed Up and Go (19 versus 10.5 seconds), had more difficulties with balance (46 versus 54 out of 56 measured on the Berg scale), and was less active and more dependent than the control group (Frenchay Activities of Daily Living Index - 24 versus 31 out of 42). The control group had a higher ($p<0.05$) perception of their quality of life in all domains of the SF 36. This study highlighted that the effects of impaired balance and mobility along with reduced functional and social independence are reflected in the diminished quality of life perceived by the fracture group.

Mossey et al (49) investigated the independent contributions to recovery from hip fracture of psychosocial factors including depression, personality, 'social connectedness', and self-rated health in 219 women age 59 and older (mean age 78.5) who were community dwelling prior to fracture. Initial assessments were conducted shortly after surgery and follow up assessments 2, 6, and 12 months later. By 12 months, 15 patients had died and 15 had entered a nursing home. Substantial declines in physical functioning though not psychosocial status was observed. Only 21 per cent (compared to 81 per cent pre-fracture) reported walking independently; fewer than 30 per cent had regained reported pre-fracture levels of physical function. The proportion with elevated depression scores at 12 months was 20 per cent, down from 51 per cent following surgery; 64 per cent rated their health excellent or good at 12 months, up from 43 per cent after surgery. Poor cognitive status and post-surgical self-rated health were predictive of mortality. Among survivors, age, pre-fracture physical functioning, and cognitive status were associated with recovery in physical function but not psychosocial status. High post-surgery depression scores, but not the other psychosocial factors, were associated with poorer recovery in both functional and psychosocial status. These findings demonstrate the importance of depressive symptoms as one determinant of recovery from hip fracture and support the need to attend to the affective status of hip fracture patients following surgery.

A recent RCT (246), which was investigating the use of hip protectors for older women at risk of hip fracture also examined the utility (preference for health) associated with hip fracture and fear of falling. They devised a time trade off technique, which estimates preference for health states by finding the point at which respondents show no preference between a longer but lower quality of life and a shorter time in full health. The results showed that 80% of the women surveyed would rather be dead than experience the loss of independence and quality of life that results from a bad hip fracture and subsequent admission to a nursing home. The term 'a bad fracture' was used from interviewing women with a previous fracture and using terminology described by them. 'A bad fracture' was referred to as being unable to return home.

3.4 Conclusion to Chapter

Most of the recent studies described have used measures of impairment, disability and quality of life. It is evident that there are many assessment tools available to the researcher. As a result of the evaluation into outcome measures I used the following measurement tools in my RCT. The Nottingham Power Rig was used to assess impairment because of the importance of leg extensor power. The functional measurements used were the Elderly Mobility Scale, the Barthel, the Functional Reach the Timed Up And Go. Perceived health status was measured using the Nottingham Health profile. These scales all have been tested for validity, reliability and sensitivity in elderly subjects. In addition they all have face validity for the patient group I was investigating and were therefore appropriate tools.

Chapter 4

General Methods

This chapter will describe the testing procedures, which were used in the Randomised Controlled Trial. Some of the procedures were also used in the pilot study.

The order of testing was as follows.

4.1 Height

4.2 Weight

4.3 Percentage body fat (247)

4.4 The Elderly Mobility Scale (211) (Appendix B)

4.5 The Barthel Index (Modified) (209) (Appendix C)

4.6 The timed up and Go Test (208)

4.7 The Nottingham Leg extensor power rig (130)

4.8 Hand held grip strength dynamometer (248)

4.9 The Nottingham Health Profile (239) (Part 1) (Appendix D)

4.1 Height

The patient was measured against a wall chart standing against the wall. Shoes were not worn. Height was measured in centimetres.

4.2 Weight

The patient sat on chair scales. Shoes were not worn. Coats and jackets were removed. Weight was measured in kilograms.

4.3 Percentage Body Fat (247)

Percentage body fat was measured using the Durnin and Womersley method of skin fold measurement using calibrated skin fold thickness callipers made by Holtain ltd. The following skinfold sites were used: Biceps, triceps, subscapular region and supra iliac region.

4.3.1 Biceps: The subject stood with his/her right arm held in the anatomical position, i.e. held by their side with the shoulder supinated. The mid position of the muscle belly of the biceps was palpated and the measurement was taken.

4.3.2 Triceps: The arm position was the same as that of the biceps. The measurement was taken midway between the acromium and the olecranon process.

4.3.3 Suprascapular: The subject medially rotated his/her right shoulder until his/her hand reached mid thoracic level in order to identify the inferior angle of the scapula. The arm was then re-positioned by the subject's side. The skinfold measurement was taken at the inferior angle of the scapula at a 45 degree angle.

4.3.4 Supra-iliac: The skinfold measurement was taken just above the iliac crest on the mid axillary line. The skinfold was measured vertically.

The callipers used had previously been calibrated in the University Department of Human Nutrition. The procedure for measuring skinfold thickness was: The thumb and the forefinger of the examiner were used to lift the skinfold allowing the calliper jaw to catch the fold approx 1cm below the examiners forefinger and thumb. Two seconds elapsed before the skinfold measurement was taken. Three readings were taken at each site with the average value being used as the skinfold score.

Once the four sites had been measured the scores were totalled and the table prepared by Durnin and Womersley was referred to. This table gives a prediction of the percentage body fat for the subject on the basis of their age and sex.

4.4 The Elderly Mobility Scale (211)

This scale measures six components of functional ability. It is carried out through direct observation and measurement of specific functional tasks.

4.4.1 Lying to Sitting, Sitting to Lying: The subject was initially lying on the top of a standard hospital bed. The subject was asked to sit up over the edge of the bed. A score of 0 was given if the subject required assistance of two or more people, 1 if the subject required assistance either verbally or physically from one other person and a score of 2 if the subject was completely independent. The subject was then asked to lie back onto the top of the bed from the seated position. Scoring was as above.

4.4.2 Sitting to Standing: The patient was asked to stand up from a standard 19-inch seat. A score of 0 was recorded if the patient was unable to achieve this without maximal assistance, a score of 1 if minimal assistance was required, a score of 2 if the patient was independent but required more than 3 seconds to complete the task and a score of 3 if the patient could perform the task in less than 3 seconds. The researcher started timing as soon as the movement was initiated.

4.4.3 Stand: The subject was asked to stand and raise their arms out in front of them and then above their head. A score of 0 was given if the subject was unable to stand without maximal support, a score of 1 if the subject could stand but required assistance to stand, a score of 2 if the subject could stand but required assistance to reach and a score of 3 if the subject could stand unsupported and reach.

4.4.4 Gait: The patient was asked to walk down a corridor. The researcher judged whether the patient was safe or unsafe in this task. A score of 0 was given if the patient was unable to walk at all, a score of 1 if the patient could walk but was unsafe in walking and turning, a score of 2 if the patient was safe walking but required a Zimmer frame or rollator to mobilise and a score of 3 if the patient was safe and required only sticks or was independent with no aid

4.4.5 Walking Speed: The patient was asked to start walking down a corridor at his or her own speed. At approximately 3 metres down the corridor was a marker; once the patient crossed this marker the researcher started the stopwatch. The patient was asked to continue walking until they had covered a 6-metre distance. Once their first foot had crossed over the line the timing was stopped. A score of 0 was given if the patient could not walk the distance, a score of 1 if the patient could manage the distance in >30 seconds, a score of 2 if the subject took between 15-30 seconds and a score of 3 if they managed the distance in under 15 seconds.

4.4.6 Functional Reach (FR): The subject stood beside a wall with his/her arm outstretched with fist clenched. The subject wore outdoor shoes or well fitting slippers while carrying out this assessment. The subject was asked to reach forward as far as he/she could without taking a step forward. The distance was measured in cms. A score of 0 was given if the patient was unable to manage this task or could manage but could reach less than 8 cms, a score of 2 was given if the subject reached between 8 – 16 cms and a score of 4 if the subject could reach over 16cms outwith their base of support. Actual sores of Functional Reach were also recorded. Figures 4.1 and 4.2 show the start and final position for the Functional reach.

Figure 4.1: The starting position for the Functional Reach Score

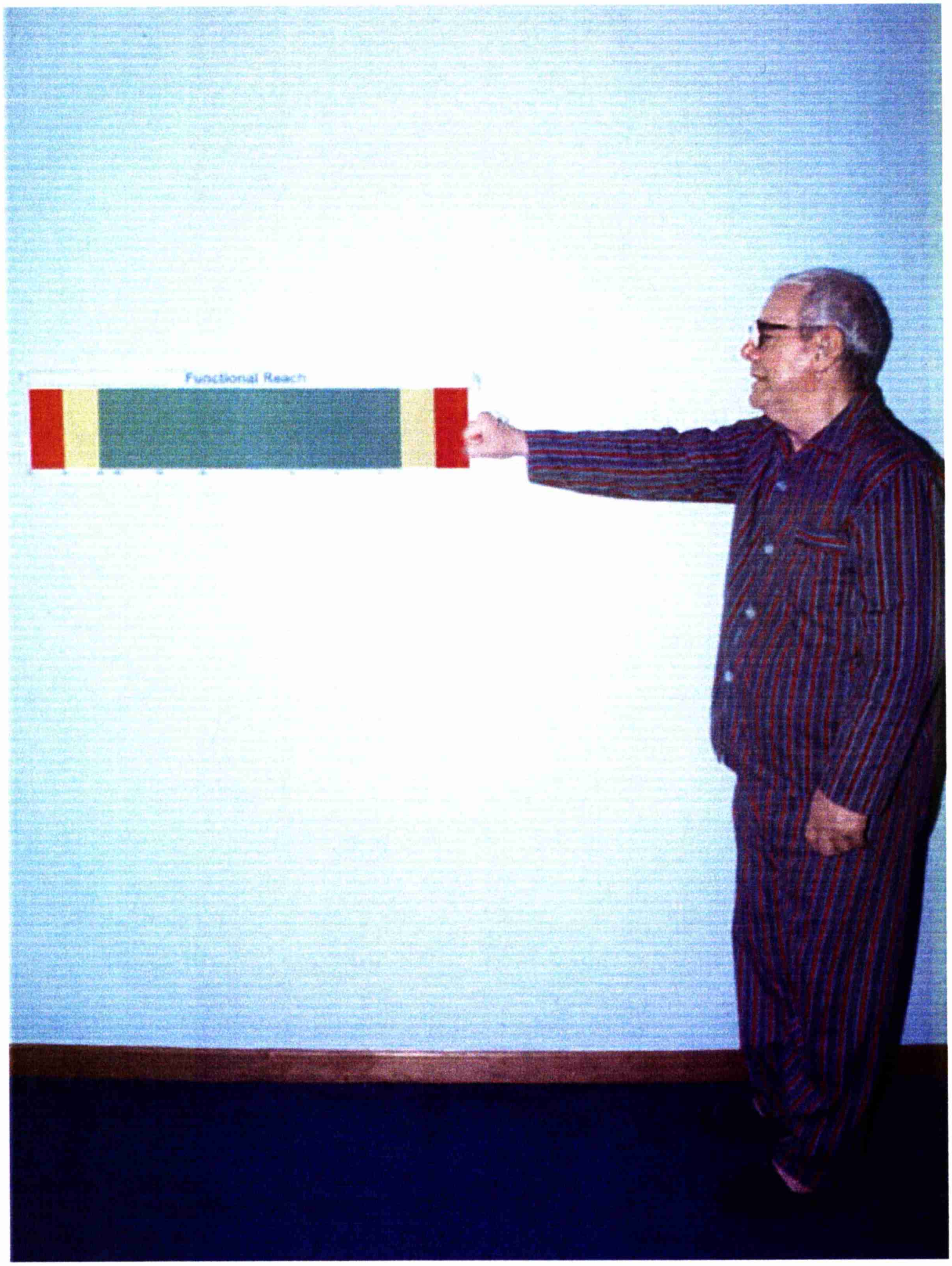


Figure 4.2: The reaching position for the Functional Reach Score

4.5 The Barthel Index (209)

This test was carried out through interview and patient observation. Guidelines as set out by Wade et al (209) were followed. The guidelines state that a patient's performance should be established using the best available evidence; therefore following the patient interview confirmation of recorded information was obtained through Nursing and Occupational Therapy records. The components of the Barthel are: Bowels, Bladder, Grooming, Toilet use, Feeding, Transferring, Mobility, Dressing, Stairs, Bathing.

4.5.1 Bowels: The components of this are: Incontinent, occasional accident and continent.

4.5.2 Bladder: The components of this are: Incontinent, occasional accident and continent.

4.5.3 Grooming: The components of this are: Needs help with personal care and independent.

4.5.4 Toilet Use: The components of this are: Dependent, needs some help and independent.

4.5.5 Feeding: The components of this are: Unable, needs help cutting or independent.

4.5.6 Transferring (bed to chair and back): The components of this are: Unable (no sitting balance), major help, minor help, and independent. The patient was asked to lie on top of the bed and transfer from the bed to the chair and back. The researcher assessed how much assistance was required.

4.5.7 Mobility: The components of this are: Immobile, wheelchair independent, walks with help of one person, independent. The patient was asked to walk a short distance and the mobility score was measured.

4.5.8 Dressing: The components are: Dependent needs help, independent.

4.5.9 Stairs: The components are: Unable, needs help, independent

4.5.10 Bathing: The components of this are: Dependent and independent.

4.6 The Timed up and Go Test (TUG) (208)

The subject was seated on a standard 19-inch seat. A marker on the floor indicated a distance of 3 metres. The subject was asked to stand up walk to the line, turn around and walk back to his/her seat. Timing was started as soon as the movement was initiated and stopped as soon as the patient was fully seated in the chair. The time was recorded in seconds.

4.7 The Nottingham Power Rig (130)

The patient was seated on the rig. The non-fractured leg was measured first. The subject was asked to place his/her non-fractured leg onto the force plate, and then to fully extend the leg. A measuring tape on the side of the seat measured the distance between the seat and the force plate with the leg fully extended. This distance was recorded. The seat was then fixed at that position. The affected limb was rested on the side bar. The subject was asked to lean slightly forward and hold his/her arms across the chest. The force plate was then brought forward so that the hip and the knee were at approximately 60 degrees flexion. This varied with each subject but was never more than 70 degrees. The researcher then made sure the flywheel was in the correct calibration position. The instruction to the patient was to push the leg straight as hard and as fast as they could without pushing their back against the seat. This movement was timed from initiation to full leg extension. The subject was given 10 attempts and the score was the average of the last five attempts. The same procedure was carried out for the fractured leg. Figures 4.3 and 4.4 show the start and final position on the Nottingham Power Rig.

Figure 4.3: The start position on the Nottingham Power Rig

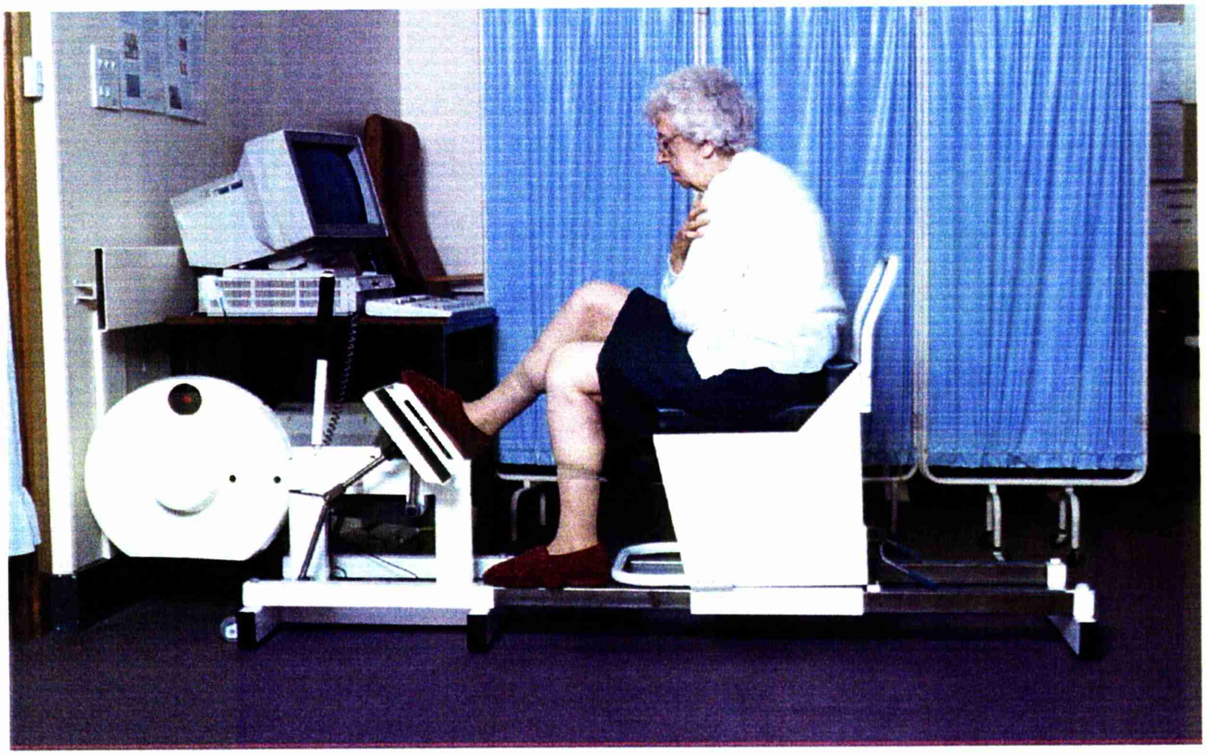
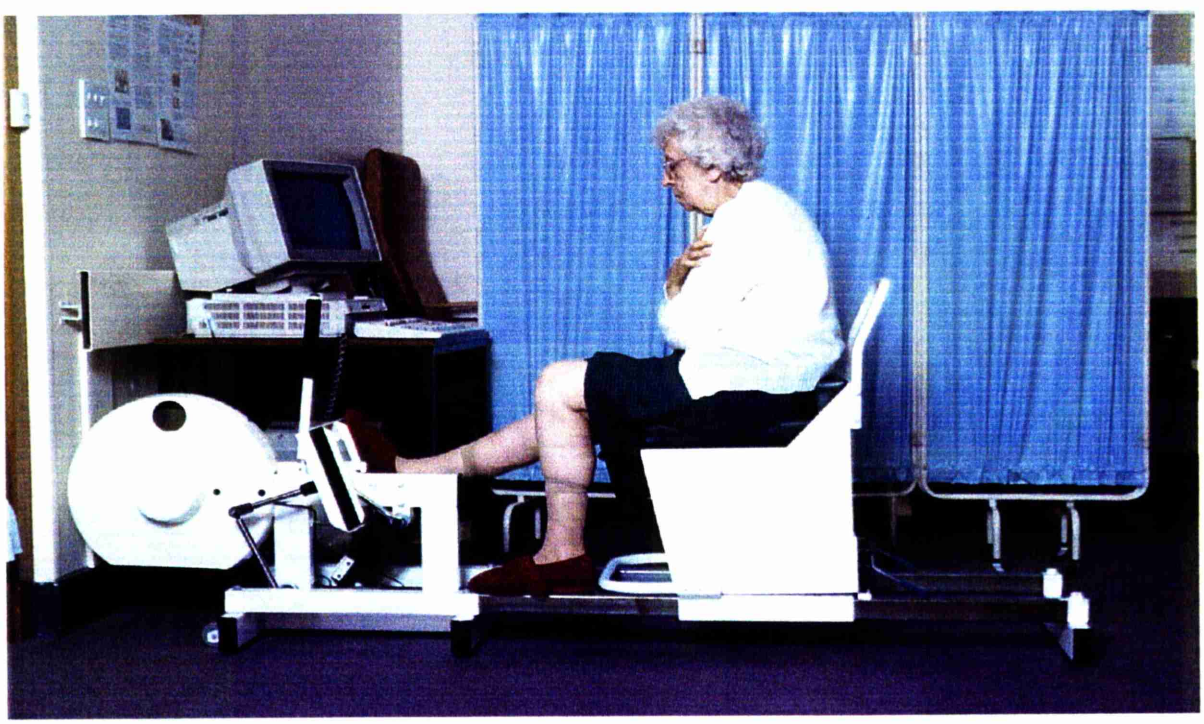


Figure 4.4: The final position on the Nottingham Power Rig



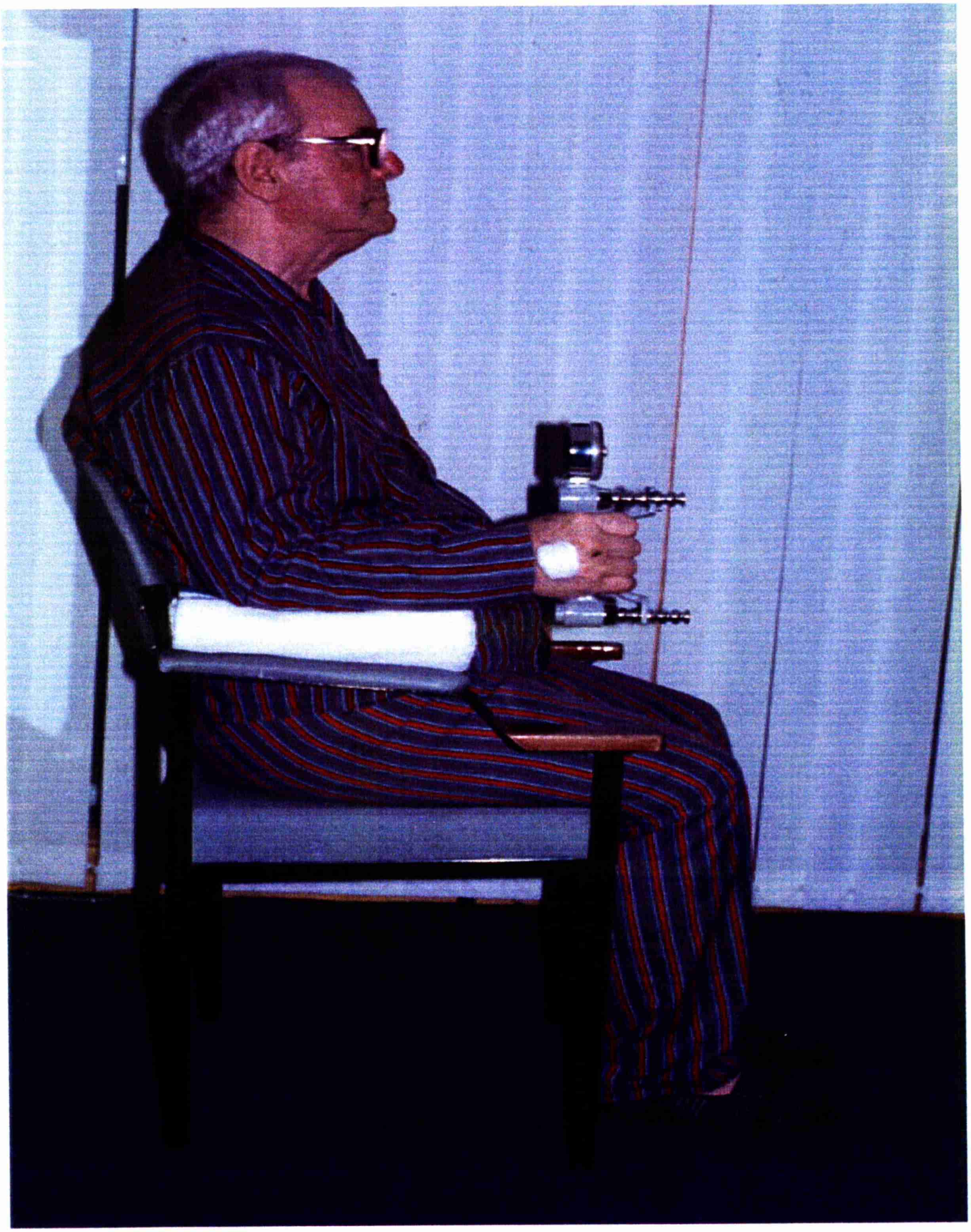
4.8 The hand held dynamometer to measure Grip Strength (248)

The subject was seated with his/her forearm resting on a table and wrist unsupported. The elbow was at 90 degrees flexion. The subject held the dynamometer in their dominant hand. The instruction to the subject was to squeeze the handle of the dynamometer as hard as they could. Three attempts were given and the best attempt was recorded. Figure 4.5 shows a patient using the hang grip dynamometer.

