Undernutrition and impaired functional ability amongst elderly slum dwellers in Mumbai, India

Mary C. Manandhar

Thesis submitted to the Faculty of Medicine of the University of London for the degree of Doctor of Philosophy

Public Health Nutrition Unit
Department of Epidemiology and Population Health
London School of Hygiene and Tropical Medicine

January 1999

Numerous Originals in Colour

DEDICATION

In memory of my sister, Hazel

ABSTRACT

This research tests the hypothesis that being underweight in older adulthood carries with it a significant risk of being functionally impaired and having poor physical performance, irrespective of sex, age or sickness. In a cross-sectional study of poor elderly people living around a major teaching hospital in the Indian city of Mumbai, data on anthropometry, self-reported functional ability (activities of daily living and mobility), and physical performance (tests of handgrip and lower body strength, manual dexterity, flexibility and psychomotor co-ordination) were collected from 1,335 non-oedematous people aged 50-96 years (mean age 60). Data on serum albumin and haemoglobin levels and clinically diagnosed morbidity were available from hospital records. Because of exclusions and missing clinical data through hospital non-attendance, statistical analyses were performed on 1,097 (458 men, 639 women) subjects. The prevalence of underweight was high (26-41%). Bivariate analyses revealed significant negative associations between most variables and advancing age, and women to be worse off than men. There was high internal consistency within dimensions of functional ability and physical performance, and strong positive associations between nutritional status and many functional ability and physical performance outcomes. Using multivariate logistic regression, results showed that being underweight (Body Mass Index <18.5 kg/m^2, and mid-upper arm circumference of <23 cms in men and <22 cms in women) carries a significantly increased risk (expressed as odds ratios) of having poor handgrip strength and dependence in mobility, dressing and bathing, independent of sex, age, morbidity and other confounders. Results were strongest for handgrip strength : using mid-upper arm circumference, underweight men were 4.5 times (95% CI 2.5-8.1), and underweight women 4.2 times (95% CI 2.5-6.9), more likely to have poor handgrip strength than normally nourished elderly in the sample. The hypothesis is upheld. This underlines the important potential of nutritional status improvement in enhancing the quality of life of elderly people in less developed countries.

TABLE OF CONTENTS

Page

CHAPTER 3 : STUDY DESIGN AND METHODS

Page

Page

Page

LIST OF TABLES

Page

Page

Page

LIST OF FIGURES

Page

LIST OF PLATES

ACKNOWLEDGMENTS

In the process of developing and testing my hypothesis, and writing this thesis, there have been many people who have helped me along the way. Firstly, I thank Dr. Suraiya Ismail for being a constant source of advice, guidance and generosity of mind and spirit. I also pay tribute to the late Ms. Erica Wheeler who first sparked my interest in this field of research. Financial and logistical support were provided by HelpAge International. I thank Mr. Mark Gorman, Mr. Graeme Jackson and Ms. Cathy Squire and other colleagues from HelpAge in London who facilitated collaboration with HelpAge India and the BGCHI in Mumbai and whose commitment carried me forward.

From Mumbai, I am greatly indebted to Dr. Perveen Anklesaria who befriended and supported me in many professional and personal ways, and whose leadership of the BGCHI will always be a source of inspiration. I also thank Dr. (Mrs) PM Pai, formerly Dean of the KEM Hospital, Dr. (Mrs) KC Gupta, formerly Head of the Pharmacology Department, Miss SM Pohujani, Mrs KN Joshi and Miss VJ Ashar of the BGCHI, and all the BGCHI staff and the nutrition team. Major General (Rtd) RS Pannu, formerly Director General of HelpAge India, deserves acknowledgment for his crucial support, as do Mr. PN Iyer, Dr. JR Singh, and Dr. Shabeen Ara, in New Delhi.

I am grateful to Dr. Joan Bassey, Dr. Paul Deurenberg, Professor John Durnin, Dr. Tamara Harris, Dr. Jeya Henry, and Dr. Geraldine McNeill for their help in developing the methodology; Mr. Mark Myatt for statistical advice; and to those at Oversley House Retirement Home, Warwickshire and the Gujerati Welfare Association, East London, who assisted in the piloting of the protocol. For proof-reading, and much more besides, I thank my mother, Valerie Marlow (any remaining faults are all mine). More thanks are due to many friends at the LSHTM Public Health Nutrition Unit who have helped, housed and uplifted me on countless occasions. To all the elderly people who I have encountered on this journey, I extend appreciation for their time and the many lessons learned.

I treasure Barun, for his love and forbearance, especially over the last year, and Ashok, for the joy.

CHAPTER 1 : INTRODUCTION

"As ageing research has evolved in recent years there has been a shift of focus from mortality and longevity to health status and quality of life. An important component of quality of life, from the perspectives of both the older individual and those responsible for his or her care, is functional independence .... there is much to be gained from understanding factors related to the development of poor functional status. Epidemiological research into this potentially fruitful area has only just begun."

Guralnik and Lacroix 1992

1.1 Hypothesis

Anthropometric indicators are already routinely used in the nutritional assessment of children for whom their predictive relationships with growth, morbidity and mortality outcomes are well demonstrated. Attention is now increasingly turning to the use of anthropometry, particularly Body Mass Index (BMI) and mid-upper arm circumference (MUAC), in the nutritional assessment of adults, and to the relationships between these indicators and health-related outcomes of morbidity, mortality and work performance. Certainly, the usefulness of any nutritional indicator lies in its ability to identify and predict those at risk in terms of an important functional health outcome, giving it validity as an assessment, monitoring and evaluation tool.

The hypothesis of this study is that being underweight in old age carries an increased risk of being impaired in functional ability and of having poor physical performance. This breaks away from the traditional outcome variables of morbidity and mortality, adopting instead functional ability, defined as the ability to perform activities of daily life without support, and poor performance in physical dimensions reflecting these activities, as its "outcome" indicators. The rationale behind this is that functional ability and dimensions of physical performance reflect essential daily living tasks, making it a more relevant outcome against which to assess nutritional status in older people. If underweight compromises functioning to the point that older persons cannot fully care for themselves, the burden on the family, and the community as a whole, will be substantial. Moreover, if nutritional status proves to be a potentially correctable source of maintaining and postponing, for as long as possible, functional ability and physical performance decline amongst community-living older people, then early nutritional intervention may have considerable beneficial impact for all concerned.

1.2 Nutrition, health and function in an ageing world

As older adults age, the risk of death becomes increasingly likely, and the long and short term causes and effects of disease, diet and lifestyle are hard to disentangle. In the complicated context of ageing biology, transitions from disease to disability, rather than disease to death, take on prime importance for older people (Harris and Feldman 1991, Brody 1988, Besdine 1990). For many elderly people, limitations in the ability to perform ordinary and basic activities are a more pressing concern in daily life than the particular disease that may have resulted in the limitations (Ensrud *et al* 1994). This all means that the traditional health measures of life expectancy and morbidity begin to appear inadequate outcomes against which to measure any health or nutritional indicator in elderly people, or evaluate preventive strategies. Instead, attention should turn to identifying and addressing the factors determining susceptibility to impaired function, and not merely ill health, in old age, one of which may well be poor nutritional status.

The older age group is the fastest growing part of the world's population (UN 1991, World Bank 1994). By 2030, it is estimated that three quarters of the world's population over 60 years old will be living in developing countries (Kinsella and Suzman 1992, World Bank 1994). The Asian continent is set to witness the largest expansion (Macfadyen 1992). Moreover, the dual phenomena of ageing and rapid urbanisation occurring in many developing countries are resulting in growing numbers of older poor adults living in the cities (Gopalan 1992, Tout 1989). The challenge for the next century is to alter focus accordingly.

Very little is known about the nature and dimensions of the problems elderly people face in urban areas in developing countries (Tabibzadeh *et al* 1989). However, some evidence indicates that many elderly people living in poor socio-economic conditions are without adequate psycho-social and economic support from the family or community. In a recent detailed study of old age in slums in several cities in the South Indian state of Karnataka, the main problems of poor old people were attributed to their socio-economic status :

> *"For persons belonging to lower social classes, where the level of literacy is low, only unskilled occupations are available with which they can hardly earn enough for survival..... the living arrangements of the aged, their relationship with family members and friends, and the nature and extent of social interaction are determined by their economic status."*
>
> *Ara 1994*

Elsewhere it has also been observed that, whereas elderly people are tolerated in rural areas, in the city they are seen as a burden because they lack adaptability to the urban culture. They become less valued and respected once they no longer contribute to the household income or lose power over important economic resources (Martin 1990).

There is considerable evidence that children and women living in urban slums and squatter settlements in developing countries are at great risk of malnutrition due to patterns of ill health, high levels of communicable disease and all the various associates of poverty (Harpham *et al* 1985, Pryer and Crook 1988, Atkinson 1992). Up to 50% of children living in slums and squatter settlements suffer from malnutrition and rates are worse than for poor children in the rural areas (Rao *et al* 1974, Tabibzadeh *et al* 1989, Shetty 1992). However, relatively little is known about such problems amongst elderly slum dwellers who still fail to appear prominently on health, nutrition and social development agendas. This is puzzling considering that the physiological, economic, and psycho-social vulnerability affecting many older people living in poor conditions means that many of them too will be at high risk of developing malnutrition.

1.3 Study area and population

India has one of the world's most rapidly expanding urban populations. Only 26 million in 1950, the urban population is expected to rise to over 1,240 million by 2000 AD, thus increasing from 17% to 34% of the total Indian population (Gopalan 1998). Over the last century, as the country's foremost industrial and commercial centre, Mumbai (formerly called Bombay) has attracted a vast number of migrants to its metropolitan area. In 1991 its population had reached approximately ten million (Municipal Corporation of Greater Bombay 1991, Crook and Dyson 1982) with an estimated 51% living in urban slums, squatter settlements or chawls (publicly-owned tenement blocks).

This study was conducted from a base within a large government hospital, the King Edward VII Memorial Hospital (Plate 1.1), located in F-South Ward of the Municipal Corporation of Greater Mumbai. F-South Ward is a defined administrative area, covering 8.8 square kilometres and with an average population density of about 53,000 people per square kilometre (Municipal Corporation of Greater Bombay 1989). It is largely occupied by slums and chawl areas of differing sizes, mills and factories, and teaching and medical institutions. Slum areas consist of irregular clusters of small permanent and semi-permanent hutments made of a patchwork of materials such as mud, cardboard sheets, plastic, wood offcuts and bricks with tiled or corrugated roofs. Hutments are divided up haphazardly with narrow alleyways and open drains (Plates 1.2 and 1.3). The chawls were built around 1930 and stand several storeys high. They have serially numbered rooms arranged in rows off a corridor running the length of the building with a common toilet block at one end on each floor.

Living arrangements in both slums and chawls are typically very overcrowded, with poor environmental and sanitation conditions, and heavy sharing of poorly maintained community toilets. Disposal of most household waste is into open drains. Both areas also suffer from irregular water and electricity, and inadequate access to health care and social services. Although some public and private outreach health services are available in these areas, the provision of facilities does not necessarily lead to utilisation by the urban poor (Yesudian 1988). The foci of any such services are overwhelmingly on maternal and child health care services, family planning and sexually transmitted disease control, with no special provision for the care of elderly people. Official mortality and morbidity patterns from these slums and chawls are unavailable, but a study conducted in one area covered by this study reported the age-specific mortality rate for the over 45-year old age group as 41/1000, with an overall mortality rate of 6.3/1000 (Yesudian 1988).

1.4 Structure of the thesis

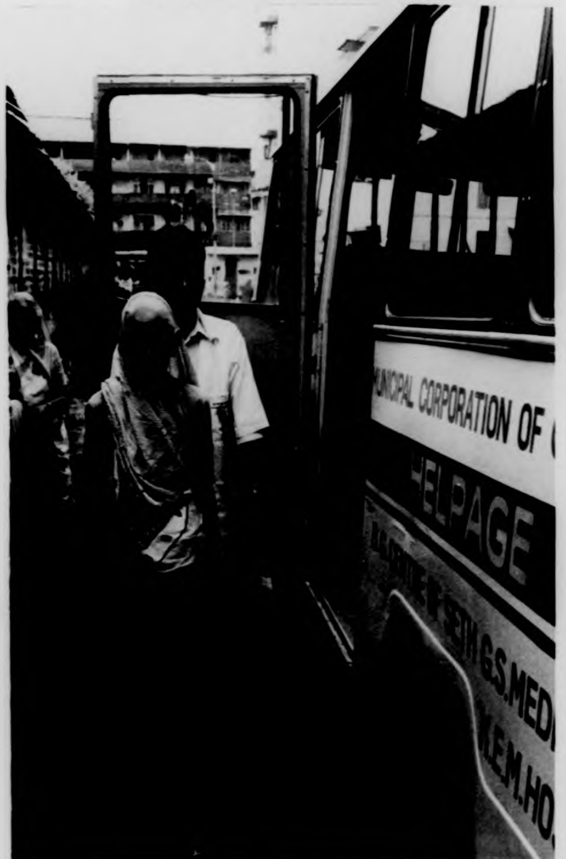
This first chapter sets out the rationale for the study and the demographic and social setting for this neglected but important field of research. Chapter 2 reviews the literature on assessment of nutritional status, functional ability and physical performance, and ill health amongst community-living elderly people, and summarises evidence for a relationship between underweight and impaired functional ability and physical performance amongst older adults. Chapter 3 details the methods used for study design, data collection and analysis. The demographic attributes of the sample, and issues of coverage and bias, are described in Chapter 4. Presentation of the results of the study begins with descriptive characteristics in Chapter 5, followed by results from bivariate statistical analyses in Chapter 6, and from multivariate analyses in Chapter 7. Chapter 8 is the discussion chapter in which the main findings from the research are analysed in relation to the existing body of knowledge. Finally Chapter 9 summarises the main findings of the study and makes recommendations for future work in this field.

Plate 1.1 KEM Hospital

Plate 1.2 Slum area

Plate 1.3 Inside a slum area

Plate 1.4 Taking an elderly lady to KEM Hospital



CHAPTER 2 : LITERATURE REVIEW

This chapter reviews the literature on functional ability and physical performance assessment, and the use and interpretation of anthropometric measurements and derived indicators in the nutritional assessment of older people. This is followed by an exploration of the current evidence for a relationship between functional ability and physical performance, and nutritional status in free-living elderly people, and a consideration of ill health as a likely confounder in the relationship. The chapter ends with a consideration of the pitfalls and problems involved with research into these themes.

2.1 The meaning and significance of functional ability

Functional ability[1] has been defined as "the ability to perform basic activities of daily life without support which is the key to overall independence and quality of life" (Guralnik *et al* 1989). In terms of the health assessment of elderly people, we must be able to identify and measure factors limiting functional ability, and we need to find ways of identifying people most at risk of losing these abilities (Yates *et al* 1993, Skelton *et al* 1994). The passage from a state of independence to that of dependence is characterized by the inability to perform activities of daily living such as getting out of bed, dressing, personal hygiene, eating and walking. Thus functional ability impairment means a decreased ability to meet one's own daily needs (Besdine 1990).

[1] Functional ability falls within the general context of disability. According to the International Classification of Impairments, Disabilities and Handicaps, disability means "any restriction or lack (resulting from an impairment) of ability to perform an activity in the manner or within the range considered normal for a human being" (WHO 1980, Fillenbaum 1996).

As a functioning member of the community, a person of any age in all cultures must be able to move around the "house" and interact with the surroundings to some degree (Beall and Eckert 1986). Walking out of doors, moving up and down steps and caring for personal needs are necessities for continued independent life in any community. In many countries, elderly people often make a significant contribution to family welfare and income by their involvement in income-generating tasks (Plate 2.1), house maintenance (Plate 2.2), child care and food preparation, thus freeing younger adults for wage-earning (Barker 1989, Ara 1994, Schade and Apt 1986). Increasingly, they may also be taking care of younger adults who are dying or debilitated from diseases such as tuberculosis (TB) and Acquired Immunodeficiency Syndrome (AIDS) or drug addiction, and taking on the roles of surrogate parents to the children of those younger adults (Joslin and Brouard 1995).

Continued participation of elderly people in the daily life of the household will depend on their level of functional ability. It may well also affect the way they are treated and respected (Martin 1990, Goldstein *et al* 1983, Ara 1994). There is evidence that, in many developing countries, especially in the growing urban areas, the extended family and traditional coping systems for older people are beginning to show signs of strain (Schade and Apt 1986, Martin 1988, Hashimoto *et al* 1992). Thus understanding the mechanisms behind the maintenance of functional ability, and devising strategies to preserve independent living for as long as possible, will have a beneficial impact on millions of elderly people and their families in a number of physical, economic, social and emotional ways. The maintenance of good nutritional status may be an important contributory factor in this. For example, if the functional ability of an elderly "bread-winner" or care-giver is compromised because of underweight, the children of that household are at high risk of becoming underweight themselves (Bailey and Ferro-Luzzi 1995). Thus, although specific terms like "independence" and "quality of life" may not mean the same, or have the same value in all cultures, preserving functional ability is of crucial importance for elderly people and their families in developing countries.

Plate 2.1 Elderly blacksmith

Plate 2.2 Elderly man making stick fence

In summary, functional ability assessment attempts to describe the impact of a variety of pathobiological processes and morbid conditions on the daily life of elderly people (Wallace and Rohrer 1990). Despite the fact that many of these processes and conditions are still incompletely understood in old age, functional ability assessment techniques have been applied at both individual and population levels to obtain needs assessments information and assist in some subsequent course of action, such as assigning goals and monitoring progress. Functional ability assessment has long been the cornerstone of rehabilitation. With population ageing, it is fast becoming the cornerstone of public health (Branch and Meyers 1987).

There is no universally accepted standard with which to measure physical function or functional ability (Guralnik *et al* 1989, Siu *et al* 1993). Many instruments for functional ability assessment have been developed, none of which are particularly refined, easily conducted or results interpreted. These have been extensively reviewed elsewhere (Kane and Kane 1981, Branch and Meyers 1987). The next two sections concentrate on functional ability assessment using self-report techniques, and tests of physical performance which reflect some important dimensions of activities of daily living.

2.2 Functional ability assessment using self-report questionnaires

Self-reporting is the most common type of functional ability assessment in geriatric programmes and research, with a long history and wide applications (Liang and Jette 1981). It has also been widely used to obtain information on perceived health status and about recent disability or surgery that may affect physical functioning. Self-reporting involves merely asking subjects, (or family member/carer in proxy reporting), whether they are capable of performing a task by themselves or with assistance. Two main types of self-report instruments have been developed.

Firstly, an **Activities of Daily Living (ADL)** self-report questionnaire assesses basic mobility and essential self-maintenance skills. Three decades ago, Katz and colleagues

(1963) demonstrated that the sequence of recovery of six "basic" activities of daily living[2] (ADL) had an intrinsic hierarchical order of difficulty among disabled elderly. Subsequently it has also been demonstrated that the same sequence of activities resembled the sequence of development of these same functions in child development, and is mirrored in old age in many societies (Katz and Stroud 1989, Fillenbaum 1996). In developing and testing their index of ADL, the Katz team not only first facilitated the measurement of functional ability, but also highlighted the importance of this outcome in the context of daily life (Spitzer 1987). Their original work has now been expanded and developed so much that for any research or programme involving the elderly the ability to perform ADLs has become a standard variable in the analyses (Wiener *et al* 1990). ADL performance has been shown to decline with age, and to be associated with levels of physical disability, mobility, flexibility, strength and physical activity (Gosman-Hedstrom 1988, Langlois *et al* 1996).

The second type is the **Instrumental Activities of Daily Living** (IADL) self-report questionnaire. Developed a few years after the Katz ADL by Lawton and Brody (1969), the IADL instrument deals with more complex activities such as housekeeping, shopping, handling money and wider mobility including using public transport. These activities are relevant to a minimally adequate social life in certain socio-cultural settings. In western settings, IADLs are more sensitive in detecting modest functional loss than ADLs, and research has also suggested that a hierarchical relationship exists between some ADL and IADL items so that a combined scale with high discriminant and predictive validity can be applied (Katz 1983, Spector *et al* 1987). However, some IADLs are gender-specific, and many are inappropriate for many non-western societies without validation (Guralnik and Lacroix 1992).

Although there are over 200 published indices that assess ADLs and IADLSs, the majority have not been adequately validated (Shah *et al* 1989). Despite this, the general consensus on self-reports is that they are deemed to give a reasonable approximation.

[2] The six ADLs are : feeding, continence, transfer or moving in and out of bed or chair, attending to self at the toilet, dressing and bathing

obtained relatively quickly. There is even evidence that they identify more accurately levels of functional impairments in elderly people than do clinical or nursing judgements (Pinholt *et al* 1987), and are predictive of death both in the institutional and the community setting (Reuben *et al* 1992, Scott *et al* 1997).

The ability to get around in one's environment is a basic human function necessary for independent activities of daily life (Wolfson 1992). Loss of **mobility** is a principal cause of a limited quality of life and increased dependence in elderly people. In a longitudinal study, decreased mobility was shown to have an association with the risk of mortality (Laukkanen *et al* 1995). Descriptions of mobility performance tests such as timed walks in elderly people can be found in the works of Tinetti (1986) and Podsiadlo and Richardson (1991). However, the Rosow-Breslau scale is usually recommended (Rosow and Breslau 1966, Fillenbaum 1996) which includes self-report questionnaires on the ability to walk half a mile and climb a flight of steps.

2.3 Physical performance tests

More objective, multi-dimensional and quantifiable information on functional ability can be obtained from performance measures. These are thought to add more appropriate information on overall functional ability as they simulate some physical attributes essential to the satisfactory performance of ADLs, and offer the potential to overcome some of the limitations of self-reports (Branch and Meyers 1987, Guralnik *et al* 1989, Reuben and Siu 1990, Seeman *et al* 1994, Sinoff and Ore 1997). Physical function measures have been found to be strong predictors of a number of important outcomes such as risk of death, institutionalization and falls (Guralnik *et al* 1995), and ADL independence and future disability in older people (Gill *et al* 1997). The wider use of objective measures of functional ability to supplement the traditional self-report measures in parallel with classic disease-orientated techniques is increasingly recommended (Williams and Hornberger 1984, Guralnik *et al* 1989, Besdine 1990, Reuben *et al* 1992, Gill *et al* 1995, Kempen *et al* 1996).

Despite the lack of a "gold standard" for overall functional ability, performance tests are already routinely combined into batteries of tests for use in the clinical setting as part of physical and occupational therapy. However, they are still not widely incorporated into the assessment of free-living elderly, or for population-based research. Batteries of simple performance tests are now being utilised in some surveys in Europe (Bassey 1990b), Scandinavia (Heikkinen *et al* 1993) and North America (e.g. the NHANES III), but similar information is very limited from elderly people in the less developed world (Guralnik *et al* 1989, Fillenbaum 1990, Fernando and Seneviratna 1993).

Functional ability has numerous dimensions or components. Its assessment must be similarly constructed (Branch and Meyers 1987). The following section describes the most important dimensions that can be assessed directly by physical tests : mobility, manual ability, flexibility, upper and lower body muscular strength, and psychomotor function.

2.3.1 Manual dexterity

The ability to use one's hands proficiently in everyday activities is required for the majority of ADL skills. A decrement in hand function causes disablement in basic ADLs and may be one of the earliest markers of impending functional decline (Jette *et al* 1990). Several versions of a simple Timed Manual Performance Test have been developed by Williams and co-workers (1982, 1994) which have proved to be highly predictive markers of functional dependency (Ostwald *et al* 1989, Mowat *et al* 1992), and mortality (Williams and Hornberger 1984). The test battery involves the performance of common place tasks such as opening fasteners, simulating eating, picking up small objects and copying a simple sentence. However, some of these may be inappropriate for use in other cultures or where the elderly population is largely illiterate. For example, a wide variety of fasteners may be unfamiliar so a simple lock and key test may suffice.

2.3.2 Flexibility and range of motion

Decreases in flexibility also typically occur with advancing age. Joints become stiff and painful, articulating surfaces are damaged, range of motion is reduced and there is accompanying gradual lack of use (Badley *et al* 1984, Bassey *et al* 1989 a, b). The individual's ability to undertake daily activities is consequently reduced. Simple, reliable, and socially acceptable performance tests, such as the earlobe test (Bergstrom *et al* 1985), sit-and-reach (Rikli and Busch 1986) and shoulder abduction (Bassey 1990 b), can assess flexibility and range of motion in elderly people living in the community. These tests have functional relevance as they simulate important movements in activities of daily life such as dressing and grooming, hanging out washing, and using shelves. Deterioration in this dimension has been linked to reduced independence (Jette *et al* 1990).

2.3.3 Muscular strength

One of the most important factors which may limit independence in functional ability is muscle weakness (Pearson 1985). Loss of muscle mass with increasing age has been demonstrated both cross-sectionally and longitudinally, using techniques such as computed tomography. Such work has documented fewer muscle fibres, a reduced cross-section of muscle area, a decrease in density of muscle fibres and an increase in intramuscular fat with increasing age, all of which are subject to a large amount of normal variation (Kuczmarski 1989, Chumlea *et al* 1991, Roubenoff and Kehiyas 1991, Frontera *et al* 1991). Reduced physical activity with age also plays an important part in muscle atrophy and loss of muscle strength, some of which has the potential for improvement with training (Frontera *et al* 1988, Fiatarone *et al* 1990, Larsson 1991), even in the presence of diseases like arthritis (Fisher *et al* 1991) and AIDS (Evans *et al* 1998). By age 70 it is estimated that muscle strength is about 35 to 45 % lower than its peak value in youth (Young *et al* 1984, Vandervoort *et al* 1986, Rutherford and Jones

1992, Young and Skelton 1994). However, this decline varies according to muscle group, and by sex (Grimby and Saltin 1983, Schultz 1995).

Physical performance tests of the muscular strength dimension of functional ability in older adults have concentrated mainly on maximal voluntary isometric[3] contraction (MVC) tests of handgrip strength, and of elbow flexor and adductor pollicis muscles of the hand and arm, and plantor flexor and quadriceps muscles in the leg.

The **power grip of the hand** requires the combined action of a number of muscles in both the hand and forearm. It is a familiar action of functional importance for many activities of daily life (such as transferring tasks, holding on to supports, opening containers, using tools, and dressing). Low handgrip strength implies considerable functional disadvantages (Kallman *et al* 1990, Bassey and Harries 1993), and may be a good marker for frailty in the elderly because of its close relationship with ADL (Schroll *et al* 1997, Davis *et al* 1998) and IADL (Judge *et al* 1996) activities, with mobility (Jette *et al* 1990, Rantanen *et al* 1994, Laukkanen *et al* 1995, Gosman-Hedstrom 1988), and with risk of falls (Wickham *et al* 1989). Handgrip strength has been shown to be more sensitive than body composition measurements to predict postoperative complications and mortality (Klidjian *et al* 1980, 1982, Phillips 1986, Webb *et al* 1989, Guo *et al* 1996). A recent study from India reported that the measurement of handgrip strength is a simple but useful functional variable that can be used to classify individuals with underweight in both clinical and community settings, and may represent a valuable adjunct to BMI (Vaz *et al* 1996). Handgrip can be measured easily in the field setting using a strain-gauge dynamometer (Bassey 1990 a).

There is evidence of large differences between young and old adults in **quadriceps muscle strength** (Young *et al* 1984, Hurley *et al* 1998), and of a progressive decrease with age, demonstrated in women (Rutherford and Jones 1992). Quadriceps muscle strength is also of great functional significance in performing daily activities. For

[1] isometric refers to muscle contraction with constant muscle length (i.e. no limb movement)

example, the muscle force of the leg extensors can be critical for the ability to stand up from a chair (Bassey *et al* 1992, Young 1986, Alexander *et al* 1991), from the floor (Brown *et al* 1995, Alexander *et al* 1997), or to climb stairs (Fiatarone *et al* 1994). It appears that lower body dysfunction caused by lack of strength in this muscle will adversely affect weight-bearing activities (Vandervoort *et al* 1990), postural stability and confidence (Hurley *et al* 1998), mobility, walking gait and speed (Brown *et al* 1995, Rantanen *et al* 1998), postural balance (Tinetti *et al* 1994 b, Liang and Chumlea 1998), independence in transferring (Bergstrom *et al* 1985) and proneness to falls and fractures (Bastow *et al* 1983, Nevitt *et al* 1989, Wickham *et al* 1989). All these may also be partly associated with declines in proprioception[4] acuity, which may itself be caused by age-related changes in muscle function (Hurley *et al* 1998).

Whilst laboratory-based studies use fixed power-rigs or chair dynamometers to measure quadriceps power and strength, community studies can use the ability (time taken) to rise repeatedly from a chair without the use of hands. This was developed as a simple standardised test relevant to activities of daily life that can indicate the level of lower body strength and power and which correlates strongly with the rig/chair methods (Csuka and McCarty 1985).

2.3.4 Psychomotor function

The ability of an individual to process, and react to, specific external information, is considered an important indicator of overall cerebral status (Panton *et al* 1990). There is an age-related decline in psychomotor function (Fozard *et al* 1994, Corey-Bloom *et al* 1996) which is also inter-related to other factors such as inactivity, disease and underweight (Kemper and Binkhorst 1993). Deterioration of this dimension of functional ability will jeopardise capacity to cope with independence in ADLs and

[4] Proprioception : conscious and unconscious awareness of body position, movement and forces acting on the body (Hurley *et al* 1998).

IADLs through increased reaction and performance time especially of complex movements and reduced motor control (Kemper and Binkhorst 1993, Joseph 1988).

Most research in this area has focused on indirect cross-sectional investigations on age, physical fitness and activity habits, and psychomotor speed (Rikli and Busch 1986, Spirduso 1980, Carter *et al* 1993). Simple and choice reaction times, tapping speed (Spirduso 1980) and a plate-tapping test (Bassey 1990 b) all provide a view of neuromuscular performance, and have been recommended to measure the speed and co-ordination skills of this dimension in elderly people in community studies (Yates *et al* 1993).

2.4 The anthropometric assessment of underweight in elderly people

Although anthropometry is now established as a routine part of nutritional status assessment, anthropometric data on community-living older adults in developing countries are still very limited (Gross and Monteiro 1989, Macfadyen 1989, James and Ralph 1994, WHO 1995). This represents a serious cause for concern given the demographic scenario outlined in Chapter 1.2. For the purposes of assessment, screening, and monitoring the effects of interventions, more information is urgently needed to address the knowledge gap concerning the nutritional status of this population group.

The anthropometric measurements and indices routinely used in children and young adults, particularly BMI (weight(kg)/stature(m)^2) and mid-upper arm circumference (MUAC), are not entirely appropriate for use in older age groups for a number of reasons. These are outlined in reviews of methodologies and interpretation of anthropometric and body compositional measurements of elderly people (Roe 1986, Chumlea *et al* 1989, Chumlea and Baumgartner 1989, Durnin 1989, Kuczmarski 1989, Lehmann 1989, Kelly and Kroemer 1990, WHO 1995). Major problems are the extent of individual variability, and the reliability of measurements in the anthropometric assessment of elderly people. Responding to the lack of information about anthropometric norms in the different sexes and amongst different racial groups in the elderly age group (Chumlea and Baumgartner 1989), concerted efforts are now underway to develop appropriate anthropometric indicators for older adults and elderly people (WHO 1995).

2.4.1 Stature and the problem of kyphosis

Stature is a crucial component of nutritional assessment through the derivation of BMI. If we define "stature" as the true maximum vertical height of a person (Roubenoff and Wilson 1993), there is no doubt that height is a dubious measure of stature in elderly people (Trotter and Gleser 1951, Miall *et al* 1967, Dequeker *et al* 1969, Kalliomaki *et al* 1973, Cline *et al* 1989, Chandler and Bock 1991, WHO 1995).

We know that man shortens with age after achieving skeletal maturity. The reasons for this include a general thinning and compression of all cartilaginous discs between vertebrae, as well as a weakening or imbalancing of muscle groups leading to the inability to maintain a fully erect posture (Brown and Wigzell 1964, Dequeker *et al* 1969, Rossman 1979, Milne and Williamson 1983, Cline *et al* 1989, Haboudi *et al* 1990, Plato 1994). Although there appear to be gender and racial differences in the onset and rate of these phenomena (Dequeker *et al* 1969, McPherson *et al* 1978), overall evidence from longitudinal studies suggests that a male of about 60-64 years old would be 5-6 cms, and by 80 years 7-8cms, shorter than he had been in his mid 20s.