4.9 The Nottingham Health Profile (239)

Parts 1 of the Nottingham Health Profile were carried out (See Appendix D). The questionnaire was carried out through interview.

Figure 4.5: Measurement of hand-grip strength



Chapter 5

The Pilot Study

5.1 Measurement of Leg Extensor Power in Osteoporotic and Frail elderly people.

5.1.1 Objective: There were three main aims of this pilot study:

1. To study the changes in leg extensor power (measured on the Nottingham Power Rig) associated with repeated measurement during a single session.
2. To study the intra-observer reproducibility of leg extensor power.
3. To examine the validity of leg extensor power in its ability to discriminate between different patient groups (community dwelling osteoporotic patients, frail elderly and patients who have sustained a proximal femoral fracture).

5.1.2 Design: Observational study, convenience sample.

5.2 Methods

The study groups comprised twenty five female osteoporosis patients (outpatient attenders at an outpatient osteoporosis physiotherapy class), 58 proximal femoral fracture patients at a median of 15 days post-operatively (inter quartile range 12-23) from the orthopaedic rehabilitation wards at Lightburn and Hairmyres hospitals and 31 frail elderly hospital inpatients awaiting residential or nursing home care. The following testing procedures were carried out. Explanation of how each testing procedure was done can be seen in Chapter 4 (4.1, 4.2 and 4.7).

- Height and body mass were measured to allow calculation of body mass index (BMI, Weight / Height^2).
- Leg extensor power was measured using the Nottingham Power Rig. One assessor carried out all measurements. All measurements were of the right leg except for the fracture group where both legs were tested. Ten measurements were taken at each visit with a 30 second rest between each attempt. When the subjects were consented they were told that if the test caused pain then they were not to continue. However all of the subjects were able to perform a full leg extension with no record of pain being noted.
- All of the osteoporotic patients were measured twice over a three-day interval. Fifteen were then measured on a third occasion after a further three days.
- Ten of the 58 proximal femoral fracture (PFF) patients were measured on two occasions over a 3-day interval. (fractured leg only)
- The twenty-seven frail ambulant patients who were awaiting residential care had measurements performed on a single occasion.

5.3 Statistical Analysis

Results are expressed as mean (standard error) except where stated. Comparisons between the different patient groups were made using the Chi-squared test, unpaired Student's t-test (2-

tailed) and Analysis of variance (ANOVA) using the Statistical Package for the Social Sciences (SPSS-PC). Differences were accepted as being statistically significant at $p \leq 0.05$.

5.4 Results Section

5.4.1 Group Characteristics

The characteristics of the different groups are given in Table 5.1. The osteoporotic group were significantly younger than the other two groups (unpaired Student t-test p=0.02 compared with PFF patients, p=0.03 compared to frail elderly group). There was no difference in age between the frail and PFF group (P=0.99). All of the subjects in the osteoporotic group were female n=25, compared to10/48 (83%) in the PFF group and 12/15 (56%) in the frail group (Chi square = 14.2 P = 0.003).

There was no significant differences in body mass or BMI between the three groups (ANOVA p=0.09, p=0.23 respectively).

5.4.2 Changes in Leg Extensor Power (measured on the Nottingham Power Rig) associated with repeated measurement during a single session.

In all patient groups there was a gradual increase in leg extensor power (LEP) over the first five attempts, at a single visit after which the measurements stabilised (Figure 5.1). The greatest power output on the first visit was attained at a median of the 7th (inter quartile range 4-9) attempt in the osteoporotic group, at the 9 th (6-10) attempt in the frail group, at the 8th (5-10) attempt for the PFF group (fractured leg) and at the 8th (5-10) attempt for the PFF group (non-fractured leg). There was a mean increase of 7.7 Watts (SE 0.8) between attempts 1-5, and a mean increase of 1.2 Watts (SE 0.5) between measures 6-10. The percentage change was also analysed for the individual groups. In the osteoporotic group there was a 75.9% (SE 18.8) increase measured LEP between attempts 1-5 compared to only a 0.4% (SE 5.5) increase between attempts 6-10. In the frail group there was a 91.8% (SE 22.2) increase in measured LEP between attempts 1-5 compared to only a 43.0% (SE 13.7) increase between attempts 6-10. In the PFF group (non-fractured leg) there was a 140% (SE 19.6) increase between attempts 1-5 compared to only a 21.7% (SE 13.1) increase between attempts 6-10. In the PFF group (fractured leg) there was a 46.3% (SE 9.9) increase in measured LEP between visits 1-5, compared to only a 5.4% (SE 3.9) increase between attempts 6-10. Table 5.2 shows the mean changes and percentage changes between attempts 1-5 and 6-10. In light of these results the mean of the last 5 attempts (measures 6 to 10 inclusive) was used in the subsequent analyses of LEP.

5.4.3 Intra-observer reproducibility of Leg Extensor Power.

When LEP was measured after a three-day interval there was a mean improvement of 3.8 watts (SE 1.6, (95% CI 0.6, 7) p=0.02, paired Student t-test) in the osteoporotic group and a mean improvement of 2.1 watts (SE 0.5, (95% CI 0.9, 3.2) p= 0.02) in the PFF group (fractured leg). The mean improvement between visit 1 and visit 2 for both groups combined was 3.3 watts (S.E 1.1, (1.1, 5.6) p=0.005). Table 5.3 shows the percentage improvements between the two groups between visits 1 and 2. The between group analysis showed a significantly higher percentage change for the PFF group compared to the osteoporotic group between visits 1 and 2. Figure 5.2 illustrates the reproducibility of leg extensor power adjusted for body weight between visit 1 and 2 for the PFF group. Figure 5.3 illustrates the reproducibility of leg extensor power adjusted for body weight between visit 1 and 2 for the osteoporotic group There were no significant differences between the second and third series of measurements in the osteoporotic group (mean change of –0.5 watts SE 2.8, (95% CI –5.5, 6.4) p= 0.87). Figure 5.4 illustrates the reproducibility of leg extensor power adjusted for body weight between visit 2 and 3 for the osteoporotic group.

5.4.4 Time to generate Leg Extensor Power

Subjects who had an LEP $\leq$ 10 watts took a significantly longer time to generate maximal LEP (n=33, time to generate power = 1.6 secs, SE 0.09), compared to those who had an LEP > 10 watts (n=94, time to generate power = 0.9 secs, SE 0.02 p = 0.01, unpaired Student t-test).

5.4.5 The validity of Leg Extensor Power in its ability to discriminate between different patient groups (osteoporotic group, the frail elderly group and patients who have sustained a proximal femoral fracture).

Table 5.4 shows leg extensor power and leg extensor power corrected for body mass (mean of last 5 attempts) in the different groups of patients. Leg extensor power (Watts/kg) in the osteoporotic group was significantly greater than in the frail group (unpaired Student t-test p= 0.003) and the PFF group (fractured leg p<0.001, non-fractured leg p<0.001). Figure 5.5 illustrates the differences in mean scores. When the data from the 3 groups (fractured leg in

PFF group) were analysed there was a significant difference among the groups (ANOVA $p<0.001$). Within the PFF group there was a significant difference with reduced LEP in the fractured compared to the non-fractured leg ($p=0.032$ paired Student t-test).

Table 5.1: Characteristics of the study groups. Results are mean (standard error).

Characteristics	Osteoporotic Group N=25	Frail Group N=31	PFF Group N=58
Age (years)	68.8 (1.0)	82.8 (1.6)	78.7 (1.1)
Sex (m/f)	0/25	12/15	7/38
Height (cm)	156.9 (0.01)	158.8 (0.03)	155.7 (0.01)
Weight (kg)	61.9 (2.1)	57.3 (2.8)	54.7 (1.5)
BMI (m/kg^2)	24.9 (0.9)	24.3 (1.2)	22.8 (0.8)

Table 5.2 Changes in Leg Extensor Power (measured on the Nottingham Power Rig) associated with repeated measurement during a single session. Results are expressed as (mean ± SE) and percentage change (±SE)

Group	Mean increase attempt 1-5	Percentage increase attempt 1-5	Mean increase attempt 6-10	Percentage increase attempt 6-10
Osteoporosis	16.9 (3.3)	75.9 (18.8)	-0.1 (2.7)	0.4 (5.1)
Frail	5.7 (1.4)	91.8 (22.2)	2.6 (0.8)	43.0 (13.7)
PFF (non-fractured leg	9.3 (1.1)	140 (19.6)	1.7 (0.9)	21.7 (13.1)
PFF (fractured leg)	2.9 (0.7)	46.3 (9.9)	0.37 (0.3)	5.4 (3.9)

Table 5.3 Percentage differences for the Osteoporotic group (visits 2-1 and 3-2) and the PFF group (fractured leg) (visits 2-1). Results are expressed as and percentage change (±SE)

	Osteoporotic Group N=25	PFF Group (fractured leg only) N=8	95% Confidence interval	P Value
Percentage increase between visit 1 and 2	6.6 (2.0))	**20.8 (4.5)**	(-23.1, -5.4)	0.03
Percentage increase between visit 1 and 2	-0.97 (3.2)			

Figure 5.1 **Leg Extensor Power (measured on the Nottingham Power Rig) with 10 repeated measurements during a single session for the Osteoporotic group, the Frail group and the Proximal Femoral fracture group. Results are expressed as mean (± standard error).**

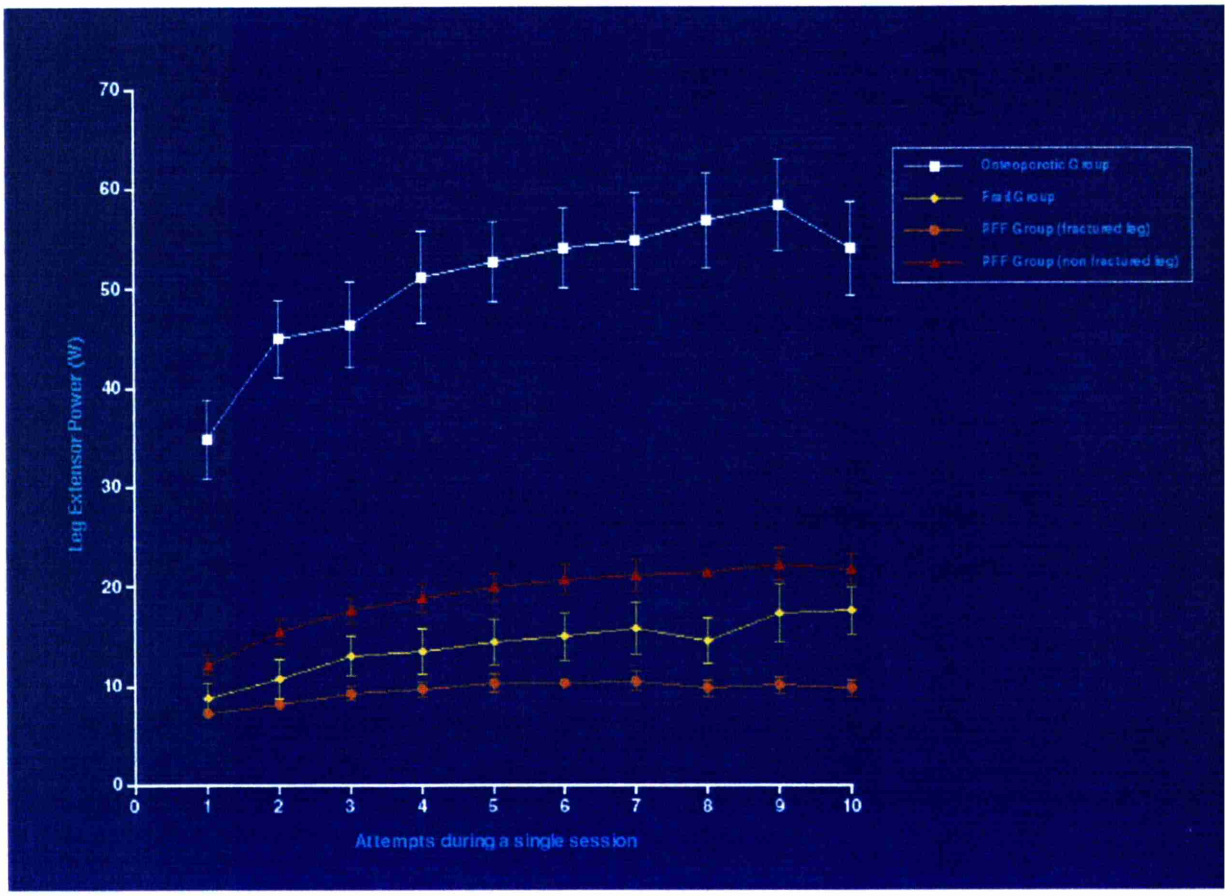


Figure 5.2: **Bland and Altman plot (249) showing mean (visit 1 and visit 2) versus the percentage difference (visit 2 minus visit 1) of Leg Extensor Power adjusted for body weight in the PFF group (fractured leg) (N=8).**

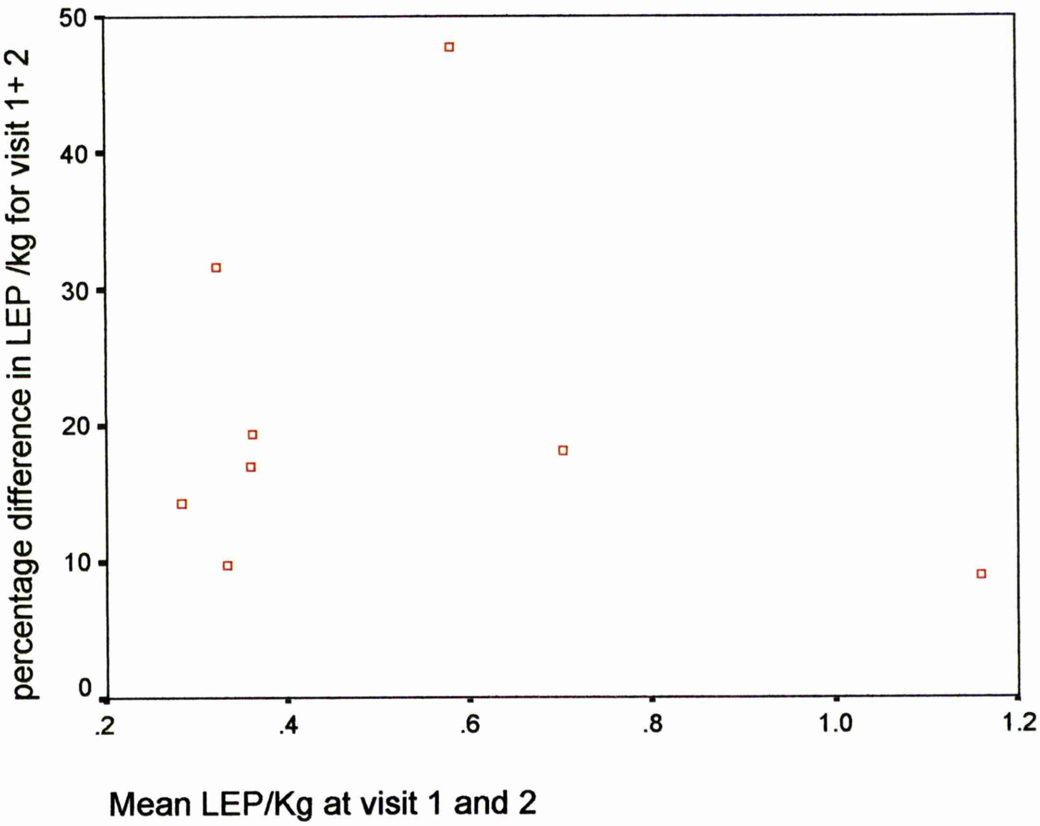


Figure 5.3: **Bland and Altman plot (249) showing mean (visit 1 and visit 2) versus the percentage difference (visit 2 minus visit 1) of Leg Extensor Power adjusted for body weight in the Osteoporotic group (N=25).**

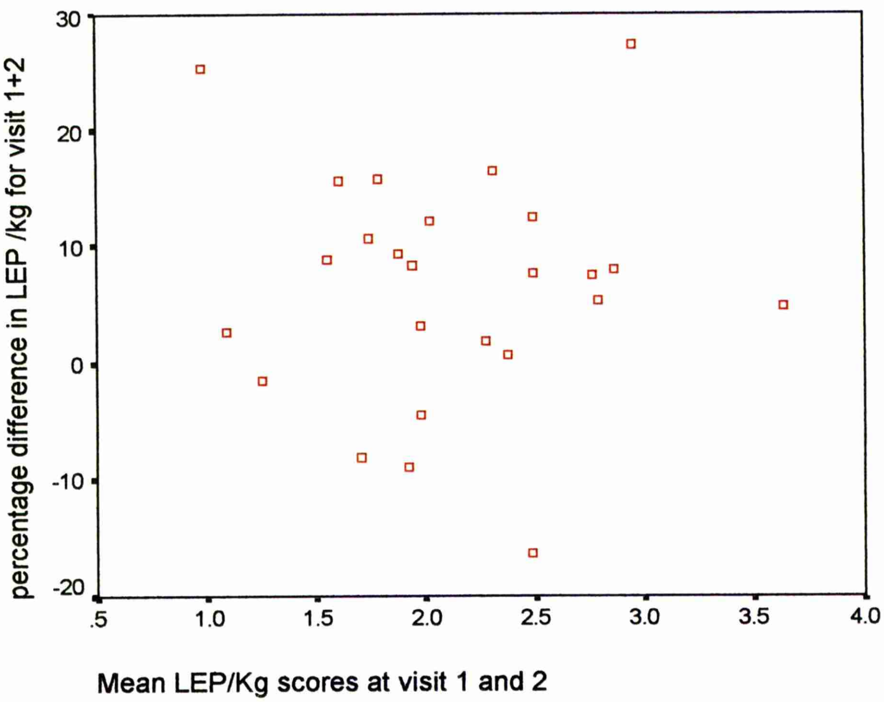


Figure 5.4: Bland and Altman plot (249) showing mean (visit 2 and visit 3) versus the percentage difference (visit 3 minus visit 2) of Leg Extensor Power adjusted for body weight in the osteoporosis group N=15

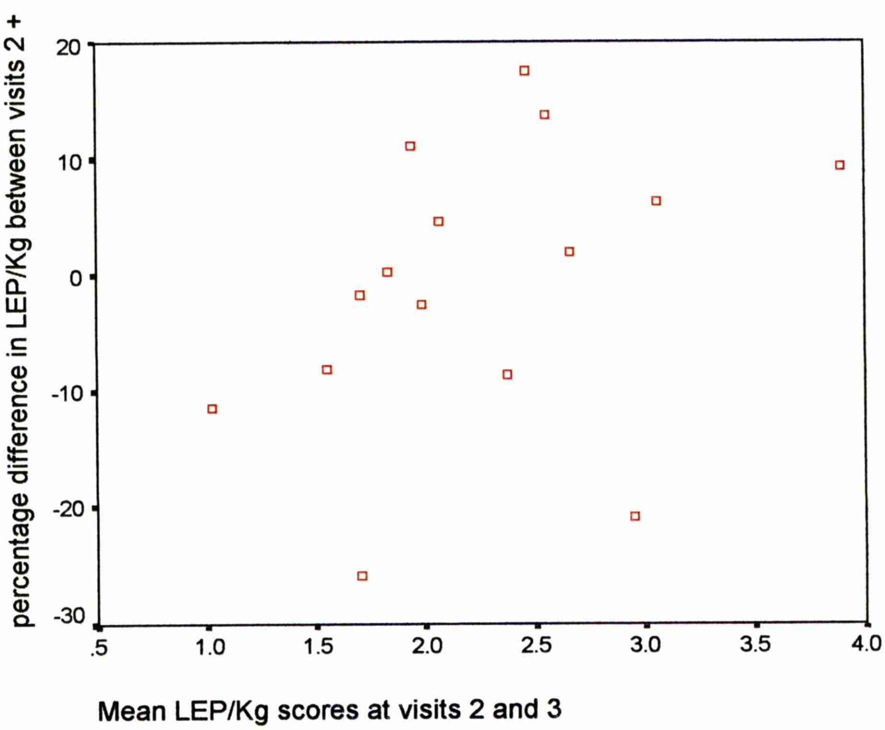
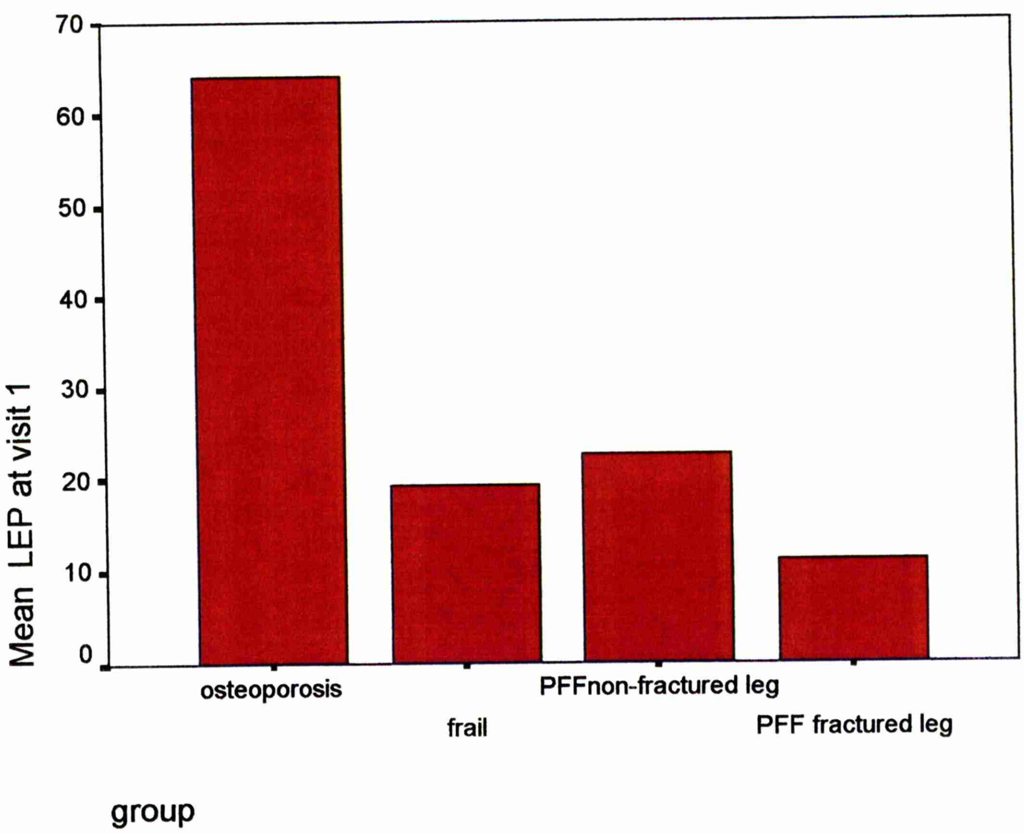


Table 5.4: Leg Extensor Power of the study groups. Results are expressed as (mean ± SE)

	Osteoporotic Group N=25	Frail Group N=31	PFF group Fractured leg N=58	PFF group Non-fractured leg N=58
Leg extensor power (Watts)	64.0 (4.8)	19.3 (2.7)	11.3 (1.13)	23.1 (2.06)
Leg extensor power adjusted for body weight (Watts/kg)	1.03 (0.06)	0.29 (0.04)	0.20 (0.02)	0.40 (0.03)
Time to generate mean leg extensor power (secs)	0.8 (0.05)	1.2 (0.07)	1.3 (0.08)	1.3 (0.2)

(Mean scores are those taken at visit 1)

Figure 5.5 Bar graph representing mean Leg Extensor Power for the osteoporotic group, frail group and the Proximal Femoral Fracture group (fractured and non-fractured legs).



Chapter 6

The Randomised Controlled Trial

Comparing 6 weeks high intensity strength training of the quadriceps with standard therapy.

6.1 Methods

This study was an open parallel group randomised controlled trial comparing the addition of 6 weeks quadriceps training (40 patients) with standard physiotherapy alone (40 patients). The training group exercised twice weekly, with 6 sets of 12 repetitions of knee extension (both legs), progressing up to 80% of their one-repetition maximum.

Randomisation was performed using computer-generated random numbers, group allocation for each study patient was concealed in a sealed envelope and held by a third party who was not otherwise involved in the study. Ethical approval was obtained through the Glasgow Royal Infirmary ethics committee.

6.1.1 Subjects

Consecutive patients admitted to Lightburn Hospital Geriatric Orthopaedic Unit for assessment and rehabilitation after surgical fixation of proximal femoral fracture were considered for entry into the study. Inclusion criteria were age $\geq$ 65 years and fracture treated surgically. Patients were excluded if they had an Abbreviated Mental Test (AMT) score (250) of less than 6. The AMT score was carried out by the researcher (SLM), within two days after admission to the GORU. A score of 6 was chosen as the cut off point for inclusion into the trial as it was decided that below this score patients would not be able to follow simple instructions. Patients were also excluded if they were 'medically unstable', this included patients who were unfit for any physiotherapy intervention, had medical problems such as patients with uncontrolled cardiac heart failure, patients who had active chest infections, patients with MRSA or any other infection which required isolation. The decision for patient exclusion was made by myself in consultation with the Consultant in charge of the ward. If the patients were immobile prior to their fracture they were also excluded. Information on previous mobility was extracted from the medical records.

6.1.2 Outcome Measures

Explanations of how these measurements were carried out are detailed in the general methods section. (Chapter 4.1- 4.8)

- The primary impairment outcome was leg extensor power, measured using the Nottingham Power Rig (130),(170). At each session the leg extensor power of both lower limbs was measured ten times, allowing a minimum of 30 seconds rest between each attempt. Results from my pilot studies data had shown that leg extensor power tended to increase over the first 4-5 attempts, and then reached a plateau. Therefore the mean of the last 5 of 10 attempts was used in my analyses. (see chapter 5.4.2)

- Grip strength was measured using a Jamar Hand Dynamometer, taking the best of three attempts (251), (106). The American Society of Hand Therapists positioning protocol for measurement of grip strength was followed (252). This protocol recommends at least three attempts are required for a valid measurement.
- The primary disability measure used was the Elderly Mobility Scale (EMS) (211). Key components include Functional Reach (222), and gait speed. These components were analysed separately as continuous variables, as well as categorised as required for the calculation of the Elderly Mobility Scale score.
- The Timed Up and Go test (TUG) (208)
- The modified (20-point) Barthel index questionnaire was used as a more general measure of disability (217), (209).
- The Nottingham Health Profile (NHP) questionnaire was used to assess quality of life (239).

All measurements were taken at baseline, at the end of the intervention period (week 6) and 10 weeks after the end of intervention (week 16). All recordings were made by myself and I was therefore not blinded to study group allocation. I did not have any involvement in the delivery of physiotherapy to either group.

6.1.3 Independent Blinded Assessor

In order to assess any potential for observer bias, an independent blinded assessor performed repeat measurements of leg extensor power in a convenience sample of 18 subjects (9 quadriceps training, 9 control group) at week 6, two days after the main study measurements. The patients selected for the repeat measurements were taken consecutively approximately midway through the recruitment process. The blinded assessor was a physiotherapy assistant working at Lightburn hospital. She was not involved in patient selection or any of the delivery of care of the study population

6.2 The Intervention

Patients in the intervention group underwent twice-weekly progressive training of their quadriceps in both the recently fractured and the non-fractured leg. The methods used were derived from programmes of exercise that have been shown to be practicable and effective in improving muscle function in elderly subjects (115),(114). Initially the investigator determined the one-repetition maximum (1RM) of the quadriceps muscle group. This measure is the maximum load that an individual can lift through the full range of knee extension. The subject sat on a raised chair in order for his/her feet to clear the floor. Then the investigator examined whether full range of motion of the knee could be achieved with no added weight. Once this was established an ankle weight (ranging from 2Kg to 10Kg) was placed around the lower limb. The subject was asked to straighten his/her knee from 90 degrees flexion to maximal knee extension. Weights were added in small increments (0.5-1Kg) resting 2 minutes between lifts, until the subject could no longer fully extend the knee.

The training was as follows:

Week 1+2: Training was at 50% of the 1RM. The subjects performed 3 sets of 12 repetitions of knee extension with each leg, comprising of 6-9 seconds per repetition, with two minutes rest period between sets. The concentric phase lasted approximately 2 seconds and the eccentric phase lasted between 5-7 seconds. These sets of exercises were carried out with knee angle from 90° to 0° and then repeated with knee angle from 10° to 0°.

Week's 3+4: The subject's 1RM was re-established and the subject then trained at 70% of their new 1RM, with sets and repetitions as above.

Week's 5+6: The 1RM was re-established and the subject trained at 80% of the new 1RM, with sets and repetitions as above.

The training protocol took approximately 30 minutes to administer on each occasion

6.2.1 Standard Therapy

Standard treatment consisted of physiotherapy (5 days per week) for approximately 20 minutes per day. Initially the treatment included bed exercises with active assisted hip flexion and abduction of the fractured leg using a re-education board. This progressed to active exercises of both the fractured and non-fractured limb. Once the patient was out of bed the physiotherapist taught the patient bed and chair transfers, gait re-education, and balance training. Practice of functional activities was carried out in the physiotherapy gym, involving sit to stand exercises, and walking practice using an obstacle course. Walking aids were changed according to the patient's level of functional dependence. Activities in the parallel bars included sidestepping, backward walking and walking over obstacles to encourage normal gait and with the aim of training of lower limb muscle groups for functional activities. Balance exercises were also practiced within the parallel bars, including standing unaided and standing in the step position.

6.3 Results Section

6.3.1 Statistical Analysis

Pilot study data was gathered to enable power calculations (253). With 40 patients per group the study had 90% power to detect a difference (at p=0.05) between the two groups in a change of leg extensor power of 0.06 Watts.kg^{-1} (equivalent to 3.3 Watts for a study group with mean weight 55Kg). The study had 80% power to detect a difference (at p=0.05) between the two groups of a 2-point change in elderly mobility scale score.

Results are expressed as mean (standard error) except where stated. Comparisons between the different patient groups were made using the Mann Whitney U test and the unpaired Student's t-test (2-tailed). Data were analysed using The Statistical Package for the Social Sciences (SPSS-PC). Differences were accepted as statistically significant at $p \leq 0.05$.

Correlation co-efficients between LEP and LEP adjusted for body weight and disability scores were assessed by calculating the Spearman rank correlation.

6.3.2 Results

Of 111 proximal femoral fracture patients admitted into the Geriatric Orthopaedic Rehabilitation Unit over the study period (February 1997-August 1998), 80 patients met the inclusion criteria and agreed to participate (figure 6.1).

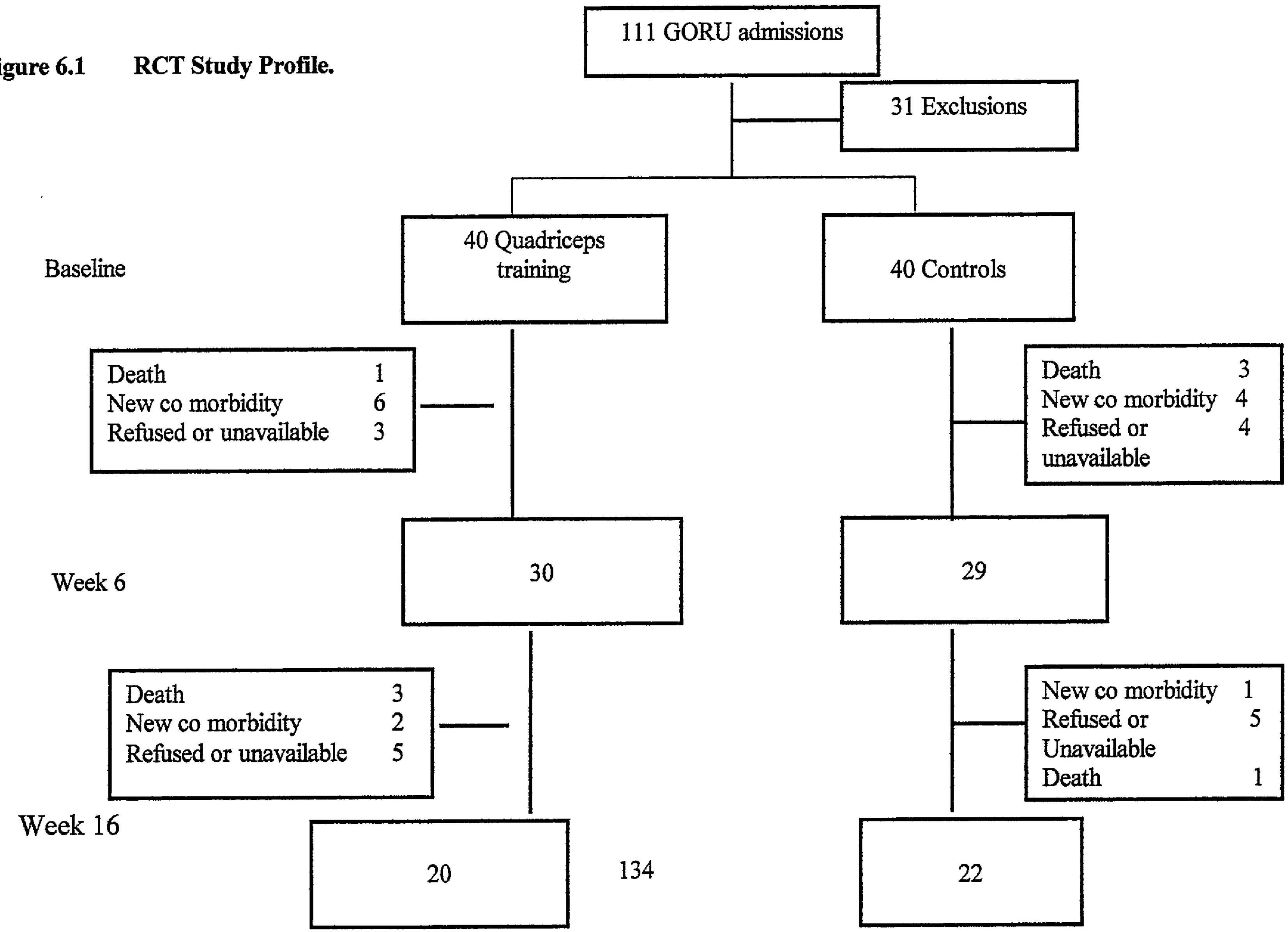
Patients in the control group entered the study at a median of 16 days after proximal femoral fracture surgery (range 13, 20) compared to 15 days (12, 24) in the quadriceps training group. There were no significant differences in key characteristics between the two study groups at baseline (table 6.1).

Prior to the fracture 29% of the patients walked independently with no aid, 47% walked with a stick or sticks and 24% walked with a walking frame. At baseline assessment all patients required personal assistance to walk and the majority (87.5%) of patients required a walking frame.

At week 16 only 10% of the patients were independent with 50% still requiring sticks to mobilize.

A total of 12 quadriceps training sessions was offered to each patient in the intervention group; the median number of sessions taken up by the 30 patients that completed the 6-week assessment was 11 (range 10, 12). Twenty-nine of the control group completed the 6-week assessment. The number of patients completing the week 16 assessment was 20 (50%) in the intervention group and 24 (60%) in the control group. Reasons for study dropouts are shown in figure 6.1.

Figure 6.1 RCT Study Profile.



There were no significant differences between the two groups in median length of hospital stay (control group median 40 days (Inter-quartile range [IQR] 28, 57) and quadriceps training group 39 (27, 50)). There was no statistical difference in discharge outcome between the two groups with 82% of all the patients returning home.

6.3.3 Leg Extensor Power

Leg extensor power increased significantly (in both the fractured and non-fractured leg) in the quadriceps training group compared to the control group (table 6.2 and 6.3). Between-group differences were apparent both at the end of intervention (unpaired Student t-test $p<0.001$) and at the end of follow-up ($p<0.001$). Table 6.4 shows the absolute changes of LEP from baseline to week 6, baseline to week 16 and week 6 to week 16 for the two groups. Table 6.5 gives the same details for LEP adjusted for body weight (unpaired student t-test). Table 6.6 shows the percentage changes from baseline to week 6 and from baseline to week 16 and week 6 to week 16 for the two groups.

6.3.4 Leg Extensor Power measured by the blinded assessor

Leg extensor power was re-measured at week 6 by the independent blinded assessor in 9 quadriceps training patients and 9 controls, and results were compared with the non-blinded assessor (table 6.7). There was a significant difference between the blinded and non-blinded assessor for measurement of the fractured leg (fractured leg mean difference between quadriceps training group and controls 3.0 Watts, 95% Confidence Interval 0.5,5.7, paired Student t-test $p=0.02$). However there was no significant difference between assessors for the non-fractured leg (mean difference 0.7 Watts, 95% CI –3.4, 4.7).

6.3.5 Combined Leg Extensor Power (fractured plus non-fractured leg)

Combined leg power is the sum of the LEP of the fractured and non-fractured limbs. Combined leg extensor power increased significantly in the quadriceps training group compared to the control group (table 6.8). Between-group differences were apparent both at the end of intervention (unpaired Student t-test $p<0.005$) and at the end of follow-up ($p<0.007$).

6.3.6 Hand Grip Strength

There were no significant between-group differences in change in grip strength. There was a significant difference between grip strength for males and females. The females only had a mean of 54% grip strength of that of the men (Table 6.9).

6.3.7 Measurements of Disability

There was a significant improvement in EMS score in the intervention group compared to the controls, with differences apparent both at the end of intervention (Mann-Whitney U test $p=0.001$) and at the end of follow-up ($p=0.026$). Functional Reach improved significantly in the quadriceps training group compared to controls (unpaired Student t-test $p\leq0.001$). However there were no significant between-group differences in TUG or gait speed. Barthel score increased significantly from week 0 to 6 in the quadriceps training group compared to controls (Mann-Whitney U test $p=0.05$), however between-group differences were no longer statistically significant at the end of follow-up. (Table 6.10). The absolute changes for the disability scores and grip strength are shown in table 6.11

Figure 6.2 shows the Elderly Mobility Scale scores at baseline, week 6 (end of study intervention) and week 16 between the two groups.

6.3.8 Correlation between the Barthel Index and the Elderly Mobility Scale

There were strong correlation co-efficients between these scales at every stage of the study. Week 0 r=0.77, week 6 r=0.78, week 16 r=0.74. Correlation co-efficient (Spearmans rank) was significant at the 0.01 level (2 tailed). Correlations made using both the control and trained group.

6.4 Perceived Health Status

6.4.1 The Nottingham Health Profile

The calculated sub-scores of the Nottingham Health Profile are given in table 6.12. In the quadriceps training group 35 subjects completed the questionnaire at baseline, 27 at week 6 and 20 at week 16. The respective numbers in the control group were 33, 27 and 21. The energy score at week 16 was significantly greater in the quadriceps training group compared to the controls (Mann-Whitney U test p=0.0185).

6.5 Outcomes for different types of fracture

There were no differences in either impairment or disability outcomes between patients with intra or extracapsular fractures. P>0.05 in all of the variables.

6.6 Relationship between impairment measures (LEP of the fractured leg) and disability scores

The data generated from this randomised controlled trial allowed me to explore further the relationship between quadriceps function and measures of physical function or disability. In this section of the thesis the relationships between LEP and measures of disability are explored.

Spearmans rank correlation coefficients between LEP of the fractured leg (training group and control group) and disability scores at baseline are presented in table 6.13. Table 6.14 presents the correlations in the training group at the end of the study intervention and at week 16. Table 6.15 presents the data for the control group. At week 6 and week 16 there were statistically significant correlation co-efficients for leg extensor power adjusted for body weight of the fractured leg and all functional scores for both the quadriceps trained group and the control group. The r values varying between 0.39 and 0.65 at week 6 and 0.15 and 0.54 at week 16 for the quadriceps trained group. The strongest correlations were seen between LEP/Kg and the EMS (r=-0.65) at week 6.

The control group showed similar correlations with r values ranging from 0.24 to 0.56 at week 6 and between 0.40 and 0.70 at week 16. The strongest correlations were seen between LEP/Kg and Functional reach (r=0.70) at week 16.

When the relationship between training induced changes in LEP/Kg with the changes in the disability scores was analysed there was a statistical significant correlation for changes in LEP/Kg and gait speed for the training group ($r=0.69$, $p=0.01$) at week 6. There were no significant training induced changes for sit to stand, timed up and go, the EMS, Barthel, Functional reach or grip strength. In the control group there was also a significant relationship between the changes in LEP/Kg and the changes in gait speed. ($r=0.41$, $p=0.05$) at week 6.

6.7 Relationship between impairment measures (Combined LEP) and disability scores

When correlations were examined for combined (fractured plus non-fractured leg) leg extensor power (training group + control group) at baseline, there were statistically significant correlations with some of the disability parameters (table 6.16).

Table 6.17 presents the correlations between combined LEP and LEP/kg and the disability scores at week 6 and week 16 for the quadriceps trained group. Table 6.18 presents the same correlations for the control group at week 6 and week 16.

In the quadriceps trained group the correlations between LEP/Kg and functional scores ranged from 0.39 to 0.69 at week 6. The strongest correlation was seen between LEP/Kg and the Elderly Mobility Scale ($r=0.69$). At week 16 the correlations ranged from 0.21 and 0.57. The strongest correlation was seen between LEP/Kg and the Timed Up and Go score ($r=-0.57$).