A measurement of height on subjects with curvature of the upper thoracic spine or **kyphosis**, which affects the ability to stand fully upright, will underestimate real stature. A recent study of over 6,000 women aged 55-80 years found that a 15 degree increase in kyphosis was associated with losing more than 4 cms in height, after adjusting for age (Ensrud *et al* 1997). The prevalence and extent of thoracic kyphosis increases significantly with age (Milne and Williamson 1983, Ensrud *et al* 1997) with effects on the spine beginning as early as 40 years of age, especially in women (Fon *et al* 1980). Rates can be high amongst elderly people[5] (Ensrud *et al* 1997). Longitudinal analysis has also shown that survival time in elderly people decreases as kyphosis increases (Milne and Williamson 1983). Spinal curvature can be assessed visually, or measured more accurately by non-invasive (surveyor's flexicurve, goniometer) or invasive techniques (radiography) (Loebl 1967, Milne and Lauder 1974, Fon *et al* 1980, Wigzell *et al* 1981, Milne and Williamson 1983, Leech *et al* 1990).

The many difficulties of measuring height accurately in old age create a great potential for underestimating stature, and consequently overestimating BMI, categories of which are recommended to define underweight and overweight in adults (James *et al* 1988, WHO 1995, Rabe *et al* 1996, Deurenberg *et al* 1989 b)[6]. Surprisingly, there are no recommendations on how best to measure height loss with age, the extent of kyphosis or the degree of angulation of spinal curvature, and when standing height should not be measured in elderly people because of these (WHO 1995). Many studies on the elderly continue to use height to derive BMI, or fail to report the proportion of subjects affected by spinal curvature so the extent of this bias is unknown (Steele and Chenier 1990, Yassin and Terry 1991, Rea *et al* 1997, Lancia *et al* 1997).

2.4.2 Armspan as an alternative estimate of stature

Alternatives measurements of stature are available. These include armspan, halfspan[7], demispan[8] and knee height[9]. The estimation of the stature of a dead individual from the length of the arm and leg bones has long been common practice in forensic science and in examining archaeological remains (Harrison *et al* 1977). Since the early work of

---

[5] For example, 16% and 30% in two UK studies (Kwok and Whitelaw 1989, Pearson *et al* 1985); 10% in a US study (Damon *et al* 1974)

[6] See Table 2.1

[7] Halfspan is the measurement of one outstretched arm from finger tip to the mid-sternal notch. It can be doubled to produce an armspan measurement

[8] Demispan is the distance between the finger roots of one arm stretched laterally and the mid-sternal notch (Bassey 1986).

[9] Knee height is the distance between the bottom of the heel pad and the top of the knee when both are flexed at 90 degrees and is measured in a sitting or recumbent position with a sliding calliper (Chumlea *et al* 1987, Kelly and Kroemer 1990).

physical anthropologists Trotter and Glesser in the 1950s (1951, 1958), there has been increasing use of other linear skeletal dimensions in living people as substitutes for height on the basis that they all remain stable with age and correlate highly with stature. Thus they can be used to estimate the maximal achieved height of the individual regardless of actual height in old age (Chumlea *et al* 1989, Mitchell and Lipschitz 1982 a).

Armspan is the horizontal distance between the longest finger tips of both arms outstretched at 90 degrees to the vertical axis with palms facing forward, and includes the width of the shoulders and length of both arms and hands (Figure 2.1). Armspan is highly correlated with height at maturity[10] and changes little if at all with age (Brown and Wigzell 1964, Dequeker *et al* 1969, Rossman 1979, Mitchell and Lipschitz 1982 b, Steele and Mattox 1987, Kwok and Whitelaw 1989, Steele and Chenier 1990, WHO 1995). However, despite the strength of correlation coefficients[11], and the temptation to accept the plausibility of the notion that armspan equals height at maturity in adulthood, we should question this universal equal relationship in the context of individual natural variation in the human species and variation between racial groups (Harrison *et al* 1977).

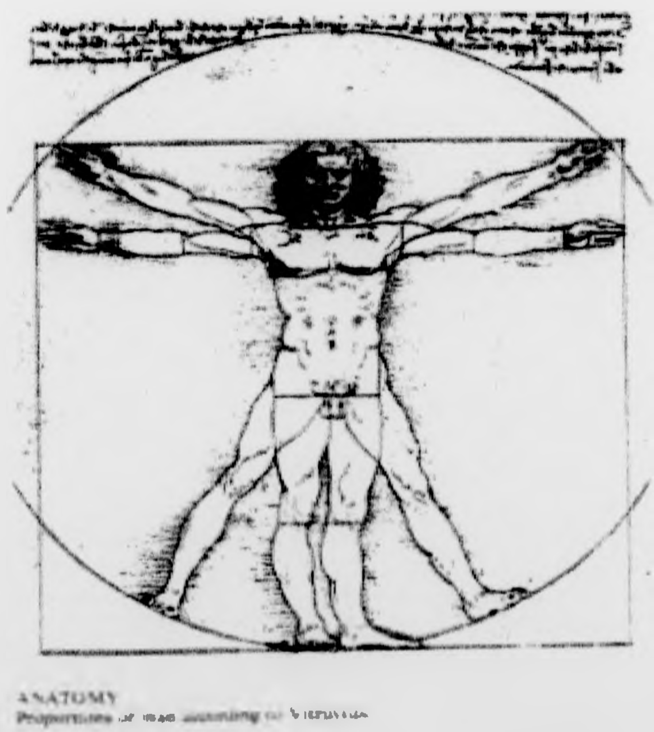
There is certainly some evidence that the relationship differs by gender (Engstrom *et al* 1981, Hibbert *et al* 1988, Kwok and Whitelaw 1991, Parker *et al* 1996 a). However, available evidence on racial differences in the relationship between height and limb lengths suggest that, with the exception of Negroes, the affects on the calculation of height at maturity may not be very significant, at least at population or group level (Davenport 1921, reported in Martin *et al* 1988, Trotter and Glesser 1951, Steele and Mattox 1987, Steele and Chenier 1990, Reeves *et al* 1996). For Caucasians, the evidence shows that armspan in groups of young adults is approximately equal to height.

[10] The notion that armspan approximates height at maturity is hardly new. Vitruvius Pollio, a Roman architect of the first century AD, noted : "if one stretches from the sole of the foot to the top of the head, and applies the measure to the out-stretched hands, the breadth will be found equal to the height (cited in Tanner 1981). This idea was taken up graphically by Leonardo da Vinci in his famous "diagram of man" at a time when artists were attempting to define ideal types by numerical rules.

[11] The lowest correlation coefficients are thought to reflect the fact that height had already begun to decline in the subjects studied (Steele and Mattox 1987, Steele and Chenier 1990, Kwok and Whitelaw 1991, Yassin and Terry 1991, Rahe *et al* 1996)

However, a proportionality existing between upper (and lower) limbs and the spine may not hold true at the individual level (Jarzem and Gledhill 1993, Kwok and Whitelaw 1991, Allen 1989). More research is undoubtedly needed, particularly amongst those of non-European ancestry, looking at the relationship between height and limb lengths in young adults of different racial groups in their 20s and 30s before any loss in height or postural change begins to occur. In the context of this thesis, data are very scarce for Indians. Pathak (1978) reported that "arm stretch appears to be well related to total height in Indians" but gave no figures.

Figure 2.1 Vitruvian Man by Leonardo da Vinci



Demispan is also highly correlated with stature (Bassey 1986). However, the disadvantages of demispan are that it cannot be used directly in the calculation of BMI but rather requires the application of two sex-specific indices based on regression equations developed from only limited data (Lehmann *et al* 1991, Golden 1996), and that standardised cut-off points, for their use as indicators of underweight or overweight, are not available (Donkin *et al* 1998). Similarly **knee height** requires the application of sex- and race- specific regression equations of height from knee height derived from data on whites and African-Americans only in the USA (Chumlea and Guo 1992, WHO 1995).

In summary then, armspan is thus a much more straightforward choice. The armspan value can merely be substituted for height in the derivation of BMI (weight(kg)/armspan(m^2) (Kwok and Whitelaw 1989, Rabe *et al* 1996). However, a better approach, as recommended by WHO (1995), is to derive height from armspan in a younger adult group for the local population being studied and to use that height in the BMI equation (weight(kg)/height-derived-from-armspan(m^2)).

2.4.3 BMI

From evidence based on studies in different population groups, BMI is highly correlated with the fat mass of the body, is a reasonably good index of the body energy stores as fat (Chumlea *et al* 1984 b), and in some age groups is highly correlated with fat-free mass (Norgan 1994). Low BMI reflects a low body energy store and a low fat free mass or lean body mass for a given stature. Thus, BMI appears to be a plausible choice for the anthropometric assessment of nutritional status in adults for epidemiological studies (Shetty and James 1994).

The recognised categories of underweight for adults up to 65 years of age using BMI are shown in Table 2.1 (James *et al* 1988, Ferro-Luzzi *et al* 1992, WHO 1995).

Table 2.1 Classification of nutritional status using cut-offs of BMI

Grade	Level of nutritional status	BMI range
III	Underweight - severe	< 16
II	Underweight - moderate	16 - 16.9
I	Underweight - mild	17 - 18.4
Normal	Normal	18.5 - 24.9
Overweight	Overweight	≥ 25

There has been recent criticism about the use of BMI as a marker of underweight in elderly people in developing countries (Pelletier and Rahn 1998). This is because BMI is influenced by declining bone mass and changes in the hydration of the fat-free body with age, changes which are still poorly understood in old age but which will limit the specificity of BMI with age amongst normal individuals compared to those with disease. BMI can underestimate body fat in elderly people because of the higher proportion of internal fat than in younger adults (Deurenberg 1989b).

The use of these BMI cut-offs as health indicators has also been questioned. A comparative study of low BMI and morbidity amongst adults in 4 developing countries reported that the threshold at which morbidity begins to rise is generally not consistent with the suggested cut-off on BMI 18.5 kg/m^2 (Garcia and Kennedy 1994). However, until many of these issues are better documented, BMI will continue to be used as the main anthropometric assessment technique for adults, including the elderly.

2.4.4 Body composition using anthropometry

Ageing is associated with many changes in body composition (Deurenberg *et al* 1989 b). The greatest discrepancies between techniques of assessing body composition occur in older adults (Bemben *et al* 1998). Important changes affecting the measurement and interpretation of the body composition of older people are :

- loss of muscle mass with advancing age (sarcopenia)
- increase in body fat, especially internally
- redistribution of fat from limbs to trunk
- decrease in body water
- muscle tissue replaced by intramuscular fat (marbling)
- changes in the compressibility and elasticity of skin

All these changes limit the validity of the traditional two-compartment model (body fat and fat-free mass, FFM) of body composition. A four-compartmental model (water, bone, fat and FFM) is less flawed but its greater complexity prevents the application of indirect anthropometric methods of assessing body composition without the use of strictly validated sex- and race -specific equations which are still largely unavailable for the older age groups (Kuczmarski 1989, Steen 1989, Durnin 1989, Chumlea and Baumgartner 1989, Deurenberg *et al* 1989a , Chumlea *et al* 1991, Reilly *et al* 1994, Visser *et al* 1994, Gallagher *et al* 1997).

Skinfold thickness measurements are commonly used to estimate body density from which body fatness (% of body weight as fat) then fat content (fat mass) and fat-free mass can then be derived using a choice of equations. The most widely used equations for the anthropometric assessment of body composition are those developed by Durnin and Womersley (1974). However, because such equations do not account for the decrease in fat-free mass or body density-associated bone mineral content loss with age, their use will underestimate the fat content and overestimate the fat-free mass. Even though new equations have been developed to alleviate this problem (Deurenberg *et al* 1989a, Lohmann 1991), it is still generally thought that they are specific only to the populations on which they were drawn up. The calculation of body density and fat-free mass from skinfolds in elderly people is also problematic because of insufficient data to validate the reliability of skinfolds in elderly people (Lohmann 1981, Cronk and Roche

1982, Durnin 1989). Such errors and limitations of many assessments of fat and fatness mean that accurate estimates of body composition of an individual elderly person are probably not yet possible (Reilly *et al* 1994).

There is no well established method of accurately estimating **muscle mass** in *vivo* (Baumgartner *et al* 1992, Heymsfield *et al* 1992 a). Fat-free mass is composed of protein, water, glycogen and mineral. One third to one-half of the protein is in skeletal muscle, with the remainder divided among other lean tissues (McMahon and Bistrian 1991). Again, although in field-based studies anthropometric measurements are still widely used to estimate muscle mass, interpretation is based on assumptions that are known to have large errors and limited validity amongst elderly people.

The measurement of **mid-upper arm circumference (MUAC)** is used as a measure of subcutaneous fat and muscle tissues in the arm, and has long been established as a marker of wasting malnutrition in children (de Onis *et al* 1997). Although MUAC by itself does not distinguish between fat and muscle, it does give a more direct estimate of the extent of peripheral tissues reserves of fat and protein than either total body weight or BMI, and changes do tend to parallel changes in muscle mass measured more directly (Gibson 1990). MUAC cut-offs for underweight and wasting have recently been recommended for adults in emergencies (James *et al* 1994, Ferro-Luzzi and James 1996). Details are given in Table 2.2.

Table 2.2 Classification of underweight using cut-offs of MUAC

Grade	Level of nutritional status	MUAC range (cms)	
		Men	Women
III	Wasting - extreme	< 16.9	< 15.9
II	Wasting - severe	17 - 19.9	16 - 18.9
I	Underweight - mild	20 - 22.9	19 - 21.9
Normal	No wasting or underweight	≥ 23	≥ 22

These cut-offs were based on rounded values for -0.5, -1.0, and -1.5 standard deviations (SD) of the range of MUAC means from a number of studies on adults 18-60 years in developing countries[12].

Decreases in **calf circumference** also reflect recent weight loss of both adipose and lean tissue (McMahon and Bistrian 1991). Low values of calf circumference have been found to relate better to degrees of malnutrition than low BMI, particularly in elderly women (Chumlea *et al* 1995). From their own research, Patrick and co-workers (1982) considered calf circumference to be a more sensitive measurement of the loss of muscle mass in the elderly than MUAC, a stance which has recently been endorsed by WHO (1995). However, calf circumference is used less frequently than arm circumference (Chumlea *et al* 1995), and very little data exist on calf circumference from elderly people living in less developed countries.

Arguably the most useful indirect way of detecting wasting in elderly people is to make an estimation of the depletion of muscle mass by calculating **arm muscle area** (AMA) (Bistrian 1980, Heymsfield *et al* 1982 b, Roe 1986). Using established equations, MUAC and triceps skinfold thickness are used to calculate mid-arm muscle area. Here again the appropriateness of these equations may be questionable due to their basic assumptions such as the cylindrical nature of the limb, a symmetric distribution of the fat around the arm, and a constant fraction of bone to muscle area (Heymsfield *et al* 1984 a). Bone density changes with age may affect the diameter of the humerus, and differences in skin compressibility occur with age (Himes *et al* 1979). Although mid-upper arm muscle area more adequately reflects the true magnitude of tissue changes than does mid-upper arm circumference alone, overestimation by as much as 20-25 %[13] was found to occur when compared to actual values from more direct laboratory measurements such as computerized tomographic cross sections of the upper arm in adults (Heymsfield *et al* 1982 a) and from magnetic resonance imaging (Baumgartner *et al* 1992). Revised equations adjusting for the cross-sectional area of bone have been

[12] India, China, Papua New Guinea, Mali, Zimbabwe, Somalia, Ethiopia, Senegal
[13] the higher value relates to greater degrees of adiposity

devised (Heymsfield *et al* 1982 a). Although these have not yet been validated for use with elderly subjects (Chumlea *et al* 1989), the corrected equations (corrected arm muscle area, cAMA) are thought to work better in thinner rather than fat individuals (Forbes *et al* 1988). In clinical studies the level of AMA correlates well with both serum albumin and with percentage of weight loss (McMahon and Bistrian 1991).

2.5 Underweight, and impaired functional ability and poor physical performance - are they related ?

This is a difficult question to answer for a number of reasons. Firstly, the focus of this research is the anthropometric assessment of underweight. Anthropometric indicators are simple predictors of subsequent health and mortality that infer information about body size and mass and amount of skeletal muscle and fatness, but these inferences are only meaningful as long as body systems are in homeostasis. They will change under disease and ageing conditions which alter the relationships of anthropometric measures to given outcomes, including functional ability (Chumlea *et al* 1997 b). Many of these changes are still poorly understood. Another major constraint to our understanding of this question is that we are concerned with community-living elderly people in developing countries on whom data for both underweight and functional ability are scarce (Macfadyen 1992). Despite the obvious differences, much will have to be inferred from studies based on adults or elderly people living in the developed world.

In the institutional setting, there is evidence that proper evaluation of an elderly patient's nutritional status is important because it has a relationship with mortality and morbidity outcomes (Friedman *et al* 1985). Low MUAC was found to be a strong predictor of subsequent morbidity in elderly patients in the USA (Sullivan and Walls 1994). A significant correlation between measures of nutritional status and risk of developing major complications, as well as mortality, was found in a study of elderly admissions to a geriatric hospital (Sullivan *et al* 1990). The nutritional impact on outcome was also found to be independent of all the other non-nutritional variables known to modulate morbidity and mortality. Non-nutritional factors of importance included functional status. A similar effect of poor nutritional status on risk of death was shown for community-living elderly in a longitudinal study of over-70 year olds in New Zealand. Low (<5th percentile) levels of BMI, cAMA and triceps skinfold thickness were associated with a significantly increased risk of subsequent mortality (Campbell *et al* 1990). A strong association between feeding dependency and both low BMI and weight loss has been documented amongst elderly nursing home residents (Fiatarone *et al* 1994).

There is far less evidence of any nutritional effects on functional ability for elderly people still living in the **community** (Institute of Medicine, 1990, Department of Health 1993, Payette *et al* 1994). Some major studies on nutrition in the elderly did not include any functional ability assessments (e.g. Boston Nutritional Status Survey). The EURONUT SENECA study included self-reports in initial assessments only later adding physical performance measures (EURONUT 1996). Most large-scale surveys of functional ability in elderly people have included health but not nutritional assessments (Heikkinen *et al* 1983).

The use of BMI for assessing underweight in adults is now being applied world-wide as the consequences of low BMI in terms of functions such as morbidity (Strickland and Ulijaszek 1993, Garcia and Kennedy 1994), work performance (Spurr 1987, Satyanarayana 1989, Pryer 1993), and even mortality become clearer (Henry 1990, Shetty and James 1994, James 1994, Allison *et al* 1997, Scott *et al* 1997). A trebling of mortality rates in Indian men (not elderly) with BMI less than 16 compared with those with BMI above 18.5 has been reported (Reddy 1991, Ferro-Luzzi *et al* 1992). For elderly people, however, the consequences of low BMI, and other anthropometric indices, in terms of every day activities and functional ability are still relatively unexplored.

A high BMI was found to be a strong independent risk factor for impaired function (reported difficulty in performing 3 or more ADL's, and some physical dimensions such as manual dexterity and flexibility) in a study of ambulatory old women in the USA. (Ensrud *et al* 1994). Similarly, a high BMI was also found to be strongly associated with poor performance in physical tests in an analysis of 3 large community-based studies of elderly in the USA (Seeman *et al* 1994), and increased the risk of disability and impaired mobility amongst older cohorts in the National Health and Nutrition Examination Survey (NHANES) - I data set (Ettinger *et al* 1994, Launer *et al* 1994). A BMI over the 75th percentile predicted loss of physical mobility assessed by scoring responses to task-related questions in a US national ageing survey (Jette *et al* 1990). BMI was negatively associated with five[14] out of seven physical performance tests as well as ADLs and IADLs in a study amongst elderly Hawaiians of Japanese origin, who tended to overweight[15] (Davis *et al* 1998). Women with a greater BMI had more difficulty in undertaking ADLs and IADLs than women with lower BMI. The Framingham Disability Study found that excess weight had an influence on elderly people's ability to perform basic life activities (Jette and Branch 1981), and being overweight was not favourable to ADL function amongst Japanese elderly women (Haga *et al* 1991). In contrast, Cauley and co-workers (1987) reported no relationship between grip strength and obesity measured by BMI in menopausal women, and an analysis of the American Longitudinal Study of Ageing found no relationship between excess weight loss and ADL functioning (Boult *et al* 1994). However, all these studies are based on elderly groups in western high income societies, amongst whom the emphasis is mainly on the risks associated with being overweight (high BMI) rather than underweight.

A recent UK study found a significant relationship between low BMI and the ability to carry shopping bags amongst community-living elderly people (Donkin *et al* 1998). But much stronger evidence of the relationship between both high and low extremes of nutritional status and functional ability impairment amongst community-living elderly is revealed in the work of Galanos and co-workers (1994). Conducting a secondary analysis of longitudinal data on people over 65 years old from the US NHANES-I Epidemiologic Follow-up Study (1982-1984), BMI[16] and functional status (assessed by

[14] including handgrip strength
[15] mean BMI of 23 (SD 4.0)
[16] based on height with no mention of height loss related to kyphosis or bent posture

three different self-report protocols, including the Katz ADL), were entered into logistic regression models along with 22 potential confounders (which included chronic disease, vision problems, cognitive status, socio-economic status and medications). The authors defined "normal" as a BMI between 21 and 30, based on the 15th and 85th percentiles of US national reference data. There was an apparent dose-response relationship between high and low extremes of BMI and functional risk while controlling for the potential confounders in the multivariate model. The authors stated :

> *"the greater the extreme of BMI (either high or low), the greater the risk for functional impairment".*

These results support the notion of a U-shaped relationship between BMI and functional ability in which BMIs at both ends of the spectrum have a detrimental effect on functional outcomes.

Some data linking nutrition status and particular dimensions of functional ability are inconsistent. For example, in terms of the flexibility and range of motion dimension of functional ability, Bassey and her team (1989 b) reported that BMI was significantly negatively related to shoulder range in women, and hypothesised that compression of fatty tissue will affect stiffness of joints and limit joint range, particularly in the presence of low muscle strength. In contrast, a Swedish study found that "lean" subjects reported more shoulder problems, more restricted range of motion and increased need for assistance in ADLs than "non-lean" individuals (Bergstrom *et al* 1985). Similar evidence of clear nutritional associations with psychomotor function and manual dexterity in elderly people has not been established.

Malnutrition can predispose to impairment of **muscular strength** dimension of functional ability if weight loss reflects the effects of loss of lean body mass. Skeletal muscle may decline by more than 60% during prolonged starvation (Durnin 1994). Sarcopenia is a generic term for the age-related loss of skeletal muscle mass (Dutta *et al* 1997). As yet, there is only limited understanding of the public health significance of sarcopenia and the mechanisms through which sarcopenia leads to an increased risk of morbidity, mortality, disability and impaired immunocompetence (Baumgartner *et al* 1995, Pahor and Kritchevsky 1998). Roe (1986) reported that arm muscle area can be used to detect declining muscle mass and muscle wasting and its functional consequences in elderly people as it had already proved predictive of morbidity and mortality in young adults (Friedman *et al* 1985, Friedman 1987). There is other evidence of the loss of muscle mass adversely affecting the functional capacity of the elderly (Hyatt *et al* 1990, Alexander *et al* 1991, Judge *et al* 1992, Evans and Campbell 1993, Wolfson *et al* 1995). Other nutritional factors relating to muscular strength, supported by strong correlations with dietary magnesium, calcium kinetics and circulating vitamin D, have also been implicated in the muscle function debate (Institute of Medicine 1990).

Studies on the adductor pollicis muscle of the hand throw some light on the relationship between muscle strength and nutritional status. In malnourished (non-elderly) patients, this muscle generated less force, fatigued faster and recovered more slowly[17] than in normally nourished patients. The authors concluded that the key factor is probably the availability of energy stores within the muscle and the ability to regenerate them from available substrate (Shizgall *et al* 1986). Furthermore, re-feeding of (young) anorexic patients can lead to a restoration of maximal relaxation rate and muscle fatigability to normal levels (Russell *et al* 1983). Working with both young and elderly subjects, Phillips *et al* (1992b) concluded that muscle atrophy and reduced force per cross-sectional area mean that older subjects have to use a higher proportion of their muscle maximal voluntary force to produce the same force as a younger subject.

In terms of evidence from handgrip studies, Mowé *et al* (1994) found that handgrip strength was significantly lower in a recently hospitalised and malnourished group of elderly, compared to a normally nourished home group. An Indian study amongst adult males found that those with low BMI (<18.5) had significantly lower maximal voluntary contraction (MVC) in handgrip than the well nourished controls, an effect that was still significant after correcting for AMA (Vaz *et al* 1996). However, this study is limited by the fact that the two groups were very dissimilar in terms of occupation, residence and

[17] in absolute terms, but not when expressed as percentage of maximal force

health status (urban-based University staff and students in the better nourished group, and hospital patients from a rural area in the underweight group).

Muscular strength presumably affects functional ability by its impact on mobility and physical activity levels, as well as basic functional ability tasks such as transferring (Rantanen and Heikkinen 1994). As the strength needed to carry out many ADLs is not large, and is generally smaller than the torques that even elderly people have available (Schultz 1995), the concept of threshold may be helpful here in describing the narrowing of safety margins between normality and abnormality of function (Young 1986, 1992). As one grows older there comes a time when maximal strength in a particular action is the same as the minimum required to perform an everyday activity. A gradual loss of strength may not be apparent until the person is suddenly unable to perform a crucial function. Assuming a rise time of less than 3 seconds, a healthy 80 year old woman is probably at, or very near to, the threshold value of quadriceps strength for rising from a low armless chair or lavatory seat. Presumably an unhealthy, malnourished old woman experiences this threshold some years earlier.

Certainly, there is evidence that the reductions in strength that occur with advancing age have negative consequences on gait, mobility and other aspects of physical performance capacity and functional ability, particularly if the age-related decline in strength is exaggerated by inactivity, or debilitating disease (Bendall *et al* 1989, Alexander *et al* 1991, Larsson 1991, Bassey *et al* 1992, Evans and Campbell 1993, Brown *et al* 1995). In a study of healthy community-living Italians over 90 years old, Ravaglia's team (1997) found that low muscle mass (assessed using anthropometry) was significantly associated with impaired functional ability. A similar result was reported amongst frail elderly Canadian women using bioelectrical impedance to assess fat-free mass (Payette *et al* 1998). However, contradictory evidence also exists. Low skeletal muscle mass (assessed by dual-energy ray absorptiometry) was not associated with self-reported physical disability in a cross-sectional analysis of Framingham Heart Study data of elderly people aged 70-95 years (Visser *et al* 1998). However, the different techniques applied to assess muscle mass may be undermining the picture.

No effect on mobility, physical activity or muscle strength or size was reported after a 10-week programme of multi-nutrient supplementation amongst 100 frail nursing home residents over 70 years old (Fiatarone *et al* 1994), nor amongst frail 60-year olds living at home after receiving a high energy nutrient dense supplement for 12 weeks (Gray-Donald *et al* 1995). However, both these elderly groups had relatively high mean BMI of 24 or 25, and the interval time between assessments was not long. No such studies have been found for community-living elderly populations amongst whom poor nutritional status is common.

In addition to muscle strength, other factors such as inadequate sensation in joints, skeletal health, kyphosis, joint impairment and pain, changes in the biomechanics of gait and balance, proprioceptive acuity, and fear, may also be important in the successful completion of functional ability tasks and thereby contribute significantly to normal daily function (Brown *et al* 1995, Dutta *et al* 1997). Moreover, thin underweight people have an increased risk of hypothermia which has an impact on lack of co-ordination, mobility and risk of accident such as fractured neck of femur (Bastow *et al* 1983, Mansell *et al* 1990).

The role of proper nutrition on **cognitive function** may also be important (Goodwin *et al* 1983, Goodwin 1989, Evans 1994). Poor cognition was significantly associated with low BMI and weight loss in studies of elderly nursing home residents (Fiatarone *et al* 1994). However, it is unclear whether sharper elderly eat better, or better nutrition aids cognition, or some other undetermined factor is responsible for both (Roe 1986). Despite the limitations of correlational data, the hypothesis that poor nutritional status can contribute to neurocognitive decline in otherwise healthy individuals and that it may also somehow be related to functional ability decline is intriguing (Goodwin *et al* 1983, Evans 1994).

In summary, although a large body of quantifiable evidence still eludes us, it does seem that underweight older subjects have decreased reserve capacity of energy and strength which appear to be detrimental to other dimensions of functional ability in everyday life.

Underweight is probably responsible for many other non-specific symptoms observed in elderly people, such as chronic fatigue, general feeling of ill-health and loss of appetite, which may eventually contribute to more pronounced malnutrition, and possibly impede normal functioning in every day life. Moreover, underweight elderly people may develop such problems rapidly and perhaps with only minor stress. Thus it does seem appropriate to hypothesise that underweight in elderly people leads to an increased risk of functional ability dependence.

Momentum for more research in this area has gathered pace in recent years. Increasing calls for the establishment of associations between physical functional ability and other indicators can be traced in the literature (Branch and Meyers 1987, Katz and Stroud 1989, Guralnik *et al* 1989, Rosenberg and Miller 1992, Ensrud *et al* 1994).

2.6 Ill health

In any investigation of association, due attention must be paid to potential confounding variables that interact with the variables whose association we are trying to determine (Margetts 1991, Weinberg 1993). The most likely independent candidates for confounding, in our hypothesised relationship between underweight and impaired function, are age itself, and ill health. These will need to be included in any predictive model, despite many methodological problems in assessment and limited good quality data on morbidity (Murray *et al* 1992 b).

Age is merely a number reflecting a wide range of changes that affect the human condition, some of which can be measured, albeit imperfectly, some of which are still poorly understood, and probably some of which remain unidentified. These limitations and unknowns necessitate the treatment of age as a confounder in the hypothesised relationship between underweight and impaired function.

There is evidence that certain **health conditions** adversely affect functional ability in elderly people. Using US national data, there is a step-wise increase in the prevalence of ADL disability with an increasing number of chronic conditions (Guralnik *et al* 1992), with visual impairments, hip fracture, cerebrovascular disease, osteoporosis and arthritis having the largest impact on disability. Rheumatoid arthritis and other musculoskeletal diseases result in a decreased range of motion in joints leading to loss of mobility, flexibility and level of independence in ADLs and IADLs (Clark *et al* 1990, Nesher *et al* 1991, Ettinger *et al* 1994). However, similar issues relating to co-morbidity and the effects of the burden of illness falling very heavily on older adults living in poverty in developing countries are not yet explored (Macfadyen 1992).

Good **data on morbidity** amongst adults of all ages from **developing countries** are scant. There is a tendency to conduct surveys that look only at one health problem in one locality and at one point in time, and hardly any of these allow for stratification of their published data into different adult age groups. Nonetheless, from existing adult morbidity studies, and extrapolating from work amongst younger groups, we can expect high levels of disease and disability amongst poor old people living in urban centres of developing countries (Murray *et al* 1992 b). The high population density found in poor urban areas facilitates the rapid transmission of communicable diseases. Poor hygiene and sanitation, and polluted air, will contribute to high levels of respiratory, pulmonary, gastrointestinal and skin diseases amongst older adults living in deprived urban areas (Kearney *et al* 1994). Moreover, because of the clinically accepted alterations in immune response with increasing age, multiple infections will also constitute a common cause of high morbidity and mortality amongst older people. Whilst the reported incidences of age-dependent diseases such as Alzheimer's disease, cardiovascular disease and late-onset (type-II) diabetes may be low amongst poor older people due to low access to health care and the scarcity of clinical diagnosis techniques, the incidence of many age-dependent disabilities, such as those caused by hip fractures, blindness and cataracts, deafness and arthritis, will be more easily discernible and probably high (Brody 1988).

Iron deficiency is the most prevalent nutritional deficiency in humans (Lynch *et al* 1982). In adults, the determinants of nutritional adequacy are the availability of dietary iron for absorption and the overall total iron content of the diet in the face of the needs for iron imposed by blood loss or pregnancy (Beutler *et al* 1988). The absorption of non-haem (e.g. in vegetable foods) iron appears to decrease as age increases (Lynch *et al* 1982) which alerts us to the possibility that iron deficiency anaemia prevalence may be high amongst elderly people who may also be reducing their intake of promoters of non-haem iron absorption such as fruit and meat. However, because of a concentration of research on children and women, only a small number of surveys provide information on the iron status of older people (Ortega *et al* 1994, Ania *et al* 1997). Iron deficiency anaemia needs to be distinguished from the anaemia of chronic disease, a frequent manifestation of a wide variety of acute and chronic disease processes and associated with iron-deficient erythropoiesis (Lipschitz 1990 b, Dallman *et al* 1984). A variety of blood parameters can be measured to assess the existence and severity of iron deficiency, the most sensitive of which is serum ferritin (Munro 1992 b), but the most widely used of which is the level of circulating haemoglobin (Cook and Finch 1979, Oppenheimer and Hendrickse 1983).