The control group showed similar correlations. At week 6 the correlations between LEP/Kg and functional scores ranged from 0.26 to 0.57, with the strongest correlation between LEP/Kg and the Barthel index (r=0.57). At week 16 the correlations between LEP/Kg and functional scores ranged from 0.32 and 0.69. The strongest correlation was seen between LEP/Kg and Functional Reach (r=0.69).

When the relationship between training induced changes in combined LEP/Kg with the changes in the disability scores was analysed there were no statistical significant correlations for any of the disability measures.

6.7.1 Combined Leg Extensor Power (fractured plus non-fractured leg) and ability to carry out various activities

The differences in mean scores of combined leg extensor power for those who could rise from a chair in less than 3 seconds compared to those who required longer than 3 seconds were measured at baseline for the two groups combined (table 6.19).

Analyses were carried out at week 6 and week 16 (table 6.20) for the quadriceps group. At week 6 there was a significant difference in mean LEP/LEP/kg for those who could rise from the chair in under 3 seconds (unpaired Student t-test $p \leq 0.05$).

This was no longer the case at week 16, however there only two patients who were unable to rise from a chair in over 3 seconds. Figures 6.3 and 6.4 show box-plots of the differences for the quadriceps trained group at week 6 and week 16.

There was no significant difference for the control group at either week 6 or week 16 (table 6.21)

Table 6.22 presents the differences in mean scores of combined leg extensor power and LEP/Kg for those who could walk 6 metres in under 15 seconds and for those who took longer at baseline (control and trained group).

Analyses were carried out at week 6 and week 16 (table 6.23) for the quadriceps group. At week 6 there was a significant difference in mean LEP/LEP/kg for those who could walk in under 15 seconds compared to those who took longer (unpaired Student t-test $p \leq 0.05$). At week 16 there was a significant difference between LEP and those who could walk in under 15 seconds compared to those who took longer. This was not the case when LEP was adjusted for body weight. Figures 6.5 and 6.6 show boxplots of the differences for the quadriceps trained group at week 6 and week 16..

There was no significant difference for the control group at week 6, but there was at week 16 (table 6.24).

Table 6.25 presents the differences in mean scores of combined leg extensor power and LEP/Kg for those who could walk independently or with a stick compared to those who required a walking frame at baseline (control and trained group).

Analyses were carried out at week 6 and week 16 (table 6.26) for the quadriceps group. At week 6 and week 16 there was a significant difference in mean LEP/kg for those who could walk independently or with a stick compared to those who required a frame (unpaired Student t-test $p \leq 0.05$). Figures 6.7 and 6.8 show boxplots of the differences for the quadriceps trained group at week 6 and week 16..

The same applied to the control group at week 6 and week 16 (table 6.27)

Table 6.1: Baseline characteristics of the study population. Results are mean (Standard error) except where stated.

Characteristics	Quadriceps training group N=40	Control group N=40
Male: female numbers	6:34	7:33
Age (years)	81.0 (1.2)	79.1 (1.3)
Height (cms)	155.6 (1.1)	154.9 (1.5)
Weight (Kg)	55.7 (1.9)	55.4 (2.5)
Body Mass Index (kg/m^2)	22.9 (0.7)	22.9 (0.7)
Number of intracapsular: extracapsular fractures	11:29	15:25
Days post-op (Median, range)	15 (12, 24)	16 (13, 20)

Table 6.2: Leg Extensor Power at baseline, at 6 weeks (end of study intervention) and at 16 weeks. Results are mean (standard error).

	Quadriceps training group			Control group		
	Baseline N=40	Week 6 N=30	Week 16 N=20	Baseline N=40	Week 6 N=29	Week 16 N=22
Leg extensor power Fractured leg (Watts)	10.1 (0.8)	**25.7*** (2.1)**	**33.0*** (3.9)**	11.4 (1.2)	17.7 (1.6)	21.2 (2.3)
Leg extensor power Non-fractured leg (Watts)	20.5 (1.6)	**34.9** (3.0)**	**40.1* (4.3)**	20.8 (2.3)	24.8 (2.5)	25.4 (2.2)

*P ≤ 0.05, **p ≤ 0.01, ***p ≤ 0.001; change in quadriceps training group compared to change in control group

Table 6.3: Leg Extensor Power adjusted for body weight at baseline, at 6 weeks (end of study intervention) and at 16 weeks. Results are mean (standard error).

	Quadriceps training group			Control group		
	Baseline N=40	Week 6 N=30	Week 16 N=20	Baseline N=40	Week 6 N=29	Week 16 N=22
Leg extensor power Fractured leg (Watts/kg)	0.18 (0.01)	**0.46** (0.03)**	**0.58** (0.06)**	0.20 (0.02)	0.33 (0.03)	0.39 (0.04)
Leg extensor power Non-fractured leg (Watts/Kg)	0.36 (0.02)	**0.63** (0.04)**	**0.70* (0.07)**	0.37 (0.03)	0.46 (0.05)	0.46 (0.04)

*P ≤ 0.05, **p ≤ 0.01; change in quadriceps training group compared to change in control group

Table 6.4: Absolute changes in Leg Extensor Power from baseline to week 6 (end of study intervention), baseline to week 16 and week 6 to week 16. Results are mean (standard error).

	Quadriceps training group			Control group		
	Week 0-6 N=29	Week 0-16 N=20	Week 6-16 N=20	Week 0-6 N=29	Week 0-16 N=22	Week 6-16 N=22
Leg extensor power Fractured leg (Watts)	**14.9*** (1.7)**	**21.8** (3.7)**	4.5 (2.3)	6.5 (1.1)	9.4 (2.3)	3.6 (1.7)
Leg extensor power Non-fractured leg (Watts)	**13.1** (2.3)**	**15.6** (4.0)**	1.2 (2.0)	4.6 (1.6)	4.2 (1.5)	0.01 (1.9)

*P ≤ 0.05, **p ≤ 0.01, ***p ≤ 0.001; change in quadriceps training group compared to change in control group

Table 6.5: Absolute changes in Leg Extensor Power adjusted for body weight from baseline to week 6 (end of study intervention), baseline to week 16 and week 6 to week 16. Results are mean (standard error).

	Quadriceps training group			Control group		
	Week 0-6 N=29	Week 0-16 N=19	Week 6-16 N=19	Week 0-6 N=29	Week 0-16 N=22	Week 6-16 N=22
Leg extensor power Fractured leg (Watts/Kg)	**0.27*** (0.02)**	**0.39** (0.06)**	0.09 (0.04)	0.12 (0.02)	0.19 (0.04)	0.08 (0.03)
Leg extensor power Non-fractured leg(Watts/Kg)	**0.25** (0.04)**	**0.29** (0.07)**	0.03 (0.04)	0.09 (0.03)	0.08 (0.03)	0.05 (0.04)

*P ≤ 0.05, **p ≤ 0.01, ***p ≤ 0.001; change in quadriceps training group compared to change in control group

Table 6.6: Percentage improvements in Leg Extensor Power from baseline to week 6 (end of study intervention), from baseline to week 16 and week 6 to week 16. Results are percentage (standard error).

	Quadriceps training group			Control group		
	Week 0-6 N=29	Week 0-16 N=20	Week 6-16 N=20	Week 0-6 N=29	Week 0-16 N=22	Week 6-16 N=22
Leg extensor power Fractured leg (% change)	**157** (15.8)**	**222.3* (34.2)**	16.5 (6.5)	63.1 (11.2)	120.0 (34.9)	38.2 (18.8)
Leg extensor power Non-fractured leg (% change)	**80.2** (12.2)**	**83.4* (18.1)**	3.8 (4.6)	26.5 (8.1)	36.2 (12.1)	30.7 (23.4)

*$P \leq 0.05$, ** $p \leq 0.001$; percentage change in quadriceps training group compared to change in control group

Table 6.7: Comparison of non-blinded versus blinded assessor: Measurements of Leg Extensor Power at week 6 in a convenience sample of 18 subjects. Results are mean (standard error).

	Quadriceps training group (N=9)		Control group (N=9)	
	Fractured leg LEP (W)	Non-fractured leg LEP (W)	Fractured leg LEP (W)	Non-fractured leg LEP (W)
Non-blinded assessor	24.7 (3.4)	33.4 (5.1)	16.3 (2.8)	19.3 (2.7)
Blinded assessor	24.5 (4.1)	34.8 (5.6)	19.2 (3.1)	21.4 (3.2)
Difference blinded minus non-blinded assessor	-0.2 (0.9)	1.4 (1.1)	**2.8 (0.9)***	2.1 (1.6)

*P=0.02 paired Student's t-test, control group versus quadriceps training group

Table 6.8: Combined Leg Extensor Power (fractured plus non-fractured leg) at baseline, at 6 weeks (end of study intervention) and at 16 weeks. Results are mean (standard error).

	Quadriceps training group			Control group		
	Baseline N=40	Week 6 N=29	Week 16 N=20	Baseline N=40	Week 6 N=28	Week 16 N=22
Combined Leg extensor power (Watts)	30.5 (2.1)	**61.2*** **(5.0)**	**73.0*** **(8.0)**	32.2 (3.3)	42.4 (3.9)	45.8 (4.6)
Combined Leg extensor power / Kg (Watts/Kg)	0.55 (0.03)	**1.0*** **(0.07)**	**1.3*** **(0.13)**	0.58 (0.05)	0.79 (0.08)	0.86 (0.08)

*$P \leq 0.005$; change in quadriceps training group compared to change in control group

Table 6.9: **Grip strength (measured in Newtons N) in men and women at baseline, week 6 (end of study intervention) and week 16.**
Results are mean (standard error).
The results from the quadriceps-trained group and control group are combined in this analysis.

	Male	Female
Grip strength (N) Test 1 (Baseline)	436.1 (37.2) (N=13)	236.6 (12.9) (N=67)
Grip strength Test 2 (N) (Week 6)	413.8 (31.1) (N=11)	261.1 (14.2) (N=48)
Grip strength (N) Test 3 (Week 16)	454.0 (49.1) (N=7)	275.8 (19.7) (N=35)

Table 6.10: Measures of functional capacity at baseline, at 6 weeks (end of study intervention) and at 16 weeks. Results are median (inter-quartile range) except where stated.

	Quadriceps training group			Control group		
	Baseline N=40	Week 6 N=30	Week 16 N=20	Baseline N=40	Week 6 N=29	Week 16 N=24
Elderly Mobility Scale	10 (7, 12)	**17.5 (16, 20)***	**18 (16, 20)***	11 (8, 12.75)	16 (14.75, 18)	17 (15.25, 19.5)
Barthel Index	13 (11, 14)	**18 (18, 19)***	19 (18, 19)	13 (11.25, 15)	18 (16.5, 18)	18 (18, 19)
Timed Up And Go (secs)	65.5 (48.5, 101.0)	36.0 (21.7, 55.0)	23.5 (15.0, 43.8)	61.0 (46.5, 79.3)	36.3 (22.3, 51.8)	28.8 (16.7, 38.5)
Functional Reach (inches) (Mean (S.E mean))	3.9 (0.4)	**6.5 (0.4)*****	**6.8 (0.4)*****	4.4 (0.4)	5.0 (0.4)	5.5 (0.5)
Gait speed (m/sec)	0.16 (0.12, 0.22)	0.29 (0.21, 0.46)	0.38 (0.27, 0.55)	0.16 (0.10, 0.22)	0.28 (0.21, 0.45)	0.42 (0.21, 0.66)
Grip strength (N) (Mean (S.E mean))	269.0 (20.6)	299.5 (22.3)	330.6 (33.8)	269.0 (21.7)	279.4 (20.2)	282.7 (25.3)

*P ≤ 0.05, **p ≤ 0.01, ***p ≤ 0.001; change in quadriceps training group compared to change in control group

Table 6.11: Absolute changes in disability scores and grip strength from baseline to week 6 (end of study intervention), baseline to week 16 and week 6 to week 16. Results are median (inter-quartile range) except where stated.

	Quadriceps training group			Control group		
	Week 0-6 N=29	Week 0-16 N=20	Week 6-16 N=20	Week 0-6 N=29	Week 0-16 N=22	Week 6-16 N=22
Elderly Mobility Scale	**6.5*** (5, 9)**	**7** (5.25, 9)**	0 (0, 1)	5 (3, 9)	6 (4, 7)	1 (0, 2)
Barthel Index	**5* (3, 6)**	5 (3.25, 6.75)	0 (0, 1)	4 (3, 5)	4.5 (3, 6)	1 (0, 1)
Timed Up And Go (secs)	22.7 (12.7, 47.7)	28.4 (19.8, 48.8)	3.1 (1.4, 8.3)	25.1 (11.7, 39.4)	38.9 (14.9, 56.5)	6.6 (2.1, 14.5)
Functional Reach (inches) Mean (S.E. mean)	**2.2*** (0.3)**	**2.4** (0.3)**	-0.05 (0.3)	0.6 (0.3)	0.8 (0.3)	0.3 (0.3)
Gait speed (m/sec)	0.14 (0.04, 0.28)	0.24 (0.06, 0.52)	0.07 (0.02, 0.15)	0.14 (0.05, 0.24)	0.20 (0.12, 0.36)	0.08 (0.03, 0.16)
Grip strength (N) Mean (S.E. mean)	4.9 (10.3)	0.5 (10.6)	0.98 (9.7)	2.0 (9.9)	20.5 (10.3)	13.4 (12.0)

*P ≤ 0.05, **p ≤ 0.01, ***p ≤ 0.001; change in quadriceps training group compared to change in control group

Figure 6.2: **Elderly Mobility Scale at baseline (EMS1), week 6 (EMS2) and week 16 (EMS3) in the Quadriceps training group and Control group. Boxplots represent medians and interquartile ranges.**

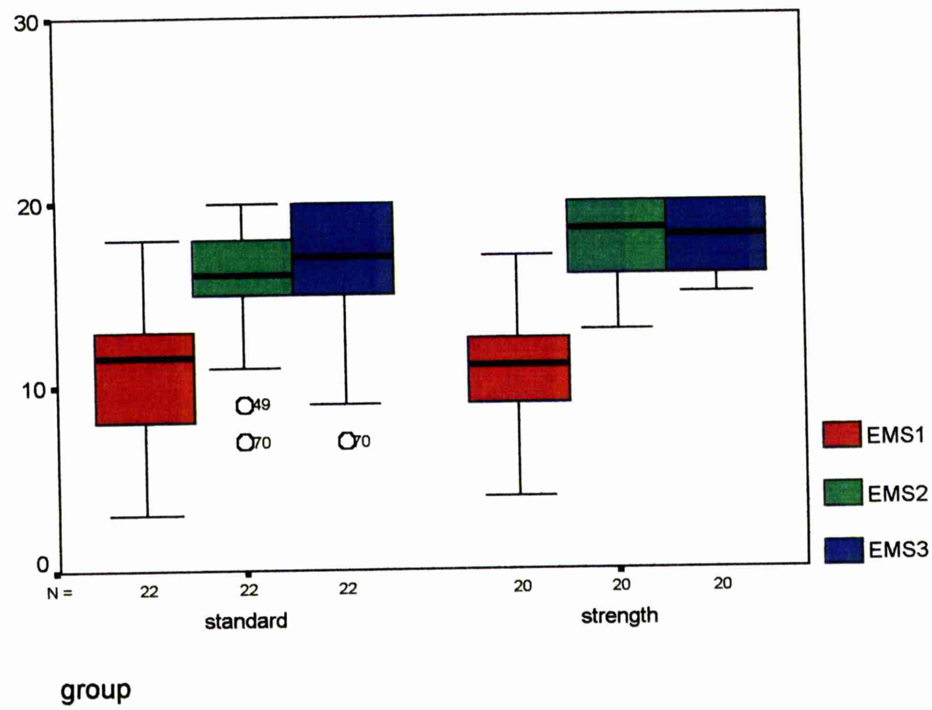


Table 6.12: The Nottingham Health Profile. Results are median (interquartile range).

	Quadriceps training Group			Control Group		
	Baseline N=35	**Week 6 N=27**	**Week 16 N=20**	**Baseline N=33**	**Week 6 N=27**	**Week 16 N=21**
Emotional reactions	27.0 (7.2,46.1)	17.6 (0.0,34.1)	8.9 (0.0,31.8)	26.9 (14.0,58.6)	13.4 (0,60.5)	28.3 (7.1,62.0)
Energy	60.8 (24.0,100.0)	39.2 (0.0,63.2)	**24.0 (0.0,60.8)***	63.2 (24.0,100.0)	60.8 (24.0,100.0)	63.2 (39.2,100.0)
Pain	35.3 (18.7,79.1)	11.2 (0.0,42.6)	10.0 (0.0,24.5)	22.9 (11.2,43.1)	20.9 (5.8,34.1)	18.7 (5.8,34.1)
Physical mobility	67.5 (56.8,78.7)	55.3 (24.2,67.5)	33.6 (0.0,61.4)	66.1 (55.5,78.7)	55.9 (35.4,68.1)	54.6 (44.7,66.1)
Sleep	61.5 (16.1,77.6)	12.6 (0.0,60.2)	12.6 (0.0,60.2)	22.4 (0.0,34.6)	38.5 (12.6,77.6)	34.3 (22.4,77.6)
Social isolation	22.0 (0.0,63.9)	19.4 (0.0,22.0)	9.7 (0.0,44.5)	22.0 (0.0,44.5)	22.0 (0.0,22.5)	22.5 (0.0,44.5)

*P=0.0185, Mann-Whitney U test, quadriceps training compared to standard care

Table 6.13: Spearman rank correlation co-efficients for Leg Extensor Power and Leg Extensor Power adjusted for body weight (fractured leg) and some functional scores and grip strength at baseline.
The results from the quadriceps-trained group and control group are combined in this analysis.

(N=80)	Sit to stand	Gait speed	Timed Up And Go	Elderly Mobility Scale	Barthel Index	Functional Reach	Grip strength
Leg extensor power fractured leg (Watts)	0.25*	0.28*	-0.33**	0.25*	0.21	0.23*	0.43**
Leg extensor power / Kg fractured leg (Watts/Kg)	0.31**	0.35**	-0.37**	0.29**	0.24*	0.19	0.28*

** Correlation co-efficient is significant at the 0.01 level (2-tailed).
* Correlation co-efficient is significant at the 0.05 level (2-tailed).

Table 6.14: Spearman rank correlation co-efficients for Leg Extensor Power and Leg Extensor Power adjusted for body weight (fractured leg) and some functional scores and grip strength at week 6 (end of study intervention) and week 16. The results are from the quadriceps-trained group only for this analysis.

		Sit to stand	Gait speed	Timed Up And Go	Elderly Mobility Scale	Barthel Index	Functional Reach	Grip strength
Week 6 (N=29)	Leg extensor power fractured leg (Watts)	0.3	0.48**	-0.44*	0.56**	0.55**	0.44*	0.62**
	Leg extensor power / Kg fractured leg (Watts/Kg)	0.39*	0.60**	-0.62**	0.65**	0.62**	0.49**	0.52**
Week 16 (N=20)	Leg extensor power fractured leg (Watts)	0.20	0.50*	-0.56*	0.49*	0.31	0.47*	0.46*
	Leg extensor power / Kg fractured leg (Watts/Kg)	0.15	0.48*	-0.54*	0.49*	0.27*	0.54*	0.22

** Correlation co-efficient is significant at the 0.01 level (2-tailed).

* Correlation co-efficient is significant at the 0.05 level (2-tailed).

Table 6.15: Spearman rank correlation co-efficients for Leg Extensor Power and Leg Extensor Power adjusted for body weight (fractured leg) and some functional scores and grip strength at week 6 (end of study intervention) and week 16. The results are from the control group only for this analysis.

		Sit to stand	Gait speed	Timed Up And Go	Elderly Mobility Scale	Barthel Index	Functional Reach	Grip strength
Week 6 (N=29)	Leg extensor power fractured leg (Watts)	0.19	0.43	-0.32	0.35	0.57**	0.27	0.49**
	Leg extensor power / Kg fractured leg (Watts/Kg)	0.31	0.46*	-0.36	0.36	0.56**	0.24	0.29
Week 16 (N=22)	Leg extensor power fractured leg (Watts)	0.38	0.40	-0.61**	0.61**	0.55**	0.79**	0.28
	Leg extensor power / Kg fractured leg (Watts/Kg)	0.47*	0.54**	-0.54	0.68**	0.67**	0.70**	0.4

** Correlation co-efficient is significant at the 0.01 level (2-tailed).
* Correlation co-efficient is significant at the 0.05 level (2-tailed).

Table 6.16: Spearman rank correlation co-efficients for combined Leg Extensor Power and Leg Extensor Power adjusted for body weight (fractured plus non-fractured leg) with various functional activities and grip strength at baseline.

The results from the quadriceps-trained and control group are combined for this analysis.

(N=80)	Sit to stand	Gait speed	Timed Up And Go	Elderly Mobility Scale	Barthel Index	Functional Reach	Grip strength
Combined Leg extensor power (Watts)	0.29**	0.34**	-0.39*	0.34**	0.29**	0.35**	0.64**
Combined Leg extensor power / Kg (Watts/Kg)	0.39**	0.43**	-0.46**	0.40**	0.35**	0.32**	0.51**

** Correlation co-efficient is significant at the 0.01 level (2-tailed).
* Correlation co-efficient is significant at the 0.05 level (2-tailed).

Table 6.17: Spearman rank correlation co-efficients for combined Leg Extensor Power and Leg Extensor Power adjusted for body weight (fractured plus non-fractured leg) with various functional activities and grip strength at week 6 (end of study intervention) and week 16.

The results are from the quadriceps-trained group only for this analysis.