Hypoalbuminaemia is diagnosed when the level of serum albumin falls below 3.5 g/dL (Gibson 1990). It indicates protein malnutrition that may be secondary to a number of disease conditions in addition to poor intake, liver failure or excessive loss in the urine (Williams 1992). Although nutrition plays an important role in albumin synthesis, it is still not clear to what extent albumin level should be considered a reliable nutritional index or a non-nutritional marker of disease presence or severity in the elderly (Friedman *et al* 1985, Corti *et al* 1994, Rall *et al* 1995).

Limitations aside, taking anaemia and hypoalbuminaemia as two commonly used biochemical markers of nutritional status, further evidence of the detrimental effects of poor nutritional status on function can be seen. The capacity for physical activity and economic productivity in adults, normal child development and reproductive performance in women are known to be severely affected by anaemia (Ohira *et al* 1981, Finch 1989, DeMaeyer *et al* 1989). Other associated symptoms of anaemia like loss of energy, tiredness, anorexia, increased susceptibility to infections, impaired maintenance of body temperature, and certain behavioural abnormalities all adversely affect well-being in many aspects of life for many (Finch 1989, Gibson 1990, Oppenheimer and Hendrickse 1983). However, in the absence of actual evidence for elderly people, we can only speculate that some, or all, of the consequences of anaemia may have detrimental effects on dimensions of functional ability and mobility, and related performance measures such as strength and psychomotor co-ordination, for this age group. There is evidence of the detrimental effects of hypoalbuminaemia on health, and even mortality amongst older people (Phillips *et al* 1989, Sullivan *et al* 1990, Hermann *et al* 1992, Rall *et al* 1995). Recent evidence points to low serum albumin being associated with the presence of impairments in Katz ADL and mobility in older people (Sullivan and Walls 1994, Corti *et al* 1994, Van Staveren *et al* 1995) and other impairments in physical function (Salive *et al* 1992).

2.7 Pitfalls and problems

Conducting field research on nutritional status and functional ability amongst communities of older people presents some particular problems. Some efforts to address and minimise these must be attempted.

2.7.1 Participation

High response rates in community-based studies are thought to be more difficult to achieve with elderly people than with any other age group (Zimmer *et al* 1985, Lemke and Drube 1992). Some studies report response rates as high as 80 or 90 % (Campbell 1986, Andrews *et al* 1986, Harris *et al* 1989, Bowling and Grundy 1997) but others are in the 60s (Milne *et al* 1971, Zimmer *et al* 1985), and some are even lower (Osler and Schroll 1992). There is no consensus about the possible reasons for low response rates amongst elderly people. Some studies have shown that older non-responders are of poorer health than respondents (Harris *et al* 1989, Rockwood *et al* 1989, Osler and Schroll 1992), have more ADL disabilities and mobility problems (Hoeymans *et al* 1998), and are more likely to be socially isolated, apathetic, depressed, and mentally impaired (Exton-Smith 1982). However, other studies have found the opposite, reporting that non-responders are more likely to be elderly people in good health, still busy in the community, and who do not see themselves as being part of the "elderly" population (Akhtar 1972, Campbell 1986).

2.7.2 How old are you ?

There are known to be problems in determining age with accuracy amongst elderly people with low levels of education (Barker 1989, Solomons *et al* 1993). Some older people are unused to, or suspicious of, completing forms or answering questions, and many do not have any formal registration of birth. Others may genuinely not remember their date of birth or simply be confused about their age. Rounding up or down is also a common phenomenon in self-reported age amongst old people, regardless of educational level.

2.7.3 Screening for cognitive status

Some assessment of cognitive status[18], memory and confusion in older people is necessary in any multi-dimensional assessment of functional ability to act as a screen in identifying those individuals incapable of understanding performance test instructions and whose responses about ADL and IADL may be suspect, such as those who have suffered a stroke (Carter *et al* 1988, Fitzgerald *et al* 1993, Merrill *et al* 1997). Advancing age appears to be a risk factor for cognitive decline (Corey-Bloom *et al* 1996). Objectively measured memory function has been shown to be related to response

[18] defined as a diminished capacity to know the world (Folstein *et al* 1985)

reliability and the amount of missing data in a large survey of the elderly (Wallace and Rohrer 1990). Instruments for assessing cognitive aspects of mental function in elderly people vary greatly in content, detail and administration time (Little *et al* 1987). Probably the most well-recognised and validated is Folstein's Mini-Mental State Examination, a scored series of 11 questions concerned with orientation, memory, attention and the ability to follow verbal and written commands. It has a high reliability, is significantly correlated with more sophisticated tests of neuropathology, and distinguishes between people with or without cognitive disturbances (Folstein *et al* 1975, 1985). A simpler assessment methodology consists of asking a series of locally-appropriate questions that relate to a person's orientation in space and time (Pfeiffer 1975, Syryani *et al* 1988). Whilst these can be used as a framework, knowledge of locally recognisable items to use in the assessment of orientation, memory and other cognitive skills is necessary before the construction of culturally meaningful questions and tests is attempted (Beall and Eckert 1986).

2.7.4 Conducting reliable anthropometric measurements amongst elderly people

No existing techniques of anthropometric assessment of the nutritional status in elderly people are entirely satisfactory mainly because observer errors for all body measurements increase with age (Chumlea *et al* 1984 a, Chumlea *et al* 1989). It is generally agreed that reliability for limb length measurements, weight, height and circumferences can be high ($r > 0.95$) but that for skinfolds is usually lower (Hall *et al* 1980, Mueller and Martorell 1988, Sullivan *et al* 1989). Greater skinfold compressibility and /or poor tissue separation in the elderly can significantly affect reliability, especially in fat individuals (Bowman and Rosenberg 1982, Chumlea *et al* 1989). Accuracy of site identification and correct positioning is also important (Martin *et al* 1988 a, Jarzem and Gledhill 1993). The reliability of armspan measurements in older people may be affected by osteoarthritis of the shoulder and wrist preventing adequate abduction and full extension (Solomons *et al* 1993), and by chronic lung disease and kyphoscoliosis (Mitchell and Lipschitz 1982 a, Parker *et al* 1996 a). It is clear that careful attention must be paid to quality control through accurate measurement techniques that minimises observer variation (Hall *et al* 1980, Mueller and Martorell 1988). Reliability data for anthropometric surveys involving elderly people are limited, and a great deal more information is needed, particularly for racial groups other than white Europeans and Americans (Solomons *et al* 1993).

2.7.5 Techniques for assessing functional ability in elderly people

The **constraints of using ADLs** have been addressed by a number of authors (Kane and Kane 1981, Liang and Jette, 1981, Fillenbaum 1984, 1990, Feinstein *et al* 1986, Guralnik *et al* 1989, Law and Letts 1989). Problems include insensitivity to changes in health status, the assumption "if you can you will" which is not necessarily true in all cases, and of making sure that the question is asked in such as way as to imply capacity rather than usual performance (Branch and Meyers 1987). There are also problematic issues like the subjectivity of many responses, and potential inaccuracy for reasons of language, comprehension, hearing, intellectual capacity, level of motivation and co-operation, or even pride (Rodgers and Herzog 1987). The EURONUT study investigators also posed the question : "is it the attitude of the elderly towards what they are expected to do as elderly persons that limits their activities ?" (EURONUT 1991 d).

Measuring functional status cross-culturally is a complex and multi-faceted task necessitating ingenuity and innovation on the part of the researcher (Beall and Eckert 1986). In non-western cultures, there may be problems of elderly people simply being unused to answering direct probing questions about their lives (Barker 1989). An elderly person's cultural environment also may not encourage or expect a certain behaviour covered in an ADL question, according to norms of social and economic status, age, sex and prestige (Syryani *et al* 1988, Barker 1989, Fillenbaum 1996). Self-ratings are subject to distortions and biases ranging from hypochondriasis to cultural norms prohibiting one from discussing certain health problems of parts of the body (Beall and

Eckert 1986). Moreover, some IADL and ADL tasks are performed in quite different ways in non-western cultures (Solomons 1992, Jitapunkul *et al* 1994).

Constraints of physical performance tests include space, time, staff and equipment requirements, motivational skills of the examiner, and motivation, comprehension and compliance of the subject (Martin *et al* 1985, Shizgall *et al* 1986, Branch and Meyers 1987, Bassey and Harries 1993, Alexander *et al* 1991, Schultz *et al* 1995). For example, in a laboratory-based study in the USA, some old adults were unwilling to complete a chair rise even when they had demonstrated that they possessed the strengths required for the rise (Alexander *et al* 1997, Schultz *et al* 1995). Psychological factors such as motivation, anxiety and non-familiarity with a task have been shown to influence handgrip strength performance (Lenmarken *et al* 1986) and chair stands (Didier *et al* 1993). Pain, stiffness, fatigue, intimidation and other psychosocial factors might also influence test performance in elderly people (Kaplan *et al* 1996). Fear of physical risks may also be involved, such as falling or angina. Moreover, large variation between normal individuals has been found in some tasks, so interpretation of results can be problematic (Pearson 1985). Attributes of test-retest reliability, validity, and sensitivity are undocumented for many physical tests and the ability of most to predict physiological functional decline is still unproved (Reuben and Siu 1990).

In conclusion, it seems prudent to interpret the results of both performance and self-reported assessments of functional ability with some caution until there is better understanding of relationships between them and the factors influencing self-reported response and performance behaviour (Reuben *et al* 1995), and until they have been used in a variety of cultural settings (Guralnik *et al* 1989, Guralnik and Lacroix 1992).

2.8 Summary

In a recent paper on nutrition in older people, there is a confident statement that :

> *"anthropometric measurements are simple predictors of subsequent ill health, functional impairment and mortality"*
>
> *Chumlea et al 1997 a*

In terms of functional ability, this statement is rather premature. Only very recently have a few papers (Ensrud *et al* 1994, Galanos *et al* 1994) started to throw some light on the relationship between nutritional status and functional ability amongst elderly people still living in the community, and these are restricted to the developed world. Thus this study represents one of the first in a new field of nutritional research. Whilst there are undoubted theoretical and practical problems involved in both nutritional and functional assessments of elderly people, such problems are no excuse for inaction. Aid workers reporting an increased vulnerability of elderly people to malnutrition over other groups, including young children, in besieged areas of Bosnia Herzegovina, stressed that the potential consequences of poor nutritional status in elderly people are sufficiently serious to warrant immediate action despite the methodological uncertainties (Vespa and Watson 1995). Whether or not impairments in dimensions of functional ability form part of these consequences for elderly people living in poor conditions in a developing country will be tested by this research.

For all age groups including the elderly, tackling the causes of malnutrition must be our ultimate goal. However, being able to measure and monitor nutritional status in relation to a functional outcome of practical importance is imperative. Thus, nutritional assessment for the elderly must be orientated towards providing useful information on transitions to functional ability impairment. We must begin by identifying in more precise ways the manner in which nutritional status contributes to the preservation or deterioration of functional abilities in older people, and vice versa.

Some evidence does suggest that nutritional status is important for the maintenance of functional ability and independence for an older adult but we do not yet have convincing evidence of the relationship. That does not mean the question is unimportant, rather that more information is needed as it could suggest possible ways in which intervention might restore either nutritional status or functional ability in elderly people.

Whilst some progress is being made in western countries, the collection of even basic data on nutrition and functional ability amongst free-living elderly people in developing countries has hardly begun. Given the emerging demographic phenomenon of ageing predominantly facing those countries, there is little time to waste.

CHAPTER 3 : STUDY DESIGN AND METHODS

3.1 Choice of site, collaboration and ethical permission

The hypothesis to be tested required access to a large number of community living elderly people in a site where malnutrition and impaired functional ability and poor physical performance would be commonplace, and where such data could be collected in the field setting. Reliable clinical data on the crucial confounding variable of co-morbidity, and preferably data on biochemical and haematological parameters related to anaemia and hypoalbuminaemia, were required.

An approach was made to the non-governmental organisation HelpAge International[1] in London for possible collaborative sites. One of its independent overseas members, HelpAge India, was already assisting a team of scientists from the Department of Pharmacology in the Seth GS Medical College and King Edward VII Memorial Hospital (KEM) in Mumbai to establish the Biomedical Gerontology Research Centre of HelpAge India (BGCHI). The stated aims of the BGCHI were to implement a service-orientated research project for poor elderly people living around the hospital, assess their health status, and to diagnose, treat and monitor chronic and acute health problems. A household census was already underway, the infrastructure was in place for the collection of extensive clinical and laboratory data, and a network of social workers existed to facilitate contact with elderly people in their own homes.

These factors led to the choice of Mumbai as an appropriate fieldwork site, and of HelpAge International, HelpAge India and the BGCHI as collaborating partners. After several visits

[1] HelpAge International is a non-governmental organisation committed to improving the lives of elderly people worldwide

to discuss the possibility of incorporation of the nutrition research into the BGCHI, a collaborative agreement was reached in late 1992. A Memorandum of Understanding was drawn up and signed by all parties, covering aspects of scientific protocol, responsibilities, ownership of equipment and data, and joint authorship. Funding was provided by HelpAge International.

Ethics Committees of both the LSHTM and the KEM Hospital approved the nutrition research (Appendix I). The Central Drugs Research Institute of India, a government body from which the BGCHI had already received official sanction and under which its main scientific and managerial staff were employed, also gave its written approval.

3.2 Study population and sample size

In 1991 the number of people over 60 years old in India stood at about 55 million, or about 6.5% of the total population of 844 million (Sharma and Xenos 1992). Older people living in the cities must now rank among India's priority concerns (Gopalan 1992).

The 1981 Census of India reported the proportion of over 50 year olds in Greater Mumbai as approximately 9% of the total population, large numbers of whom are living in slums and chawls where most of the projected rise in the city's population is likely to occur (Sharma and Xenos 1992). Although Municipal figures published from the 1991 census gave the total population of F-South Ward as 417,136, a detailed age- and sex-wise breakdown of the Ward's older population in slums and chawls was not available. Working only in the larger slum and chawl settlements in the Ward, the BGCHI estimated that there were approximately 3,300 adults over 50 years old, based on local and national figures for the proportion of elderly in cities overall, and the size and composition of the study area. Because of the later start and earlier finish of the nutrition research, the present study aimed to cover one third (approximately 1,100) of the BGCHI subjects. Following the BGCHI strategy of serial coverage of all elderly people living in the larger slum and chawl areas within the defined administrative area of F-South Ward, this nutrition research in effect adopted a "convenience" non-random sample.

The question of **sample size** is pertinent here. The calculation of sample size and power is related to the concept of the significance test, and based on a measure of how likely a chosen test is to produce a statistically significant result based on a population difference of a given magnitude (Mascie-Taylor 1993). In the context of this study, the distributions of nutritional or functional ability indicators in elderly people in slums were unknown. Thus, at an early stage in the research, a calculation was made on the basis of predictions of mortality using the age-specific mortality rate from one of the chawl communities (Yesudian 1988) which indicated that a sample size of 2,500 subjects would have given a 65% chance of declaring a significant difference between death rates in a normal versus a malnourished population at the .05 level. However, as a number of logistical and other constraints meant that mortality data could not be collected, further sampling calculations were not attempted, and the "convenience" approach substituted instead.

3.3 Protocol and timetable

The protocol was developed by the researcher at the London School of Hygiene and Tropical Medicine (LSHTM). It draws strongly on standard texts on anthropometry, and on a combination of sources for functional ability. The full protocol, including instructions for physical tests, questionnaires and coding, is given as Appendix II. Anthropometric measurements and functional ability techniques were finalised after consultation and training with researchers experienced in community-based assessments of elderly people. In the UK, practice session and piloting of the final protocol took place amongst elderly volunteers in two locations : a residential home (Caucasian) in rural central England, and an urban community centre (Gujerati Indian) in east London. Fieldwork data collection took place in Mumbai between March 1993 and March 1994.

3.4 Research team and training

On arrival in Mumbai, a project office was established within the BGCHI at the KEM Hospital. Fieldwork was co-ordinated by the researcher who recruited, trained and supervised a local team (female medical doctor, social scientist field supervisor, six fieldworkers, two social workers) most of whom had previous experience of social work or primary health care in slums. Field staff underwent a three week training in all anthropometric and functional ability techniques and received an illustrated handbook describing all the standardised methodologies. Questionnaires and instructions for measurement procedures and performance tests were first translated into the local language (Marathi) and then checked for accuracy in back translation by an independent language teacher.

After practising all aspects of the protocol on each other and members of BGCHI staff, the field team conducted a three-day practice session and pilot study amongst elderly volunteers in a slum community in a different part of the city. Questionnaire amendments, verbal instructions, measurement sequence and techniques for controlling the flow of subjects were then finalised. Regular short refresher day trainings were held, and a written and practical examination was also administered halfway through the fieldwork to ensure that field staff continued to revise theory and practice standard techniques.

3.5 Subject recruitment and protocol sequence

Visiting door-to-door, BGCHI social workers conducted a household census of the largest slum and chawls in F/South Ward from which a list of all those over 50 years old was extracted. The nutrition field team then set up a temporary clinic in each community by turn in F/South Ward. About 30 elderly people were contacted daily from the census list by the social workers and invited to the field clinic. An awareness programme using local organisations and word of mouth was used to publicise the clinics.

3.5.1 For the field clinic

All the anthropometric measurements, physical tests and questionnaires were conducted by a team of four observers on same-sex subjects in small temporary field clinics, and in cubicles made private with makeshift partitions. Each subject signed (or made a thumb impression) an informed consent form, after both social workers and medical officer in the field had fully explained the BGCHI objectives, facilities, examinations and confidentiality on several previous occasions in home visits. Each subject was measured at the field clinic in the following sequence :

1. Informed consent, personal details, brief examination (Plate 3.1)
2. Cognitive screen, ADL and mobility questionnaire (Plate 3.2)
3. Physical performance tests
4. Anthropometric measurements

This sequence normally lasted 20-30 minutes, varying according to the level and type of disability, and co-operation and comprehension of the subject. Those identified by the medical officer as having high fever, abnormally high blood pressure, palpitations or who were drunk were excluded and seen on another occasion. Where possible all parts of the protocol were performed on deaf, mute or blind subjects with the assistance of carers and some ingenuity on the part of the field staff. Home visits were also made to cover housebound[2] sick and frail elderly people identified by the community survey. In such cases the protocol was adapted to cope with both the home and the person's own problems.

3.5.2 For the hospital Outpatient's Department (OPD)

After the assessments in the field clinic, instructions were then given to each subject by the medical officer for reporting fasting to the BGCHI's own OPD at the KEM hospital on the following working day. All subjects were transported to and from the hospital by the BGCHI van, accompanied by social workers well known in the communities. In the OPD, subjects participated in the final two parts of the research protocol :

5. Blood samples for analysis of haemoglobin and albumin (Plate 3.3)
6. Full medical examination and specialist investigations

3.6 Age determination and age groupings

Assuming that self-reported age alone would be inaccurate (see section 2.7.2), a series of other questions related to well-known local and national historical events (e.g. the "Quit India" movement, dock explosion in 1944, religious riots) were asked as well as a secondary series about age at birth of first surviving child and that child's age. A "best guesstimate" was the mean of all the responses.

2 Housebounds were defined as people who had been unable to leave their homes during the last week for whatever reason, and were classified by both BGCHI social workers and the nutrition team visiting the house

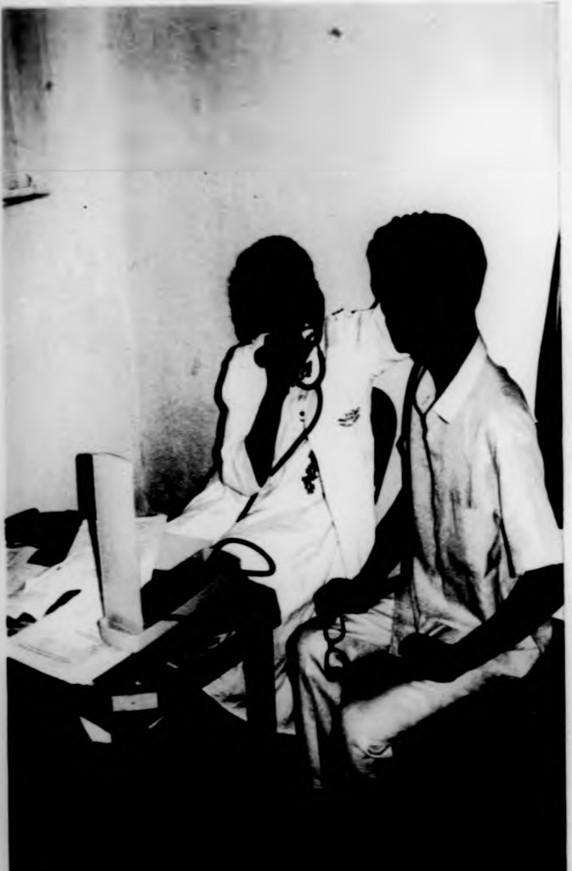


Plate 3.1 Brief medical examination in the field clinic

Plate 3.2 Conducting an interviewer-administered questionnaire in the field clinic

There is no consistent definition of "elderly". International organisations often refer to the elderly as those over 60 years of age (UN 1991, WHO 1995), basing this on the upper quintile of the population. However, the equivalent upper quintile in many developing countries may mean including people younger than this (Wahlqvist *et al* 1994). Moreover, because of long-term malnutrition, disease, strenuous work patterns and generally harsh life conditions for many adults in developing countries, the process of biological ageing occurs earlier and proceeds faster than amongst adults living in the developed world, so that an individual may be biologically old at chronological age lower than 60 years (Kalache 1991). For these reasons, the age of 50 was chosen as the cut-off to define the "elderly" population in this study.

Initially, for descriptive analyses, five age groups were used : 50-54, 55-59, 60-64, 65-69 and 70 and above. For bivariate and multivariate analyses, two age groups, 50-64, and 65 years and above, were used (variable name TWOAGES). Although some anthropometric and functional variables showed a marked falling off above age 70 years, inaccuracies associated with age determination as well as the comparatively small numbers of men and women over 70 years of age (which would limit the use of some statistical tests), led to the choice of a cut-off for the older group at age 65.

3.7 Anthropometric measurements

Six anthropometric measurements of weight, standing height, armspan, mid-upper arm and maximal calf circumferences, and triceps skinfold thickness were conducted according to standard methodologies (Weiner and Lourie 1981, Lohman *et al* 1988, WHO 1995) :

Weight was measured on digital weighing scales (Soehnle model S Sport no. 770102), calibrated in 100 g units and recorded to the nearest 0.1 kg (Gordon *et al* 1988). The scales were placed on level ground adjacent to a wall. Subjects removed any heavy items in their pockets or sari waist pouches such as keys and coins. No correction was made for voiding prior to the measurement or the weight of clothing[3].

Standing height was measured to the nearest 0.1 cm using an adapted portable height stadiometer manufactured by CMS Weighing Equipment of Camden, London. The subject stood upright with heels, hips, shoulders and back of the head touching the pole as much as possible, in a relaxed position with arms hanging loosely at the side and head in the Frankfort plane. The head piece was pushed down to rest on the crown of the head at maximum inspiration (Plate 3.6). No information was collected on either time of day (Lampl 1992) or work load/activity patterns and "spinal creep" (Hoe *et al* 1994), although these are known to cause short-term fluctuations in height. Their relative significance is considered small compared to the importance of positioning error and normal individual variability (Mueller and Martorell 1988).

Armspan was measured anteriorly to the nearest 0.5 cms using a flexible steel tape (3m Stanley tape, model 32-031) (Brown and Wigzell 1964, Steele and Mattox 1987, Martin *et al* 1988, Kwok and Whitelaw 1991). The subject stood in the same position as for height, against a wall wherever possible, or sitting if unable to stand (Plate 3.4).

Mid-upper arm circumference (MUAC) was measured on the left side of the body whenever possible using the same flexible steel tape used in the armspan measurement. The arm midpoint was first marked using the distance between the tip of the shoulder (acromial process) and the tip of the elbow (olecranon process), and the mid-arm circumference was then measured with the arm hanging loosely at the side of the body (Plate 3.5).

3 all very light cotton, weighing less than 0.5 kgs

Plate 3.3 Collecting blood at the KEM Hospital OPD

Plate 3.4 Taking an armspan measurement

Plate 3.5 Taking a MUAC measurement

Plate 3.6 Taking a height measurement

Calf circumference was measured in the recumbent position with the maximal point determined visually, and using the same steel tape as MUAC. Both circumference measurements were taken to the nearest 0.1 cm, and care was taken to ensure that the tape fitted snugly around the skin but not so tight that it compressed the tissue.

Triceps skinfold thickness measurements were taken in rapid succession using Holtain Tanner/Whitehouse callipers (Plate 3.7). The skinfold was released between each replicate measurement and fingers remained holding the skinfold whilst the callipers were applied. Measurements were recorded to the nearest 0.2 mms after at least 3 seconds to allow for the increased compressibility of skin in older subjects (Chumlea *et al* 1984 a).

Triceps skinfolds were taken in triplicate, but all other measurements were taken only twice. Subjects moved between replicate measurements. Anthropometric measurements that could not be taken in the standard way due to deformity, amputation, physical pain or any other reason were recorded as missing values.

The visual presence of **kyphosis**, bent knees, and any other physical or postural deformity affecting the correct positioning of any measurement, was noted on the recording form by the observers after verification by the medical officer. As fluid retention and **oedema** are known to affect the accurate measurement of weight, circumferences and skinfold measurements (Fanelli 1987), any visible oedema on feet, ankles, legs, arms or face was noted by the medical officer and field observers.

3.8 Anthropometric measurement error

Each weighing scale was calibrated regularly against local cast-iron weights (total 40 kgs), stadiometers were inspected regularly for damage, and skinfold callipers were checked against wood of known and constant thickness. Recording error was minimised by daily checking of recording forms for obvious mistakes, with any suspect measurement repeated later. As a safeguard against imprecision, pre-set limits were used for repeated measurements (Chumlea *et al* 1984b, 1987, Mueller and Martorell 1988). These were : 0.2 kgs for weight, 1 cm for height and armspan, 0.5 cms for arm and calf circumferences, and 1 mm for triceps skinfolds. If a repeat set of measurements did not fall within its specified pre-set limit the measurement set was repeated.

Intra- and inter- observer errors were calculated for all measurements at the end of the initial training period and mid-way through the fieldwork on 20 elderly volunteers from a day-care centre near the study site. Measurement sessions were conducted blind so that no reference could be made to previous results, and anatomical sites were not marked. The two error estimates recommended to determine reliability, the technical error of measurement (TEM), and the coefficient of reliability (R), were calculated using the equations for more than two observers (Ulijaszek and Lourie 1994). TEM is defined as the squared root of the sum of squared differences of replicates divided by twice the number of pairs, and it provides information in the units of measurement. If intra- and inter- observer TEM approach a reference value, and if there are no biases in measurement, then the measurement can be considered accurate. Reliability (R) refers to the proportion of the between-subject variance in a measured population which is free from measurement error (a function of the subjects and not the observer (s)), and it allows comparison of measurement errors for different variables (Mueller and Martorell 1988). R ranges from 0 to 1 : the closer the value approaches 1, the smaller the error introduced by the observer (s) and the more reliable the measurement (Chumlea *et al* 1990).

3.9 Derived variables

Body Mass Index (BMIHT) was derived using the ratio weight kg/height m^2. However, as described in section 2.4.1, it is important to remember that standing height taken in subjects with kyphosis will not give a reliable measurement of stature and thus cannot be used for the calculation of the BMI. This is because for subjects with kyphosis, the standing height measurement will underestimate maximum attained (real) adult stature, and hence BMI will be overestimated. Thus BMI based on measured height was used only for those cases **without** kyphosis. As both the medical officer and the measurers noted any kyphosis or bent knees at the clinical examination as well as during the anthropometric measurement session, it is very unlikely that any such deformity was missed.

For those subjects diagnosed as having kyphosis or bent knee posture, an alternative Body Mass Index **(BMIHTAS)** was then calculated using the normal weight kg/height m^2 equation but substituting a variable called **HTAS (height derived from armspan)** for height. Using armspan in the anthropometric assessment of older people requires two steps : firstly, derivation of a regression equation to quantify the relationship between height and armspan in the population under consideration, and secondly, the calculation of a variable for height calculated from armspan using this equation in the derivation of an alternative BMI. This is all based on the assumption that armspan cannot be used as a direct substitute for height in older people, although this may be possible in younger adults (see 2.5.2).

Ideally, data from young adults in their twenties from the same population should be used to derive regression equations that describe the relationship between height and armspan. In the absence of such data in this study, regression equations for predicting stature from armspan were derived from the data set for the youngest age group in the study, the 50 to 54 year olds, to create the new variable : HTAS. Using the non-kyphotics cases only for this age group (n=317), the regression equations for HTAS = (slope * armspan) + intercept are :

Men $HTAS = (0.71 * armspan) + 40.3$

Women $HTAS = (0.67 * armspan) + 43.8$

These equations were used in the absence of any other available in the literature for this ethnic group, and on the assumption that the least height loss would have occurred in this age group compared to the rest of the data set. Henceforth, in this thesis BMI refers either to :

(a) BMI derived from height for those cases without kyphosis, or

(b) BMI derived from height estimated from armspan for kyphotic cases

An index of muscularity, arm muscle area (AMA) was derived from the mid-upper arm circumference and triceps skinfold measurements, using published sex-specific equations (Frisancho 1990). Despite a lack of consensus on the extent of changes in bone density with age, further adjustment for bone area to give a **corrected arm muscle area variable (cAMA)** was made in this study because there is some evidence to suggest that the extent of error[4] is less variable in lean arms (Heymsfield *et al* 1982 a, Forbes *et al* 1988). The equations used were :

Men $(MUAC - (\pi \times Triceps))^2 / (4 \times \pi) - 10.0$

Women $(MUAC - (\pi \times Triceps))^2 / (4 \times \pi) - 6.5$

The derivation of other body composition variables of fat-free mass and body density was not attempted due to the questionable appropriateness and reliability of existing equations in elderly people (section 2.4.4).

4 arm muscle area corrected for bone area may be overestimated by 15-25% in thin adults (Heymsfield *et al* 1982)

3.10 Defining underweight

Underweight was classified according to the cut-offs of BMI given in Table 2.1 and MUAC given in Table 2.2. No other definitions of underweight using other anthropometric indicators such as calf circumference or cAMA were used[5].

3.11 Functional ability assessment - self-report questionnaires

Table 3.1 summarises the 6-item ADL questionnaire (based on Katz *et al* 1963, 1970), the three questions related to gross mobility (based on the work of Rosow and Breslau 1966), and other questions related to self-reported health, and recent disability onset, recent illness or surgery (Full details of questions asked and the scoring system for responses can be found in Appendix II).

Table 3.1 Functional ability dimensions by self-report questionnaire

ADL	MOBILITY	HEALTH
Continence	Walk half mile	Self-assessed health
Toilet use	Climb stairs / steps	Recent onset of disability / surgery / injury
Self-feeding	Travel outside community	
Transfer		
Dressing		
Bathing		

[5] whilst an approach such as taking a cut-off of - 2 SD from the mean, or below the 15th percentile, of the US reference data for older people (Frisancho 1990) could have been attempted in terms of cAMA, no such data exist for calf circumference.

All questionnaire and coding texts were translated into Hindi and Marathi, backtranslated into English and piloted for accuracy of meaning, cultural applicability and standardisation. Mobility responses were also verified by direct observation of walking only in both the clinic and hospital settings by the clinician. No conflicts between observation and self-reported ability to walk were noted.

The scoring for all self-reported questions[6] was as follows, such that a high score represented a high level of functional ability :

Totally dependent	=	*1*
Partially dependent	=	*2*
Totally independent	=	*3*

A composite ADL score was calculated for each subject from the sum of all the individual ADL scores (range 6 to 18). A composite mobility score (range 3 to 9) was constructed in a similar way from the three mobility items.

3.12 Physical performance tests

Table 3.2 lists the physical performance tests used in the study. Full details of all instructions and procedures for each of these tests can be found in Appendix II.

Manual dexterity was assessed by the time taken to open a locally available front-opening padlock using one hand (dominant) only. The lock was held firmly on a table top by the observer in front of the subject who was timed from picking up the key to successfully opening the lock.