		Sit to stand	Gait speed	Timed Up And Go	Elderly Mobility Scale	Barthel Index	Functional Reach	Grip strength
Week 6 (N=29)	Combined Leg extensor power (Watts)	0.31	0.49**	-0.46*	0.60**	0.54**	0.49**	0.58**
	Combined Leg extensor power / Kg (Watts/Kg)	0.39*	0.62**	-0.64**	0.69**	0.63**	0.53**	0.48**
Week 16 (N=20)	Combined Leg extensor power (Watts)	0.27	0.60**	-0.66**	0.58**	0.39	0.54*	0.58**
	Combined Leg extensor power / Kg (Watts/Kg)	0.21	0.51*	-0.57*	0.50*	0.32	0.52*	0.27

** Correlation co-efficient is significant at the 0.01 level (2-tailed).
* Correlation co-efficient is significant at the 0.05 level (2-tailed).

Table 6.18: Spearman rank correlation co-efficients for combined Leg Extensor Power and Leg Extensor Power adjusted for body weight (fractured plus non-fractured leg) with various functional activities and grip strength at week 6 (end of study intervention) and week 16. The results are from the control group only for this analysis.

		Sit to stand	Gait speed	Timed Up And Go	Elderly Mobility Scale	Barthel Index	Functional Reach	Grip strength
Week 6 (N=29)	Combined Leg extensor power (Watts)	0.24	0.44**	-0.42*	0.46*	0.60**	0.28	0.63**
	Combined Leg extensor power / Kg (Watts/Kg)	0.30	0.49**	-0.44*	0.43*	0.57**	0.26	0.45*
Week 16 (N=22)	Combined Leg extensor power (Watts)	0.42	0.59**	-0.61**	0.69**	0.72**	0.77**	0.45*
	Combined Leg extensor power / Kg (Watts/Kg)	0.40	0.39	-0.51*	0.61**	0.62**	0.69**	0.32

** Correlation co-efficient is significant at the 0.01 level (2-tailed).
* Correlation co-efficient is significant at the 0.05 level (2-tailed).

Table 6.19: Combined Leg Extensor Power (fractured plus non-fractured leg) of patients who could rise from a chair ≥ 3 seconds versus those who took < than 3 seconds. Results are taken at baseline and expressed as mean (standard error).

The results from the quadriceps-trained and control group are combined for this analysis.

	Sit to stand ≥ 3 seconds N= 73	Sit to stand < 3 seconds N=7	95% CI of the difference	P value
Combined Leg extensor power (Watts)	31.4 (2.1)	31.1 (6.3)	(-14.4, 13.6)	0.96
Combined Leg extensor power / Kg (Watts/Kg)	0.56 (0.03)	0.64 (0.09)	(-0.12, 0.28)	0.43

The sit to Stand is a component of the Elderly Mobility Scale

Table 6.20: Combined Leg Extensor Power (fractured plus non-fractured leg) of patients who could rise from a chair ≥ 3 seconds versus those who took < than 3 seconds. Results are taken at week 6 (end of study intervention) and week 16 and expressed as mean (standard error).

The results are from the quadriceps-trained group only for this analysis.

		Sit to stand ≥ 3 seconds N=5	Sit to stand < 3 seconds N=24	95% CI of the difference	P value
Week 6 (N=29)	Combined Leg extensor power (Watts)	43.3 (5.0)	**65.0 (5.8)**	(5.0, 48.4)	0.03
	Combined Leg extensor power / Kg (Watts/Kg)	0.75 (0.12)	**1.2 (0.07)**	(0.66, 0.79)	0.02
		Sit to stand > 3 seconds N=2	Sit to stand < 3 seconds N=16	95% confidence interval of the difference	P value
Week 16 (N=18)	Combined Leg extensor power (Watts)	48.5 (16.9)	76.9 (9.6)	(-31.7, 88)	0.3
	Combined Leg extensor power / Kg (Watts/Kg)	0.73 (0.4)	1.4 (0.16)	(-0.6, 1.3)	0.7

The sit to Stand is a component of the Elderly Mobility Scale

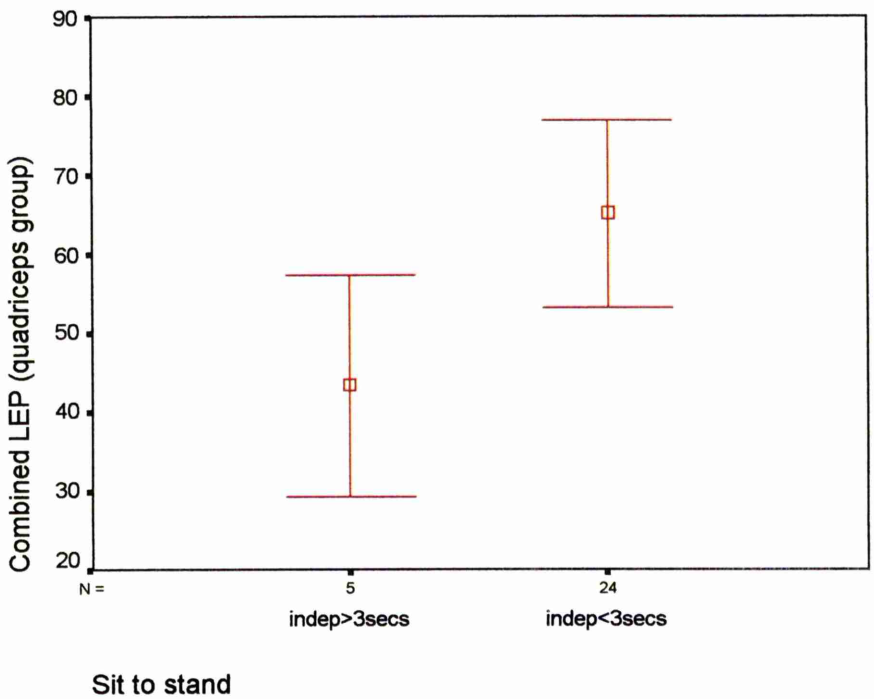
Table 6.21: Combined Leg Extensor Power (fractured plus non-fractured leg) of patients who could rise from a chair ≥ 3 seconds versus those who took < than 3 seconds. Results are taken at week 6 (end of study intervention) and week 16 and expressed as mean (standard error).
The results are from the control group only for this analysis.

		Sit to stand ≥ 3 seconds N=13	Sit to stand < 3 seconds N=15	95% CI of the difference	P value
Week 6 (N=28)	Combined Leg extensor power (Watts)	38.9 (5.0)	45.5 (5.9)	(-9.7, 22.8)	0.4
	Combined Leg extensor power / Kg (Watts/Kg)	0.69 (0.12)	0.88 (0.09)	(-0.12, 0.5)	0.2
		Sit to stand > 3 seconds N=4	Sit to stand < 3 seconds N=15	95% confidence interval of the difference	P value
Week 16 (N=19)	Combined Leg extensor power (Watts)	30.9 (6.1)	51.9 (5.9)	(-4.3, 46.4)	0.09
	Combined Leg extensor power / Kg (Watts/Kg)	0.60 (0.15)	0.96 (0.08)	(-0.02, 0.72)	0.06

The sit to Stand is a component of the Elderly Mobility Scale

Figure 6.3: Relationship between combined Leg Extensor Power (fractured plus non-fractured leg) at 6 weeks (end of study intervention) and timed ability to stand from a 19 inch chair. Bars represent mean and 95% Confidence intervals.

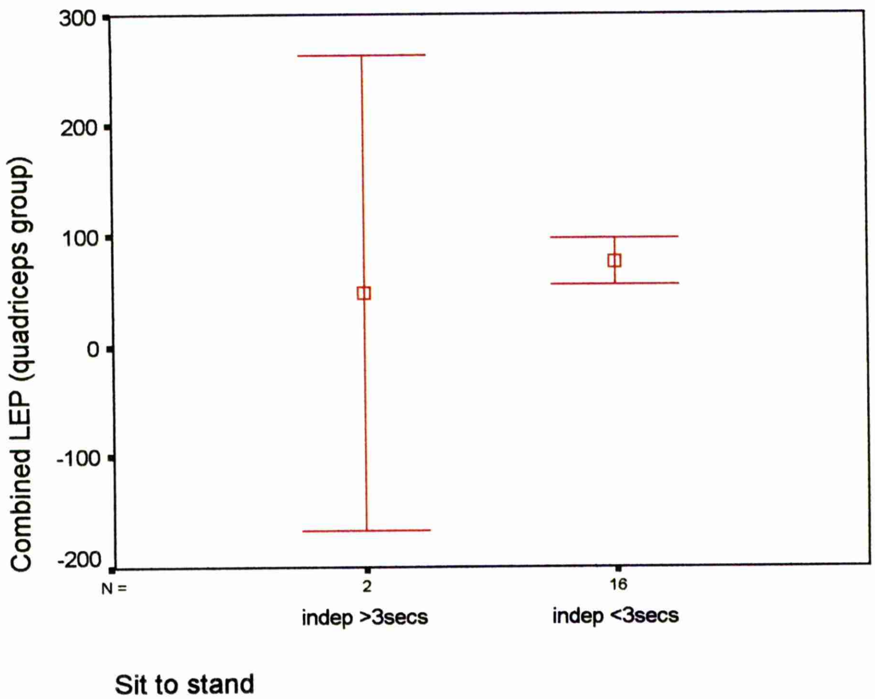
The results are from the quadriceps-trained group only for this analysis.



The timed sit to stand is a component of the Elderly Mobility Scale

Figure 6.4: **Relationship between combined Leg Extensor Power (fractured plus non-fractured leg) at 16 weeks and timed ability to stand from a 19 inch chair. Bars represent mean and 95% Confidence intervals.**

The results are from the quadriceps-trained group only for this analysis.



The timed sit to stand is a component of the Elderly Mobility Scale

Table 6.22: Combined Leg Extensor Power (fractured plus non-fractured leg) for those who could walk ≤15 seconds versus those walked in >15 seconds. Results are taken at baseline and expressed as mean (standard error). The results from the quadriceps-trained and control group are combined for this analysis.

	Timed walk <15 seconds N= 4	Timed walk over 15 seconds N=76	95% CI of the difference	P value
Combined Leg extensor power (Watts)	41.5 (10.8)	30.9 (2.0)	(-7.4, 28.6)	0.25
Combined Leg extensor power / Kg (Watts/Kg)	**0.83 (0.23)**	0.55 (0.03)	(0.02, 0.53)	**0.03**

The timed walk is a component of the Elderly Mobility Scale

Table 6.23: Combined Leg Extensor Power (fractured plus non-fractured leg) for those who could walk ≤15 seconds versus those walked in >15 seconds. Results are taken at week 6 (end of study intervention) and week 16 and expressed as mean (standard error).

The results are from the quadriceps-trained group only for this analysis.

		Timed walk <15 seconds N=11	Timed walk over 15 seconds N=18	95% CI of the difference	P value
Week 6 (N=29)	Combined Leg extensor power (Watts)	**79.8 (7.5)**	49.9 (5.3)	(11.5, 48.1)	0.002
	Combined Leg extensor power / Kg (Watts/Kg)	**1.4 (0.09)**	0.89 (0.06)	(0.33, 0.78)	0.001
		Timed walk ≤15 seconds N=12	Timed walk over 15 seconds N=8	95% CI of the difference	P value
Week 16 (N= 20)	Combined Leg extensor power (Watts)	**85.8 (11.5)**	54.9 (6.3)	(0.16, 63.4)	0.04
	Combined Leg extensor power / Kg (Watts/Kg)	1.4 (0.12)	1.0 (0.1)	(-0.12, 0.97)	0.16

The timed walk is a component of the Elderly Mobility Scale

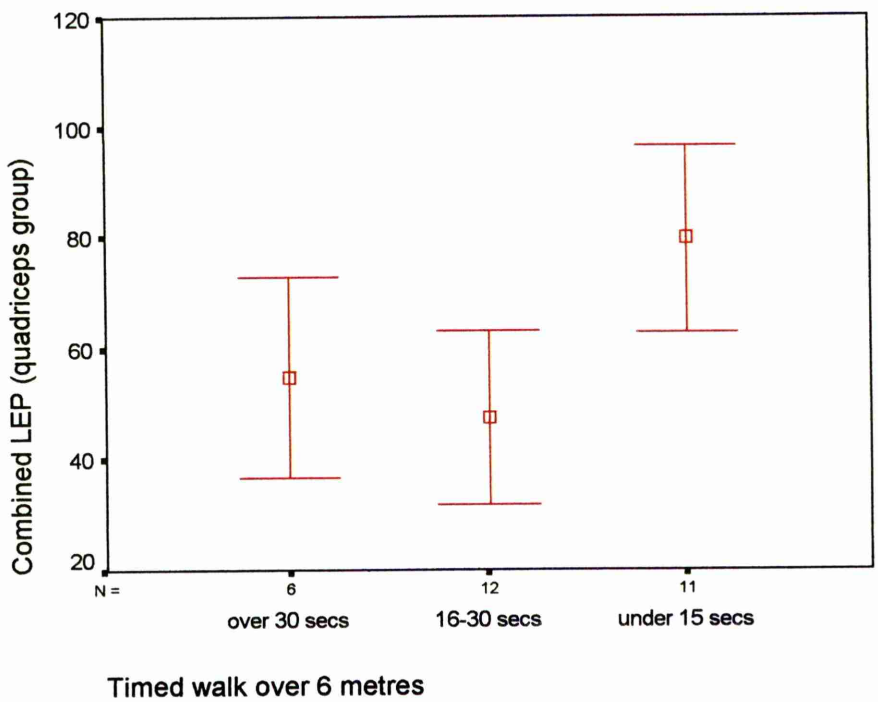
Table 6.24: Combined Leg Extensor Power (fractured plus non-fractured leg) for those who could walk ≤15 seconds versus those walked in >15 seconds. Results are taken at week 6 (end of study intervention) and week 16 and expressed as mean (standard error).
The results are from the control group only for this analysis.

		Timed walk <15 seconds N=11	Timed walk over 15 seconds N=17	95% CI of the difference	P value
Week 6 (N=28)	Combined Leg extensor power (Watts)	50.2 (7.2)	37.4 (4.3)	(-3.3, 28.8)	0.1
	Combined Leg extensor power / Kg (Watts/Kg)	0.90 (0.12)	0.72 (0.09)	((-0.14, 0.50)	0.2
		Timed walk ≤15 seconds N=9	Timed walk over 15 seconds N=13	95% CI of the difference	P value
Week 16 (N=22)	Combined Leg extensor power (Watts)	**61.7 (8.0)**	34.8 (2.9)	(11.3, 42.5)	0.002
	Combined Leg extensor power / Kg (Watts/Kg)	**1.04 (0.13)**	0.73 (0.05)	(0.03, 0.58)	0.03

The timed walk is a component of the Elderly Mobility Scale

Figure 6.5: **Relationship between combined Leg Extensor Power (fractured plus non-fractured leg) at week 6 (end of study intervention) and timed walk over 6 metres. Bars represent mean and 95% Confidence intervals.**

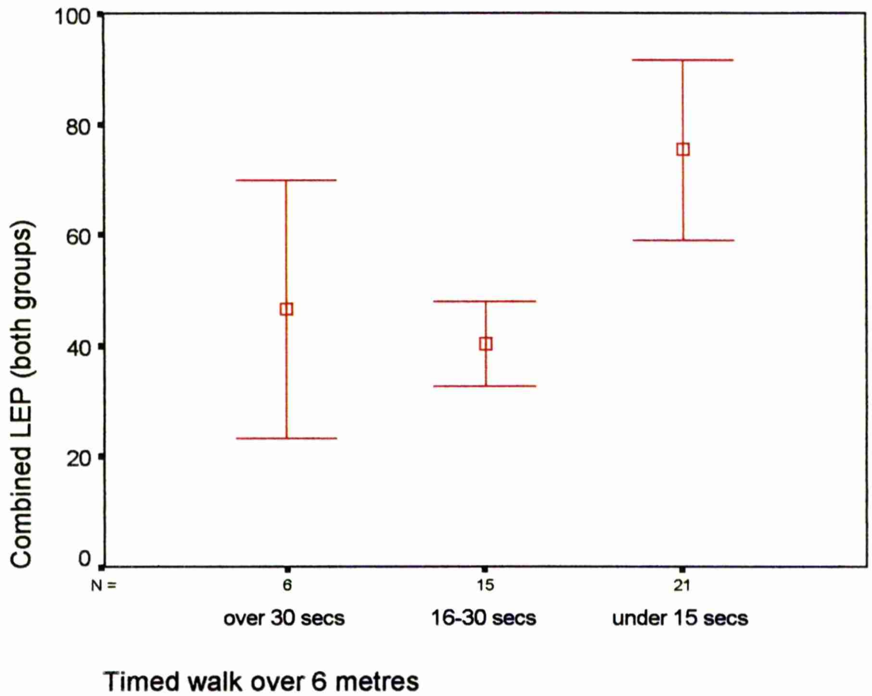
The results are from the quadriceps-trained group for this analysis.



The timed walk is a component of the Elderly Mobility Scale

Figure 6.6: **Relationship between combined Leg Extensor Power (fractured plus non-fractured leg) at week 16 and timed walk over 6 metres. Bars represent mean and 95% Confidence intervals.**

The results are from the quadriceps-trained group for this analysis.



The timed walk is a component of the Elderly Mobility Scale

Table 6.25: Combined Leg Extensor Power (fractured plus non-fractured leg) for those who could walk independently (with or without sticks) versus those who were mobile but unsafe or walked with a frame. Results are taken at baseline and expressed as mean (standard error).
The results are from the quadriceps-trained group and control group for this analysis.

	Independent / sticks N=3	Mobile but unsafe/frame N=3	95% CI of the difference	P value
Combined Leg extensor power (Watts)	42.9 (11.1)	30.9 (2.0)	(-8.8, 32.6)	0.25
Combined Leg extensor power / Kg (Watts/Kg)	0.75 (0.2)	0.56 (0.03)	(-0.1, 0.49)	0.19

Walking aid and mobility is a component of the Elderly Mobility Scale

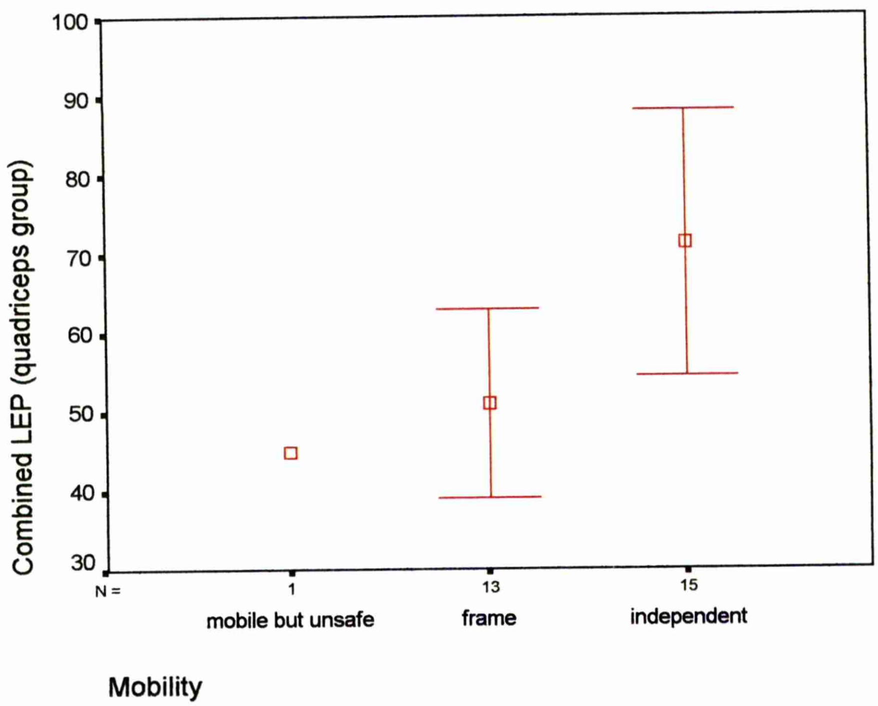
Table 6.27: Combined Leg Extensor Power (fractured plus non-fractured leg) for those who could walk independently (with or without sticks) versus those who required a walking frame. Results are taken at week 6 (end of study intervention) and week 16 and expressed as mean (standard error).

The results are from the control group only for this analysis.

		Independent / sticks N=14	Walking with a frame N=14	95% CI of the difference	P value
Week 6 (N=28)	Combined Leg extensor power (Watts)	**52.6 (5.4)**	32.2 (4.4)	(6.15, 34.7)	0.007
	Combined Leg extensor power / Kg (Watts/Kg)	**0.99 (0.1)**	0.59 (0.07)	(0.13, 0.69)	0.005
		Independent / sticks N=15	Walking with a frame N=7	95% CI of the difference	P value
Week 16 (N=22)	Combined Leg extensor power (Watts)	**53.2 (5.6)**	30.0 (3.5)	(5.0, 41.4)	0.01
	Combined Leg extensor power / Kg (Watts/Kg)	**0.97 (0.08)**	0.63 (0.08)	(0.04, 0.62)	0.03

Walking aid and mobility is a component of the Elderly Mobility Scale

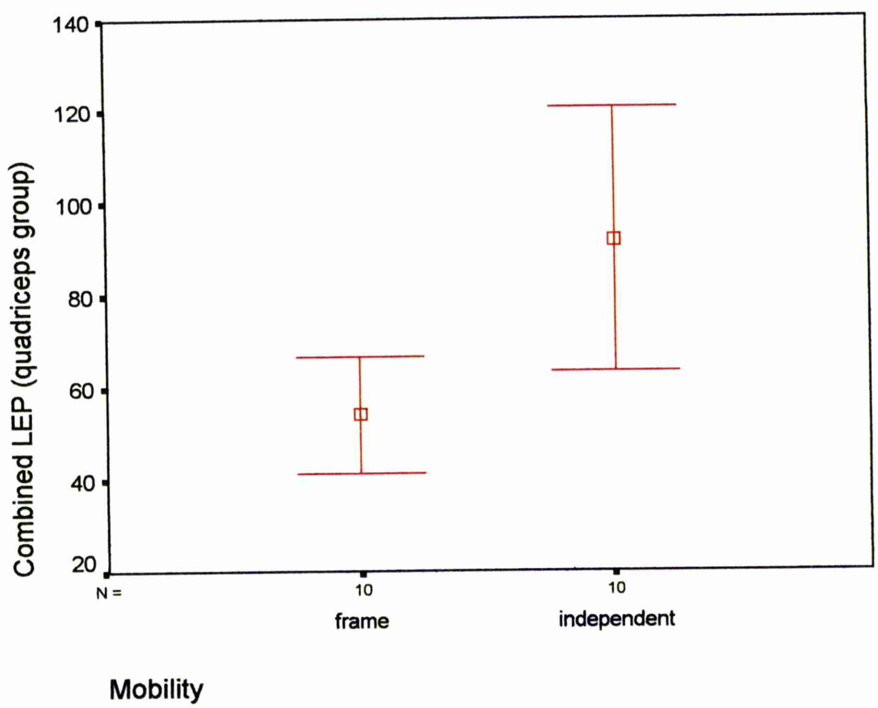
Figure 6.7: Relationship between combined Leg Extensor Power (fractured plus non-fractured leg) at week 6 (end of study intervention) and aid used. Bars represent mean and 95% Confidence intervals. The results are from the quadriceps-trained group for this analysis.