[6] The scoring for self-reported health was as follows :
Very poor health = 1 Moderately healthy / not very ill = 2 Very healthy = 3

Table 3.2 Physical performance tests

DIMENSION	Test	Equipment	Reference
Manual ability	Lock and key	Padlock, key, stopwatch	US NIH[7], 1990
Flexibility	Shoulder rotations	None	US NIH, 1990
Handgrip strength	Handgrip dynamometry	Holtain dynamometer	Bassey 1990 b
Leg / trunk strength	Five chair stands	Armless chair, stopwatch	Bassey 1990 b
Psychomotor skill and co-ordination	Plate-tapping test	3 paper shapes on table top, stopwatch	Bassey 1990 b

Flexibility was assessed by scoring the subject's ability to rotate the shoulders internally and externally (gleno-humeral abduction) when the subject was standing, or seated if unable to stand[8]. Scoring was consistent with the ADL/mobility methodology with 1 corresponding to poor ability and 3 to no difficulty. The scores for internal (Plate 3.8) and external rotations were added together to produce an overall flexibility score.

Handgrip strength was assessed by measuring handgrip strength in kgs (maximal voluntary contraction) using a Holtain handgrip dynamometer held across the body and the subject seated in a relaxed position. Each subject was allowed one trial attempt during which the handle of the dynamometer was adjusted for hand size. Three attempts were made on each hand, and then a final attempt was made using the dominant hand. This method allowed sufficient time to become familiar with the equipment and technique but not enough for the muscles to become tired. The maximum result is used in the analysis (Plate 3.10).

[7] NHANES III Physical Function Examination Protocol, US National Institutes of Health
[8] see Appendix II, p 278-9

Plate 3.7 Taking a triceps skinfold measurement

Plate 3.8 Performing an internal shoulder rotation test

Plate 3.9 Performing a plate-tapping test

Plate 3.10 Performing a handgrip dynamometry test

Leg (quadriceps) / trunk strength was assessed by timing 5 chair stands (rising unaided from a straight-backed armless chair placed against a wall or other solid support). The subject was instructed to fold their arms across their chest and to perform 5 chair stands as fast as possible but without causing pain or discomfort (see Plate 3.10. for seated position).

Psychomotor skill and co-ordination were assessed using a plate-tapping test. Three paper shapes of set dimensions were fixed to a tabletop at a set distance apart, and the subject was instructed to touch the two outer shapes (circles) 25 times as fast as possible using one hand passing across the body whilst the other hand stayed fixed on the middle shape (square). Two attempts were taken and the fastest time taken for the analysis. The standard distances between the shapes were reduced by an arbitrary 5 cms for men and 10 cms for women in an attempt to account for the differences in average height and armspan between a US population and the study subjects. Wherever possible the table legs were altered to ensure that the table top was level with the subject's navel (Plate 3.19).

To minimise the possibility that cognitive status would affect understanding of instructions (section 2.7.3), a demonstration preceded each test. Verbal encouragement was also given to encourage motivation and performance. These five tests were chosen on the basis of having a plausible relationship with important dimensions of functional ability, as well as on the following practical criteria :

- required a minimum amount of equipment
- could be administered easily in cramped clinic/home conditions
- were culturally acceptable
- did not involve a high level of physical risk or exertion for the elderly subjects

Applying these criteria led to the rejection of several other physical functional tests such as timed walk and lung spirometry.

3.13 Defining "impaired" and "poor performance"

All **self-reported variables** of functional ability were further re-coded to produce dichotomous impaired versus unimpaired variables. Any level of impairment (original coding 1 or 2) was recoded as "presence of impairment"= 1, whereas the original coding 3 was recoded as "fully able, no impairment present" = 0. This strategy has the advantage of eliminating interpretational problems surrounding the degree of partial assistance in a task as assessed by the self-report questions. Adopting the method used by Ensrud *et al* (1994) in their recent paper on correlates of functional impairment in old people, the frequencies of the total number of ADL and mobility tasks impaired (to any extent) were calculated for each individual. For ADLs these ranged from 0 to 6, and for mobility, from 0 to 3. Difficulty in performing three or more ADLs was then recoded into a new variable "IMPADL" and taken to represent overall impaired ADL performance. The same was done for the three mobility variables to create "IMPMOB", or overall impaired mobility taken to be difficulty in performing two or more of the three mobility variables. For the purposes of the multivariate logistic regression analysis, these dichotomous variables "IMPADL" and "IMPMOB" were taken to represent overall impaired function.

Using a standard epidemiological approach, scoring for all continuous **physical tests** performance was calculated after first examining the distributions and allocating a score of 1-3 on the basis of the 25th and 75th quartiles of the distribution. A similar approach was used to produce a dichotomous variable for flexibility based on the 25th percentile of the overall score. "Poor performance" was taken to refer to the worst quartile of the distribution, with the rest as unimpaired. Care was taken to ensure that the scoring was in the right direction (e.g. below the 25th percentile for keytime meant fast time, and thus a high score of 3 whereas below the 25th percentile for handgrip strength meant poor strength, and thus a low score of 1). Whilst this is a commonly used approach, this part of the study methodology could be criticised on the grounds that it uses an arbitrary cut-off rather than identifying a cut-off based on the strongest significant results. However, this choice does not assume a particular distribution for the data and applies a population-referenced definition rather than a criteria-referenced definition of impairment. Those amongst the missing values who failed to complete a test or who complained of pain and discomfort were re-coded as "impaired". No attempt was made to calculate an overall composite score for functional ability based on physical test performance.

3.14 Functional ability measurement error

Self-report questionnaires were not repeated. Whilst this might be seen as a serious omission, reliability studies completed within a short period after initial interviews cannot necessarily confirm or reject the original data because a repeat interview will have a different response burden to the original interview (Lemke and Drube 1992). Maybe the interviewer-participant rapport may be different, or the non-response pattern cannot be replicated. The possibility of the subject remembering and repeating previous responses is also a potential problem, and simply repeating a question after a short interval and getting a different response does not help us to know whether the first or second response is actually the correct one, or indeed if either is so. Despite this, some studies report very high test-retest reliability for ADLs using different testing methods and time intervals ranging from 1 day to nearly a year (Andrews *et al* 1986, Collin *et al* 1988, Smith *et al* 1990, Ensrud *et al* 1994). In retrospect, more attention should have been paid to this issue, possibly by a repetition of a systematic number of ADL and mobility self-report questionnaires (e.g. 5-10% of the total number selected randomly) after a short interval by visiting the elderly subjects in their homes, and calculating Kappa coefficients for inter-rater reliability and repeatability (Jitapunkul *et al* 1994). In the absence of a recognised test-retest procedure, Guralnik and Lacroix (1992) recommended the cross-sectional analysis of self-report measures to establish internal consistency. This was attempted using Guttman split-half reliability coefficients (Norusis/SPSS 1990) (section 3.19.1).

Similarly, no retrospective examination of repeatability for physical tests was attempted. The existing literature on physical tests is not very helpful in this matter, except to warn about possible training effects in repeat performance, and to highlight the general lack of attention to test-retest reliability in most studies. There are no guidelines on how to conduct such reliability exercises, nor how to interpret their results. A 5-10% repetition 10-15 minutes apart was used in a recent study (Ensrud *et al* 1994), whereas 1 and 2 week retest intervals have been used by others (Payette *et al* 1998, Seeman *et al* 1994). Perhaps one of these should have been adopted in this research.

3.15 Screening for cognitive status

In recognition of the issues outlined in section 2.7.3, some attempt was made to control for cognitive status by asking four questions thought to give an indication of a person's orientation in time and space as a simple cognitive screen. Each subject was asked to name the present day of the week and month, and present and previous national leader, with responses scored like the ADL self-reports :

1 = incorrect response, "don't know" response (low score)
2 = first incorrect response and/or some hesitation
3 = immediate first correct response (high functioning score)

Short-term memory was also tested using an object recall test in which 15 small familiar, low cost and locally available objects were selected by the team. These were : padlock, comb, box of matches, plastic bangle, pack of incense sticks, cup, plastic flower, religious statue[9], pen, teaspoon, envelope, packet of coloured *tikkas*[10], soap, currency (*rupee*) note and a *betel* nut used for chewing. The objects were covered and placed on a tray. At the

---

[9] changed according to the religion of the subject
[10] used by women to mark married status

start of the physical tests session, subjects had one minute to look at and memorise these objects for recall later. At the end of the tests section (approximately 15 minutes), the subject was asked to recall as many objects as possible in one minute. No help was given by the field assistants.

A composite cognitive status variable (MENTAL) was then made combining the results of the screen questions and the memory test. The lowest response to the screen (3 or less) and the memory test (less than 5 objects recalled) were combined and considered impaired for the purposes of the analysis. Again these categories were recoded as "impaired" and "non-impaired" to create a dichotomous variable for logistic regression analysis. Data on the presence of neurological disorders was also available to validate this.

3.16 Indicators of ill health

A comprehensive medical examination was conducted on each subject by BGCHI medical staff on hospital premises[11]. This examination consisted of the recording of past medical history, present complaints and symptoms (Plate 3.4), a clinical examination and special investigations such as chest X-ray and electrocardiogram where necessary, and the collection of blood for biochemical and haematological variables (Plate 3.3). Diagnostic data from all of these were made available to the nutrition researcher with diseases classified according to The International Classification of Diseases (WHO 1980). No attempt was made to define multiple pathology.

For the purposes of logistic regression, all morbidity data, excluding that for anaemia and hypoalbuminaemia, were categorised into two dichotomous variables : major morbidity (MAJMORB) and minor morbidity (MINMORB), as shown in Table 3.3. below. Based on

[11] these clinical diagnoses were made by BGCHI medical staff, not the author, and they were not made in the author's presence. Thus the author cannot verify the accuracy of the diagnoses.

the advice of a consultant epidemiologist[12], diseases were allocated to the major morbidity variable on the grounds that they were probably exerting a considerable detrimental effect on functional ability, with diseases that were probably exerting only a minor effect allocated to the minor morbidity variable. For example, people with chronic illnesses like diabetes mellitus may still have good functional ability if the diabetes is well-controlled and there is no other complication (Kua and Ko 1994). No diagnoses of HIV/AIDS were available, nor was there any information on polypharmacy.

Table 3.3 Classification of diseases into dichotomous variables

VARIABLE (dichotomous)	DISEASE (variable name)
MAJOR MORBIDITY	Tuberculosis (TB) Cancer Chronic Obstructive Pulmonary Disease (COPD)[13] Cardiovascular disease (CV)[14] Liver, endocrinological and metabolic disease (LEM) Neurological disease (NEURO)[15] Musculoskeletal disease (MUSCSKEL)[16] Leprosy
MINOR MORBIDITY	Diabetes Upper respiratory tract infection (URTI) Urogenitary infection (UROGEN) Skin disease (SKIN) Gastrointestinal disease (GI) Hypertension (HYPERTEN) Psychological disease (PSYCHO)

Because of their use as markers of nutritional status, data for **haemoglobin and albumin** were handled separately from the other indicators of ill health. Laboratory investigations of haemoglobin and serum albumin were executed using standard routine methodology with

[12] provided by Mark Myatt, Brixton Health, Llanidloes, Wales
[13] includes bronchitis and pneumonia
[14] includes congestive heart failure, angina, ischemia, infarction, but excludes hypertension
[15] includes stroke, dementia
[16] includes rheumatism and osteoarthritis of any kind

attention paid to the maintenance of good quality control. Venous blood (30 ml) was collected with a disposable scalp vein needle and plastic syringe from each fasting subject who attended the BGCHI OPD clinic in the KEM hospital between 9 and 10 am. Blood samples were promptly separated and stored in the freezer at -10 degrees Celsius until further use.

Haemoglobin (g/dL) was determined using the cyanmethemoglobin method on CBC-5 Coulter Cell Counter. Serum albumin (g/dL) was assayed using the Bromocresol green method analysed automatically on an Asca Chemical Autoanalyser. All analysis was conducted by BGCHI technical staff, and results recorded manually into a ledger before being coded and entered into the computer. Results on haemoglobin and serum albumin were made available to the author. Table 3.4 summarises the criteria used to define anaemia and hypoalbuminaemia.

Table 3.4 Criteria for defining anaemia and hypoalbuminaemia

DIAGNOSIS	Blood parameter	Cut-off criteria		Reference
		Men	Women	
Anaemia	Haemoglobin g/dL			
all		< 13	< 12	WHO 1972.
severe		≤ 6.9	≤ 6.9	
moderate		7-8.9	7-8.9	
mild		9-12.9	9-11.9	
Hypoalbuminaemia	Serum albumin g/dL	< 3.5	< 3.5	Sauberlich *et al* 1974 (Gibson 1990)

It is important to distinguish between established and recent dysfunction. All participants were also asked if they had undergone any surgery or had developed a **new disability** in the previous 6 months. No special attention was paid to long-established disability on the assumption that people successfully adapt to maximise their performance of their activities of daily life and mobility tasks. All participants were also asked about the extent of their daily smoking and drinking behaviours.

3.17 Vision and hearing loss

Many older adults have conditions that limit their eyesight and hearing and that will affect their functional abilities (Appollonio *et al* 1989, Bess *et al* 1989). The diagnoses of the presence of absence of bilateral or unilateral cataracts was treated as a separate independent variable (CATARACTS). Due to limited expertise, no other diagnoses were made possible for other diseases causing sight loss such as macular degeneration glaucoma and retinol diseases.

Problems with **hearing** may affect people's ability to understand questions or instructions such as those required in functional ability assessments. Any degree of impairment, either self-reported or noted by the observer or doctor, or use of hearing aid was classified as being a "case". No clinical hearing evaluation was possible.

3.18 Data coding, entry and cleaning

All data entry forms were checked daily for omissions and obvious inconsistencies, and double checked if necessary. Data entry was done in the SPSS/PC Data Entry module (SPSS 1987). Computer entries of all data were systematically double checked against raw data sheets or hospital ledgers by the researcher. Obvious errors were checked and, if necessary, measurements repeated.

3.19 Statistical analysis

All statistical analyses[17] except logistic regression were performed with the Statistical Package for Social Sciences, SPSS/PC version 4.0 (SPSS 1987). Logistic regression analyses were performed using the statistical package LOGISTIC (v3.11Ef) (Dallal 1988).

3.19.1 Descriptive and bivariate statistics

Histograms and box plot procedures were used to determine whether or not continuous variables were approximately normally distributed. For normally distributed data, T tests (two groups) and analysis of variance (ANOVA) (three groups or more) were used to determine whether or not group differences were significant. The relationships between anthropometric variables and age were first explored using linear regression and plotting residuals and, in the case of non-linear relationships, with t-tests.

Pearson product moment correlation coefficients (*r*) were obtained for the examination of the relationships between normally distributed continuous independent variables. Scatter diagrams were first applied to determine whether the relationships were linear, and to show the direction and strength of the relationship. There are several points to remember when interpreting Pearson's *r*. Firstly, the closer *r* is to 1 (whether positive or negative), the stronger the relationship between two variables. Conversely, the nearer *r* is to zero the weaker the relationship between the two variables (Bryman and Cramer 1990). The following guidelines were used to describe the strength of the correlation : below 0.19 is very low; 0.20 to 0.39 is low; 0.40 to 0.69 is modest; 0.70 to 0.89 is high; and 0.90 to 1 is very high (Cohen and Holliday 1982). Secondly, significance can be achieved in many

[17] statistical advice was provided at various stages of analysis by Mark Myatt, consultant epidemiologist, Brixton Health, Llanidloes, Wales

bivariate relationships if numbers are large, as is the case in this study. Finally, the interpretation of *r* should always carry the caveat that correlation is not the same as cause : a strong *r* only tells us that the variables are related but not that one variable causes the other.

The Mann-Whitney U test[18] was used for exploring differences between dichotomous variables (impaired/unimpaired functional ability; poorest quartile/above for physical performance measure; presence or absence of morbidity), and the continuous variables. The Kruskall-Wallis H test was used to analyse the differences between underweight assessed by grades of BMI, and by grades of MUAC, and the four continuous physical test, and two blood, variables. One-way anovas were used to analyse the relationships between underweight assessed by grades of BMI, and by grades of MUAC and other normally distributed continuous variables.

Pearson's Chi Squared test (χ^2) was used to determine whether the prevalences of scored, grouped and dichotomous variables related to sex, age group, hospital attendance, presence or absence of oedema and kyphosis, housebound or otherwise, and to describe frequencies. Pearson's Chi Squared and Fisher's Exact test[19] were also used to explore associations between groups of two categorical variables (impaired versus unimpaired self-reports; presence or absence or disease; variables grouped according to classifications). More information about the magnitude and direction of these associations can be obtained from the calculation of confidence intervals for relative risk. However, this strategy was not adopted during this stage of the analysis on the grounds that multivariate analyses using logistic regression will handle all relevant variables simultaneously and produce adjusted measures of risk.

[18] in which normality and equality-of-variance assumptions are not needed

[19] When all the cells of the chi-squared table had expected values more than 5, Pearson's chi-square test was used. If any expected cell value in the chi-squared test fell below 5, the Fisher's Exact Test of association was used and the two-tailed p-value reported (Quigley and Myatt 1994).

Finally, the internal reliability of the six individual ADL and three mobility items and their composite scores was checked by calculating Cronbach's Alpha correlation coefficient. This is a measure of the internal consistency of the test based on the observed correlations and covariances of the tasks with each other (Norusis SPSS/PC 1990). There is an underlying assumption that the items on the scale are positively correlated with each other as they are measuring, to a certain extent, a common entity. Split Half Alphas were also calculated after eliminating continence to produce a 5-item ADL scale, and eliminating continence and feeding to produce a 4-item ADL scale.

3.19.2 Multivariate analyses

The relationships between underweight and the various dimensions of functional ability were analysed using multivariate logistic regression models which can simultaneously adjust for the confounding effects of age, sex, co-morbidity and other variables considered to be potential confounders. Separate categorical models were analysed to determine which "exposure" variables for underweight were most strongly associated with functional ability impairment as the "outcome". Firstly, subjects with high BMIs (over 25) were excluded from this level of the analysis. Only the two established classifications for underweight using anthropometry (BMI/MUAC cut-offs) were used.

Data files were then converted from SPSS/PC .sys files to .REC files to render them compatible with EPI-INFO files for use in the LOGISTIC software programme. Selected variables, all of which had been identified as being significantly associated with impaired function in bivariate analyses, were entered into multivariate logistic regression models. Each logistic regression model was refined using a backwards elimination technique which systematically excludes non-significant odds ratios and adjusts for the effects of the other variables in the model. Non-significant variables were not removed simultaneously. Instead, the least significant variable in each model was removed, and the model then re-fitted (Quigley and Myatt 1994). A high elimination criterion of $p < 0.05$ was used. Model re-fitting continued until all the variables in the model were significant and contributed to the model's description of the data, after which further removal of variables from the model would be inappropriate (Altman 1991).

The strategy of analysis was to produce tables of results giving the numbers and proportions of impaired versus non-impaired cases, 95% confidence intervals, and the odds ratios with the p-value for significance level for the likelihood ratio statistic. In this study, the odds ratio gives a measure of the estimated probability, or risk, of being functionally impaired amongst the underweight against the risk of being functionally impaired amongst the normally nourished. An odds ratio less than 1 indicates a protection from functional ability impairment whereas an odds ratio greater than 1 predisposes to functional ability impairment. For example, an odds ratio of 4.5 for handgrip strength and underweight would mean that the odds against being functionally able (in terms of handgrip strength) in the presence of underweight are 4.5 to 1. The 95% confidence interval for each odds ratio provides an indication of the likely magnitude of the effect. The inclusion of the value 1.0 in the 95% C.I. range indicates no increased or decreased risk whereas the exclusion of 1.0 indicates an increased or decreased risk of having the specified outcome (Altman 1991).

Logistic regression is a modification of the linear model in which :

$$y = a + Bx$$

becomes :

$$y = \frac{1}{1 + e^{-a + Bx}}$$

which constrains y to lie between 0 and 1 (unimpaired and impaired) (Lachenbruch 1992). The exposure variable can be continuous or categorical variables, but the dependent "outcome" variable, in this case, a dimension of functional ability impairment, needs to be dichotomous. The standard linear regression model does not constrain y to lie between 0 and 1 : it allows y to range between - infinity and + infinity). This means it cannot be used with a binary outcome variable (or any non-continuous variable). Thus, an additional rationale for using logistic regression in this study is that the variables for functional ability based on self-reporting (ADL dimensions, mobility dimensions, health etc) were non-continuous variables, thus excluding their analysis using the 'standard' linear model. A decision rule was then also applied to all functional ability variables, even the continuous ones, that yielded a binary variable: unimpaired versus impaired (see section 3.13).

The aim of logistic regression is to identify factors for the purposes of prediction : in this study this technique is used to answer the question "how good a predictor is underweight of functional ability impairment ?" As logistic regression analysis directly estimates the probability of an event occurring whilst allowing for the testing of the effects of a number of variables simultaneously, its use is being recommended in nutritional research as well as epidemiology (Mascie-Taylor 1994).

CHAPTER 4 : COVERAGE AND DEMOGRAPHIC ATTRIBUTES

4.1 Exclusions from the data set

Out of an eligible population frame estimated to be 1,695, a total of 1,398 people were seen in the field clinics during the fieldwork period. However, of these 1,398 cases, 301 could not used be used in the final logistic regression analyses because of a number of reasons. The progression of cases lost to the original data set is summarised in Table 4.1.

Table 4.1 Flow chart of progression of losses to study sample

Total eligible sample				1695
	LESS	*n*	% loss	
	Non-participants at field clinic	297	17.5	1398
	Those under 50 years old	63	3.7	1335
	Those with oedema	38	2.2	1297
	Non-attenders at OPD	200	11.8	1097
	Totals	598	35.3	

After **age verification** questions, 63 out of the 1,398 people measured in the field clinics were judged to be below 50 years of age and have been excluded from the analysis, leaving a study sample of **1,335**.

Out of the 1,335 subjects over 50 years old who attended the field clinics, 38 (18 males, 22 females) had noticeable **oedema** (2.8%). Oedema was much more common in the feet and ankles (74%) than in the upper body (26%). No associations were found between the presence of oedema and either age or sex. Fluid retention and oedema are known to affect the accurate measurement of many anthropometric variables such as weight, circumferences and skinfolds, depending on the severity and location in the body. Indeed, this study found that oedematous subjects were significantly heavier (*$t=4.9$, $df=1326$, $p<.0001$*), and had significantly greater skinfolds and circumferences (*$p<0.0001$*) than non-oedematous subjects. With oedema having such a significant effect on many anthropometric measurements, it was decided to exclude all cases with oedema from further analysis. This leaves a total non-oedematous sample size of **1,297** (531 males and 766 females).

For the majority of functional ability variables the presence of oedema had no significant effects. Similarly, no differences were found in morbidity prevalences or haemoglobin levels between oedematous and non-oedematous groups. Mean serum albumin for oedematous subjects was significantly less than the mean in the non-oedematous group of women aged 50 to 64 years (*$t=3.76$, $p<0.0001$*) although the actual level (3.6 g/dL compared to 4.0 g/dL in the non-oedematous group) was still within the acceptable range. There was no such effect in men.

As described in section 3.5, all subjects seen for anthropometry and functional ability assessment in the field clinics were asked to attend the hospital OPD on the next working day for blood sampling and full clinical examination to enable disease diagnosis. Table 4.1 shows that out of the 1,297 community clinic sample (with those under 50 years and those with oedema already excluded), 200 subjects did not attend the hospital OPD which meant that data on their biochemistry and clinical morbidity were not collected.

4.2 Demographic characteristics of the final data set for analysis (n=1097)

With all those under 50 years old, with oedema and without blood and morbidity data excluded, the bivariate and multivariate stages of the data analysis were conducted on a final data set of 1,097 cases. Table 4.2 shows the demographic characteristics of these **1,097** elderly subjects presented by sex and in five year age groupings.

Table 4.2 Overall demographic characteristics by sex and age

	ALL n	%	MALE n	FEMALE n	M : F ratio
TOTALS	1097	100	458	639	42 : 58
Age groups					
50 - 54	329	30	106	223	32 : 68
55 - 59	264	24	102	162	39 : 61
60 - 64	241	22	122	119	51 : 49
65 - 69	135	12	72	63	53 : 47
≥ 70	128	12	56	72	44 : 56
50 - 64	834	76	330	504	40 : 60
≥ 65	263	24	128	135	49 : 51

The overall sex ratio was 42:58 in favour of females (458 males; 639 females). However, looking at the breakdown of this by age group, the picture is not uniform, with proportionally far more women in the two youngest age groups below 60 years, a more equal ratio of women to men between 60 to 69, and then a reversal back to the younger pattern. It is not clear why this should be. There is evidence that older women (over 60 years) tend to predominate in urban slum areas (UN 1979), including in South Asia (Martin 1988). In this study, there may have been more younger male non-participation bias caused by the marked gender division of work in which women are home-based and can manage time to visit the nearby clinic whereas men leave the community in search of work. Attempts were made to minimise this by holding periodic Sunday clinics.

There was an age range from 50 to 96 years. Just over half (54%, n=593) were under 60 years old and 46 % (n=504) over 60. Only 128 (12%) were over 70 years old. Males in the whole sample were significantly older than women ($\chi^2=28.8$, $df=4$, $p<0.0001$).

The number of **housebound** elderly subjects was 23 (2.1%). There was no association with sex (11 males, 12 females), but as expected housebound subjects were significantly older than non-housebound subjects ($\chi^2=56.4$, $df=4$, $p<0.0001$), and well over half were over 70 years old. This was also found in the original sample (n=1335) in which there were 32 housebounds before exclusion of cases.

In terms of **settlement type**, 58% (n=777) were from the slums and 42% (n=558) from the chawls. The male : female ratios for slum and chawl dwellers were not significantly different from the sex ratio for the entire sample. Based on the assumption that both slum and chawl dwellers were from low income levels of society, both groups are handled jointly for the rest of the analysis.

Socio-economic data on the sample cases were extracted from a larger survey conducted by the BGCHI (Anklesaria 1995) and provide background information on social and residential status. Well over half (58%) of the elderly people seen in this study had no education at all, the rest having only basic schooling and low levels of literacy, especially amongst women. Only a third of the subjects seen were self-supporting, the rest being dependent on others. The vast majority (98%) lived with other family members or friends with only 2% living alone. Most elderly people (95%) lived in a single room, with on average 5 other people. Hinduism was their dominant religion. Nearly three quarters of all subjects had lived in Mumbai slums for over 20 years. Other data extracted on income and pensions confirmed that the sample represented people from the lowest tiers of society.

4.3 Biases

Bearing in mind the issues outlined in section 2.7.1, potential biases caused by both non-participation (failure to attend the first field clinic for the anthropometry and functional ability assessments) and non-attendance (those who were measured at the field clinic but then failed to attend the hospital OPD for clinical examination and blood analyses) need to be addressed.

4.3.1 Non-participation bias

From the original census records, a total of 297 eligible subjects did not participate at the field clinic. When added to the 63 cases who had overestimated their ages, this gives a participation success rate of 79%. A significant sex difference was found, with women more likely to be participants than men ($\chi^2=22.8$, $df=2$, $p<0.0001$), and the overall male:female ratio amongst the non-participants was 56:44, a reversal of that in the participant sample[1]. For both sexes, non-participation was significantly higher in the younger old (below 65 years) than in the older old (over 65 years) ($\chi^2=8.1$, $df=2$, $p<0.001$ in males; $\chi^2=21.5$, $df=2$, $p<.0.0001$ in females). Using socio-economic information recorded in the initial survey, approximately 40% of all non-participants were working, of which 82% were men. Non-participant subjects of both sexes under 65 years were far more likely to be working than those over 65 years ($\chi^2=27.1$, $df=2$, $p<0.0001$ for men; $\chi^2=7.1$, $df=2$, $p<0.001$ for women)[2]. In this study, it seems reasonable to assume that working non-participants were in better health and had higher functional ability than participants.

[1] This finding contrasts with a UK study which found that men often responded better than women "because women are more fully occupied than men and are less willing to spare time for examination" (Milne *et al* 1971).
[2] The proportion of older working non-participants in this study corresponds closely to the analysis of the 1981 census results in which 40% of the entire Indian population over 60 years old were found to be working, and of these 83% were men and only 17% women (Sharma and Xenos 1992).

4.3.2 Non-attendance bias

The 200 cases who attended the field clinic but did not then attend the hospital OPD represent a further loss of 12% from the original eligible population frame.

Table 4.3 Distribution of reasons given for non-attendance at the hospital OPD

Reason given for non-attendance	Males	Females	All
Busy with work or search for work	31	15	46
Not traced or had moved away	9	12	20
Disinterested because in "good health"	6	5	11
Gone to village	2	4	6
Hospitalised	2	2	4
Fear of blood collection or hospitals	2	2	4
Died between census and follow-up	2	0	2
Missed housebound	0	1	1
Absent at follow-up, no reason obtained	2	3	5
Totals	56	44	100

An attempt was made to encourage these non-attenders to come to the hospital by sending social workers door-to-door. Subjects over 60 years old were targeted in a questionnaire that asked non-attenders to specify their reasons for not coming to the hospital OPD. As shown in Table 4.3, for 100 non-attenders over 60 years of age (representing 50% of all non-attenders) work, or the search for work, were the main reasons given for non-attendance at the hospital OPD.

Whilst information on the differences between participants/attenders and non-participants/non-attenders for the blood and morbidity variables is unavailable, it was possible to test whether or not the two groups (1,297 versus 1,097) differed significantly in demographic, anthropometric and functional ability attributes. Testing with χ^2 and the Z-test revealed no significant differences between the basic statistics and distributions of the two groups in terms of demographics, nor for functional ability assessed by physical tests and by self-reports when matched for sex and age. The only exception to this was that recently disabled females were more likely to attend the hospital OPD than the non-disabled women, regardless of their age. However, this is not surprising as many newly disabled were attending the hospital anyway to have cataract surgery, physiotherapy or other assistance, such as the fitting of prostheses. No significant differences in anthropometric and derived variables were found between the data sets in women when matched for age. However, whilst younger men did not show such differences, older non-attending men had poorer nutritional status than those who did attend the OPD. This is demonstrated by significantly lower mean weight ($t=2.54$, $df=149$, $p=0.012$), BMI ($t=2.82, df=139$, $p=0.005$), triceps skinfold ($t=3.34, df=150$, $p=0.02$), MUAC ($t=3.21$, $df=150$, $p=0.002$), calf circumference ($t=2.66, df=150$, $p=0.009$) and arm muscle area ($t=3.00$, $df=150$, $p=0.003$) in the non-attenders.

In summary, unless there was an underestimation of the true population of the over 50's due to absence or deliberate falsification caused by hostility or fear, the original population studied is generally representative of low-income elderly people living in the large slums and chawls in F/South Ward of Greater Mumbai. However, the final data set used for further analyses was based on complete cases, consisting of 1,097 cases, and carries some biases caused by exclusion of oedema cases, non-participation and non-attendance. Whilst attempts were made to minimise their extent, there does appear to be some non-participation bias towards the working male, and some non-attendance bias towards the undernourished older male.

CHAPTER 5 : DESCRIPTIVE RESULTS

This chapter presents the characteristics of nutritional, functional and performance, and morbidity variables by sex, and by age group. Attention is also paid to other self-reported variables such as being housebound, recently disabled or with poor self-reported health, and of being diagnosed as having kyphosis.

5.1 Anthropometry and underweight

5.1.1 Descriptives by sex and age

Summary descriptive statistics for all anthropometric variables and derived variables, BMI and cAMA, by age group for 1,097 subjects are presented in Table 5.1 (men) and Table 5.2 (women). Exclusion of the oedema cases (see 3.2) had eliminated much of the skewness and kurtosis in the distributions of all variables which then approximated normality so that transformations were deemed unnecessary.

Sex exerted a significant effect on all raw anthropometric variables and derived cAMA. Men were significantly heavier ($t=11.92$, $df=1088$, $p=<0.001$) and taller ($t=35.86$, $df=1085$, $p=<0.001$) than women, and had longer armspans ($t=32.41$, $df=1050$, $p=<0.001$), thicker arm ($t=4.98$, $df=1095$, $p=<0.001$) and calf circumferences ($t=10.79$, $df=1092$, $p=<0.001$) and larger arm muscle areas ($t=8.83$, $df=1094$, $p=<0.001$). In contrast, mean triceps skinfold thickness was smaller in men than in women ($t=11.36$, $df=1095$, $p=<0.001$). Mean BMI was similar for the sexes (20.5 for men and 20.6 for women).

Means of most anthropometric variables except height and armspan showed a downward but non-linear trend with increasing **age**, with a marked step effect at the age cut-off 70 years in both sexes, particularly in women. Tables 5.1 and 5.2 show the relationships of age with anthropometric variables by sex when the sample is broken down into two age groups (50-64 years, 65 and above). In men, a significant negative effect of age group was found in only cAMA and MUAC whereas all variables except armspan are significantly associated with older age in women.

As described in section 2.7.4, efforts were made to achieve good **reliability** as part of the quality control of anthropometric measurements. The results of error calculations (*TEM*) for the initial post training and mid-point periods were almost identical and ranged from 0.1 to 0.4. The full results for the mid-point period are given in Appendix III. The lowest TEM's were for weight, and the highest for triceps skinfold thickness and armspan. All intra- and inter-observer TEM's for which standards are available (for height, arm circumference, and triceps skinfolds thickness) were within, or close to, the acceptable limits for TEM at the 0.95 level for subjects aged 18-65 (Frisancho 1990, Ulijaszek and Lourie 1994). Many reliability coefficients were above 0.90[1], indicating that a measure is 90% free from measurement error.

For those without oedema and/or kyphosis, the frequencies of **missing values** are also given in Tables 5.1 and 5.2. The highest number of missing values occurred for armspan (4%), and weight (0.5%). Missing values for armspan were the result of amputations, missing or deformed fingers, or painful arthritis in the shoulders and hands. The missing cases for height and weight were caused by the inability to stand and were mostly housebound cases. In this study, 61 out of 1,097 subjects without kyphosis or oedema had missing values for one or more anthropometric measurements, giving a measurement failure rate of 5.6%.

[1] A reliability coefficient of 0.99 means that occasional gross measurement error is unlikely to have important consequences (Ulijaszek and Lourie 1994).

Table 5.1 Summary statistics for anthropometry by age group - men

	Age grp	*n*	mean	SD	min	max	missing	test of significance fo age difference
Weight kg	All	455	53.2	11.0	29.2	101.8	3	*t (453)=0.89, p=0.373*
	50 - 64	328	53.4	11.2	29.2	101.8	2	
	≥ 65	127	52.4	10.4	30.5	85.4	1	
Height m @	All	454	1.61	0.07	1.41	1.78	4	*t (452)=1.07, p=0.28*
	50 - 64	327	1.62	0.06	1.41	1.78	3	
	≥ 65	127	1.61	0.07	1.41	1.76	1	
Height m #	All	391	1.62	0.06	1.45	1.78	4	*t(389)=0.39, p=0.69*
	50 - 64	300	1.62	0.06	1.47	1.78	3	
	≥ 65	90	1.62	0.07	1.45	1.75	1	
Armspan m	All	434	1.70	0.07	1.48	1.92	24	*t(432)=0.00, p=0.81*
	50 - 64	316	1.70	0.07	1.47	1.92	14	
	≥ 65	118	1.70	0.07	1.53	1.85	10	
MUAC cm	All	458	24.1	3.3	15.1	34.5	0	*t (456)=2.06, p=0.04*
	50 - 64	330	24.3	3.4	15.1	34.5	0	
	≥ 65	128	23.6	3.0	17.0	31.5	0	
Calf circumf cm	All	458	29.3	3.4	20.9	39.0	0	*t(456)=1.58, p=0.114*
	50 - 64	330	29.5	3.5	20.9	39.0	0	
	≥ 65	128	28.9	3.2	21.1	36.5	0	
Triceps skinf mm	All	458	10.2	4.5	3.0	27.9	0	*t(456)=1.21, p=0.227*
	50 - 64	330	10.1	4.4	3.0	27.9	0	
	≥ 65	128	10.7	4.8	3.6	26.2	0	
cAMA cm^2	All	458	25.3	8.2	5.1	54.8	0	*t (456)=3.68, p=<0.001*
	50 - 64	330	26.1	8.5	5.1	54.8	0	
	≥ 65	128	23.0	6.7	9.5	42.1	0	
BMI kg/m^2	All	447	20.5	3.8	11.9	35.2	11	*t(445)=0.06, p=0.95*
	50 - 64	326	20.5	3.8	11.9	33.1	4	
	≥ 65	121	20.5	3.7	13.0	35.2	7	

@ *includes those with kyphosis*
\# *excludes those with kyphosis*

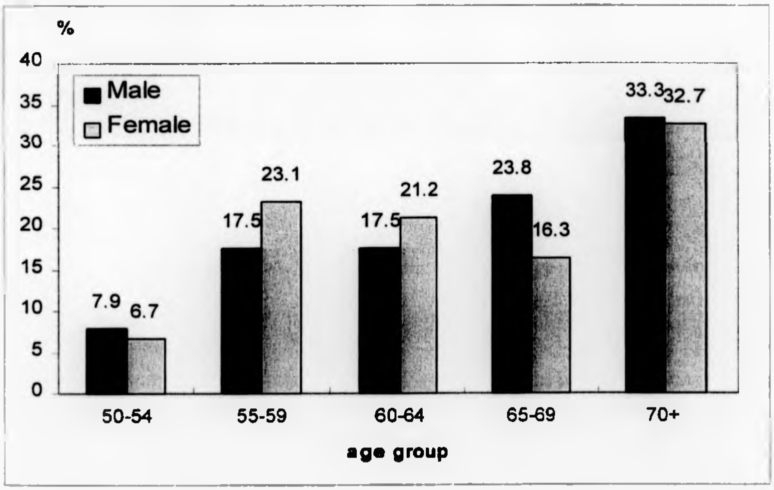
Table 5.2 Summary statistics for anthropometry by age group - women

	Age grp	*n*	mean	SD	min	max	missing	test of significance for age difference
Weight kg	All	635	45.3	10.5	23.4	93.0	4	*t* (633)=4.05, p=0.000
	50 - 64	501	46.2	10.4	24.0	93.0	3	
	≥ 65	134	42.1	10.1	23.3	77.3	1	
Height m @	All	633	1.48	0.06	1.31	1.65	6	*t* (631)=3.11, p=0.002
	50 - 64	501	1.48	0.06	1.31	1.65	3	
	≥ 65	132	1.46	0.06	1.32	1.59	3	
Height m #	All	531	1.48	0.06	1.31	1.65	4	*t* (529) =1.44, p =0.14
	50 - 64	449	1.48	0.06	1.31	1.65	2	
	≥ 65	82	1.7	0.06	1.35	1.59	2	
Armspan m	All	618	1.55	6.9	1.32	1.78	21	*t* (616)=1.16, p=0.248
	50 - 64	490	1.55	7.1	1.31	1.78	14	
	≥ 65	128	1.55	6.2	1.40	1.70	7	
MUAC cm	All	639	23.0	3.8	13.8	34.3	0	*t* (637)=5.38, p=<0.001
	50 - 64	504	23.4	3.8	14.4	34.3	0	
	≥ 65	135	21.5	3.6	15.2	31.3	0	
Calf circumf cm	All	636	27.0	3.5	17.8	37.3	3	*t* (634)=5.38, p=<0.001
	50 - 64	503	27.4	3.5	17.8	37.3	1	
	≥ 65	133	25.6	3.4	17.8	35.5	2	
Triceps skinf mm	All	639	14.2	6.4	2.0	38.7	0	*t* (637)=4.81, p=<0.001
	50 - 64	504	14.8	6.6	2.0	38.7	0	
	≥ 65	135	11.9	5.4	2.5	24.4	0	
cAMA cm^2	All	638	21.3	6.6	5.1	46.9	1	*t* (636)=4.77, p=<0.001
	50 - 64	503	21.9	6.6	5.1	46.8	1	
	≥ 65	135	18.9	6.4	7.2	37.8	0	
BMI kg/m^2	All	629	20.6	4.3	10.7	36.2	10	*t* (627)=3.59, p=<0.001
	50 - 64	499	20.9	4.2	11.7	36.2	5	
	≥ 65	130	19.4	4.3	10.7	31.4	5	

@ includes those with kyphosis
 # excludes those with kyphosis

The overall prevalence of **kyphosis** was 15.2% (*n=168*) with no significant effect of sex. However, Figure 5.1 shows an overall increase in kyphosis prevalence with age in both sexes. Overall, those suffering from kyphosis are significantly older than those without kyphosis ($\chi^2 = 119.26$, *df=4*, $p=<0.001$). Men aged 50-64 had a kyphosis prevalence of 8% which rose to 28.1% in the older age group. The equivalent prevalences for women were 10.5% in the younger age group and 37.8% in the over 65's.

Figure 5.1 Prevalence of kyphosis by sex and age group



Although mean measured heights were lower in kyphotic cases in both sexes, the differences did not reach significance overall. None of the other anthropometric variables were significantly negatively affected by the presence of kyphosis with the exception of BMI in men aged 50-64 years ($t=3.63$, *df=342*, $p=<0.001$). This effect on BMI was not seen in the older age group, nor in women of either age group. The proportion of cases on whom height could not be measured either due to kyphosis or other reason (missing value) was considerably larger (16.2 %) than the proportion of cases with missing values for armspan (4%).[2]

5.1.2 Prevalence of underweight

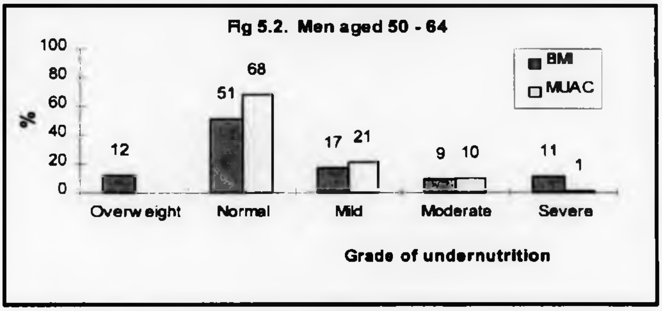
Figs 5.2 to 5.5 summarise the distribution of the different levels of underweight by sex and by two age groups according to the two methods of classification using BMI and MUAC described in section 2.11. In women, increasing age brings a significant negative effect as the prevalence of underweight using both MUAC and BMI cut-offs in older women is significantly higher (by 12% using BMI, and by 19% using MUAC) than in the younger women. The latter is consistent with the increased prevalence of severe wasting (MUAC<16 cms) and of weight loss in older compared to younger women. There was a lesser but non-significant trend in men.

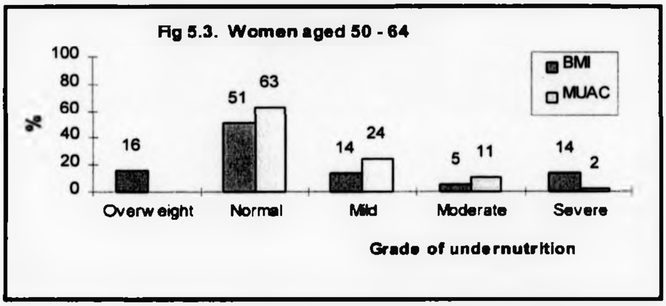
Overall, using BMI classifies 379 cases (35%) as underweight (BMI<18.5), with 149 cases (14%) of the total classified as severely underweight (BMI<16). Using MUAC the overall proportion classified as underweight is similar, 34% *(n=362)*, but only 2% (n=19) are classified as severely underweight. However, taking the overall prevalence masks certain differences by sex and age, as shown in Table 5.2.

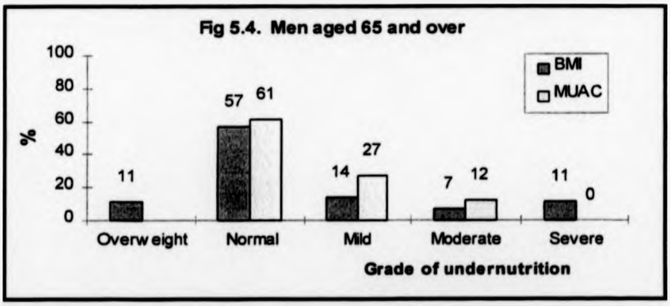
Using MUAC classifies a larger proportion of women as underweight, especially in the older age group, than does the BMI classification. In contrast, MUAC classifies less men as underweight but the differences between the two methods are not as large. The proportions similarly classified as underweight by both methods are 94% for younger men and 85% for older men, with lower figures for women : 82% for the younger group and 80% for the older group.

[2] This difference clearly illustrates the advantage of using this long bone substitute for stature in the anthropometric assessment of older people in whom kyphosis is a common problem.

Figures 5.2 to 5.5 Distribution of underweight using BMI and MUAC classifications







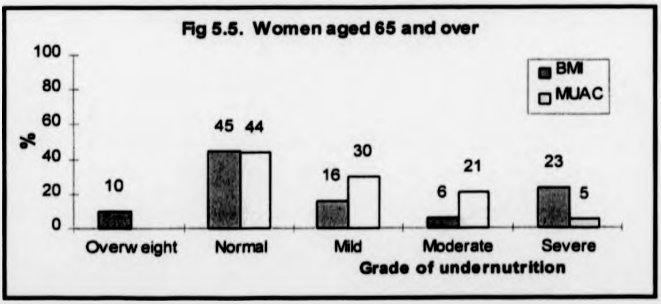


Table 5.3 Comparing underweight prevalences using two methods of classification

%	USING BMI			USING MUAC		
	Under-nourished	Normal	*signif test for age difference*	Under-nourished	Normal	*signif test for age difference*
MEN						
All	35	65		26	74	
50-64	37	63		25	75	
≥ 65	31	69	*ns*	29	71	*ns*
WOMEN						
All	35	65		41	59	
50-64	33	67		36	64	
≥ 65	45	55	χ^2=7.55, =0.006	56	44	χ^2=17.6, p=<0.001
signif test for sex differ		*ns*		χ^2 = 25.01, p=<0.001		

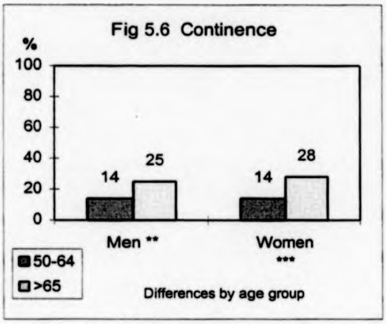
5.2 Functional ability

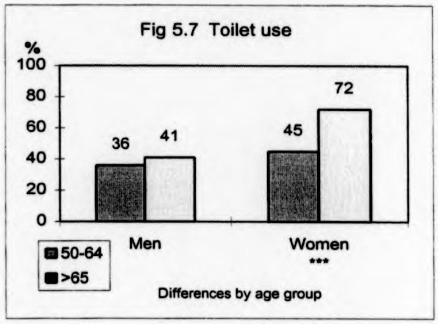
5.2.1 Self-report questionnaires

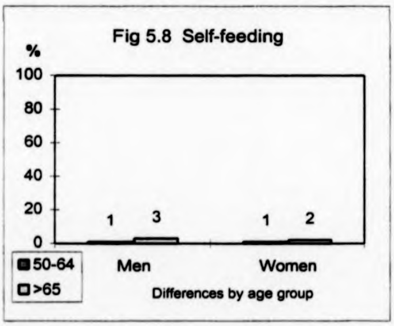
Overall, the highest levels of **ADL impairment** reported were for the abilities to transfer and use the toilet independently, whilst the lowest level of impairment reported was for the ability to self-feed (Table 5.4). Levels of impairment for dressing and bathing independently were also low. Women were significantly more impaired than men for toilet use and transfer ability, but the levels of impairment for the other four ADL's were similar. Women also had a higher mean number of total ADL impairments than men.

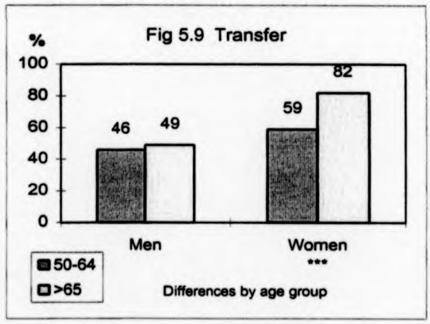
Overall, there was a **negative effect of increasing age** on the level of ADL dependency, both taking each ADL task individually and counting the number of ADL tasks impaired.

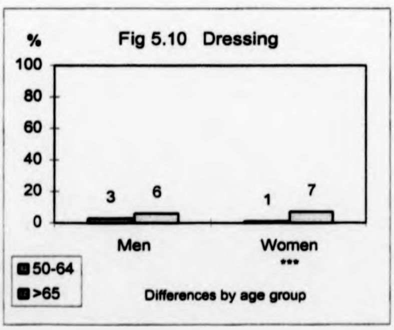
Figs 5.6 to 5.11 Frequencies of any degree of impairment in 6 ADL tasks

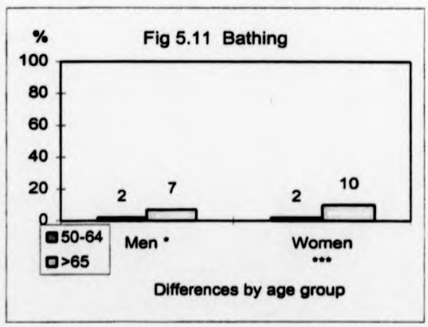












*Levels of significance : * = p< 0.05, ** = p < 0.001, *** = p < 0.0001*

Figs 5.6 to 5.11 show the frequencies in percent of any degree of impairment in each of the 6 ADL tasks by age group, and show differences by sex for toilet use and transfer for which women reported more impairment. With the exception of feeding, older women were significantly more dependent in all five remaining ADL tasks than younger women (continence $\chi^2 = 15.415$, $p=0.0009$, transfer $\chi^2 = 24.65$, $p=<0.001$, toilet use $\chi^2 = 29.73$, $p=<0.001$, dressing $\chi^2 = 12.15$, $p=0.0019$, bathing $\chi^2 = 17.412$, $p=0.0003$) but although there was a similar trend for older men the differences between the age groups only reached significance for continence ($\chi^2 = 28.52$, $p=0.0035$) and bathing ($\chi^2 = 5.477$, $p=0.023$).

Table 5.4. Prevalence of any impairment for each ADL task by sex

	ALL		MEN		WOMEN		
	n	%	n	%	n	%	*significance test for sex difference*
Continence	185	17	77	17	108	17	*ns*
Toilet use	498	45	172	37	326	51	$\chi^2 = 20.72$, $p = <0.01$
Feeding	16	2	9	2	7	1	*ns*
Transfer	623	57	214	47	409	64	$\chi^2 = 32.48$, $p = <0.001$
Dressing	33	3	17	4	16	3	*ns*
Bathing	43	4	17	4	26	4	*ns*

The **correlation coefficients** between the 6 ADL tasks are shown in a matrix in Table 5.5. The strongest correlation is between dressing and bathing, followed by toilet use and transfer. Feeding had reasonably strong correlations with both dressing and bathing in men. All other correlations in both sexes were small.

There is a high reliability of the ADL scale with a Cronbach Alpha Correlation coefficient of 0.61 for women and 0.72 for men (Table 5.6). As dressing and bathing, and toilet use and transfer, have already been shown to be highly correlated, the calculation of Split Half Alpha correlation coefficients is appropriate, with dressing and bathing forming one half of the split, and toilet use, feeding and transfer the other half, and continence eliminated. This leads to an improved internal reliability, and eliminating both continence and feeding to produce a 4-item scale causes Part 1 Alpha to rise even higher[3].

Table 5.5 Correlation matrix* for ADL tasks

		Continen	Feed	Toilet	Transfer	Dressing
ALL	Continence	1.00				
	Feeding	0.17	1.00			
	Toilet use	0.13	0.16	1.00		
	Transfer	0.13	0.15	0.75	1.00	
	Dressing	0.18	0.48	0.25	0.25	1.00
	Bathing	0.15	0.42	0.28	0.26	0.80
MEN	Continence	1.00				
	Feeding	0.22	1.00			
	Toilet use	0.16	0.27	1.00		
	Transfer	0.12	0.24	0.77	1.00	
	Dressing	0.28	0.61	0.35	0.31	1.00
	Bathing	0.30	0.58	0.38	0.29	0.79
WOMEN	Continence	1.00				
	Feeding	0.12	1.00			
	Toilet use	0.11	0.07	1.00		
	Transfer	0.13	0.07	0.74	1.00	
	Dressing	0.11	0.33	0.18	0.22	1.00
	Bathing	0.05	0.27	0.22	0.24	0.81

* *all are significant at the $p < 0.0001$ level*

[3] It seems reasonable to exclude continence as many agree that continence is an unreliable self-reported ADL and that it does not represent the same type of dimensions as the other ADLs thereby rendering it a dubious component of any composite ADL scales (Ebrahim *et al* 1985, Spector *et al* 1987, Kempen and Suurmeijer 1990). Justification for the elimination of feeding is less obvious although there may have been some misinterpretation of the question or cultural inappropriateness (self-feeding in this context use mainly hands and not utensils as the original question implies).

Table 5.6 Reliability statistics for ADL scales

	ALL			MEN			WOMEN		
No. of items in scale	6	5	4	6	5	4	6	5	4
Scale mean	16.7	13.9	10.9	16.8	14.0	11.0	16.5	13.7	10.7
Scale variance	1.9	1.5	1.4	2.2	1.7	1.5	1.7	1.4	1.3
Alpha coefficient	0.66	0.70	0.71	0.72	0.75	0.75	0.61	0.66	0.69
Split Alpha Part 1		0.67	0.86	-	0.70	0.87	-	0.64	0.84
Split Alpha Part 2		0.89	0.89	-	0.88	0.88	-	0.89	0.89

For 5 item ADL : For Split Alpha : Part 1 = feeding, toilet use, transfer Part 2 = dressing, bathing
For 4 item ADL : For Split Alpha : Part 1 = toilet, transfer Part 2 = dressing, bathing

Mobility problems are very common. Table 5.7 shows that almost 60% reported difficulty walking a short distance, and nearly 80% had difficulty climbing a flight of stairs. The vast majority (81%) of poor travellers were women which suggests there may be something gender-specific about this question which has affected the response. Women were significantly worse at the other two mobility tasks than men. The level of impairment in each mobility task was higher in people over 65 years, although these differences were significant only for walking ($\chi^2=6.618$, $p<0.01$ in men; $\chi^2=8.216$, $p<0.0042$ in women) and for travel ($\chi^2=26.48$, $p<0.001$ in men; $\chi^2=24.43$, $p<0.001$ in women) in both sexes, and not for stair climbing (Figs 5.12 to 5.14). The total number of mobility tasks impaired also rose significantly with age in both sexes ($\chi^2=26.44$, $p<0.0001$ *in men;* $\chi^2=31.73$, $p<0.0001$ *in women*). Figure 5.15 shows how increasing age had a highly significant negative effect on the prevalence of being impaired in two or more mobility tasks (IMPMOB variable), and again how much more impaired women were than men in either age group. Overall impairment in ADL's was highly significantly associated with overall impairment in mobility in both sexes ($\chi^2=55.79$, $p<0.001$ in men; $\chi^2=55.76$, $p<0.001$ in women).

Figs 5.12 to 5.17 Prevalence of impairment in mobility and other self-reports

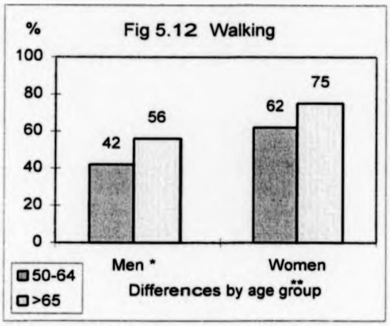


Fig 5.12 Walking

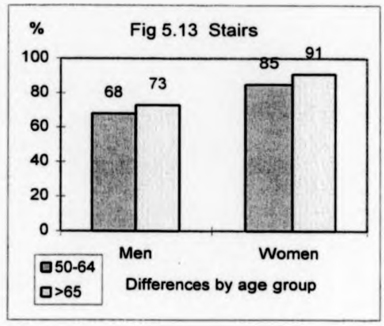


Fig 5.13 Stairs

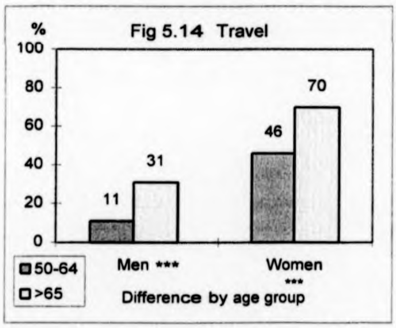


Fig 5.14 Travel

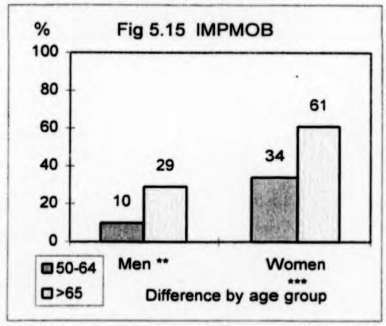


Fig 5.15 IMPMOB

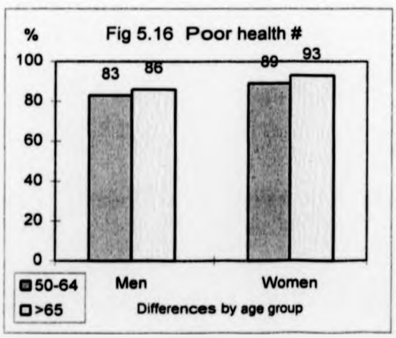


Fig 5.16 Poor health #

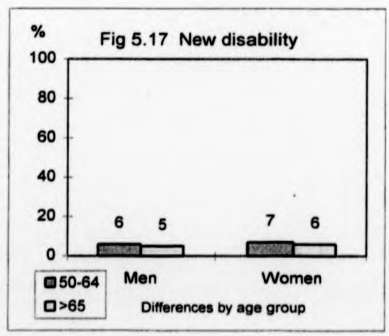


Fig 5.17 New disability

*Levels of significance : * = $p < 0.05$, ** = $p < 0.001$, *** = $p < 0.0001$*

 # poor health refers to all assessments of health except "very healthy"

Table 5.7 Prevalence of any impairment for each mobility task by sex

	All		Men		Women		*significance test for sex difference*
	n	%	n	%	n	%	
Walk	621	57	210	46	411	64	$\chi^2 =$ *47.74, p=<0.001*
Stairs	866	79	316	69	550	86	$\chi^2 =$ *37.08, p= <0.001*
Travel	406	37	77	17	329	52	$\chi^2 =$ *138.6, p= <0.001*
IMPMOB *	324	30	70	15	254	40	$\chi^2 =$ *76.73, p= <0.001*

* *impairment in at least two mobility tasks*

Surprisingly, the inter-item correlations for mobility were not particularly strong (Table 5.8). Table 5.9 presents the reliability statistics for a three-item mobility scale. Internal reliability was fairly high, with Alpha correlation coefficients of 0.77 for men and 0.66 for women.

Table 5.8. Correlation matrix* for mobility

		Walk	**Stairs**	**Travel**
ALL				
	Walk	1.00		
	Stairs	0.55	1.00	
	Travel	0.45	0.38	1.00
MEN				
	Walk	1.00		
	Stairs	0.60	1.00	
	Travel	0.48	0.36	1.00
WOMEN				
	Walk	1.00		
	Stairs	0.48	1.00	
	Travel	0.40	0.35	1.00

* *all are significant at the* $p < 0.0001$ *level*

Table 5.9. Reliability statistics for mobility items

	ALL	MEN	WOMEN
Scale mean	7.2	7.6	6.8
Scale variance	1.6	1.5	1.5
Alpha coefficient	0.71	0.74	0.66

Figs 5.16 and Fig 5.17 show the prevalences of self-reported **poor health**[4] and recent disability or surgery by sex and age group. Good health was reported in only 13% of cases overall, with no difference in the prevalence between the sexes. The overall prevalence of **recent disability** or surgery was low (6%) and did not differ significantly between the sexes. Neither the level of poor self-reported health nor the incidence of recent disability or surgery was associated with older age, nor was either associated with being housebound. Only 12 cases (4 men and 8 women) were classified as having **poor cognitive status**, and the overall prevalence of cognitive impairment amongst poor ADL, mobility and physical test performers was mostly low, averaging about 2%. The highest prevalences (12%) were amongst those with bathing, dressing, and self-feeding problems but statistical significance testing between impaired cognitive status and functional ability impairment was not possible because of small cell numbers.

5.2.2 Physical performance tests

Basic descriptive statistics[5] for the four continuous physical performance test variables by sex and age group are presented in Table 5.10. As expected, men were much stronger

[4] includes self-reported "very poor health" and "moderately healthy/not very ill", but not "very healthy"
[5] Out of the continuous phsyical test performance, only handgrip was approximately normally distributed. As distributions for the other timed tests had some kurtosis and were slightly skewed, non-parametric tests have been applied to analyses of these physical test variables.

than women, having a mean handgrip strength of 23 kgs compared to only 13 kgs in women. In both sexes, there is a significant decrease in handgrip strength with advancing age (Fig 5.18). Values for both men and women were 5 kgs less for the over 70's than for the youngest age group, 50-54 years.

Table 5.10. Descriptive statistics for continuous physical test variables

	MEN			WOMEN			
	mean (SD)	min	max	mean (SD)	min	max	signif test of sex diff
Handgrip (kgs)							
All	22.9 (6.5)	7	44	13.4 (4.5)	1	31	*t=8.55 (df1096), p=<0.001*
50-64	23.7 (6.5)	7	44	14.0 (4.4)	2	31	
≥ 65	20.8 (6.5)	6	9	11.1 (4.2)	1	25	
significance test for age difference	*t=4.65 (df 456), p=<0.001*			*t=6.94 (df 633), p=<0.001*			
Chair rises (secs)							
All	15.2 (5.1)	5	48	18.7 (7.1)	8	74	*Z =10.34, p=<0.001*
50-64	14.9 (5.1)	5	48	18.0 (6.4)	8	74	
≥ 65	16.1 (5.2)	9	36	21.4 (8.9)	10	69	
significance test for age difference	*Z= 1.96, p=0.005*			*Z= 0.6601, p=0.509*			
Lock open (secs)							
All	7.2 (4.4)	2	31	11.0 (8.4)	2	108	*Z =12.03, p=<0.001*
50-64	6.9 (4.0)	2	31	10.3 (7.2)	2	108	
≥ 65	8.2 (5.4)	2	31	13.6(11.8)	2	108	
significance test for age difference	*Z = 2.299, p=0.0215*			*Z = 1.996, p= 0.0459*			
Plate-tap (secs)							
All	25.8 (9.3)	7	82	31.9 11.4)	6	163	*Z =-10.90, p=<.0001*
50-64	25.1 (8.7)	7	75	30.6 10.6)	6	163	
≥ 65	27.6(10.5)	13	82	37.2 12.9)	18	88	
significance test for age difference	*Z= 2.9212, p=0.0035*			*Z = 2.567, p=0.0103*			

Women were significantly slower than men at all timed tests, and in both sexes, increasing age negatively affected performance (Figs 5.19 to 5.21). There was a distinct falling off in flexibility performance after age 70 years in both sexes, shown in Fig 5.22, with impairment significantly worse amongst those over 65 than those aged 50-64 years (χ^2 =*43.81, p=<0.001*). Significantly more women than men had some impairment in shoulder flexibility (χ^2 = *10.31, p=0.0009*).

Table 5.11 gives the percentiles for the four continuous physical tests. As described earlier in section 2.12 (b), the worst quartile of the distribution for each sex was used to code performance as "poor" to create artificial, but epidemiologically acceptable, cut-offs. Using these dichotomous physical test variables, women with **poor cognition** were significantly worse in all five physical test dimensions. In men, poor cognitive status was not associated with poor handgrip, flexibility or chair-rise time but all men with poor cognitive status fell into the poor performance category for plate-tapping and key opening measures.