Walking aid and mobility is a component of the Elderly Mobility Scale

Figure 6.8: Relationship between combined leg extensor power (fractured plus non-fractured leg) at week 16 and aid used. Bars represent mean and 95% Confidence intervals.

The results are from the quadriceps-trained group for this analysis.



Walking aid and mobility is a component of the Elderly Mobility Scale

Chapter 7

Discussion

7.1 Introduction

In this chapter the improvements in impairment and disability following a high intensity-training programme will be discussed. Leg extensor power was my primary impairment outcome measure, as well as using this in the RCT I carried out pilot work on its practicability, validity and reproducibility. Bassey et al (170) have carried out most of the development work for the Nottingham Power Rig; therefore many comparisons will be made to her work. It appears that Lamb et al (176) are the only authors to have published descriptive data using the Nottingham Power Rig on proximal femoral fracture patients. The Elderly Mobility Scale was the primary disability measure. Disability measurements are now widely used in studies and comparisons will be made to mine. The results from this study will be compared to other studies that have used similar protocols on elderly subjects. Justification of the scales used will also be discussed as well as the study limitations.

7.2 Summary of Impairment Improvements

My RCT found that high intensity quadriceps training improves leg extensor power in elderly patients rehabilitating after proximal femoral fracture. Benefits were maintained at 10 weeks after the intervention. The differences in change in leg extensor power between the quadriceps training group and the control group were large; from baseline to the end of the intervention period (at week 6) leg extensor power increased by 157% in the fractured leg in the quadriceps training group compared to an increase of only 63% in the control group (table 6.6). Other studies have found improvements in muscle strength in healthy and frail elderly groups following strength training interventions (Table 2.1). To my knowledge there are no other published studies that have measured leg extensor power using the Nottingham Power Rig following a similar training intervention in proximal femoral fracture patients. Studies by Fiatarone (115),(114), however highlighted that even the frailest group of elderly have the potential to gain from strength training. The results from my RCT reinforce the potential benefits of exercise training in frail elderly people who have had a proximal femoral fracture.

7.3 Comparison of my RCT and studies using the Nottingham Power Rig

In this section studies that have used the Nottingham Power Rig to measure leg extensor power will be discussed. Bassey et al (170) carried out the first studies using the Nottingham Power Rig. One of the early studies investigated 26 residents in a chronic care hospital (13 men mean age 88.5$\pm$6 years and 13 women mean age 86.5$\pm$6 years). All patients had previous history of falls and many had multiple health problems. There was no record of any patient having previously sustained a proximal femoral fracture. Thirteen of the group were said to spend most of the day in a wheelchair. Performance measures included timed chair rises, stair climbing and a 6.1 metre walk. Analysis was carried out to investigate whether there were correlations between these functional performance measures and leg extensor power. In order to investigate this Bassey combined (the summed scores of left plus right leg) the leg extensor power scores adjusted for body mass for both the men and women. Bassey found that there were strong correlations between leg extensor power and all the measures of performance. In order to investigate whether this was similar in proximal femoral fractures I carried out the same analysis with both groups at week 6 and week 16. Table 7.1 shows the correlation co-efficients that Bassey et al found and those in my study. Although my data are consistent with the findings of Bassey, the correlation co-efficients for chair rising and walking speed were not as strong. My patients had recently undergone major surgery and this could in part account for this difference.

Table 7.1: Relationship between combined leg extensor power (left plus right leg) and functional performance for the subjects in the study by Bassey et al (170) and my RCT.
The results from the quadriceps-trained and control group are combined for this analysis.

	Bassey (170)	My Study Data	
Performance activity	Correlations with combined Leg Extensor Power adjusted for body weight (W/Kg)	Correlations with combined LEP adjusted for body weight for the PFF group at week 6	Correlations with combined LEP adjusted for body weight for the PFF group at week 16
Chair rising speed (s^{-1})	**0.65***** (N=24)	**0.45**** (N=57)	**0.33*** (N=37)
Stair climbing speed (m/s)	**0.81***** (N=22)	Not tested	Not tested
Walking speed (Km/h) ++	**0.80***** (N=25)	**0.52**** (N=57)	**0.47**** (N=41)
Stair climbing power (W)	**0.88***** (N=23)	Not tested	Not tested

*** P<0.001. (170)

**Correlation co-efficient is significant at the 0.01 level (2 tailed) for PFF group.

* Correlation co-efficient is significant at the 0.05 level (2 tailed) for PFF group.
Spearmans rank correlation co-efficients used for PFF data.

++ Measured in m/s in PFF study group.

Combined LEP/Kg is the sum of the left plus right leg and is the independent variable.

Another study (105) using twenty healthy elderly women with a mean age of 84±3.1 year investigated correlations between walking speed and combined (left plus right leg) LEP ($r=0.5$ $p<0.05$). This relationship between combined LEP and walking speed was similar to my findings ($r=0.47$ at week 16), yet my population were possibly more similar to those in the Bassey study as they were a frail group compared to this healthy group. The study also measured quadriceps strength, hip abductor and extensor strength and investigated correlations with these measures. When multiple regression analysis was carried out on these variables, they found that combined quadriceps strength (left plus right leg) was the only significant predictor of walking speed, accounting for 44% of the variance ($p<0.001$). The authors also investigated correlations between Functional Reach and combined LEP (left plus right leg) and found a positive correlation ($r=0.7$, $p<0.001$). Functional Reach also correlated with hip abductor strength, and combined quadriceps strength. The multiple regression analysis showed that combined LEP was the most significant independent predictor accounting for 49% of the variance ($p<0.001$). The positive correlation between Functional Reach and combined LEP in my study was similar to that of Smith et al (105) at week 16. At week 6 (end of study intervention) $r = 0.47$ ($p<0.01$) and at week 16 $r = 0.61$ ($p<0.01$). Both quadriceps trained and control groups were used for this analysis.

From the studies outlined above there does appear to be a relationship between functional activities and LEP, however Bassey (170) has found in a frail group with multiple pathologies that these relationships appear to be stronger than in the healthy group studied by Smith et al (105). My findings in a frail group recovering from a proximal femoral fracture have not found the same strength of relationship of that of Bassey, although my subjects had a reduced LEP compared to the Bassey subjects. A possible explanation for this could be the greater range of values for LEP in the Bassey subjects. This however was not the case. More analysis of frail groups including proximal femoral fracture patients after a longer period post surgery is needed to establish the strength of relationship between functional activities and combined LEP in frail elderly groups.

7.3.1 Comparisons of Combined (left plus right leg) Leg Extensor Power

Bassey et al (170) also analysed the differences of combined LEP (left plus right leg), between men and women. The combined LEP for men in the Bassey study was 123±14.2 W (n=12) compared to a combined LEP in my male group at week 6 of 68.1±25.7 W (n=11) and at week 16 of 82.3+36.4 W (n=7). The women in the Bassey study had a mean combined LEP of 60.0± 0.2 W, compared to my female group who had a combined mean of 48.2±24.7 W (n=46) and 54.1± 29.4 W (n=35) at weeks 6 and weeks 16 respectively (these data include trained and control groups). When power was adjusted for body weight there was no significant difference between men and women (W/Kg combined legs) at weeks 6 or week16 in my study population but that was not the case in the Bassey study where women were significantly weaker when scores from both legs were combined and adjusted for body weight. There were insufficient men in my study group to perform meaningful statistics. The differences in LEP between my study and Bassey's study highlight the frailty of the proximal femoral fracture population investigated.

Table 7.2 shows the combined leg extensor power of the Bassey subjects and the patients in my study at week 16. The table shows the LEP for both the quadriceps-trained and control groups.

Table 7.2: Combined leg extensor power (left plus right leg) of the subjects in the Bassey

Study (170) and my RCT. Results are mean (Standard error)

	Men Bassey N=13	Men Quadriceps group) week 16 N=4	Men Control group week 16 N=3	**Women Bassey N=13**	Women strength group week 16 N=16	Women control group week 16 N=19
Combined LEP (W)	**123±14.2**	92.3±23.6	68.8±7.0	**60±9.2**	68.3±8.1	42.2±4.7
Combined LEP/Kg (W/Kg)	**1.86±0.19**	1.38±0.27	1.01±0.1	**1.10±0.17**	1.27±0.14	0.84±0.08

The Bassey data is bolded.

The subjects in the study by Bassey et al (170) are older (13 men mean age 88.5±6 years and 13 women mean age 86.5±6 years) compared to my study group (13 men mean age 75.6±7 years and 67 women mean age 80.9±7 years). However, the women in the Bassey study have a similar leg extensor power to the women in my quadriceps-trained group when a comparison of their 'best leg' (34.8±5.1W) to the non-fractured leg of my study group is made at week 6 (32.2 ±3.0W) and week 16 (37.6±10.4W).

7.3.2 Leg Extensor Power and Gait Speed measured in Proximal Femoral Fracture Patients.

Lamb et al (176)} carried out a descriptive study examining leg extensor power in proximal femoral fracture patients. Forty previously healthy women (median age 83 range 76-96) were recruited 1 week after surgical fixation of their proximal femoral fracture. When comparing leg extensor power between my group of patients and those selected in the Lamb study it is apparent that my group, although younger are frailer. The patients studied by Lamb et al (176) had a mean leg extensor power of 0.35 W/Kg for the fractured leg and 0.75W/kg for non-fractured leg. In comparison my patient group had a mean baseline LEP of the fractured leg of 0.18 W/Kg and 0.36 W/Kg for the non-fractured leg. One possible reason for this may be due to the fact that Lamb et al (176) measured patients in the acute setting who had been classified as 'healthy' prior to the fracture (median Barthel 20 90% CR 16-20), whereas my group were selected for Geriatric rehabilitation. These patients are generally frailer and have more functional problems. Approximately 40-50% of patients following hip fracture require this type of rehabilitation (15) and the others either return directly home or return to a nursing home, therefore Lamb would have included this 'fitter' group in her analysis. Another factor could which could have contributed to differences in LEP scores may have been slight differences in apparatus and also which LEP value was used to measure leg extensor power. Lamb et al (176) stated that a maximum of 10 attempts were made during a single session and the peak score within those attempts was recorded as the LEP value. In my pilot study and RCT an average of the last 5 attempts out of 10 was taken as the value for LEP. This would only account for a small difference.

Lamb et al (176) also measured gait speed, over a 10-foot walkway and found that the group had a median gait speed of 0.13m.sec $^{-1}$. The median gait speed for my group (measured over 6 metres) was 0.16 m.sec $^{-1}$ at baseline. Both are much lower than gait speed over similar distances for healthy 79-year-old subjects (0.97m.sec $^{-1}$) (254). Smith et al (105) studied 20 healthy elderly subjects (mean age 84 $\pm$ 3.1) and measured the 6 metre walk from a standing start. The subjects in this study had a mean gait speed of 1.4 m.sec $^{-1}$. Skelton et al (255) also investigated gait speed in 52 healthy elderly women over the age of 75. The mean gait speed over a 118 metre corridor before any intervention in the training group was again 1.4 m.sec $^{-1.}$

The fact that the gait speeds in my study group and that of Lamb's were much reduced may in part be due to the stage of rehabilitation after a proximal femoral fracture. At the end of my intervention the controls and quadriceps-training group had gait speeds of (0.42 and 0.38m.sec^{-1}). This is comparable to the group of elderly subjects with a variety of chronic conditions that Bassey tested. The median time taken to walk over a 6.1 metre walkway at maximum speed was equivalent to 0.54m.sec $^{-1}$, with a range from 0.18 to 0.69m.sec $^{-1}$ in that study (170). These gait speed measurements were still lower than those reported for healthy groups mentioned above.

7.3.3 Leg Extensor Power in Healthy Elderly Groups

Skelton et al carried out a cross-sectional study (141) examining the effects of healthy aging on muscle strength, power and potentially related functional ability. In the age group 80-84 (similar to my study group) the healthy elderly group had much higher LEP with values of 1.8 W/Kg for men and 1.4 W/Kg for women.

The healthy elderly women in the study by Smith et al (105) had mean LEP value of 66.3 (SD ±25.5W) of the stronger leg.

This again emphasises the frailty of the group we were measuring. Skelton et al (141) and Smith et al (105) both used a slightly modified Nottingham Power Rig. This will be discussed in section 7.17.2.

7.3.4 Leg Extensor Power in patients awaiting unilateral knee arthroplasty

A further study assessed the repeatability of LEP using the Nottingham Power Rig on patients awaiting a primary unilateral knee arthroplasty (256). The values of LEP for the subjects who had a mean age of 72 (S.D 8) were 59.3 W (S.D 29.9) for the affected limb and 82.1 W (S.D 40.7) for the unaffected limb at test 2. These values again are much higher than those seen in my RCT.

7.3.5 Leg Extensor Power in Community dwelling Fallers

Another recent study has investigated muscle strength and power in community dwelling fallers (257). This study investigated asymmetry in lower limb strength and power, and found that both asymmetry and poor lower limb explosive power may be more predictive of future falls than measures of strength, in older women who are community dwelling.

The studies that have been discussed have investigated leg power using the Nottingham Power Rig in an elderly population. To date there are no other published studies that have measured LEP in proximal femoral fracture patients after an intervention. Other studies have assessed power using functional activities such as stair climbing ability and gait speed in intervention studies.

7.4 The Functional Threshold Concept

The functional threshold concept postulates that there is a distinct value of aerobic power, muscle power and muscle strength below which a person cannot perform specific tasks, independent of an individual's characteristics such as age or gender. The decline in these physiological parameters can lead to functionally important activities becoming increasingly difficult for individuals to perform and could eventually lead to the inability to perform basic tasks of daily living. From previous work carried out (258),(97) it seems apparent that large numbers of healthy elderly are at, or near to, functionally important strength / power related thresholds and so have either lost or are in danger of losing the ability to perform basic activities of daily living. This factor may be especially apparent in women, due to the fact that women may have lower power/weight ratios and therefore may be closer to this functional threshold (171). Data from the National fitness survey found nearly half of all 70-74 year old women tested (only 15% men) had a power to weight ratio below 1.5W/Kg (97).

It is interesting to note from the National Survey that took place in England and Wales (171), that the functional threshold of leg extensor power was initially defined as 3 W/Kg. This value was stated as the minimal value, which was required to climb stairs unaided. Further analysis of this survey has since been carried out (172) and new threshold values have been suggested. From the data a power / weight ratio of greater than or equal to 2.5 W/Kg (in the dominant leg) is required to be confident of being able to mount a 50 cm step without the use of a handrail: 32% of men and 75% of women aged 50-74 years had power / weight ratios below 2.5 W/Kg. It was also stated that when the power / weight ratio is less than 1.5 W/Kg, some people will not manage a 30cm step and less than 30% of people will be able to manage a 50cm step. The male advantage was even more apparent when considering the lower threshold. Only 7% of men but 28% of women aged 50-74 years had a power / weight ratio below 1.5 W/Kg.

The data from my RCT allowed investigation of whether the concept of a functional threshold was applicable to functional performance of proximal femoral fracture patients.

At the end of my intervention none of the patients in my study group achieved unilateral leg power values of 1.5W/Kg even in the non-fractured leg. At week 16 only one patient from the quadriceps-training group had an LEP score of 1.6 W/Kg. This patient also had an Elderly Mobility Score and Barthel score of 20. When the combined power (fractured plus non-fractured leg) was assessed at week 6, 13.5% (8/59) had an LEP score of >1.5 W/Kg. Of these 8 patients 7 were from the quadriceps-trained group. These patients also had a median Elderly Mobility score of 20 (S.E. 0.5) and could all rise from a chair in under 3 seconds. When the combined power was measured at week 16, 13.6% (6/44) had an LEP score of >1.5 W/Kg. Of these 6 patients 4 were from the quadriceps-trained group. The median Elderly Mobility score for these patients was 20 (S.E. 0.4), this highlights once again that the patients in my study were all functionally very dependent.

In my pilot study 25 osteoporotic women (mean age 68.8 $\pm$ 1.0 S.E years) who were attending an exercise class had an LEP measurement taken on the Nottingham Power Rig. These patients cannot be labelled 'healthy', however they were fully independent. The mean LEP/Kg (right leg measured) for this group was 1.0 W/Kg. Even when peak mean values were assessed this brought the value to only 1.1W/Kg. These values are well below those of the National Fitness Survey (172), yet all of these women were community dwelling and none required any assistive devices to walk. Step climbing ability however was not assessed. It is however possible that this group had lower muscle power than subjects without osteoporosis as studies have shown that osteoporotic women may have reduced quadriceps muscle function compared to healthy controls (259), (260). Rutherford et al (260) found that women with osteoporotic fractures had a lower isometric maximum voluntary force / cross sectional area of their quadriceps than age-matched controls. The majority of the subjects in the Rutherford study had vertebral fractures, and most were less than 70 years. The subjects in my pilot study all had a diagnosis of osteoporosis but none had had a recent recorded vertebral fracture.

I also investigated whether there was a relationship between LEP/Kg of the fractured leg and functional performance measures at baseline and after the study intervention. At baseline there was an association between LEP/Kg and all the performance measures except for functional reach, however the associations were not very strong. After the intervention the quadriceps trained group showed significant correlations between LEP/Kg and all the functional measures with the strongest relationships seen between LEP/Kg and gait speed (r=0.60), timed up and go (r=0.62), EMS (r=0.65), Barthel index (r=0.62). The relationships remained statistically significant at week 16 (table 6.14). For the control group at week 6 there was a significant association between LEP/Kg and gait speed (r=0.46) and the Barthel index (r=0.56); at week 16 the r values ranged from (0.4 to 0.70) (table 6.15). I also compared the training induced changes in LEP/Kg with the corresponding training induced changes in functional scores for the quadriceps group. The only significant relationship from this analysis was for changes in LEP/Kg and changes in gait speed (r=0.69). This association was no longer statistically significant at week 16.

When the same associations were investigated for combined LEP/Kg (fractured plus non-fractured leg) and functional performance measures there were significant associations even at baseline with r values ranging from (0.32 to 0.51) for both the quadriceps training and control groups. At week 6 there was again correlations with LEP/Kg and all the functional measures with r values ranging from (0.39 to 0.69) for the quadriceps trained group. When the training induced changes were considered for combined LEP/Kg and functional performance measures for the quadriceps trained group there were no significant associations for any of the parameters.

Smith et al (105) also found a strong correlation between functional reach and total LEP (r=0.7). This was stronger than the correlation found between my intervention group at week 6 for LEP/Kg and functional reach (r=0.53). Skelton et al (141) investigated the correlations between summed (left plus right leg) LEP/Kg and chair rise time in a group of healthy men and women. She found correlations for women (r=0.56) and for the men (r=0.38). In my study I found similar results with an association between combined LEP/Kg and sit to stand for the quadriceps trained group at week 6 (r= 0.39).

Skelton et al (196) also investigated the effects of 12 weeks of progressive resistance training on LEP and selected functional abilities of healthy women aged 75 and over. They found an association between LEP and reduction in time to rise from the kneeling position on the floor but not between training induced changes in LEP and changes in kneel raise time. The possible reason for this may be that the subjects were all functionally able and therefore any changes in function might be expected to be small. In my study the only association between training induced changes of LEP/Kg with changes in functional ability was seen in gait speed for the quadriceps trained group at week 6. My study group were more dependent in basic functional activities then Skelton's cohort, therefore one might have expected stronger associations between training induced changes in LEP/Kg and functional scores. The lack of strong associations in my study group may have been in part due to the functional scales used. In the scales used there were not many timed activities, (gait speed and timed sit to stand in under or over three seconds). Stronger associations might have been seen if more timed activities were included such as actual time to stand up and stair rise time. A future study should maybe include these activities.

I also investigated whether there were significant differences in LEP/Kg values between those patients who could stand from a chair in under 3 seconds and those who could not after the intervention period (table 6.20). At week 6 there was a significant difference in the quadriceps group for those who could achieve this. This was not the case for the control subjects. For the timed walk there was also a significant difference in the quadriceps trained group for those who could walk under 15 seconds and those who took longer ($P=0.001$) at week 6. At week 16 this was the case for the LEP value but not when adjusted for body weight. At week 6 there was no difference for the control group for those who could walk under 15 seconds and those who took longer, however at week 16 there was ($p=0.03$). The LEP/Kg values for the control group however were still lower than those for the quadriceps trained group. When the relationship between those who could walk independently or with sticks compared to those who required a walking frame there was again a significant difference at week 6 and week 16 for both quadriceps trained and control groups. This latter analysis is perhaps not as important as there may have been other reasons for keeping a patient on a walking frame such as balance disorders, other medical conditions and safety issues. A specific power related threshold below which for example patients were unable to rise from a chair was not found, however this could in part be due to the technique of this manoeuvre. The assessment of sit to stand in the Elderly Mobility Scale does not stipulate whether a patient should or should not use his/her arms. Whether a patient used his/her arms to stand or not was not documented and therefore this could influence the results discussed above.