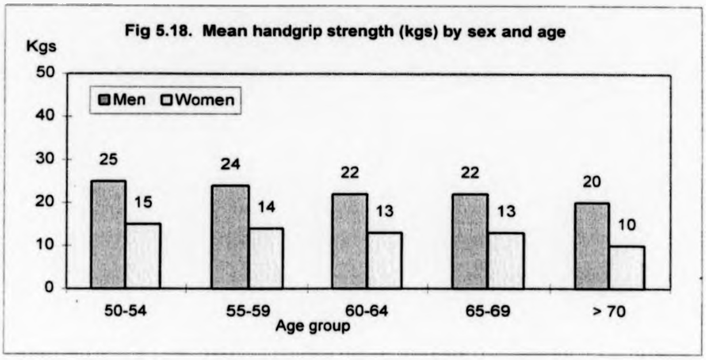
Table 5.11 Percentiles and missing cases for physical test variables

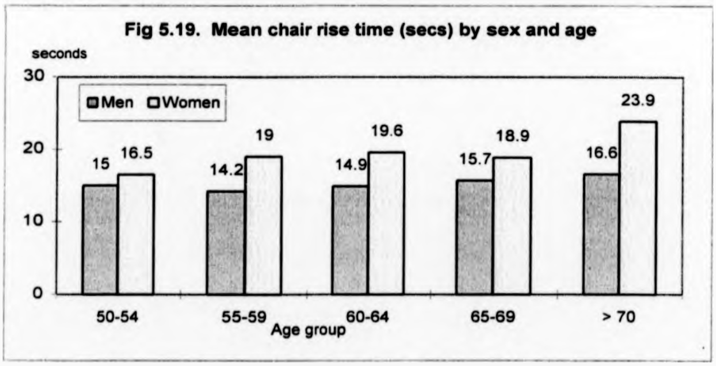
	MEN						WOMEN					
%ile	5	25	50	75	95	*missing*	5	25	50	75	95	*missing*
Variable												
Handgrip (kgs)	13	18	23	27	34	0	7	10	13	16	21	4
Chair rise time (secs)	9	12	15	17	25	19	11	15	17	21	32	35
Lock key time (secs)	3	5	6	9	16	6	4	6	9	13	24	7
Plate-tap time (secs)	16	20	24	29	41	15	20	25	30	36	51	8

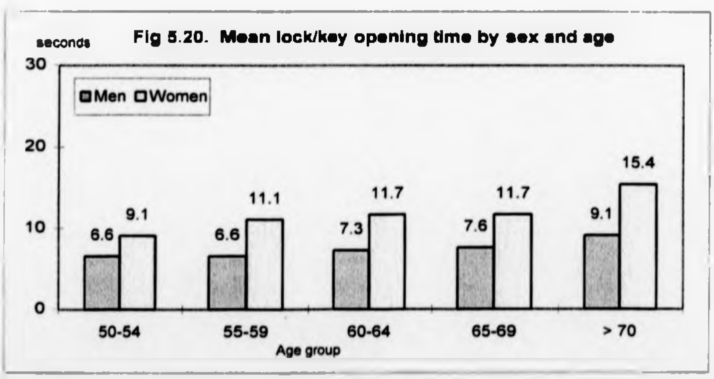
The chair stand test had the highest number of **missing cases** (Table 5.11). This was followed by the plate-tapping and lock and key tests. Some of these missing values represent an inability to complete the task due to pain or limb damage, but they also include situations in which the test could not be performed satisfactorily (housebound people seen in cramped homes), and refusals[6]. Only 4 cases failed to attempt the handgrip test, complaining of painful arthritis in the hands and wrists.

[6] Chair rises had once been a form of punishment in Indian schools which may have affected willingness to perform the test

Figs 5.18 to 5.22 Physical test performance by sex and age group







Figs 5.18 to 5.22 Physical test performance by sex and age group (ctd)

Fig 5.21. Mean plate-tap time (seconds) by sex and age

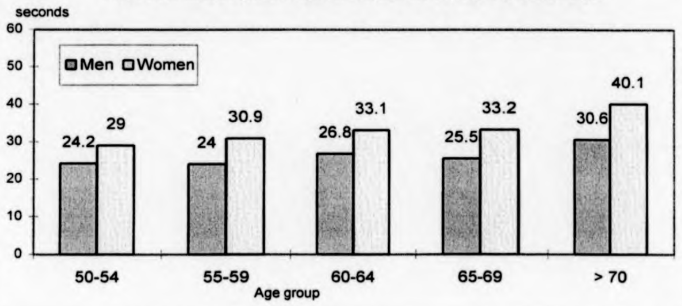
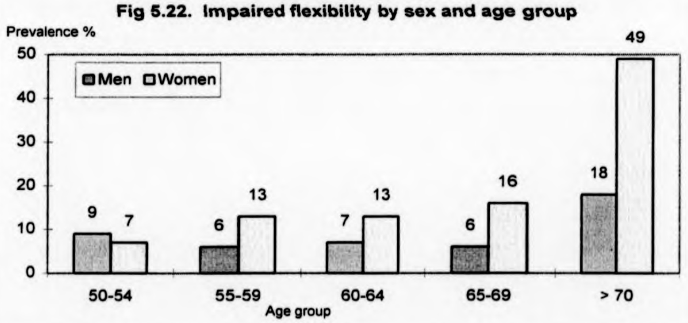


Fig 5.22. Impaired flexibility by sex and age group



5.3 Morbidity

Cataracts were by far the most common problem, followed by musculoskeletal disease and hypertension (Table 5.12). Women suffered significantly more musculoskeletal disease than men *(χ^2=39.53, p=<0.001)*, whereas men had significantly more neurological problems *(χ^2=9.12, p=0.002), COPD (χ^2=17.17, p=0.0003)*, and TB *(χ^2=16.54, p=<0.001)* than women. There were no significant sex differences for any other morbidity condition.

Table 5.12. Prevalence of disease conditions in decreasing order by sex

Disease condition	Prevalence %			
	Men	Women	All	*test of significance for age difference*
Cataracts	71	73	72	χ^2=11.28, p=0.00078 #
Musculoskeletal	36	*** 55	47	
Hypertension	19	20	20	χ^2=4.32, p=0.0375 @
Skin	14	12	13	χ^2=5.21, p=0.0224 #
COPD	*** 11	5	7	
Gastrointestinal	7	7	7	
Cardiovascular	5	7	6	
TB	*** 8	3	5	
Diabetes	6	4	5	
Neurological	** 6	2	4	
URTI	5	3	4	
Urogenitary	1	1	1	
Cancer	0.2	0.5	0.4	
LEM	0	0.3	0.2	
Leprosy	0.2	0	0.2	
Hearing impairment	4	1	3	
MINMORB	* 50	43	46	
MAJMORB	*** 23	15	18	

*Levels of significance for sex difference : * p<0.05, ** p < 0.001 *** p < 0.0001*
 # increased prevalence of condition associated with younger age group
@ increased prevalence of condition associated with older age group

Noting that smoking and drinking are known risk factors for some diseases, the overwhelming majority of smokers (93%) and all those who admitted to drinking regularly were men.

Taking the population overall, as well as for each sex separately, there were no significant associations between age and morbidity conditions, except for more cataracts and skin disease in the younger age group and more hypertension in the over 65 year-olds. The prevalence of MAJMORB (diseases thought to have a significant impact on functional ability) was 18%, and for MINMORB (diseases thought to have a minor impact on functional ability) 46%, with men significantly more affected in both variables than women (MINMORB $\chi^2=4.122$, $p=0.0426$; MAJMORB $\chi^2=12.04$, $p=0.0005$).

5.4 Blood analyses

Haemoglobin values were approximately normally distributed in both sexes. Mean serum haemoglobin in women was significantly lower than in men ($t=13.17$, $df=1080$, $p=<0.001$). In women it was also significantly lower in the older group compared to those aged 50-64 years, but there was no such effect in men.

Anaemia was extremely common in this population, particularly amongst women in whom the prevalence was 52%. (Table 5.14). In women the prevalence of anaemia also rose significantly with increasing age, from 48% in the 50-64 year olds to 64% in those over 65 years. Most of the anaemia in both sexes fell into the mild category with only small proportions (12% in women and 4% on men) falling into the moderate category, and even less in the severe (1%). However, the mean hemoglobin for women above 65 years was 11.5, which fell below the WHO cut-off for anaemia, and even for those aged 50-64 the mean fell on the cut-off. Whilst only 22% of men fell below the cut-off (13 gm/dL), this prevalence was still relatively high and the mean hemoglobin for both age groups was only 0.5 gm/dL above the cut-off. The level of anaemia in men was not associated with age.

Table 5.13 Mean serum haemoglobin (gm/dL) by sex and age group

	Men				Women			
	mean	sd	range	n	mean	sd	range	n
All	13.5	2.1	5.3 - 18.9	451	11.9	1.8	5.2 - 16.8	631
50-64	13.4	2.1	5.3 - 18.9	327	12.0	1.7	5.2 - 16.8	499
≥ 65	13.6	2.0	7.9 - 18.1	124	11.5	1.8	7.4 - 15.8	132
significance test for age difference			*ns*			*t=2.39, df 629, p=0.018*		

Table 5.14 Prevalence of anaemia by sex and age group

	Men		Women	
%	Anaemic #	Normal	Anaemic !	Normal
All	22	78	52	48
50-64	21	79	48	52
≥ 65	22	78	64	36
significance test for age difference	*ns*		*χ^2=11.10, p=<0.001*	

 # WHO cut-off < 13.00 gm/dL *! WHO cut-off < 12.00 gm/dL*

Serum albumin values were also approximately normally distributed in both sexes. Again women had significantly lower mean albumin values than men (*t=3.36, df=1077, p=0.001*). In both sexes mean albumin was lower in the older age group but only significantly so amongst women.

The prevalence of **hypoalbuminaemia** was not significantly different between the sexes (Table 5.16). In women the prevalence was positively associated with increasing age but there was no such effect in men.

Table 5.15 Mean serum albumin (gm/dL) by sex and age group

	Men				Women			
	mean	sd	range	*n*	mean	sd	range	*n*
All	4.12	0.47	2.10-5.10	449	4.02	0.46	2.60-5.20	630
50-64	4.13	0.47	2.10-5.10	326	4.06	0.43	2.60-5.20	498
≥ 65	4.08	0.47	3.00-5.10	123	3.89	0.53	2.60-5.00	132
significance test for age difference			*ns*		*t =3.44, df= 628, p= 0 < 0.001*			

Table 5.16 Prevalence of hypoalbuminaemia by sex and age group

	Men		Women	
%	Hypoalb	Normal	Hypoalb	Normal
All	7	93	10	90
50-64	7	93	7	93
≥ 65	8	92	19	81
significance test for age difference	*ns*		*χ^2=17.18, p=0.0003*	

5.5 Associations with being housebound, recently disabled and in poor health

Table 5.17 summarises the main associations found between nutritional, functional and health variables and sex and age group. Other associations were found with other self-reported variables that also merit mention.

Housebound subjects were significantly lighter (*t=5.27, df=1088, p=<0.001)* and leaner with smaller arm muscle areas (*t=4.15, df=1094, p=<0.001)* than non-housebound subjects. Mean BMI's were more than 3 points lower in housebounds than in non-housebounds. Using the MUAC classification 74% of housebound cases were underweight compared to only 34% of normal cases, a difference which is highly significant (χ^2*=16.2, p=0.0001)*. With the exception of continence, being housebound was very strongly associated with individual ADL and mobility impairments in both sexes, as well as with the mean number of impaired tasks (POORADL), the mean total ADL score and the overall level of impairment in ADL and mobility. On average, housebounds were impaired in 4 ADL tasks compared to only 1 in the non-housebound group. Housebounds were also poor test performers. For example, housebound men had a mean handgrip strength of only 12 kg compared to a mean of 23 kg in the normal group *(t=9.13, df=546, p=<0.001)*. In women the difference in mean values was not as large (8 and 14 kg respectively) but was still highly significant (*t=4.20, df=633, p=<0.001)*. There were similar figures for flexibility and plate-tapping performances. In most cases of morbidity, significance testing was not attempted due to small numbers, but, out of the 23 housebound cases, 11 had bilateral cataracts, 7 had hypertension, 4 had unilateral cataracts and 2 each had musculoskeletal disease, COPD, gastrointestinal tract and skin diseases.

The self-report question about **health** proved to have strong associations with underweight, poor functional ability and physical performance, and diagnosed illness. Poor health was significantly associated with low MUAC *(t=2.62, df 456, p=0.010*) and cAMA *(t=2.60, df*

456, p=0.011) values in men, but not in women, whereas it was significantly associated with most self-reported functional ability variables in both sexes. In men, poor health was associated with poor performance in all 5 tests, but for women this was only true for chair rises and flexibility. For those morbidity variables in which numbers were sufficient for significance testing, poor health was significantly associated with the presence of musculoskeletal disease (χ^2=*11.7, p=00063*) (91% of those with musculoskeletal disease reported poor health). There were similar but smaller associations for hypertension (women only), skin disease and TB (men only), and low levels of haemoglobin and albumin in both sexes.

The detrimental effects of **recent disability**, injury or surgery were much less marked. There was no association between this variable and any anthropometric or body compositional variable. Recent disability was associated with IMPMOB (χ^2=*4.89, p=0.127*) in women but not with IMPADL in either sex. Women reporting recent disability or surgery had a significantly lower mean handgrip strength, lower flexibility score and slower test times than the normal group, but in men the means of both groups were similar. In terms of overall morbidity, this variable was only associated with the presence of cataracts (χ^2=*13.17, p=0.0003*) and cancer (χ^2=*13.49, p=0.0203*).

5.6 Summary

This chapter has presented the main descriptive statistics for 9 anthropometric and derived variables, 2 classifications of underweight, 9 self-reported variables of Activities of Daily Living and mobility, several composite variables for overall ADL and mobility, 5 physical performance tests of functional ability, 17 categories of morbidity and two blood analyses. Attention has been paid to the different distributions and prevalences by sex, and by the two age groups 50-64 and over 65s.

Table 5.17 Summary of sex, age group and other associations

	sex diff	higher value	MEN age diff	WOMEN age diff	higher value	associations sig p<0.05 level men	women
Mean							
Weight	***	men		***	young	a	a
Height	***	men		**	young		
Armspan	***	men					
MUAC	***	men	*	***	young	a b	a
Calf circumf	***	men		***	young	a b	a
Tricep skinfold	***	women		***	young	a	a
cAMA	***	men	***	***	young	a b	a
BMI					young	a	a
Prevalence of (%)							
underweight - BMI				**	old	a b	
underweight - MUAC	***	women		***	old	a b	
Impaired / poor performance (%)							
Continence			**	***	old	b	b
Toilet use	***	women		***	old	a b	a b
Feeding						a	a
Transfer	***	women		***	old	a b c	a b
Dressing				***	old	a b	a c
Bathing			*	***	old	a b	a c
IMPADL	*	women	**	***	old	a b c	a b
Walk	***	women	*	**	old	a b	a b c
Stairs	***	women				a b	a b
Travel	***	women	***	***	old	a b	a b
IMPMOB	***	women	***	***	old	a b	a b c
Handgrip strength	@	men	***	***	young	a b	a c
Lower body strength	@	women	**	***	old	a b	b c
Psychomotor skill	@	women	**	***	old	a b	a c
Manual dexterity	@	women	**	***	old	b	a c
Flexibility	@	women		***	old	a b	a b c
Presence of (%)							
Bilateral cataracts				*	young		c
Musculoskeletal	***	women					a b
Hypertension				*	old		b
Skin				*	young	b	
COPD	***	men					
TB	***	men				b	
Anaemia	***	women		***	old		
Hypoalbuminaemia				***	old	b	a b

a = housebound *b = poor self-reported health* *c=recent disability onset/injury/surgery*
Levels of significance p * = *p < 0.05* ** *p = < 0.001* *** *p= < 0.0001*

Table 5.17 summarises the main associations found between all the anthropometric, functional ability, physical performance, morbidity and blood variables by sex and age group, and associations with being housebound, having poor self-reported health and recent disability onset or surgery are also presented where applicable. There are many significant sex differences in the variables. As expected, increasing age also has important negative associations with many variables. It is clear then that both sex and age will need to be controlled for at an early stage in any multivariate analysis, regardless of other interactions between the variables. The next chapter looks at the most interesting and significant interactions between variables at a bivariate level before embarking on the main analysis of the thesis, that is the quantification of the risk of being functionally impaired or having poor physical test performance in the presence of underweight.

CHAPTER 6 : RESULTS - BIVARIATE ANALYSES

Before exploring the hypothesised relationship between underweight and impaired functional ability and poor physical performance using multivariate analysis, an examination of bivariate relationships in the data set is necessary. This provides the setting for the multivariate analysis and the final discussion which follow and allows for a deeper understanding of the characteristics of the study population. The strategy for bivariate analysis has already been described in Chapter 3. All bivariate analyses were conducted using separate sex groups. No attention was paid to age in this stage of the analysis, with the exception of the consideration of kyphosis.

The results of testing for Pearson's Product Moment Correlation Coefficient (Pearson's r) are presented in Table 6.1. However, it should be noted that firstly, the distributions of some physical tests are not strictly normally distributed, and secondly, although their r's are reported in the table, some relationships are not linear. It should also be remembered that the significance level is affected by the number of cases. In this study, sample size is large so that, even though for some bivariate combinations (such as amongst physical test variables, and between physical test and anthropometric variables) r is small, it is possible to conclude that the relationships found could not have arisen by chance and that relationships of approximately these sizes hold in the population (Bryman and Cramer 1990).

The results of Mann-Whitney testing are given in Tables 6.2 to 6.8. The means of the continuous physical performance tests, and the prevalences of flexibility impairment, at each level of nutritional status classified by BMI and MUAC cut-offs, were tested for differences using the Kruskall-Wallis H test (continuous test means) and Pearson's Chi squared test (prevalences of flexibility impairment). The results are presented by sex in Table 6.9.

Table 6.1. Correlation matrix (Pearson's *r*) for continuous independent variables by sex

		Wt	Ht	AS	BMI	Calf	MUAC	Tric	cAMA	Hand	Chair	Plate	Lock	Hb
MEN	Height #	0.41												
	Armspan	0.39	0.83											
	BMI	0.92	*ns*	*ns*										
	Calf circumf	0.83	0.17**	0.19**	0.82									
	MUAC	0.87	0.17**	0.18**	0.87	0.81								
	Triceps skinf	0.75	*ns*	*ns*	0.76	0.66	0.75							
	cAMA	0.74	0.17**	0.18**	0.73	0.71	0.91	0.42						
	Handgrip	0.47	0.29	0.28	0.38	0.44	0.46	0.26	0.46					
	Chair rises	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	-0.28				
	Plate-taps	-0.21	-0.22	-0.18**	-0.14*	-0.21	-0.21	*ns*	-0.23	-0.42	0.43			
	Open lock	*ns*	-0.13*	-0.16*	*ns*	-0.14*	*ns*	*ns*	*ns*	-0.29	0.19	0.26		
	Haemoglobin	0.24	*ns*	*ns*	0.23	0.21	0.26	0.19**	0.23	0.19	*ns*	-0.16**	-0.12*	
	Albumin	0.23	*ns*	*ns*	0.26	0.26	0.29	0.20	0.27	*ns*	-0.15*	*ns*	*ns*	0.34
WOMEN	Height #	0.45												
	Armspan	0.39	0.80											
	BMI	0.94	0.11*	0.12*										
	Calf circumf	0.91	0.35**	0.30	0.88									
	MUAC	0.90	0.24	0.21	0.92	0.89								
	Triceps skinf	0.79	0.14*	*ns*	0.83	0.80	0.89							
	cAMA	0.84	0.29	0.28	0.82	0.80	0.91	0.62						
	Handgrip	0.43	0.34	0.32	0.36	0.45	0.43	0.46	0.47					
	Chair rises	*ns*	*ns*	0.11*	*ns*	*ns*	*ns*	*ns*	*ns*	-0.20				
	Plate-taps	-0.19	-0.19	-0.15**	-0.15**	-0.22	-0.21	-0.18	-0.18	-0.32	0.39			
	Open lock	-0.18	-0.12*	*ns*	0.17	-0.16	-0.18	-0.15**	-0.17	-0.28	0.21	0.33		
	Haemoglobin	*ns*	*ns*	*ns*	*ns*	*ns*	0.11*	*ns*	0.12*	0.11*	-0.12*	*ns*	-0.11*	
	Albumin	0.14**	*ns*	*ns*	0.16	0.18	0.21	0.20	0.18	*ns*	-0.14**	-0.12*	*ns*	0.30

Key: *# excludes kyphotics* *Levels of significance for p: *=p<0.01 **=p<0.001 Rest =p<0.0001* *ns = non-significant*

Table 6.2 Differences in means of continuous variables by level of impairment in self-reports - men

MEN		n	Weight mean p kgs	BMI mean p	MUAC mean p cms	Calf cir mean p cms	Tricep mean p mms	cAMA mean p cms2	Hb mean p gm/dl	Albumin mean p gm/dl	Grip mean p kgs	Plate mean p secs	Chair mean p secs	Lock mean p secs
Continen	Able	381	53.4	20.5	24.2	29.5	10.2	25.6	13.5	4.1	23.1	25.2	14.9	6.9
	Impaired	77	52.0	20.3	23.7	28.5	10.6	23.4 *	13.1	4.1	21.8	28.8	17.0 **	8.7 **
Feeding	Able	449	53.3	20.5	24.2	29.4	10.3	25.4	13.5	4.1	23.0	25.7	15.1	7.2
	Impaired	9	43.3 **	18.4	21.6 *	24.7 ***	10.2	19.6 *	12.9	3.9	16.0 **	36.1	24.7 *	12.5 *
Toilet	Able	286	53.7	20.6	24.4	29.5	10.3	26.1	13.4	4.1	24.1	23.7	14.4	7.1
	Impaired	172	52.2	20.2	23.4 *	29.0	10.1	23.9 **	13.6	4.1	20.9 ***	29.4 ***	16.8	7.6
Dressing	Able	441	53.4	20.5	24.2	29.4	10.3	25.4	13.5	4.1	23.2	25.4	15.0	7.1
	Impaired	17	46.7 *	19.4	22.4 *	26.3 ***	8.6	21.5 *	13.1	3.8 *	15.8 ***	43.3 ***	23.5 ***	10.2 *
Transfer	Able	244	53.1	20.5	24.3	29.4	10.2	25.9	13.4	4.1	23.9	23.9	14.2	6.8
	Impaired	214	53.2	20.5	23.9	29.2	10.3	24.5	13.6	4.1	21.7 ***	28.0 ***	16.4 ***	7.7
Bathing	Able	441	53.3	20.5	24.2	29.4	10.3	25.4	13.5	4.1	23.2	25.4	15.1	7.1
	Impaired	17	48.2 *	19.2	22.4 *	26.9 **	9.4	20.5 **	13.2	3.8 **	15.7 ***	44.5 ***	22.3	9.9
Walk	Able	248	54.8	20.9	24.7	30.0	10.9	26.4	13.6	4.2	25.1	22.9	14.1	6.5
	Impaired	210	51.2 ***	20.0 **	23.5 ***	28.6 ***	9.5 **	23.9 ***	13.3	4.1	20.3 ***	29.4 ***	16.7 ***	8.1 **
Stairs	Able	142	54.6	21.0	24.8	30.0	10.8	27.0	13.6	4.1	25.4	22.6	13.8	6.7
	Impaired	316	52.5 *	20.2 *	23.8 **	29.0 **	10.0	24.5 **	13.4	4.1	21.8 ***	27.3 ***	15.9 ***	7.5 *
Travel	Able	381	54.2	20.7	24.4	29.7	10.5	26.0	13.6	4.2	24.0	24.2	14.5	6.6
	Impaired	77	48.0 ***	19.2 **	22.5 ***	27.5 ***	8.9 **	21.5 ***	12.9 *	3.9 ***	17.6 ***	34.7 ***	19.1 ***	10.7 ***

*Levels of significance for p (Mann-Whitney tests) : *=p<0.05 **=p<0.001 ***=p<0.0001*

Table 6.3 Differences in means of continuous variables by level of impairment in self-reports - women

WOMEN		*n*	Weight	BMI	MUAC	Calf cir	Tricep	cAMA	Hb	Albumin	Grip	Plate	Chair	Lock
			mean *p* kgs	mean *p*	mean *p* cms	mean *p* cms	mean *p* mms	mean *p* cms2	mean *p* gm/dl	mean *p* gm/dl	mean *p* kgs	mean *p* secs	mean *p* secs	mean *p* secs
Continen	Able	531	45.6	20.8	23.1	27.1	14.3	21.5	13.5	4.1	13.7	30.1	18.3	10.7
	Impaired	108	44.1	20.0	22.5	26.4 *	13.8	20.3 *	13.1	4.1	12.2 **	36.4 ***	21.0 ***	12.7 *
Feeding	*Able*	632	45.3	20.6	23.0	27.0	14.2	21.3	13.5	4.1	13.4	31.8	18.7	11.0
	Impaired	7	50.4	21.6	23.0	26.8	15.1	20.8	12.9	3.9	9.3 *	49.3 **	20.7	12.5
Toilet	Able	313	44.6	20.2	22.9	26.9	14.1	21.0	13.4	4.1	14.4	29.8	17.2	9.6
	Impaired	326	46.1	21.0 *	23.1	27.1	14.4	21.6	13.6	4.1	12.5 ***	34.0 ***	20.2 ***	12.4 ***
Dressing	Able	623	45.5	20.7	23.1	27.1	14.3	21.4	13.5	4.1	13.5	31.6	18.7	10.6
	Impaired	16	39.5 *	18.3	20.3 *	23.5 **	11.7	16.1 **	13.1	3.8 *	8.4 ***	48.0 *	21.4	30.5 **
Transfer	Able	230	43.6	19.9	22.6	26.7	13.7	20.6	13.4	4.1	14.4	29.5	16.5	9.6
	Impaired	409	46.3 **	21.0 **	23.2	27.2	14.5	21.7 *	13.6	4.1	12.8 ***	33.3 ***	20.0 ***	11.9 *
Bathing	Able	613	45.5	20.7	23.1	27.1	14.3	21.5	13.5	4.1	13.6	31.5	18.6	10.7
	Impaired	26	40.2 *	18.6 *	20.5 **	23.9 ***	11.4 *	16.6 ***	13.2	3.8 **	9.0 ***	44.0 **	22.6 *	20.5
Walk	Able	228	45.6	20.6	23.2	27.1	14.3	21.7	13.6	4.2	14.6	29.3	16.4	10.0
	Impaired	411	45.2	20.6	22.9	26.9	14.2	21.1	13.3	4.1	12.7	33.4 ***	20.1 ***	11.6 *
Stairs	Able	89	45.1	20.4	23.0	27.1	14.4	20.8	13.6	4.1	15.1	29.0	16.2	9.7
	Impaired	550	45.4	20.7	23.0	27.0	14.2	21.4	13.4	4.1	13.1 **	32.4 **	19.1 ***	11.2 *
Travel	Able	310	46.9	21.1	23.5	27.7	15.2	21.8	13.6	4.2	14.6	29.6	17.5	9.7
	Impaired	329	43.9 **	20.2 *	22.6 **	26.4 ***	13.3 ***	20.8 *	12.9 *	3.9 ***	12.3 ***	34.2 ***	19.9 ***	12.2 ***

*Levels of significance for p (Mann-Whitney tests) : *=$p<0.05$ **=$p<0.001$ ***=$p<0.0001$*

Table 6.4 Differences in means of continuous variables by presence or absence of disease @ - men

			Weight		BMI		MUAC		Calf cir		Tricep		cAMA		Hb		Albumin		Grip		Plate		Chair		Lock	
MEN			mean	*p*	mean	*p*	mean	*p*	mean	*p*	mean	*p*	mean	*p*	mean	*p*	mean	*p*	mean	*p*	mean	*p*	mean	*p*	mean	*p*
			kgs				*cms*		*cms*		*mms*		*cms2*		*gm/dl*		*gm/dl*		*kgs*		*secs*		*secs*		*secs*	
		n																								
Cataract	None	135	54.9		20.9		24.4		29.8		10.9		25.6		13.3		4.1		23.1		25.9		16.0		7.5	
	Present	323	52.4	*	20.3		24.0		29.1		10.0		25.1		13.5		4.1		22.8		25.7		15.0	*	7.1	
Muscskel	None	293	52.6		20.3		23.9		29.2		10.0		24.9		13.3		4.1		23.0		25.9		15.0		7.6	
	Present	165	54.2	*	20.8	*	24.5		29.6		10.7	*	25.9		13.7		4.1		22.6		25.6		15.6		6.6	*
Hyperten	None	369	52.1		20.0		23.8		29.0		9.8		24.6		13.4		4.1		22.8		25.5		15.1		7.1	
	Present	89	57.4	***	22.0	***	25.5	***	30.7	***	12.1	***	28.1	***	13.7		4.2		23.4		27.1		15.8		7.7	
Skin	None	395	52.7		20.4		24.0		29.2		10.1		25.0		13.4		4.1		22.6		26.2		15.4		7.2	
	Present	63	55.7		21.2		24.8		30.2	*	11.0		26.8		13.7		4.1		24.9	*	23.3	*	13.9	*	7.4	
COPD	None	407	53.7		20.6		24.3		29.5		10.5		25.6		13.4		4.1		23.1		25.7		15.4		7.3	
	Present	51	49.2	**	19.2	**	22.6	**	28.0	**	7.9	***	22.9	*	13.7		4.2		21.2	*	26.5		13.4	*	6.9	
Gastroint	None	424	53.2		20.5		24.2		29.3		10.3		25.3		13.5		4.1		22.9		25.9		15.1		7.2	
	Present	34	52.0		20.0		23.6		29.4		9.5		24.4		13.2		4.1		22.2		23.6		16.6		7.1	
Cv	None	437	53.1		20.4		24.1		29.3		10.2		25.2		13.5		4.1		22.9		25.6		15.2		7.2	
	Present	21	54.8		21.5		24.7		29.7		11.1		26.3		13.2		4.1		23.2		28.9	*	16.3		8.9	
TB	None	420	53.9		20.8		24.4		29.6		10.5		25.8		13.5		4.1		23.2		25.6		15.1		7.3	
	Present	38	45.4	***	17.2	***	21.2	***	26.6	***	7.1	***	19.1	***	12.7	*	3.9	**	19.9	**	28.1		16.3		6.8	
Diabetes	None	430	52.9		20.4		24.1		29.4		10.1		25.2		13.4		4.1		22.9		25.8		15.2		7.3	
	Present	28	57.8	*	21.6		25.1		30.3		12.4	**	26.2		14.2		4.2		22.1		24.7		15.8		6.0	
URTI	None	437	53.0		20.5		24.2		29.3		10.3		25.3		13.5		4.1		22.8		25.6		15.2		7.2	
	Present	21	54.8		19.9		23.4		29.2		9.8		23.4		12.5	*	3.9	*	23.8		28.4		15.2		7.2	
Neuro	None	431	53.5		20.6		24.2		29.4		10.4		25.4		13.5		4.1		23.1		25.2		15.2		7.2	
	Present	27	47.2	**	18.4	**	22.8	*	28.0	*	8.5	*	22.8		12.9		4.1		19.2	**	34.7	***	16.2		7.9	

*Levels of significance for p (Mann-Whitney tests) : *=p<0.05 **=p<0.001 ***=p<0.0001*

@ only for diseases with prevalence of 2 % or more

Table 6.5 Differences in means of continuous variables by presence or absence of disease @ - women

WOMEN		n	Weight mean p (kgs)	BMI mean p	MUAC mean p (cms)	Calf cir mean p (cms)	Tricep mean p (mms)	cAMA mean p (cms2)	Hb mean p (gm/dl)	Albumin mean p (gm/dl)	Grip mean p (kgs)	Plate mean p (secs)	Chair mean p (secs)	Lock mean p (secs)
Cataract	None	171	46.7	21.3	23.7	27.7	15.1	22.5	12.2	4.1	13.2	31.7	18.3	10.1
	Present	468	44.8 *	20.4 *	22.8 **	26.8 **	13.9 *	20.9 **	11.7 **	4.0	13.5	32.0	18.8	11.4
Muscskel	None	286	43.5	19.9	22.3	26.4	13.1	20.1	11.7	3.9	13.2	33.1	18.6	11.9
	Present	353	46.9 ***	21.2 ***	23.6 ***	27.5 ***	15.1 ***	22.3 ***	12.0 *	4.1 *	13.6	31.0 *	18.8	10.3
Hyperten	None	510	44.1	20.2	22.6	26.6	13.6	20.7	11.9	4.0	13.4	31.4	18.2	10.8
	Present	129	50.1 ***	22.5 ***	24.7 ***	28.5 ***	16.8 ***	23.8 ***	11.8	4.0	13.5	34.1 **	20.8 **	11.8
Skin	None	561	45.6	20.7	23.1	27.1	14.4	21.4	11.9	4.0	13.4	32.0	18.9	11.1
	Present	78	43.3 *	20.0	22.5	26.4 *	13.2	20.6	11.8	4.0	13.8	31.5	17.1	10.1
COPD	None	610	45.6	20.7	23.1	27.1	14.4	21.5	11.9	4.0	13.5	31.8	18.8	11.0
	Present	29	40.0 **	18.3 **	20.4 ***	25.0 **	10.7 **	16.9 ***	11.8	3.8 *	12.2	34.1	16.8	11.9
Gastroint	None	595	45.4	20.7	23.1	27.1	14.3	21.3	11.9	4.0	13.5	31.8	18.7	10.9
	Present	44	42.8	19.5	22.4	25.6 *	12.8	20.7	11.6	4.1	12.4	34.9	19.4	12.1
Cv	None	595	45.2	20.6	23.0	27.0	14.2	21.2	11.9	4.0	13.4	31.8	18.6	11.0
	Present	44	46.2	21.1	23.7	27.6	15.2	22.4	12.1	4.1	13.0	33.2	19.7 *	14.1
TB	None	621	45.5	20.7	23.1	27.1	14.3	21.4	11.9	4.0	13.4	32.0	18.7	11.0
	Present	18	41.0	18.6 *	21.3 *	25.5 *	12.0	18.2 *	11.7	3.9	13.3	30.9	18.1	10.8
Diabetes	None	614	45.1	20.5	22.9	26.9	14.1	21.1	11.8	4.0	13.4	31.8	18.6	11.1
	Present	25	52.3 **	23.4 ***	25.3 **	29.0 **	16.9 *	25.8 **	12.5	4.1	13.7	34.6	20.7	8.8
URTI	None	620	45.4	20.6	23.0	27.0	14.3	21.3	11.9	4.0	13.4	32.0	18.8	11.1
	Present	19	44.3	20.1	22.1	26.8	12.5	20.3	12.0	4.1	14.5	29.5	16.6	9.2
Neuro	None	624	45.4	20.6	23.0	27.0	14.2	21.3	11.9	4.0	13.4	31.9	18.7	10.9
	Present	15	42.5	20.0	22.4	26.7	13.4	20.3	12.2	4.2	13.3	33.6	19.1	14.9

*Levels of significance for p (Mann-Whitney tests) : *=p<0.05 **=p<0.001 ***=p<0.0001*

@ only for diseases with prevalence of 2 % or more

Table 6.6 Differences in means of continuous variables by summary categorical variables - men

MEN		n	Weight	BMI	MUAC	Calf cir	Tricep	cAMA	Hb	Albumin	Grip	Plate	Chair	Lock
			mean *p* *kgs*	mean *p*	mean *p* *cms*	mean *p* *cms*	mean *p* *mms*	mean *p* *cms2*	mean *p* *gm/dl*	mean *p* *gm/dl*	mean *p* *kgs*	mean *p* *secs*	mean *p* *secs*	mean *p* *secs*
UN bmi	None	289	59.0	22.6	26.0	31.0	12.4	29.0	13.9	4.2	24.6	24.8	15.0	6.9
	Present	158	42.8 ***	16.5 ***	20.9 ***	26.4 ***	6.4 ***	18.8 ***	12.7 ***	4.0 ***	20.3 ***	26.9 *	15.4	7.7
UN muac	None	339	57.3	21.9	25.6	30.6	11.7	28.7	13.8	4.2	24.5	24.9	15.0	7.0
	Present	119	41.2 ***	16.3 ***	19.8 ***	25.8 ***	6.2 ***	15.6 ***	12.4 ***	3.9 ***	18.4 ***	28.4 **	15.8	8.0
Anaemia	None	354	54.4	20.8	24.6	29.7	10.7	26.3	14.3	4.2	23.4	24.9	15.1	7.0
	Present	97	48.6 ***	19.0 ***	22.5 ***	28.0 ***	8.8 ***	21.7 ***	10.5 ***	3.8 ***	20.7 ***	29.0 **	16.0	8.2 *
Hypoalb	None	416	53.7	20.6	24.4	29.5	10.4	25.8	13.6	4.2	23.1	25.3	15.0	7.2
	Present	33	45.8 ***	17.7 ***	21.4 ***	27.0 ***	7.8 ***	19.0 ***	11.3 ***	3.1 ***	20.4 *	31.6 **	18.3 **	8.2
MAJMOR	None	354	54.2	20.8	24.5	29.6	10.7	26.0	13.5	4.1	23.4	25.4	15.3	7.2
	Present	104	49.7 ***	19.2 ***	22.8 ***	28.2 ***	8.5 ***	22.8 ***	13.2	4.0	21.3 **	27.2 *	15.1	7.2
MINMORB	None	231	51.4	20.0	23.7	28.7	9.7	24.4	13.3	4.1	22.4	25.7	15.1	7.2
	Present	227	55.0 **	20.9 *	24.6 **	29.9 ***	10.8 **	26.2 *	13.6	4.1	23.3	25.9	15.3	7.3
IMPADL	None	413	53.4	20.5	24.2	29.4	10.3	25.5	13.4	4.1	23.3	25.0	14.9	7.1
	Present	45	51.2	20.2	23.2	28.1 *	9.9	22.6 *	13.7	4.0	19.4 ***	34.5 ***	19.3 ***	9.0 *
IMPMOB	None	388	54.0	20.7	24.4	29.6	10.5	25.9	13.5	4.1	23.9	24.3	14.6	6.7
	Present	70	48.1 ***	19.2 **	22.6 ***	27.6 ***	8.9 **	21.6 ***	13.0 *	3.9 **	17.2 ***	35.5 ***	19.3 ***	10.6 ***

*Levels of significance for p (Mann-Whitney tests) : *=p<0.05 **=p<0.001 ***=p<0.0001*

Table 6.7 Differences in means of continuous variables by summary categorical variables - women

WOMEN			Weight	BMI	MUAC	Calf cir	Tricep	cAMA	Hb	Albumin	Grip	Plate	Chair	Lock
			mean *p*	mean *p*	mean *p*	mean *p*	mean *p*	mean *p*	mean *p*	mean *p*	mean *p*	mean *p*	mean *p*	mean *p*
			kgs		*cms*	*cms*	*mms*	*cms2*	*gm/dl*	*gm/dl*	*kgs*	*secs*	*secs*	*secs*
		n												
UN bmi	None	408	51.0	23.0	25.1	28.8	17.5	24.5	11.9	4.1	14.5	30.8	18.8	10.1
	Present	221	35.2 ***	16.2 ***	19.4 ***	23.9 ***	8.6 ***	15.8 ***	11.8	3.9 ***	11.6 ***	33.8 **	18.6	12.1 **
UN muac	None	380	51.5	23.1	25.5	29.0	18.0	25.2	12.0	4.1	14.7	30.4	18.8	9.9
	Present	259	36.2 ***	16.8 ***	19.3 ***	24.0 ***	8.7 ***	15.6 ***	11.7 *	3.9	11.5 ***	34.3 ***	18.5	12.7 **
Anaemia	None	306	46.3	20.9	23.4	27.3	14.5	22.1	13.3	4.2	14.1	30.6	18.0	9.9
	Present	325	44.4 *	20.3	22.7 *	26.7 *	14.0	20.5 **	10.5 ***	3.9 ***	12.8 **	33.0 *	19.4 *	12.0 **
Hypoalb	None	570	45.8	20.8	23.3	27.2	14.6	21.7	12.0	4.1	13.7	31.4	18.5	10.6
	Present	60	41.0 ***	18.9 ***	21.1 ***	25.6 ***	11.6 ***	18.3 ***	10.9 ***	3.2 ***	11.1 ***	35.5	20.7	14.2
MAJMOR	None	546	45.7	20.8	23.2	27.1	14.5	21.6	11.9	4.0	13.5	31.6	18.8	10.7
	Present	93	43.0 *	19.7 *	22.1 *	26.2 *	12.8 *	19.8 *	11.8	4.0	12.7	33.6	18.4	12.6
MINMORB	None	362	44.2	20.2	22.6	26.7	13.7	20.5	11.9	4.0	13.3	31.0	18.3	10.9
	Present	277	46.8 **	21.3 **	23.6 **	27.4 *	14.9 *	22.3 ***	11.9	4.0	13.5	33.2 *	19.2 *	11.2
IMPADL	None	547	45.5	20.7	23.1	27.2	14.3	21.5	11.9	4.1	13.8	30.9	18.2	10.3
	Present	92	44.3	20.0	22.3 *	25.9 **	13.7	19.9 **	11.7	3.9 *	11.2 ***	38.2 ***	22.3 ***	15.5 ***
IMPMOB	None	385	46.4	21.0	23.4	27.5	14.8	22.0	12.0	4.0	14.4	29.6	17.4	9.8
	Present	254	43.7 **	20.1 *	22.4 **	26.2 ***	13.4 *	20.3 **	11.7 *	4.0	11.9 ***	35.5 ***	21.0 ***	12.9 ***

Levels of significance for p (Mann-Whitney tests): *=p<0.05 **=p<0.001 ***=p<0.0001

Table 6.8 Differences in means of nutritional variables by status of physical test performance

			Weight kgs		BMI		MUAC cms		Calf cir cms		Tricep mms		cAMA cms2		Hb gm/dl		Albumin gm/dl	
	Performanc	*n*	*mean*	*p*	*mean*	*p*	*mean*	*p*	*mean*	*p*	*mean*	*p*	*mean*	*p*	*mean*	*p*	*mean*	*p*
MEN																		
Handgrip	Able	338	55.3		21.1		24.8		30.0		10.8		26.8		13.6		4.1	
	Poor	120	46.9	***	18.6	***	22.2	***	27.5	***	8.6	***	20.8	***	12.9	**	4.0	
Plate-tap	Able	333	54.5		20.7		24.5		29.7		10.6		26.2		13.6		4.1	
	Poor	125	49.6	***	19.7	**	23.1	***	28.2	***	9.4	*	22.8	***	13.2		4.1	
Chair rise	Able	333	53.5		20.5		24.3		29.5		10.2		25.8		13.6		4.2	
	Poor	125	52.2		20.3		23.7		28.8	*	10.3		23.8	*	13.2		4.0	**
Open lock	Able	341	54.0		20.7		24.4		29.7		10.4		25.9		13.5		4.1	
	Poor	117	50.6	**	19.9	*	23.3	**	28.3	***	9.7	*	23.2	**	13.3		4.1	
Flexibility	Able	419	53.3		20.5		24.2		29.4		10.3		25.3		13.5		4.1	
	Poor	39	51.5		20.2		23.7		28.4		9.9		24.3		13.3		3.9	
WOMEN																		
Handgrip	Able	465	47.4		21.4		23.9		27.9		15.4		22.8		12.0		4.1	
	Poor	174	39.7	***	18.5	***	20.7	***	24.7	***	11.1	***	17.3	***	11.6	**	3.9	**
Plate-tap	Able	476	46.4		21.0		23.4		27.5		14.8		22.0		12.0		4.1	
	Poor	163	42.2	***	19.6	***	21.8	***	25.7	***	12.5	***	19.3	***	11.6	*	3.9	***
Chair rise	Able	456	44.9		20.6		23.0		27.0		14.2		21.3		12.0		4.1	
	Poor	183	46.4		20.7		23.0		26.9		14.3		21.4		11.6	**	3.9	**
Open lock	Able	479	46.2		21.0		23.4		27.4		14.8		21.8		12.0		4.0	
	Poor	160	42.8	***	19.6	**	21.9	***	26.0	***	12.5	***	19.7	***	11.6	*	4.0	
Flexibility	Able	542	45.7		20.7		23.2		27.2		14.5		21.7		12.0		4.0	
	Poor	97	43.1	*	19.9		21.8	**	25.9	**	12.9	*	19.1	***	11.4	**	3.9	**

*# p-values are for Mann-Whitney non-parametric tests : *=p<0.05 **=p<0.001 ***=p<0.0001*

Table 6.9 Differences in means of physical test variables by classifications of underweight

			Handgrip kgs			Plate-tap secs			Chair time secs			Lock open secs			Flexibility %	
			n	*mean*	*SD*	*n*	*mean*	*SD*	*n*	*mean*	*SD*	*n*	*mean*	*SD*	*Able*	*Impaired*
MEN	**BMI**	*underweight*														
	< 16	*severe*	49	17.9	5.0	47	26.9	10.8	47	15.5	5.7	49	7.3	4.6	96	4
	16 - 16.9	*moderate*	37	19.1	5.2	36	27.2	12.9	34	16.1	6.3	36	8.1	5.1	89	11
	17 - 18.4	*mild*	72	22.4	5.9	71	26.7	8.3	70	15.0	5.2	72	7.7	4.5	90	10
	18.5 - 24.9	*normal*	235	24.2	6.1	231	25.0	7.6	230	15.2	4.8	232	6.9	4	94	6
	> 25	*overweight*	54	26.2	6.5	53	23.8	7.6	53	14.0	4.4	54	7.2	5.3	93	7
	p			***			*ns*			*ns*			*ns*		*ns* @	
	MUAC cms	*wasting*														
	< 16.9	*extreme*	1	14.0		1	34.9		1	16.5		1	4.3		100	0
	17 - 19.9	*severe*	27	16.2	4.9	25	29.5	12.7	24	16.6	7.6	27	8.0	5.4	89	11
	20 - 22.9	*mild*	91	19.1	5.3	86	28.0	12.5	85	15.6	5.6	88	8.1	4.8	88	12
	> 23	*normal*	339	24.5	6.1	331	24.9	9.3	329	15.0	4.7	336	7.0	4.2	93	7
	p			***			*			*ns*			*		*ns* @	
WOMEN	**BMI**	*underweight*														
	< 16	*severe*	97	10.6	4.0	96	36.0	8.4	95	19.0	8.4	96	13.3	10.4	83	17
	16 - 16.9	*moderate*	32	11.9	3.4	32	33.2	8.8	31	16.7	4.3	32	11.0	5.7	78	22
	17 - 18.4	*mild*	89	12.6	4.0	89	31.6	8.1	86	18.8	8.2	89	11.2	7.6	84	16
	18.5 - 24.9	*normal*	309	14.1	4.3	307	30.9	10	298	18.8	6.8	308	10.5	6.8	87	14
	> 25	*overweight*	98	15.8	4.3	98	30.5	9.2	90	18.7	6.3	98	8.9	5.1	89	11
	p			***			*			*ns*			**		*ns* @	
	MUAC cms	*wasting*														
	< 15.9	*extreme*	16	8.4	4.0	16	47.4	15.2	12	21.6	8.4	14	18.1	10.6	65	35
	16 - 18.9	*severe*	82	10.3	3.8	81	35.7	11.8	79	18.9	8.5	81	12.7	8.8	75	25
	19 - 21.9	*mild*	158	12.4	3.6	156	32.2	8.8	154	18.1	7.5	158	12.2	9.7	87	13
	> 22	*normal*	379	14.7	4.4	378	30.4	9.5	359	18.8	6.5	379	9.9	6.1	87	13
	p			***			***			*ns*			**		** @	

*Levels of significance for p (@ using Pearson's Chi Squared test, rest use non-parametric Kruskall-Wallis test : *=p< 0.05, **=p< 0.001, ***=p< 0.0001*

Table 6.10 Prevalence of impairment in functional ability in relation to health status

		Impairment in							
		Dress	***Transfer***	***Bath***	***ADL***	***Walk***	***Stairs***	***Travel***	***Mobility***
MEN									
Anaemia	None	3	47	3	10	43	68	14	13
	Present	5	47	5	8	55 *	72	27 **	24 **
Hypoalbuminaemia	None	3	46	3	10	44	69	15	14
	Present	6	61 *	9	9	64 *	76	33 **	30 *@
Majmorb	None	4	47	5	11	42	65	17	15
	Present	2	46	1	6	61 ***	82 **	17	16
Minmorb	None	3	46	3	9	47	73	16	15
	Present	5	47	4	11	45	65 **	18	16
WOMEN									
Anaemia	None	1	61	3	11	59	85	50	35
	Present	3	66	4	17 *	68 *	87	53	44 *
Hypoalbuminaemia	None	1	62	3	13	64	86	52	39
	Present	10 ***@	77 *	15 ***@	23	67	87	42	40
Majmorb	None	2	63	4	14	63	86	51	38
	Present	5 *@	71	8	18	72	89	57	50 *
Minmorb	None	2	66	4	13	63	84	50	38
	Present	3	62	4	16	66	88	54	42

*Levels of significance for p (@using two-tailed p from Fisher's Exact test, rest use Pearson's Chi Squared test) : *=p< 0.05, **=p< 0.001, ***=p< 0.0001*

Table 6.11 Prevalence of poor physical test performance in relation to self-reported functional ability

	% with poor performance	MEN Handgrip	MEN Plate-tap	MEN Chair rise	MEN Open lock	MEN Flexibility	WOMEN Handgrip	WOMEN Plate-tap	WOMEN Chair rise	WOMEN Open lock	WOMEN Flexibility
Dress	Normal	25	25	25	25	6	26	25	28	24	14
	Impaired	65 @	82 @	88 @	53 **@	71 @	63 @	63 @	69 @	81 @	63 @
Transfer	Normal	21	19	18	21	5	20	17	12	17	8
	Impaired	32 *	36	38	30 *	13 **	32 **	30	38	29	19
Bath	Normal	25	25	25	25	6	26	24	27	24	14
	Impaired	65 @	82 @	88 @	47 *@	65 @	62	58	65	46 *	50 @
ADL	Normal	25	23	24	23	6	25	22	23	22	12
	Impaired	42 *	64	62	47	33 @	42	46	60	46	36
Walk	Normal	13	13	17	19	4	21	16	15	19	10
	Impaired	42	44	40	34	13	31 **	31	37	29 *	18 **
Stairs	Normal	13	13	15	*20*	4	15	17	14	*19*	6
	Impaired	32	34	33	*28 ns*	10 *	29 **	28 *	31	*26 ns*	17 **
Travel	Normal	20	19	22	19	5	18	16	20	18	9
	Impaired	58	69	53	57	25	36	34	37	32	21
Mobility	Normal	20	19	22	20	5	20	16	19	18	9
	Impaired	61	73	56	56	27	38	39	43	35	24

*All are significant at the p< 0.0001 level except for : * p < 0.05 and ** p < 0.001. ns = non-significant*

@ significance value from two-tailed p, Fisher's Exact Test. All the rest are from Pearson's Chi Squared test

Figs 6.1 to 6.4 Prevalence of poor physical test performance by nutritional status (BMI / MUAC)

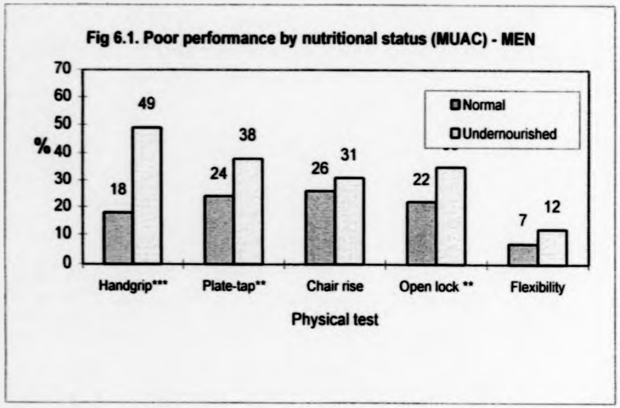


Fig 6.1. Poor performance by nutritional status (MUAC) - MEN

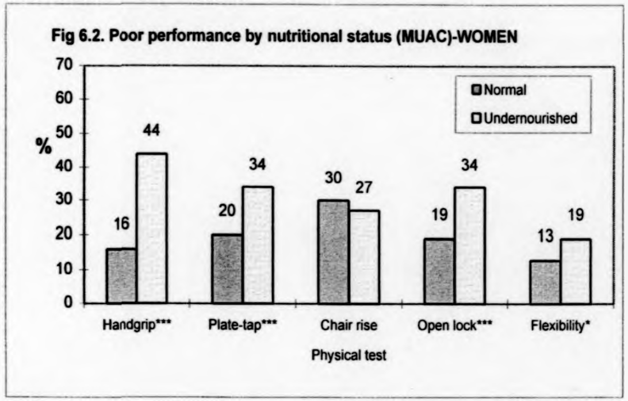


Fig 6.2. Poor performance by nutritional status (MUAC)-WOMEN

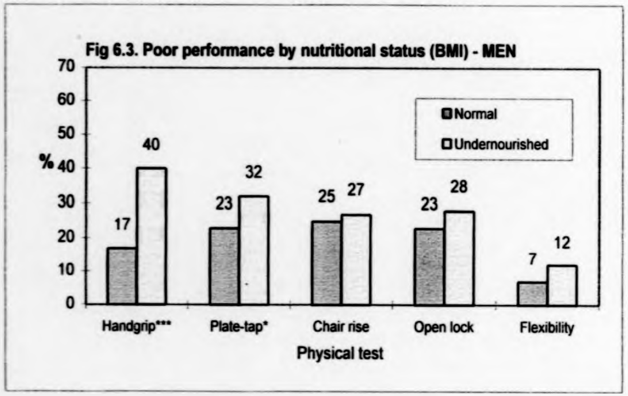


Fig 6.3. Poor performance by nutritional status (BMI) - MEN

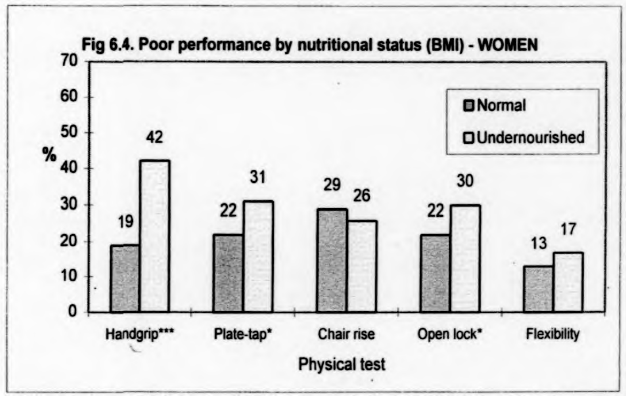


Fig 6.4. Poor performance by nutritional status (BMI) - WOMEN

Figs 6.5 to 6.8 Prevalence of impairment in self-reported functional ability by nutritional status (BMI / MUAC)

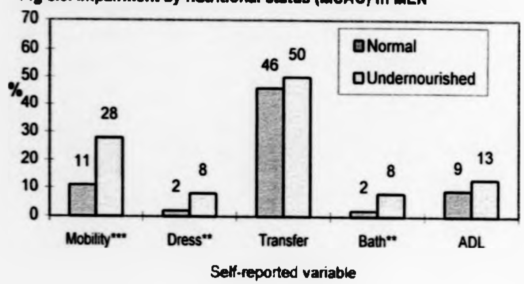


Fig 6.5. Impairment by nutritional status (MUAC) in MEN

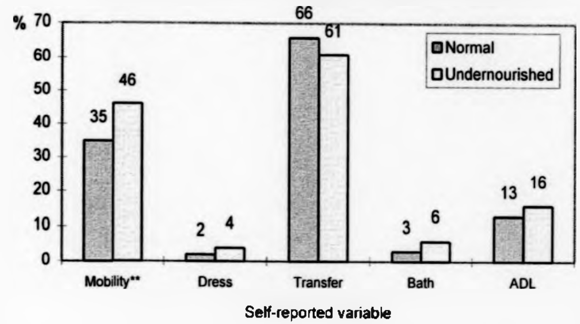


Fig 6.6. Impairment by nutritional status (MUAC) in WOMEN

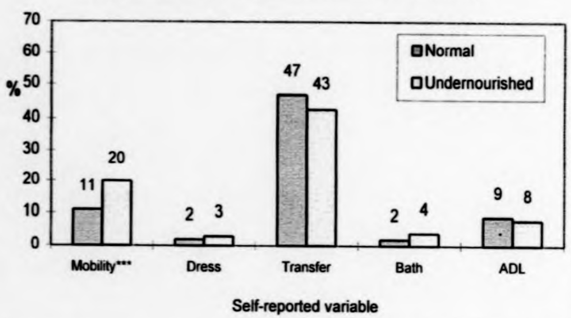


Fig 6.7. Impairment by nutritional status (BMI) in MEN

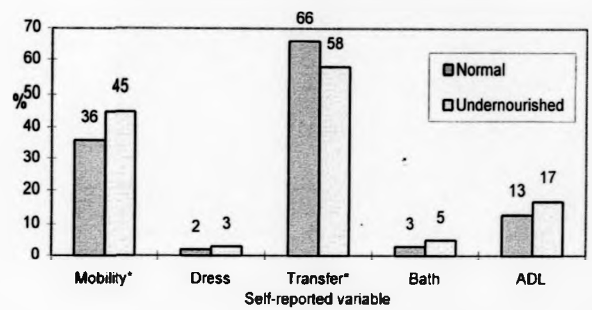


Fig 6.8. Impairment by nutritional status (BMI) in WOMEN

Figs 6.9. to 6.12. Prevalence of ill health by level of nutritional status (BMI / MUAC)

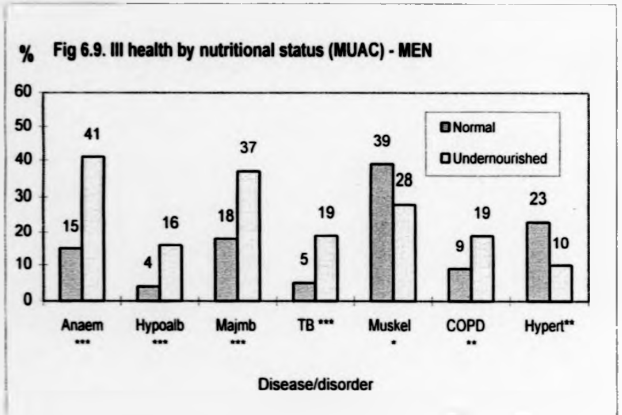


Fig 6.9. Ill health by nutritional status (MUAC) - MEN

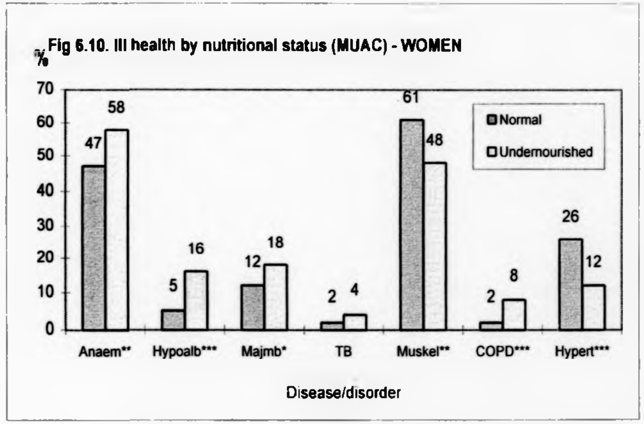


Fig 6.10. Ill health by nutritional status (MUAC) - WOMEN

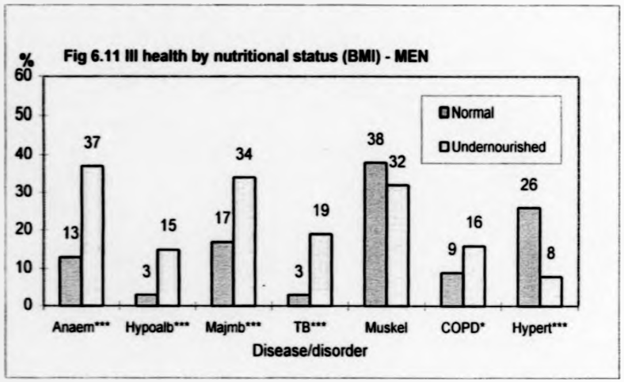


Fig 6.11 Ill health by nutritional status (BMI) - MEN

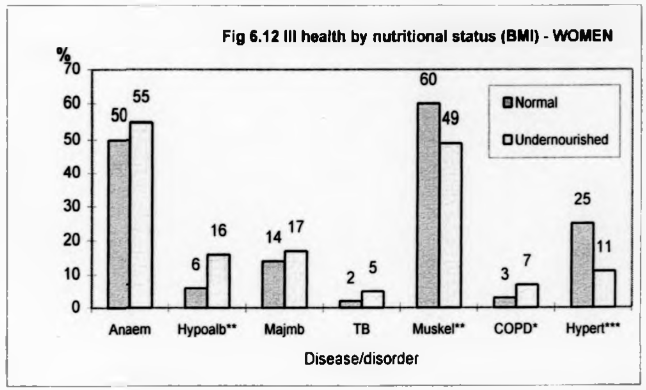


Fig 6.12 Ill health by nutritional status (BMI) - WOMEN

The results of the exploration of associations between groups of categorical variables using Chi-squared tests are presented according to sex in Tables 6.10 (composite health status and self-reported functional ability) and 6.11 (self-reported functional ability and dichotomous physical performance test variables). Similar analyses were used to explore the associations between underweight and functional ability impairment and poor performance (Figs 6.1 to 6.8), and between underweight and ill health (Figs 6.9 to 6.12).

6.1 Relationships amongst nutritional status variables

As expected, correlation coefficients between anthropometric and the two derived variables, BMI and cAMA, were positive, with many demonstrating very high levels of significance (Table 6.1) There were some exceptions to this : height and weight are moderately correlated, and the two circumferences and cAMA and the two stature variables only weakly so. Triceps and cAMA are moderately correlated in women but only weakly so in men. Both the non-significant correlations between both height/armspan and BMI, and the very high correlations between BMI and weight, are expected.

6.2 Relationships amongst functional ability and performance test variables

Chapter 5 (section 2.1) has already referred to the close inter-relationships between the 6 ADL, and 3 mobility tasks (Tables 5.6 and 5.9). There were similarly modest correlations between physical performance test variables. Handgrip strength is significantly associated with other timed tests performance : as handgrip rises the time taken to perform the other tests decreases. Similarly all the three timed test performances are significantly positively correlated with each other in both men and women (Table 6.1).

When all five physical test variables are considered in their dichotomous forms, poor performance in all five physical tests is significantly associated with impaired ability in all self-reported ADLs and mobility, with the exception of manual dexterity and the ability to climb stairs in both men and women. (Table 6.11). Tables 6.2 and 6.3 illustrate how the means of physical test performances significantly differ according to the level of impairment in ADLs and dimensions of mobility. Worse performance test results are much more common amongst those classified as impaired than those classified as fully able. These differences are particularly marked in handgrip strength for self-feeding ($F=10.58$, df 456, $p=0.0012$), toilet use ($F=28.65$, $df456$, $p=<0.001$), dressing ($F=21.92$, df 456, $p=<0.001$), transfer ($F= 14.22$, df 456, $p=0.0002$), bathing ($F=22.69$, df 456, $p=<0.001$), and all three mobility variables in men (walk : $F= 2.05$, df 456, $p=<0.001$; stairs : $F=31.86$, df 456, $p=<0.001$; travel : $F=71.86$, df 456, $p=<0.001$). A similar pattern is seen for the plate-tapping test (psychomotor skill). In women, the physical test performances are significantly worse amongst those who are impaired in their level of toilet use, and the ability to transfer. Mean handgrip strength is significantly lower in the impaired group of women for all ADL (continence : $F=9.96$, df 633, $p=0.0017$; self-feed : $F=5.02$, df 633, $p=0.0254$; toilet : $F=28.73$, df 633, $p=<0.001$; transfer : $F=19.85$, df 633, $p=<0.001$; dress : $F=19.67$, df 633, $p=<0.001$; bath : $F=26.08$, df 633, $p=<0.001$) and mobility (walk : $F=26.42$, df 633, $p=<0.001$; stairs : $F=14.61$, df 633, $p=<0.001$; travel : $F=46.09$, df 633, $p=<0.001$) variables. Not surprisingly, in both sexes, mean chair rise performance (lower body strength) is significantly lower amongst those reporting transfer problems than for those who describe themselves as fully able. Lock opening time (manual dexterity) is significantly slower amongst those reporting difficulties dressing, but not for feeding[1]. Performance (comparison of means) of all continuous physical test variables is significantly worse in those classified as impaired according to the two composite self-reported functional ability variables of IMPADL and IMPMOB (Tables 6.6 and 6.7).

6.3 Underweight, and functional ability and physical performance

There are a number of strong positive relationships between anthropometric and derived variables of nutritional status and physical test performances (Table 6.1). For example, handgrip strength increases with increasing MUAC. The regression line suggests that, for each cm increase in MUAC, handgrip increases by 0.9 kg in men and by 0.5 kg in women, with very similar figures for calf circumference (0.8 and 0.6 respectively). For each point increment in BMI, handgrip strength rises by 0.7 kg in men and by 0.4 kg in women. For

[1] this supports the earlier suspicion that the feeding question may be inappropriate in a context where feeding utensils such as spoons and knives are seldom used

the timed physical test variables, particularly plate-tapping time, for which there are highly significant results in both sexes, slower performances (poor ability) are correlated with lower anthropometric parameters.

Table 6.8 reveals also that poor handgrip strength, psychomotor skill (plate-tapping), and manual dexterity (lock opening) performances are mostly highly significantly associated with lower mean anthropometric variables in both men and women. Poor chair rise performance was only associated with lower mean calf circumference and cAMA in men. Poor flexibility was significantly associated with lower mean anthropometric and derived parameters in women, but not at all in men. These relationships are confirmed by looking at the changes in means for the continuous physical test variables according to grades of underweight (Table 6.9). In both sexes, for handgrip strength, plate-tapping and lock opening times, mean performances are significantly positively associated with nutritional status. Taking the dichotomous variables for underweight and applying the non-parametric Mann-Whitney test for differences between groups gives similar results (Tables 6.6 and 6.7) for handgrip strength and for plate-tapping performances but not for lock and key time.