7.5 Why measure muscle power?

Because of the possible selective atrophy of the type II fibres (119), (97) muscle power may be more sensitive to age related losses in muscle function than strength and therefore might be a more relevant measurement than strength. The reason for its greater sensitivity may be because the speed component of power makes it dependent on fast fibres. Older men and women who required the use of an assistive device to perform tasks such as rising from a chair and walking have approximately 50% less leg extensor power than those who could complete these tasks without assistance (170). The ability to generate force rapidly is a critical component of ambulation. Preservation of strength while important may not result in preservation in the ability to perform mobility related tasks (261). This evidence provided a strong rationale for a study investigating the effects of high intensity strength-training programme on lower limb power in proximal femoral fracture patients.

7.6 Other studies investigating strength-training programmes of the Quadriceps muscle group

There is good evidence for decline in muscle strength with ageing. This may be an important contributor to reduced ability to perform routine activities of daily living (262), (263), (141), (142). There is also good evidence that this decline in muscle strength is at least partly reversed by resistance exercise (99), (114), (115), (142),(264). However the majority of the early work has been carried out in healthy elderly subjects.

A major limitation of many of the early studies in this area was that few were randomised controlled trials. Skelton (191) stated in 1996 that more than 40 training studies had considered one or more measures of strength in older subjects but only a quarter of them had been randomised and controlled, and even fewer had considered functional ability or balance. Therefore these studies had mainly focused on impairment without due consideration to disability and were not necessarily of a good quality.

Although much of the earlier work was not in the form of RCT's many of these studies are still of interest, as they have established the practicability of various training interventions in elderly patients.

Aniansson et al (124) carried out an observational study into the effects of physical training, specifically of the quadriceps. This was one of the earliest studies. Prior to this, studies had investigated the reduction in muscle strength with ageing, but had not investigated the effects of training. Aniansson et al trained twelve 69-74 year old men with no medical problems 3 times a week for 12 weeks. Only body weight was used as a resistance. The training was considered to be of moderate intensity. The static and dynamic (Isokinetic) muscle strength in the quadriceps increased significantly with training. Muscle biopsies were obtained from the vastus lateralis muscle for fibre, capillary and enzyme activity analysis. The fibre composition was altered after training with a significantly higher proportion of Type II fibres, mainly due to an increase in Type II A fibres. The relative area of the Type II fibres also significantly increased with training. The authors concluded that the ageing human skeletal muscle remains trainable and that the training response is similar to that seen in younger age groups.

Skelton et al (191) carried out an 8-week strength training study. It comprised progressive resistance strength, postural and functional task training. Quadriceps strength increased by 20% in healthy elderly women. The authors hypothesised that at the end of the training intervention these women were therefore stronger than they had been for as many as 8-12 years.

7.7 Training Protocols

The training protocol followed in my RCT was fairly similar to other studies but was the minimum length expected to promote physiological changes from a musculoskeletal training programme (265), (266). The reasons for this were largely pragmatic, as we had limited funding and time resources. However a comment by O'Neil et al who studied subjects for 8 weeks and found significant increases in strength suggested that shorter term programmes might be effective and practical, and thus the future research should examine the minimum amount of training needed to maintain strength gains derived in this manner (182).
Muscle temperature is known to play an important part in regulating the speed at which muscles can shorten and therefore in determining power output. A warm up therefore could possibly influence the ability to produce power output. In my RCT prior to both the assessment and the training, the patients walked from the ward to the physiotherapy gymnasium. This was considered to be an adequate warm up.

I modelled my training intervention on the randomised controlled trial by Fiatarone (115). They studied 100 frail nursing home residents. The mean (±SE) age of the 63 women and

37 men enrolled in the study was 87.1 $\pm$ 0.6 years (range, 72 to 98); 94 percent of the subjects completed the study.

The muscle groups trained in this study were the hip extensors and the knee extensors. For each muscle group, the resistance was set at 80 percent of the one-repetition maximum (1RM). To maintain the intensity of the stimulus, the load was increased at each training session, as tolerated by the subject. Strength testing was repeated every two weeks to establish a new base-line value.

Training sessions lasted 45 minutes and were separated by one day of rest. Each repetition lasted six to nine seconds, with a one- to two-second rest between repetitions and a two-minute rest between the three sets of eight lifts.

In my study measurement of the one-repetition maximum (1RM) was made (Chapter 6.2 gives details of how this was done). Training was then started at 50% of the maximum, but was also re-measured every 2 weeks and the patients then trained at a higher percentage of the 1RM, eventually the patients were training at 80% of the 1RM.

The subjects in the study by Fiatarone had muscle strength increases of 113 $\pm$ 8 percent in the subjects who underwent exercise training, as compared with 3 $\pm$ 9 percent in the non-exercising subjects ($P<0.001$). Gait velocity increased by 11.8 $\pm$ 3.8 percent in the exercisers but declined by 1.0 $\pm$ 3.8 percent in the non-exercisers ($P = 0.02$). Stair-climbing power also improved in the exercisers as compared with the non-exercisers (by 28.4 $\pm$ 6.6 percent vs. 3.6 $\pm$ 6.7 percent, $P = 0.01$), as did the level of spontaneous physical activity. Cross-sectional thigh-muscle area increased by 2.7 $\pm$ 1.8 percent in the exercisers but declined by 1.8 $\pm$ 2.0 percent in the non-exercisers ($P = 0.11$). They concluded that high-intensity resistance exercise training is a feasible and effective means of counteracting muscle weakness and physical frailty in very elderly people. In addition to these findings they also found that the subjects who were initially the weakest but did not have severe muscle atrophy had the largest benefit from weight-lifting exercise. This pattern, as well as the large gain in strength as compared with the modest change in muscle area, suggests that improved neural recruitment of existing but underused skeletal muscle may have accounted for most of the functional improvement.

I did not measure changes in muscle strength as muscle power was my primary outcome, after 6 weeks of a similar training intervention, albeit shorter and only twice weekly I found power increases of 157% in the quadriceps-trained group.

Fiatarone concluded that, low muscle mass and muscle weakness are strongly related to impaired mobility in the frail elderly, and this relation is independent of the effects of chronic disease, dementia, depression, and other characteristics of advanced age. These results reinforced the evidence to date that the aging musculoskeletal system retains its responsiveness to progressive resistance training, and most important, the correction of disuse is accompanied by significant improvement in the levels of functional mobility and overall activity.

An earlier study by Fiatarone (114) investigated the feasibility and physiological consequences of high resistance strength training in the frail elderly. This study was not a randomised controlled trial but is one that is referred to often in the literature supporting the benefits of training in this population. The training protocol was very similar to mine, and some of the functional outcomes were similar. Ten subjects who were residing in a rehabilitation centre were recruited into the study. Their mean age was 90 ± 1 years. Outcome measures included the one-repetition maximum (1RM) of the quadriceps, a timed chair stand and gait observations were made over a 6-metre walkway. The 8-week training protocol used was an adaptation of standard rehabilitation principles of progressive-resistance training employing concentric and eccentric muscle contraction (267). The initial 1RM was used to set the load for the first week 50% of 1RM. The subjects trained 3 times per week and subjects performed three sets of eight repetitions with each leg in 6-9 seconds per repetition, with a 1-2 minute rest between each set. By the second week or as tolerated the load was increased to 80% of the 1RM. The 1RM was re-measured every 2 weeks and the training stimulus adjusted to keep the load at 80% of the new 1RM. Subjects in this study had a mean dynamic quadriceps strength of 9.0 ± 1.4 Kg on the right and 8.9 ± 1.7Kg on the left. After the training intervention there were significant improvements in strength 174% ± 13% of the quadriceps. Absolute weight lifted increased from 8.02 ± 1.0 KG to 20.6 ± 2.4Kg with the right leg and from 7.6 ± 1.3 Kg to 19.3 ± 2.2Kg with the left leg. The major finding from this study was that high intensity weight training is capable of inducing dramatic increases in muscle strength in frail men and women up to 96 years of age. Gait speed was also measured over a 6-metre walkway and the subjects who could complete this distance had a mean gait speed of 0.14 $m.sec^{-1}$ at baseline compared to a mean gait speed of 0.2$m.sec^{-1}$ after the intervention. These values are similar to the gait speeds of my study population at baseline, suggesting they are a similar population in terms of walking ability. (mean gait speed 0.17$m.sec^{-1}$ for the quadriceps group at baseline and 0.19 $m.sec^{-1}$ for the control group. At week 6 and week 16 the mean values were 0.35$m.sec^{-1}$ and 0.33 $m.sec^{-1}$ respectively). My study group actually walk faster at the end of the intervention.

This training intervention was similar to mine as training was initially started at 50% of the 1RM and the duration of the intervention was 8 weeks.

Both of these studies by Fiatarone studied were of frail elderly subjects. I therefore adapted their programmes for a group of proximal femoral fracture patients. Although other studies have used similar protocols in healthy subjects it was important to model a programme that had used a frail population.

Another important study to mention, using healthy subjects is the one carried out by Charette et al (99). As well as measuring strength gains following a 12 week resistance training programme they also aimed to determine whether increases in muscle strength were associated with changes in cross sectional fibre area of the vastus lateralis muscle. Twenty-seven women (mean age 69±1.0 (S.E) yr) were randomly assigned to exercise or control group. Muscle strength was measured using the 1RM. Training started at 65% of this value and a set of 7 exercises was prescribed. Three sets of 6 repetitions were performed 3 times a week of each of the seven prescribed exercises (leg press, leg flexion, leg extension, hip abduction, hip adduction, hip flexion, hip extension). The intensity of training was increased to 70% after 5 weeks and then 75% after 8 weeks. In addition to these increases in intensity, the 1RM values were adjusted immediately before increasing the intensity to accommodate increases in maximal strength. The concentric phase of the exercise was performed over 2 seconds and the eccentric phase over 3 seconds. Muscle biopsies were taken from the subjects at baseline and at completion of the study. The biopsies identified that there was a significant increase in mean fibre area for the type II fibres. The conclusions drawn from this study were that a progressive weight training programme can produce significant strength gains in elderly women and such gains were also associated with increases in type II muscle fibre area. The possible mechanisms they suggested for this were:

1. An improvement in neuromuscular recruitment
2. Muscle hypertrophy, or an increase in muscle size due to an increase in the size if the individual myocytes.

Although they found increases in type II fibres, there was no significant change in the type I fibres. They suggested that the possible cause of this was that this type of resistance exercise is relatively selective for type II.

Charette et al (99) incorporated more lower limb exercises into the study, however the training intensity was similar to mine in terms of training at a high percentage of the 1RM. This reinforced the reasoning for carrying out a high intensity-training programme for patients with proximal femoral fracture. In addition Aniansson has already suggested that in proximal femoral fractures patients, the type II fibres may be reduced compared to age matched controls. Type II fibres are necessary for rapid force development and are therefore necessary for functional activities. It has already been demonstrated that 1 year after proximal femoral fracture only 40% of patients who had been previously ambulant without a walking aid prior to the fracture returned to that state. For the majority, walking was most severely compromised. Mobility is essential to independence yet the reasons behind the causes of impairment after proximal femoral fracture are still unknown. I have hypothesised that the quadriceps muscle is a major factor in mobility status and if training programmes can influence leg extensor power then functional tasks such as ambulation and basic activities of daily living could be improved.

7.8 High Intensity versus lower intensity strength programmes

The intensity of training seems to be a critical variable, with higher intensity training leading to larger increases in strength. The position stand of the American College of Sports Medicine stated that in general, the lower the stimulus the lower the training effect, and the greater the stimulus the greater the effect in terms of strength, cardiovascular and endurance training (268). Several studies have reinforced the superiority of high-intensity, dynamic resistance training for the acquisition of maximal strength, even in patients of advanced age and those with chronic disease (269),(270). Other studies have found improvements in strength however with moderate and lower intensity programmes (271),(131). Most of the studies investigating lower intensity programmes however, have only had modest improvements of <20% (272), (273), (266). The intensity of training required to improve power is not as clear cut as that for strength, however my randomised controlled trial reinforced those of Fiatarone and others (115),(135) demonstrating the additional benefits of improved mobility and function associated with the physiologic changes observed in muscle power with high intensity programmes.

7.8.1 Possible reasons for such large Improvements in Leg Extensor Power

My subjects in the training group had substantial increases in LEP after the intervention (157% compared to 63% in the control group). There could be various reasons for this improvement. Firstly it has been stated in the literature that very often individuals who are the weakest make the most improvement upon starting an exercise programme. This is especially apparent in subjects who have a reserve of lean tissue (268). I cannot speculate whether the patients in my study had a large reserve in lean tissue, however they were certainly a very weak group in terms of leg extensor power. The large gains made during the early stages of training are thought to be primarily due to neural adaptations. Although the training was only for 6 weeks it was of a high intensity and the subjects were also having additional daily standard physiotherapy. Fiatarone also found large percentage improvements in strength following 10 and 8 week programmes and her study group were also very frail.

7.8.2 Maintenance of power/ strength after training programme

I found that even at week 16, 10 weeks after the training had finished the patients in the training group maintained their improvements in leg power. The possible reasons for this are that because the group were functionally more independent as measured by the Elderly Mobility Scale they were possibly more active. Because the patients were able to do basic functional tasks, the likelihood is that they were carrying out these tasks and thereby maintaining their levels of independence. Another study (187) carried out a 9 week training programme on both young and old men and women. After the training programme the 1RM of the quadriceps had improved significantly in all groups. Measurements were then taken 31 weeks later after a period of de-training. The muscle quality (1 repetition maximum production per unit of muscle mass) after this 31 week period of de-training. remained significantly elevated above baseline levels in young men and women and older men but not in the older women. The authors hypothesised that these results indicate that factors other than muscle mass contribute to strength gains with strength training in young and older men and women. These factors continue to maintain strength levels above baseline for up to 31 weeks after cessation of training in young men and women, and in older men. Fisher et al (274) also found maintenance of muscle strength in osteoarthritic knee patients who had undergone a rehabilitation programme on muscle strength, endurance, speed, and function. The average increase in all measured parameters was 10% and 25% after two and four months of rehabilitation, respectively. Improvements were sustained for eight months after rehabilitation. Conversely there is also evidence suggesting that after training cessation the benefits are not maintained (275). This decline in strength after cessation of a training programme is thought to be attributed to the reversal of the neural adaptations that have occurred with training.

7.9 Grip Strength

For reasons of cost and simplicity of measurement studies have used hand grip dynamometry to measure muscle strength (108), (109), (276). However this approach has disadvantages as the muscle group being tested is not responsible for weight bearing activities, and isometric activity is rare in daily life. Relationships between the strengths of different muscle groups are usually too weak for prediction with explained variances (r^2) of less than 50%. Therefore hand grip cannot necessarily be used as a general measure of strength (277). Despite this many researchers have used hand grip strength as the primary outcome of muscle performance in training studies. We found no significant change in hand grip strength after the intervention. However we found significant correlations between grip strength with LEP of the non-fractured leg at baseline, week 6 and week 16 (r=0.66, 0.61 and 0.58 respectively, P>0.001). My results can be compared to that from cohorts measured by Bassey et al (106) and Skelton (141). The mean ages of the subjects in these two studies were 74-76 and 80-84 respectively. Bassey found that women (n=561) had 57% lower grip strength than the men (n=359). I found that the women (n=67) in my study had 54% hand-grip strength compared to the men (n=13). There are differences between the three groups, with my study group appearing to have stronger grip strength. Caution should be taken however as different apparatus and techniques were in these studies. This could account for some of the differences between the studies.

Table 7.3: Comparison of hand grip strength in healthy elderly groups and proximal femoral fracture patients. Results are Mean (Standard deviation)

	Bassey (106)		Skelton (141)		My RCT study data	
	Men N=359	Women N=561	Men N=10	Women N=10	Men N=13	Women N=67
Grip Strength (N)	332 (±91)	191 (±62)	379 (±49)	226 (±39)	436.1 (±134.2)	236.5 (±106.3)

7.10 Studies investigating functional change following Proximal Femoral Fracture

There have been few good randomised trials investigating the physiotherapy components of rehabilitation following proximal femoral fracture. Most of the studies investigating outcome of hip fracture patients have considered systems of care as opposed to components of the rehabilitation process (278), (279), (78), (79). There have been some studies however that have actually investigated specific interventions. Baker et al (67) did carry out an RCT investigating the rehabilitation outcome of two methods of gait re-training on forty elderly women who had a proximal femoral fracture. Twenty were randomised into a conventional gait retraining programme and the other twenty received treadmill gait retraining. Isometric muscle strength of hip flexion, abduction and knee extension was also measured. A mobility ranking scale was also used. The results indicated that the treadmill group were more successful than the standard therapy group in overall mobility ranking, however there was no difference in actual gait parameters. Sixty five percent of the treadmill group regained their pre-fracture mobility rating, compared to only 40% of the standard group. There were also significant difference for hip abduction for both limbs and knee extension of the non-fractured leg. This was one of the first actual physiotherapy studies after proximal femoral fracture, however the results were mainly based on sub-group analyses reducing the statistical power of the study. This was however one of the first attempts to quantify treatment effect following a novel form of intervention and this may still be an area that requires further investigation.

A more recent RCT was that of Sherrington (87). The patients in this trial were 7 months post surgery. Limitations to this study are similar to mine in that it was not a blinded study and therefore open to investigator bias. It is also unclear in the study what the controls did or did not do in the 1-month intervention period. Sherrington did measure gait speed over a mean of 6 metres and found a significant improvement for the intervention group. Gait speed values were 0.46 $m.sec^{-1}$ and 0.51 $m.sec^{-1}$ for the intervention group before and after. At week 16 my study demonstrated gait speeds of 0.38 $m.sec^{-1}$ in the strength group. These scores relate to about 3-4 seconds difference in walking speed over 6 metres between the two study groups. The protocols for measuring the gait speeds were slightly different with the patients in the study by Sherrington et al walking at a comfortable speed over the longest available floor space. The distance walked was then measured using a measuring wheel. The mean distance walked was 6 metres in both the study and control group. From the description in the text it is not apparent whether the patients had a static or a moving start.

Functional Reach scores for the patients in the Sherrington study at the end of the intervention were similar to my quadriceps trained group at the end of the intervention. The Sherrington intervention group had a mean reach of 15.7 cm and the controls a mean reach of 16.9. The quadriceps group in my study had a mean reach of 16.3 cm and the control group a mean reach of 12.5cm at week 6.

It would appear from the results of the Sherrington study that after 7 months post-fracture the measurements of both gait speed and Functional Reach are fairly similar to my study group, who were approximately 4.5 months post fracture. One researcher has already suggested that after 4 months there is minimal further improvement (57). Marotolli et al (72) measured functional levels pre-fracture at 6 weeks and 6 months post-fracture. Their data suggested that there was minimal functional gain after 6 weeks.

Madsen et al (8) in their cohort study investigated the relationship between quadriceps strength, level of current physical activity and bone mass. The subjects involved were 47 post proximal femoral fracture patients (mean of 17 months post surgery). Measures included isokinetic strength of quadriceps, walking and stair climbing speed. They found that even after 17 months there was a strength deficit of the fractured leg of 18% compared to the non-fractured leg. In comparison to age matched controls from a previous study they also found that the strength of the non-fractured leg was some 25% lower than the control group. They found that quadriceps strength of the fractured leg was associated with walking speed and stair climbing speed and supported the need for strength training programmes in this population. In my study I also found an association between lower limb power adjusted for body weight and walking speed, with both combined leg power for the fractured and non-fractured leg (r=0.62 at week 6 and 0.51 at week 16 for the quadriceps trained group) and also with LEP/Kg of the fractured limb (r=0.60 at week 6 and 0.48 at week 16 for the quadriceps trained group). It is worth noting that my patients were only 4 months post-fracture compared to 17 months in this study. In my study at baseline there was a deficit in leg power of 50% between the fractured and non-fractured leg. At the end of the quadriceps-training programme this was reduced to 27% and finally at 16 weeks this was further reduced to 18%.

7.11 Intracapsular versus Extracapsular Proximal Femoral Fractures

My sample size was too small for meaningful comparison of outcome for intra/extra capsular fractures (27/53) and we did not find any statistically significant differences between the different fracture type in either functional score (Elderly Mobility Scale, $P>0.05$ or LEP, $P>0.05$). However other studies have found differences in outcome, with extracapsular fracture patients doing worse (4), (3), (6). There were far greater numbers in these studies and outcome was studied over a longer period of time. My RCT was balanced in terms of fracture type in the intervention and control groups, avoiding bias in outcome due to this factor.

7.12 Summary of Disability improvements

The improvements that I observed in leg extensor power in the quadriceps training group were accompanied by a significant reduction in disability, as measured by an increase in the Elderly Mobility Scale total score. The mean difference in change was 2.5 points at week 6 and 1.9 at week 16. This confirms the findings of another study, which used the Elderly Mobility Scale to determine the effect on rehabilitation and have found it to be sensitive to direct improvements in mobility after physiotherapy intervention in a group of elderly day hospital attenders (234). This study compared the Elderly Mobility Scale in relation to the Barthel Index and the Functional Ambulation category and found it was more sensitive to improvement than either of these scales (234).

In addition I found an increase in Barthel score with quadriceps training at the end of the intervention phase, indicating an improved ability to perform basic activities of daily living.

Of the different components of the Elderly Mobility Scale, which were analysed separately, Functional Reach was the only one that showed significant improvement with quadriceps training.

The Functional Reach has already been shown to be sensitive and reliable and it is easy to use in the clinical setting. It has been previously shown to have predictive validity in identifying recurrent fallers in community dwelling male veterans (224). The characteristics of my patients indicate that they are likely to be at high risk of falls. It is possible that the improvements in Functional Reach that I have demonstrated may be associated with reduced risk of falls in this group. It has also been suggested that Functional Reach is more than just a measure of balance. Daubney et al (227) found that the force generating capacity of the ankle muscles was found to be predictive of how well a patient can reach, highlighting the fact that the Functional Reach also encompasses lower limb strength.

There is however some conflicting evidence as to whether Functional Reach does actually measure dynamic balance (228), however postural control is complex, involving the co-ordinated actions of the biomechanical, sensory, motor, and central nervous systems. No one, simple measure therefore could incorporate all these physiological activities into a simple test. Another study has questioned its use with patients with cognitive impairment (233), however the patients in my study all had an AMT score of greater than 6 and could all understand the simple instructions to carry out the test. The test is also easy to administer, it involves minimal equipment and has been validated with elderly subjects. All the patients in my study group who were able to stand unsupported could manage to undertake the test after simple instruction.

Quadriceps training did not significantly improve gait speed or timed up and go. It is possible that the patients improved in their walking and transfer ability, with for example a more stable safer gait, even though the time taken in these tasks was not reduced. It may be the case that when a patient changes from a walking frame to sticks for example that gait speed reduces.

Another reason behind the lack of change may be that the timed up and go test may not be a sensitive tool to use in this patient group. A recent study has questioned the reliability of the timed up and go test. (233). A nation-wide representative survey of elderly people in Canada (N = 2,305) found both the Functional Reach and the timed up and go to be unreliable and not feasible tools for use with elderly subjects, specifically those with cognitive impairment.

7.13 Summary of Perceived Health Status

There was a tendency for all the different domains of the Nottingham Health Profile to improve in the quadriceps training group compared to controls. However this reached statistical significance only for energy at the end of follow up. This perceived health status measures give reassurance that quadriceps training is generally well tolerated, and is not accompanied by increased pain.

7.13.1 Comparison with other Studies

The impact of proximal femoral fractures on perceived health status is still not that well established, even though it is believed that physical, psychological and social functions are affected to varying degrees (13). A recent case-control study examined the longitudinal change in health related quality of life following proximal femoral fracture in elderly subjects, 32 patients with proximal femoral fractures and 29 sex-matched control subjects. Perceived health status instruments used were the SF36 (210) and the revised Osteoporosis Assessment Questionnaire (OPAQ2) (280) on two separate occasions, within 1 week of fracture and 12-15 weeks after fracture. The controls completed both questionnaires on two occasions 12 weeks apart. This study found that at 3 months post-fracture there was a significant reduction in the following domains of the SF36 – Physical function, Vitality and Social function and in the OPAQ2 Physical function, Social activity and General health. The baseline scores also indicated that compared to the age matched controls the proximal femoral fracture group had lower scores for all domains and deteriorated over the 3-month period. The control group demonstrated little change over the 3-month period.

A between group analysis of my results indicated that over the 3-month period post-fracture in my control group there was no change with regard to any of the domains of the Nottingham health profile, however in the trained group there was a significant increase in the energy domain and a trend towards significance in the emotional domain. A recent RCT (281) investigated the impact of a programme of muscle strengthening and physical conditioning on impairment and disability in chronic stroke subjects. The intervention was a 10-week (3 days/week) programme consisting of a warm-up, aerobic exercises, lower extremity muscle strengthening, and a cool-down. As well as impairment measures the Nottingham Health Profile was used to measure disability. They found significant improvements for all the selected outcome measures (Human Activity Profile, Nottingham Health Profile, and gait speed) for the treatment group ($p < .001$). In terms of overall training effects, the 13 subjects demonstrated increases in strength of the affected major muscle groups, in the Human Activity and Nottingham Health Profiles, and in gait speed and rate of stair climbing without concomitant increases in either quadriceps or ankle plantarflexor spasticity. The conclusions drawn from this study were that 10-week combined programme of muscle strengthening and physical conditioning resulted in gains in all measures of impairment and disability. This study is similar to mine as frail groups were being assessed and a strength training intervention was administered.

7.14 Methodological Issues around the use of the Nottingham Power Rig

The importance of measuring leg power as opposed to strength has been discussed and therefore I felt it important to use power as my primary outcome measure. The Nottingham Power Rig had previously been developed by Bassey et al (130) and was found to be safe and acceptable for all age groups and levels of capability. Lamb (176) also measured LEP in a group of proximal femoral fracture patient's one-week post surgery with no adverse effect. It was considered therefore to be a suitable and more direct measure of leg extensor power than other methods such as gait speed or timed stair climb. This method could also measure both fractured and non-fractured legs separately.

I have found that the Nottingham Power Rig to be a simple practicable measurement tool for frail elderly and elderly patients rehabilitating after proximal femoral fracture. This study extended the findings of Bassey et al (130),(170) to elderly proximal femoral fracture patients. All subjects were capable of being tested on the power rig despite their age and frailty. However, since the development of the Nottingham Power Rig limitations within its design have been raised regarding the fixed inertia of the flywheel (282). This is thought to potentially disadvantage weaker subjects, since the fixed inertia could correspond to a higher percentage of their maximum strength and consequently not represent the maximal value of power. This could have introduced bias within this study, with regard to the absolute values of power, however the design of the study was randomised and both groups were similar at baseline. This could however partially account for why the values of LEP in my study were very low. A new system is being developed which can vary the inertial system and thereby potentially reduce this bias (283).

Another evaluation of the rig (284) found that due to the design of the footplate the heel end of the footplate travels further than the toe end. A computer simulation demonstrated that a constant thrust directed from the hip to the heel end caused 34% more energy to be imported to the flywheel than when directed to the toe end. Direct experiment confirmed this finding. The authors therefore modified the footplate to ensure minimal variation in the sites of application of the centre of foot pressure. I did not use a modified rig set up and again this could have made executing the extension thrust harder for the weaker subjects and thereby exaggerated the loss of explosive power.

Despite these design flaws all of the subjects in the study except for one were able to generate a push through the fractured leg. The one patient who was unable to push through the force plate complained of pain at the fracture site and therefore no measurement was taken.

A practical difficulty that many of my patients experienced was an inability to put the resting leg on the floor as described in the original paper describing the measurement apparatus (130). In view of this I instructed the patient to have their resting foot placed on the parallel bar (not the foot bar at the base of the seat), which gave the patient a stable secure position and ensured that the resting leg remained inactive. Figure 4.1 shows the starting position of the subject on the Nottingham Power Rig.

I found significant increases with repeated measurements of LEP during a single visit in all patient groups. All patient groups showed a progressive increase in measured LEP over the first five attempts after which there was a levelling off between the 6th and 10th attempt. This method of testing differed to Bassey et al who allowed the subjects to have two or three sub-maximal efforts and then at least five maximal efforts. The final value accepted within this final five was the value that was equal to or a little below the previous one. Peak power was taken as the highest value in these last five attempts. Lamb et al (176) gave the patients a maximum of 10 attempts and took the peak value within that. Peak power output was attained between the 5th and 10th attempts in all my patient groups during a single visit. There is no definite argument for or against taking the mean or the peak, however I hypothesised that a peak power measure could have produced error through poor technique (for example trunk movement) and therefore could give an erroneous result. I therefore chose the mean score of the last 5 attempts, as this may give a more reproducible and representative score than a single maximal value.

7.15 Leg Extensor Power in Frail, Proximal Femoral Fracture patients and an Osteoporotic group

As expected there was a significant difference in LEP between an osteoporotic group and the frailer groups. The osteoporotic group were younger than the other two patient groups, and this may have contributed to the differences seen in LEP. However it is clear that the Nottingham Power Rig can discriminate readily between the fractured and non-fractured legs in patients rehabilitating after proximal femoral fracture. My results are in accord with what might be expected i.e. reductions in leg extensor power with age and frailer groups. This therefore helps to confirm the validity of the Nottingham Power Rig as a measuring tool in rehabilitation studies in the elderly. Bassey et al had already validated the tool for use with specific populations. (130).

7.15.1` Time to generate Leg Extensor Power

Power increases with velocity of movement up to an optimum velocity. The rig was designed to produce a steady manageable resistance to the push for subjects varying greatly in their ability to produce power. For each individual the pedal speed is relatively constant in the face of a rapidly accelerating flywheel. The resistance offered by the system to the subject is related to the amount of acceleration the subject provides; stronger subjects face an appropriately larger resistance. An inevitable consequence of this is that the duration of the push is shorter the stronger the individual. My data reinforced this finding, as subjects with lower power scores took longer to generate LEP. The subjects tested in Bassey paper took between 0.25-0.40 seconds to carry out the push, however this did include young healthy subjects (age range 20-86 years). My patients took an average of 1.1 seconds when including the measurement of the fractured and non-fractured limbs. The fact that the weaker subjects took longer could also reflect the design of the rig as mentioned in 7.14.

The ability to generate power quickly may be an important factor in fall prevention and maintenance of basic functional tasks.

7.16 Choice of Functional Scales

There is no single functional scale, which is the 'Gold Standard', however there are many different scales used in elderly rehabilitation. My primary functional outcome measure was the Elderly Mobility Scale. The Elderly Mobility Scale has been found to have concurrent validity with the Barthel Index (211), (234) and has also been found to be a valid, reliable and sensitive measuring tool for use in elderly patients undergoing rehabilitation (285),(234). As well as this the Elderly Mobility Scale has face validity as it measures aspects of function, which are relevant to my patient group.

The Barthel index has been used in many rehabilitation studies and is the most recognisable scale in terms of physical functional assessment. I used this scale in my study to compare the changes of the Elderly Mobility Scale.

The Functional Reach score which is also a assessment tool in its own right has been found to be a predictor of individuals who are at a high risk of falling (222), which again is very important in my patient group. It has been validated against the centre of pressure excursion (222). It is a simple measure, which is easy to carry out and does not require sophisticated expensive equipment.

7.17 Issues around the Study Design

7.17.1 Patient Group selected

Of the 111 patients admitted into the ward 80 were randomised into the study. This is 72% of the patient group, which is representative of patients admitted to a GORU unit. I did not take those patients who were medically unwell, or who were severely cognitively impaired. Patients admitted to the GORU from the acute ward make up for approximately 50% of all hip fractures admitted to the Glasgow Royal Infirmary. This group are the frailest group, and therefore the ones requiring most rehabilitation input.

7.17.2 Study Limitations

There are some limitations to my study design. The first is the fact the study was not blinded. This was because there was not enough funding to employ a second research assistant. The fact that the research assistant was not blinded to the intervention raises the possibility of observer bias. I tried to assess whether such bias had occurred by asking an independent blinded assessor to re-measure leg extensor power in a sub-sample of 18 patients. There was a significant difference between the blind and non-blinded assessor for measurement of leg extensor power of the fractured leg in the trained group. This was not the case for the non-fractured leg. However the magnitude of difference was small compared to the changes in leg extensor power achieved by the quadriceps training programme, and therefore it is unlikely that observer bias is an important confounding factor.

7.17.3 Attrition Bias

It is apparent that by week 16, I was only able to obtain measurements on 50% of my study population. However this is not unlike many other studies involving this patient group (283), (48) and is more to do with the fact that this group is a frail group. Other problems included bringing patients back to the hospital after discharge. These problems ranged from transport difficulties to inability to contact the patient. Options for future studies might be to devise a portable measure for muscle power, use a functional test, which correlates strongly with power and carry out the measurements in the individuals' home. The fact that I had lost 50% of the study population by week 16 however does affect the generalisability of my results.

7.17.4 Attention Control

As mentioned in section 6.2 the quadriceps group had an extra 60 minutes per week intervention whereas there was no extra input for the control group. The reasons for this were financial. There was no resource to implement a non-specific intervention for the control group. There is the possibility therefore that some of the improvements obtained in the quadriceps trained group were due to the additional contact time from the therapist. Psychological factors such as improved motivation could have contributed to this, however the extra time amounted to 1 hour per week and therefore this would seem unlikely. However in any future work it may be appropriate to implement an attention control such as reminiscence therapy in order to provide a 'placebo' intervention and to simulate the contact patients receive in an intervention group. This would eliminate such a bias.

7.18 Future Studies

There is much work needed into the rehabilitation component of hip fracture management. The latest SIGN guidelines have highlighted this need, as there was few well designed randomised controlled trials in this area. The Cochrane database has also outlined that Geriatric rehabilitation interventions are complex and not easy to quantify easily. (This may be a reflection of the fact that not many good studies have been carried out in this area). Another Cochrane review (65), which was updated in April 2000, highlighted the need for good randomised trials in physiotherapy after proximal femoral fracture. It is important to investigate this area further to identify effective treatment strategies, which will produce better outcomes for these patients. My study has highlighted the fact that with a simple structured intervention of high intensity strength training functional benefits can be gained. However it was a single unit study and work will need to be carried out over many sites to investigate whether different physiotherapists in a variety of clinical settings can reproduce these benefits. If other components of rehabilitation in these units are investigated to the same degree outcomes could improve further for these patients.

Structured strength training interventions should also be investigated in other frail groups undergoing rehabilitation, as many of these patients will have muscle weakness to some degree, which limits their functional capacity.

Other studies into this population could involve strengthening other muscles around the hip, for example the hip abductors. One study (105) has already established normative data for hip abductor strength for women aged between 81 and 90 years. This study found a significant correlation between summed hip abductor strength and gait speed, suggesting that the hip abductors do play an important part in gait. Following hip surgery this muscle group will be affected by the incision. This in turn could affect the patients' ability to mobilise after surgery. An important follow up of this study could measure the hip abductor strength of proximal femoral fracture patients using the same methods as Smith et al (105) and compare the values of hip strength in proximal femoral fracture patients to aged matched controls. Comparisons could also be made between fractured and non-fractured legs and for a healthy versus a non-healthy group. Correlations could also be investigated between gait speed and hip strength in the proximal femoral fracture group.

7.19 Conclusions to Findings

There are few studies of specific rehabilitation interventions for elderly proximal femoral fracture patients. Studies have in general concentrated on the administrative structure of care, while little is known of the optimum rehabilitation interventions to be included. A systematic review of co-ordinated multidisciplinary approaches for in-patient rehabilitation after proximal femoral fracture found a non-significant trend towards benefit (78). It seems likely that if the effectiveness of individual components of rehabilitation were improved, the overall impact of co-ordinated programmes of rehabilitation would be enhanced.

In a recent editorial (261) it was stated that 'the preservation of muscle power into late life can greatly decrease the risk of disability and enhance functional independence. Research into strategies to increase muscle power in old people and to prevent the age-related loss of muscle power should be seen as a very high priority'. My trial has shown that a high intensity strength-training programme of the quadriceps does improve leg extensor power and functional independence. Evans et al (261) had suggested that muscle strength training may not always produce an optimum in muscle power and that exercises, incorporating more rapid force generating movements of a lower intensity should be considered. My results would suggest that a high intensity programme can induce changes in muscle power and my results are consistent with other studies (115), (177), which have assessed power either using pneumatic resistance machinery or using timed stair climbs.

There was a tendency for all the different domains of the Nottingham Health Profile to improve in the quadriceps training group compared to controls. However this reached statistical significance only for energy at the end of follow up. The perceived health status measures give reassurance that quadriceps training is generally well tolerated, and is not accompanied by increased pain.

A strength of my study was that the majority of the patients (72%) admitted to the Geriatric Orthopaedic Rehabilitation Unit were entered into the study. The study groups were well matched in terms of baseline characteristics, including fracture type. Compliance to treatment and follow-up was 75% at the end of study intervention. However I did lose 40-50% of patients in each group by the time of final follow-up. This reflects the very frail nature of the population studied, with major co-morbidity resulting in many of the study drop-outs. Lastly rehabilitation programmes for elderly proximal femoral fracture patients are likely to vary between units (78). It is possible that Geriatric Orthopaedic Rehabilitation Units with different standard physiotherapy practice from ours might have greater or lesser effect from adding quadriceps training to the rehabilitation process. Could my programme of additional quadriceps training have had non-specific beneficial effects mediated through additional therapist contact, rather than as a specific effect of the muscle training? This is unlikely. There were only 2 quadriceps training sessions per week, and the non-specific contact was likely to have been brief, compared to other rehabilitation activities on the ward.

Despite these limitations the findings from my study are very encouraging. Progressive high-intensity quadriceps training resulted in large increases in leg extensor power and reduced disability after proximal femoral fracture. The training programme was well tolerated by frail elderly subjects. In order to evaluate whether the results from this study are generalisable to most elderly people rehabilitating after a proximal femoral fracture a large multi-centre trial is necessary. It may be worth exploring the effects of quadriceps training in other disorders associated with muscular weakness and disability.

To conclude, this study raises the prospect of improved outcomes for this patient group. It is a simple, practical and structured approach to physiotherapy and is one which could be utilised both in the hospital and in patients homes.

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Appendix A

A randomised controlled trial of additional quadriceps training in patients rehabilitating after a proximal femoral fracture (PFF).

CONSENT FORM

You are invited to participate in a study to determine the possible benefits of strength training of your leg on top of your standard physiotherapy treatment. The following measurements will be made at the beginning and end of physiotherapy.

1) Muscle power of both legs.
2) Body weight.
3) A simple test of balance and functional ability.
4) Hand grip strength.
5) A short walking test
6) A questionnaire

Participants will be randomly allocated to standard physiotherapy or physiotherapy and strength training. The group receiving strength training will be seen twice weekly additional to their standard treatment. The strength training will involve lifting small weights with your legs. Two different exercises will be performed over a 6 week period, following which you will be re-assessed.

Please note that if you agree to take part, this research project may be of little benefit to you but the results may help other patients in the future.

If you do not wish to take part in the Research project or if at any time you wish to stop taking part in the strength training section you may do so. The care, which you are presently receiving, will not be affected in any way.

I, (Name) .... of (Address) ....

....

agree to take part in the research project/study described above.

Dr/Mr .... has explained to me what I have to do, how it might affect me and the purpose of the research project.

Signed .... Date ....

Witness .... Date ....

PLEASE CONTACT SARAH L MITCHELL ON 211 4778 IF YOU HAVE ANY QUERIES REGARDING YOUR TREATMENT.

Appendix B

THE ELDERLY MOBILITY SCALE (211)

Lying to sit — Score
2 Independent
1 Needs help of 1
0 Needs help of 2 ______

Sit to lying
2 Independent
1 Needs help of 1
0 Needs help of 2+ ______

Sit to Stand
3 Independent ≤ 3 seconds
2 Independent > 3 seconds
1 Needs help of 1 (verb/phys)
0 Needs help of 2+ ______

Stand
3 Stands without support + can reach
2 Stands without support needs help to reach
1 Stands but needs support
0 Stands only with physical support ______

Gait
3 Independent (inc sticks)
2 Independent with frame
1 Mobile with walking aid but erratic/unsafe turning (occ sup)
0 Needs physical help to walk or constant supervision ______

Timed Walk 6 metres
3 Under 15 seconds
2 16 - 30 seconds
1 Over 30 seconds
0 Unable ______

Functional Reach
4 Over 16 cm
2 8 - 16 cm
0 under 8 cm or unable ______

FUNCTIONAL REACH =

TOTAL ______

Appendix C

The Modified Barthel Index (209)

Bladder

0= Incontinent (or needs to be given enemata)
1= Occasional accident (once a week)
2= Continent

Bladder

0= Incontinent, or catheterised and unable to mange alone
1= Occasional accident (maximum once per 24 hours)
2= Continent

Grooming

0= Needs help with personal care
1= Independent face/hair/teeth/shaving (implements provided)

Toilet use

0= Dependent
1= Needs some help, but can do something alone
2= Independent (on and off, dressing, wiping)

Feeding

0= Unable
1= Needs help cutting, spreading butter, etc
2= Independent

Transfer (bed to chair and back)
0= Unable, no sitting balance
1= Major help (one or two people, physical), can sit
2= Minor help (verbal or physical)
3= Independent

Mobility

0= Immobile
1= Wheelchair independent, including transfers
2= Walks with help of one person (verbal or physical)
3= Independent (but may use any aid; for example, stick)

Dressing

0= Dependent
1= Needs help but can do about half unaided

Appendix D

The Nottingham Health Profile (Part 1) (239)

Listed below are some problems people may have in their daily life.
Look down the list and put a tick in the box under **yes** for any problem you have at the moment. Tick the box under **no** for any problem you do not have.

Please answer every question. If you are not sure whether to say yes or no, tick whichever answer you think is more true at the moment.

	YES	NO
I'm tired all the time	....	....
I have pain at night	....	....
Things are getting me down	....	....
I have unbearable pain	....	....
I take tablets to help me sleep	....	....
I've forgotten what its like to enjoy myself	....	....
I'm feeling on edge	....	....
I find it painful to change position	....	....
I feel lonely	....	....
I can only walk about indoors	....	....
I find it hard to bend	....	....
Everything is an effort	....	....

I'm waking up in the early hours of the morning	....	....
I'm unable to walk at all	....	....
I'm finding it hard to make contact with people	....	....
The days seem to drag	....	....
I have trouble getting up and down stairs or steps	....	....
I find it hard to reach for things	....	....

Remember if you are not sure whether to answer yes or no to a problem, tick whichever answer you think is more true at the Moment.

	YES	**NO**
I'm in pain when I walk	....	....
I lose my temper easily these days	....	....
I feel there is nobody I am close to	....	....
I lie awake for most of the night	....	....
I feel if I'm losing control	....	....
I'm in pain when I'm standing	....	....
I find it hard to dress myself	....	....
I soon run out of energy	....	....

	YES	NO
I find it hard to stand for long (e.g. at the kitchen sink, waiting for a bus)	....	....
I'm in constant pain	....	....
It takes me a long time to get to sleep	....	....
I feel I am a burden to people	....	....
Worry is keeping me awake at night	....	....
I feel that life is not worth living	....	....
I sleep badly at night	....	....
I'm finding it hard to get on with people	....	....
I need help to walk about outside (e.g. a walking aid or someone to support me)	....	....
I'm in pain when going up and down stairs or steps	....	....
I wake up feeling depressed	....	....
I'm in pain when I'm sitting	....	....

NOW GO BACK TO PAGE 1 AND MAKE SURE YOU HAVE ANSWERED YES OR NO TO EVERY QUESTION ON ALL THE PAGES