Figs 6.1 to 6.4 show how the prevalence of impairment in many physical test performances is significantly associated with underweight in both sexes. The prevalence of poor performance in handgrip strength is about 30% higher in underweight (MUAC) men (χ^2=45.45, p=<0.001) and women (χ^2=64.81, p=<0.001) than in those with normal nutritional status. The differences were lower (23%) for poor handgrip performance with underweight classified by BMI, but still highly significant (men : χ^2=27.55, p=<0.001; women : χ^2=38.74, p=<0.001). The same pattern can be seen for plate-tapping performance and underweight classified using the two different methods. Underweight classification by MUAC resulted in significant associations with lock and key time in both men and women, and flexibility in men, whereas no such associations were found for lock and key time for men, nor for flexibility in women when the BMI classification was applied.

Overall, these results show that, as underweight becomes more severe, performance in some dimensions of physical functional ability declines. Moreover, underweight classified by MUAC was associated with higher proportions of functionally impaired performances than was underweight using BMI.

6.4 Underweight and morbidity

Lower means for most anthropometric and derived variables were found for those with COPD and TB (Tables 6.4 and 6.5). Conversely, higher means for most anthropometric variables were found with hypertension. Higher means were also found with musculoskeletal disease and diabetes in women, in whom haemoglobin and albumin values[2] were also higher, but only reached significance for musculoskeletal disease. In men, the presence of neurological disease was associated with significantly lower mean anthropometric values (except cAMA), but this was not the case for women. Mean haemoglobin and albumin levels were significantly lower in men with TB and URTI than men without these diseases.

Figs 6.9 to 6.12 show that underweight (MUAC) was associated with higher levels TB (χ^2=21.94, p=<0.001), COPD (χ^2=8.78, p=0.0034), and MAJMORB (χ^2=18.64, p=0.00002), in men, and COPD (χ^2=12.8, p=0.0034) and MAJMORB (χ^2=3.6, p=0.047) in women. Conversely, there were higher levels of musculoskeletal diseases and hypertension amongst those who were not classified as underweight. Again, using BMI to classify underweight resulted in weaker or non-existent associations than when MUAC was used.

Figs 6.9 and 6.10 show that the prevalences of both anaemia and hypoalbuminaemia were significantly higher in underweight older men (anaemia : χ^2=36.53, p=<0.001; hypoalbumianemia : χ^2=18.73, p=0.00002) and women (anaemia : χ^2=8.17, p=0.00426; hypoalbumianemia : χ^2=18.88, p=0.00001) using the MUAC classification. The results were similar for underweight using BMI although they failed to reach significance for anaemic women (Figs 6.11 to 6.12). Differences in mean haemoglobin and albumin

[2] Small positive correlations between the two blood variables and other continuous variables should be interpreted cautiously because the size of a correlation coefficient and the nature of a regression equation will be affected by the amount of variance in either of the variables (Bryman and Cramer 1990). We expect the correlation coefficients to be small when the relationships are not between variables of equally wide variance.

values by level of underweight using BMI and MUAC grades (data not shown) also confirm that low levels of both these blood markers are consistent with the diagnosis of underweight. Mean haemoglobin was only 12.3 gm/dL for severely underweight (BMI classification) men but was significantly higher (above 13.8 gm/dL) for normally nourished men. Equivalent significant results for albumin were 3.9 gm/dL and 4.3 gm/dL respectively. For women the differences were smaller and of lesser significance using the BMI classification. However, differences for haemoglobin only failed to reach significance for the MUAC classification. In men, anaemia was associated with regular smoking behaviour (χ^2*=6.10, p=0.0143)*, and underweight (BMI) with regular drinking (χ^2*=6.71, p=0.0096)*.

6.5 Functional ability and phsyical performance, and morbidity

Chi-squared analyses revealed few significant associations between the presence of disease conditions and self-reported ADL and mobility impairments. Exceptions to this were the findings that the presence of musculoskeletal disease was significantly associated with toilet *(*χ^2*=13.14, p=0.00029)* and transfer *(*χ^2*=13.60, p=0.00023)* impairment in men, and toilet (χ^2*=10.04, p=0.00153)*, dressing *(*χ^2*=15.93, p=0.00007)*, bathing *(*χ^2*=6.56, p=0.01040)*, and transfer (χ^2*=13.37, p=0.00026)* impairment in women. Neurological disease and COPD were also both associated with impaired transferring in women.

However, there is more evidence that the presence of at least some diseases adversely affects functional ability when assessed by physical test performance. Table 6.4 shows that mean handgrip strength was significantly lower for men suffering from TB (χ^2*=5.33, p=0.02095*), and mean plate-tapping time was slower for those with cardiovascular disease (χ^2*=5.42, p=0.01990)* and neurological disease (χ^2*=18.39, p=0.00099*). The picture was different for women for whom mean plate-tapping time was significantly slower amongst those with musculoskeletal disease than those without it (χ^2*=10.85, p=0.0099*), and mean plate-tapping (χ^2*=8.76, p=0.00307)*, and chair rise times (χ^2*=13.83, p=0.00020)* were both significantly slower for those with hypertension. However, in men, the presence of COPD was linked to better performance for lower body strength (χ^2*=6.97, p=0.00827)*. Another unexpected finding is that mean performances for handgrip strength, and plate-tapping and chair rise times were worse for men with skin disease. The proportion of those with poor flexibility performance was significantly more only amongst men with neurological disease *(χ^2=6.92, p=0.01994)* and women with TB *(χ^2=4.74, p=0.02946)*.

Continuous blood indicators of nutritional status were positively but fairly weakly correlated with physical test performances (Table 6.1)[3]. Physical test performance is significantly worse amongst those with anaemia compared to those without, except for chair rise time in men, in whom a similar trend fails to reach significance (Tables 6.6 and 6.7). Those with hypoalbuminaemia also have a tendency towards worse performance means than the normal groups, although these differences fail to reach significance for lock opening time in men, and only achieved significance for handgrip strength in women *(F=19.29, df 625, p=<0.001)*. Taking the self-reported variables for functional ability, overall mobility impairment is significantly higher in anaemic as well as hypoalbuminaemic men (Table 6.10). The prevalence of impairment in the abilities to dress *(χ^2=18.46, p=0.0002)*, transfer *(χ^2=4.86, p=0.0276)*, and bathe *(χ^2=24.28, p=<0.001)* independently were significantly higher amongst hypoalbuminaemic women, as were overall ADL *(χ^2=5.41, p=0.0207)*, and mobility *(χ^2=5.73, p=0.0167)* impairment in anaemic women.

No associations were found between any functional ability dimension and either health-related behaviour or hearing loss in women. However, the onset of recent disability or surgery was significantly associated with poor flexibility *(χ^2=6.75, p=0.0094)*, and impairment in dressing *(χ^2=9.44, p=0.0021)*, bathing *(χ^2=7.41, p=0.0065)*, and walking *(χ^2=4.99, p=0.0255)*, in women. In men, regular drinking was associated with dependence in walking *(χ^2=5.54, p=0.0185)*, and impaired hearing with dependence in mobility tasks *(χ^2=5.46, p=0.0195)*, and poor handgrip performance *(χ^2=13.54, p=0.00023)*.

6.6 Kyphosis and other variables

Kyphosis appears to be strongly associated with indicators of underweight, poor function ability and physical test performance, and ill health (Table 6.12). In women of all ages the

---

[3] see Footnote 2 above

presence of kyphosis was significantly associated with poor performance in all physical tests, with dependence in mobility except for stair climbing, and with dependence in toilet use, dressing and transferring. In men there were no associations between kyphosis and poor manual dexterity and flexibility, nor for dependence in feeding, dressing or bathing whereas there were strong associations with all mobility tasks. The presence of kyphosis was also significantly associated with underweight using both classifications, and in both sexes in each age group, with the exception of the over 65s using BMI in women. Significant associations were also found between the presence of kyphosis in women and having musculoskeletal disease and anaemia (young group only), and anaemia and hypoalbuminaemia in younger men.

6.7 Summary

This chapter has explored differences and associations between bivariates. There is considerable evidence of strong inter-relationships within groups of both nutritional status, and between functional ability and physical performance, variables. As expected, there is also evidence for relationships between impaired functional ability and poor performance, and some disease conditions. Confirming what we would expect, the presence of certain diseases is significantly associated with nutritional status, whether assessed by anthropometry, derived variables or biochemical markers. In this study, the presence of TB and COPD in both men and women, and neurological disease in men, were all associated with underweight. Other diseases such as hypertension, musculoskeletal disorders and diabetes were also associated with nutritional status, but in the opposite direction : the presence of these disease was associated with higher nutritional status values (probably representing the "overnourished" end of the spectrum). The vast majority of these results are consistent with accepted wisdom, and biologically plausible reasons for linkages between variables already exist.

The bivariate results also reveal evidence of some strong relationships between underweight and functional ability impairment and poor performance in these poor older people. Levels of anthropometric indicators of underweight, particularly MUAC, BMI, and cAMA, are associated with poorer levels of functional ability and physical test performances. Upper body strength as assessed by handgrip dynamometry emerges as the functional ability dimension that most frequently and most strongly positively associates with the level of nutritional status, as well as with morbidity. Most of the other physical dimensions, assessed by timed tests and coded flexibility performance, also provide some evidence of similar associations with nutritional status. The exception is lower body strength, as assessed by timed chair rise, which appears to be the least important[4]. Self-report techniques of functional ability assessment also show similarly strong positive associations with nutritional status. The most consistent amongst these are : the ability to dress, bath, walk and travel, and the composite ADL and mobility variables, IMPADL and IMPMOB.

Trends from these bivariate analyses indicate that there is certainly potential in pursuing the hypothesis further. Moreover, statistical logic and laws tell us that these bivariate results give only a partial picture : although informative and suggestive, they do not take into account the effects of confounding variables that may be influencing both variables independently. For example, Chapter 5 has already described how handgrip performance in both sexes, and nutritional status in women, both decline significantly with increasing age. The finding reported in this chapter that handgrip strength also declines significantly with deteriorating nutritional status thus needs to be corrected for age as an important confounding variable, as well as for any other potential confounders, (possibly cognitive status, and some morbid conditions such as TB). Multivariate analyses now need to be applied to address the hypothesis. Using appropriate multivariate techniques, and the variables that have emerged most strongly in these bivariate analyses, the next step is to identify whether, and how to what extent, factors of underweight may predict functional ability impairment.

[4] This might be due to a combination of motivational problems performing this test in this particular setting, and poor validity of the test itself. An alternative interpretation may be that there was really no difference between the underweight and the normally nourished groups because of a truly high prevalence of proximal muscle weakness affecting the ability to rise from the chair, which may also account for the high prevalence of reported difficulty in transferring. A possible explanation of this might be a high prevalence of osteomalacia.

Table 6.12 Associations between kyphosis, underweight, poor function and disease

		MEN			WOMEN		
		all	50-64	≥65	all	50-64	≥65
With kyphosis	n	52	25	27	89	43	46
	%	13.2	8.7	25.0	16.0	10.4	39.0
Underweight							
using BMI		x	x	x	x *	x *	
using MUAC		x	x	x	x **	x **	x **
Poor performance							
Handgrip strength		x	x	x	x *	x *	x *
Chair rise time		x	x **	x **	x	x	x
Plate tap time		x	x	x	x	x	x
Key open time					x	x	x
Flexibility					x	x	x
Dependent in							
Toilet use		x	x	x	x	x	x
Dressing					x **	x **	x **
Transferring		x **	x **	x **	x **	x **	x **
Walk		x	x	x	x *	x *	x *
Stairs		x	x	x			
Travel		x	x	x	x **	x **	x **
IMPMOB		x	x	x	x	x	x
Presence of							
Musculoskel disease					x *	x *	x *
Anaemia		x	x		x *	x *	
Hypoalbuminaemia		x*	x *		x *		

Levels of significance (χ^2 *test*) * = $p < 0.05$ ** = $p < 0.001$ x = < 0.0001

CHAPTER 7 : RESULTS - MULTIVARIATE ANALYSES

"When you cannot measure it, when you cannot express it in numbers, you have scarcely, in your thoughts, advanced to the stage of science, whatever the matter may be"

William Thomas Kelvin[1]

The aim of this final analysis is to answer the question : how good a predictor is underweight of functional ability impairment in this population of elderly people ? Bivariate analyses have already shown that some of the functional ability variables appear to be significantly associated with being underweight, although some associations may be due to confounding, particularly from increasing age and ill health. Logistic regression analysis will now be used to determine the risk of having functional ability impairment in the presence of underweight, independent of age and indicators of disease, anaemia, visceral protein status, disability and health-related behaviour.

7.1 Preparation for analysis using logistic regression

A background to the rationale for choosing logistic regression as the multivariate analysis strategy, and the interpretation of results, has already been given in 3.19.2.

7.1.1 Exclusion of cases with BMI above 25

The hypothesis under investigation is that underweight older people are more likely to be functionally impaired than those normally nourished, irrespective of other variables in the study. To look at this relationship it is necessary to exclude from the data set those who are neither underweight nor normally nourished, but rather overweight or obese. The full data set on 1,097 cases includes 152 cases (54 men and 98 women) with BMIs over 25, as well as 21 cases for whom BMI is not available due to the absence of the

[1] British mathematician and physicist (1824-1907)

weight, height or armspan measurements. These cases were excluded to create a new data set of 924 (393 men and 531 women) cases, all with a BMI below 25.

Table 7.1 Comparison of proportion of cases with conditions present by data set

	MEN		WOMEN	
Variables	1097 full data set %	924 Logistic Regression data set %	1097 full data set %	924 Logistic Regression data set %
EXPOSURE				
Underweight				
BMI	35	40	35	42
MUAC	26	41	29	47
INTERACTING CONFOUNDERS				
Anaemia	21	22	51	52
Hypoalbuminaemia	7	8	9	10
Major morbidity	23	24	15	15
Tb	8	9	3	3
COPD	11	5	1	5
Cv	5	4	7	7
Musculoskeletal disease	36	36	55	54
Neurological disease	6	6	2	2
Minor morbidity	50	48	43	41
Kyphosis	14	13	16	17
Cognitive impairment	1	1	1	1
Regular smoking	23	24	1	1
Regular drinking	33	34	1	1
Recent disability onset / surgery	6	6	6	6
Impaired sight / cataracts	71	72	73	73
Impaired hearing	4	4	1	1
OUTCOMES				
Impaired physical performance				
Handgrip strength	26	27	27	30
Leg strength	27	26	29	28
Psychomotor skill	27	27	25	26
Manual dexterity	26	26	25	26
Flexibility	9	7	15	15
Impaired mobility (IMPMOB)	15	14	40	40
Impaired ADLS				
Toilet use	38	38	51	48
Dressing	4	2	3	2
Transferring	47	45	64	61
Bathing	4	2	4	4

Table 7.1 details the proportions of those with functional ability impairment, and the presence of morbidity and potential confounders for both the full data set (1,097) and the data set on which the logistic regression models were performed (924). There were no significant differences in the proportion of impairment for any functional ability

dimensions between the two data sets. Thus, the removal of those with high BMI did not introduce a bias in terms of the characteristics of functional ability impairment. Similarly, there were mostly no significant differences in the prevalences of morbidity, disability and behaviour variables between the two data sets. However, it is interesting to note that a significantly smaller proportion of men were affected by COPD in the logistic regression data set (1%) compared to the 6% in the full data set, which suggests that the level of prevalence of COPD is positively associated with a high rather than a low BMI.

7.1.2 Selection of variables

Table 7.1 provides a summary of the variables that were entered into the logistic regression models. Eligibility for inclusion was based on significant (at a significance level of $p<0.05$) pairwise associations between the variable and the outcome of interest. Logistic regression analysis was limited to those variables likely to contribute significantly to the discriminating power of the test.

The independent (exposure) variable was underweight : The definition of being underweight was based on either having a BMI less than 18.5, or a MUAC of less than 23 cms for men and 22 cms for women, as described in Tables 2.1 and 2.2. Normally nourished refers to those with a BMI between 18.5 and 24.9, (all those having a BMI of 25 or above already excluded), or a MUAC of 23 cms and above for men and 22 cms or above for women.

The dependent (outcome) variables were impaired functional ability or poor performance in a physical test : To examine the association between underweight and each of the different dimensions of functional ability and performance, models were constructed and refined for each of the following dichotomized outcome variables : handgrip strength, plate-tapping time, key opening time, chair stands time, flexibility score, overall impaired mobility, and independence in dressing, bathing, transferring and using the toilet[2].

Independent potential confounders were :

(a) **Morbidity** : each model contained the composite variable, MINMORB. In terms of variables covered by the MAJMORB variable, individual diseases that had been found to be most strongly associated with underweight from the bivariate analyses were entered into every model. These were : TB, COPD, CV, musculoskeletal disease and neurological disease. If none of these appeared significant, the model was then repeated entering the composite variable MAJMORB in place of the separate variables.

(b) **Kyphosis** : as bivariate analyses had shown that kyphosis was significantly associated with a number of nutritional, functional and morbidity variables, kyphosis was included in all models for both men and women.

(c) **Health behaviour** : drinking and smoking were entered into models for men but not for women[3].

(d) **Disability** : the presence or absence of cataracts was entered into every model for both sexes. The variable for recent disability onset / recent surgery was entered only into models for women[4].

(e) **Cognitive status** :the variable "mental", based on the results of cognitive screen responses and a short-term memory recall test, was entered into all models as a confounding variable.

Being **housebound** was not included as an outcome variable on the assumption that other functional ability variables, particularly mobility, would reflect this.

---

[2] Because of the validity and interpretational problems associated with the use of the composite ADL variable (IMPADL) which incorporates continence and self-feeding, this variable was not used in the multivariate analyses.
[3] this is because no associations had been found between these health-related behaviours and any functional or nutritional variables in women.
[4] Disability was not associated with any variables in men.

7.1.3 Modelling

The methodology for logistic regression analysis was stepwise backward elimination of non-significant associations (see 3.19.2). Initially all variables were entered into the model but then progressively eliminated on the basis of significance testing, and a threshold p-value for the likelihood ratio statistic of $p < 0.05$. As sex is a major confounder, all models were stratified according to sex. Separate models were also developed for the two classifications for underweight using either BMI or MUAC cut-offs. Age was first entered as a continuous independent variable to produce "global" models for each sex. The data were then explored using TWOAGES as a dichotomous age group (50-64, or 65 and above) independent variable, and by creating separate models for each of the two age groups for each sex.

7.2 Results

All tables of results give a summary of the predictive risk by odds ratios (OR), 95 % confidence intervals (95% C.I.), and the significance level (likelihood ratio test p-value) for the different variables of functional ability and poor performance in the presence of underweight.

The full results using age as a continuous variable can be found in Appendix IV. As expected, increasing age emerged as the variable that most consistently appeared significant in all the models, except for poor flexibility, and impairment in toilet use and climbing stairs in men. Age was a significant risk factor for all types of functional ability impairment and poor performance in women. For each yearly increase in age beyond 50 years[5], the risk of poor handgrip strength increases 1.07 in men and 1.08 times in women in the presence of underweight (BMI). Smoking, drinking and hearing impairment were not found to be associated with an increased risk of any functional ability impairment or poor performance in either sex, but the presence of cataracts was associated with an increased risk in women.

[5] as it is entered as a continuous variable, the OR reported for age represents the direction and extent of risk per unit increase (year above 50 years)

7.2 Logistic regression results using age group - men

OUTCOME Functional ability / performance	n (able : unable)	EXPOSURE Nutrition indicator / confounder	ODDS RATIO (95% C.I.)	p-value
Handgrip strength	387 (281 : 106)	**Underweight (BMI)**	**3.0386 (1.8615-4.9601)**	.0000
		≥ 65 years old	2.9310 (1.7465-4.9187)	.0000
		Kyphosis	1.9671 (1.0373-3.7304)	.0399
		Underweight (MUAC)	***4.3669 (2.6665-7.1515)***	*.0000*
		≥ 65 years old	*2.9782 (1.7949-4.9416)*	*.0000*
Leg strength	387 (285 : 102)	Hypoalbuminaemia	2.4980 (1.1484-5.4335)	.0236
		Kyphosis	2.0667 (1.1013-3.8785)	.0261
		≥ 65 years	1.7333 (1.0440-2.8775)	.0354
Psychomotor skill	387 (284 : 103)	Neurological disease	3.9958 (1.6667-9.5791)	.0019
		Kyphosis	3.8977 (2.1116-7.1907)	.0000
Manual dexterity	393 (292 : 101)	≥ 65 years	1.9494 (1.2006-3.1653)	.0076
Flexibility	393 (365 : 28)	Hypoalbuminaemia	3.0455 (1.0629-8.7258)	.0582
Toilet use	393 (251 : 142)	Neurological disease	3.7914 (1.5297-9.3971)	.0030
		Kyphosis	3.1799 (1.7106-5.9113)	.0002
		Musculoskel disease	2.1609 (1.3887-3.3625)	.0006
Dressing	393 (384 : 9)	Minor morbidity	4.0084 (0.8222-19.5425)	.0584
		Underweight (MUAC)	*6.4507(1.5510-26.8289)*	*.0079*
		Minor morbidity	*5.2025 (1.0411-25.9970)*	*.0259*
Bathing	393 (384 : 9)	Minor morbidity	4.0084 (0.8222-19.5425)	.0584
		Underweight (MUAC)	***11.6262 (2.3290-58.0379)***	*.0008*
		Minor morbidity	*5.6195 (1.1190-28.2207)*	*.0199*
Transfer	393 (216 : 177)	Kyphosis	2.7370 (1.4617-5.1251)	.0013
		Neurological disease	2.5041 (1.0159-6.1726)	.0405
		Musculoskel disease	2.2452 (1.4637-3.4441)	.0002
Mobility (3 tasks)	393 (337 : 56)	Kyphosis	3.8540 (1.9186-7.7415)	.0002
		≥ 65 years	3.7873 (2.0205-7.0992)	.0000
		Underweight (BMI)	**1.99772 (1.0531-3.7121)**	.0337
		≥ 65 years	*3.6163 (1.9317-6.7699)*	*.0001*
		Kyphosis	*3.3275 (1.6147-6.8570)*	*.0015*
		Underweight (MUAC)	***2.5707 (1.3518-4.8886)***	*.0044*

Italicised font is used for all those variables that emerged as significant predictors of impairment using the MUAC classification of underweight

Tables 7.2 (men) and 7.3 (women) present the results using the dichotomous variable TWOAGES in the models[6]. When underweight was found to have a significant effect,

[6] The likelihood of underweight predicting an adverse functional outcome in the model is only borderline in men for some outcome variables (Table 7.2. : poor flexibility, dependence in dressing and bathing). These results are still presented even though the exposure variable of interest (underweight) did not emerge as significant predictor, having controlled for the effects of all other variables apart from the remaining variable reported. With the application of a strict exclusion rule of $p<0.05$, relatively small numbers of cases in the unable groups, and an underlying biological plausibility, there is still some justification in reporting these results.

the data are given for underweight classified by both BMI as well as for underweight classified by MUAC, with the latter given in *italicised font*, along with the other significant independent predictor variables in the model. Being underweight is more important than being over 65 years old in terms of the risk of having poor handgrip strength, with the exception of women classified as underweight using BMI.

Table 7.3 Logistic regression results using age group - women

OUTCOME Functional ability / performance	n (able : unable)	EXPOSURE Nutrition indicator / confounder	ODDS RATIO (95% C.I.)	p-value
Handgrip strength	523 (367:156)	≥ 65 years old	3.3187 (2.1193-5.1969)	.0000
		Underweight (BMI)	2.4337 (1.6281-3.6380)	.0000
		Recent disabil/surgery	2.4185 (1.1119-5.2606)	.0269
		Anaemia	1.6733 (1.1133-2.5150)	.0127
		Underweight (MUAC)	***3.3345 (2.2018-5.0499)***	***.0000***
		≥ 65 years old	*3.1051 (1.9674-4.9007)*	*.0000*
		Recent disabil/surgery	*2.7065 (1.0247-2.3442)*	*.0142*
		Anaemia	*1.5499 (1.0247-2.3442)*	*.0372*
Leg strength	524 (380:144)	Recent disabil/surgery	3.0068 (1.3996-6.4597)	.0057
		≥ 65 years	2.2682 (1.4153-3.6350)	.0008
		Kyphosis	2.5524 (1.5319-4.2526)	.0004
		Anaemia	1.7040 (1.1244-2.5823)	.0114
Psychomotor skill	531 (392:139)	*≥ 65 years*	*3.3731 (2.1533-5.2841)*	*.0000*
		Major morbidity	*1.9665 (1.1643-3.3214)*	*.0129*
		Minor morbidity	*1.8651 (1.2309-2.8259)*	*.0031*
		Underweight (MUAC)	***1.6357 (1.0813-2.4745)***	***.0195***
Manual dexterity	524 (385:139)	*Kyphosis*	*2.3659 (1.4556-3.8455)*	*.0006*
		Underweight (MUAC)	***1.7838 (1.1892-2.6757)***	***.0050***
		Anaemia	*1.7498 (1.1580-2.6440)*	*.0074*
Flexibility	531 (451:80)	≥ 65 years	3.9308 (2.2702-6.8063)	.0000
		TB	3.5407 (1.1504-10.8979)	.0367
		Recent disabil/surgery	2.9725 (1.2362-7.1475)	.0214
		Kyphosis	2.2137 (1.2232-4.0065)	.0101
		Anaemia	1.8241 (1.0629-3.1304)	.0268
Toilet use	531 (276: 255)	≥ 65 years old	3.8125 (2.4281-5.9863)	.0000
Dressing	525 (515 : 10)	Hypoalbuminaemia	6.8689 (1.8359-25.6999)	.0065
		≥ 65 years	6.5333 (1.6017-26.6490)	.0061
Bathing	525 (507 : 18)	Hypoalbuminaemia	6.2921 (2.2779-17.3799)	.0009
		≥ 65 years	4.7178 (1.7283-12.8782)	.0024
Transfer	531 (208 : 323)	≥ 65 years	3.9925 (2.3794-6.6994)	.0000
		COPD	3.0863 (1.1860-8.0314)	.0133
		Musculoskel disease	1.8682 (1.2910-2.7033)	.0008
Mobility (3 tasks)	531 (319 : 212)	Recent disabil/surgery	3.2604 (1.5021-7.0771)	.0022
		≥ 65 years	2.6001 (1.6633-4.0645)	.0000
		Kyphosis	1.8745 (1.1399-3.0827)	.0134

Italicised font is used for all those variables that emerged as significant predictors of impairment using the MUAC classification of underweight

An underweight (using MUAC) man is four times as likely to have poor handgrip strength than a normally nourished man, independent of all other variables in the model, including age group. However, there is a lower (tripling) risk of having poor handgrip strength in older men using BMI after the effects of underweight are removed.

Tables 7.4 (men) and 7.5 (women) present the results of models treating each sex and age group separately. These confirm the predictive role of underweight already described. They also indicate which confounding variables are of most interest (most notably kyphosis and anaemia, but also hypoalbuminaemia, neurological disease, musculoskeletal disease, TB, cataracts and recent disability/surgery) if the analysis were to proceed in the direction of a causative rather than a predictive argument.

Table 7.6 summarises the main results from all the logistic regression models. All tables of multivariate results have clearly shown that, for both men and women and both age groups, there is a significantly increased risk of having **poor handgrip strength** in the presence of underweight. This increased risk is independent of all other variables that were entered into the models. The finding is particularly striking if we remind ourselves how poor handgrip strength was strongly significantly associated with many nutritional, functional and health variables in the bivariate analyses, as summarised in Table 7.7. However, being underweight did not make it more likely that men or women in either age group suffered poor performance in any of the other dimensions of functional ability measured by physical test, with the exception of manual dexterity in younger women classified as underweight using MUAC.

In terms of self-reported functional ability, multivariate analyses reveals a significantly increased risk of **impaired mobility** in men, with the exception of older men classified as underweight using BMI, and being underweight (using MUAC) also carried an increased risk of being unable to dress independently in young men and bathe independently in older men[7]. Underweight did not carry an increased risk of being impaired in either mobility or ADLs for women.

---

[7] The 95% confidence intervals for these last two variables are large due to small numbers in the "unable" group

Table 7.4 Logistic regression results using separate age group models - men

OUTCOME Functional ability / performance	n (able : unable)	EXPOSURE Nutrition indicator / confounder	ODDS RATIO (95% C.I.)	p-value
50 - 64				
Handgrip strength	286 (225 : 61)	**Underweight (BMI)**	**3.7886 (2.0780-6.9073)**	**.0000**
		Underweight (MUAC)	***4.4635 (2.4559-8.1122)***	***.0000***
Leg strength	286 (222 : 64)	Major morbidity	0.4888 (0.2341-1.0206)	.0448
Psychomotor skill	282 (216 : 66)	Neurological disease	4.5708 (1.7630-11.8504)	.0015
		Kyphosis	4.1570 (1.7630-11.8504)	.0021
Manual dexterity	286 (223 : 63)	Underweight (BMI)	1.1391 (0.6481-2.0021)	0.6512
Flexibility	286 (268 : 18)	Neurological disease	4.500 (1.3276-15.2529)	.0303
Toilet use	286 (184 : 102)	Kyphosis	4.7797 (1.9299-11.8373)	.0004
		Neurological disease	2.9894 (1.1309-7.9018)	.0259
		Musculoskeletal disease	2.3549 (1.4018-3.9560)	.0011
Dressing	286 (280-6)	Minor morbidity	5.8527 (0.6751-50.7421)	.0611
		Minor morbidity	*8.0071 (0.8951-71.6300)*	*.0283*
		Underweight (MUAC)	***7.2255 (1.2570-41.5346)***	***.0218***
Bathing	286 (282 : 4)	Underweight (BMI)	4.2308 (0.4347-41.1784)	.1766
		Underweight (MUAC)	***7.9870 (0.8184-77.9500)***	***0.493***
Transfer	286 (157 : 129)	Kyphosis	4.2958 (1.6759-11.0116)	.0013
		Musculoskeletal disease	2.7836 (1.6300-4.7536)	.0001
		Minor morbidity	1.8685 (1.1088-3.1486)	.0172
Overall mobility (3 tasks)	286 (261 : 25)	**Underweight (BMI)**	**3.9639 (1.6137-9.6876)**	**.0017**
		Undernutrtion (MUAC)	***3.1368 (1.3646-7.2104)***	***.0078***
≥ 65				
Handgrip strength	105 (60 : 45)	Anaemia	2.8333 (1.1052-7.2637)	.0273
		Underweight (MUAC)	***4.1667 (1.7418-9.9673)***	***.0009***
Leg strength	105 (67 : 38)	Hypoalbuminaemia	9.0000 (1.6058-50.4430)	.0066
Psychomotor skill	105 (68 : 37)	Kyphosis	3.0978 (1.2590-7.6221)	.0132
Manual dexterity	107 (69 : 38)	Underweight (MUAC)	2.2246 (0.9553-5.1804)	.0637
Flexibility	105 (96 : 9)	Anaemia	5.8978 (1.4360-29.4258)	.0146
		Musculoskeletal disease	6.5005 (1.4360-29.4258)	.0184
Toilet use	107 (67 : 40)	Kyphosis	2.2367 (0.9202-5.4364)	.0754
Dressing	107 (104 : 3)	Kyphosis	6.3200 (0.5497-72.6683)	.1253
Bathing	107 (102 : 5)	Kyphosis	4.8750 (0.7690-30.9039)	.0911
		Underweight (MUAC)	***10.069 (1.0793-93.932)***	***.0198***
Transfer	107 (59 : 48)	Kyphosis	2.1818 (0.8973-5.3049)	.0822
		Underweight (MUAC)	***2.1059 (0.9152-4.8455)***	***.0776***
Overall mobility (3 tasks)	107 (76 : 31)	Kyphosis	5.000 (1.9607-12.7504)	.0006
		Kyphosis	*3.7036 (1.3732-9.9887)*	*.0099*
		Underweight (MUAC)	*2.5208 (0.9656-6.5809)*	*.0617*

Italicised font is used for all those variables that emerged as significant predictors of impairment using the MUAC classification of underweight

Table 7.5. Logistic regression results using separate age group models - women

OUTCOME Functional ability / performance	n (able : unable)	EXPOSURE Nutrition indicator / interaction confounder	ODDS RATIO (95% C.I.)	p-value
50 - 64				
Handgrip strength	409 (313 : 96)	Recent disability / surgery	3.7104 (1.5624-8.8111)	.0031
		Underweight (BMI)	**2.7021 (1.6700-4.3719)**	**.0000**
		Anaemia	1.7913 (1.1031-2.9089)	.0176
		Recent disability / surgery	*4.3705 (1.7914-10.6627)*	*.0012*
		Underweight (MUAC)	***4.1664 (2.5122-6.9096)***	***.0000***
		Anaemia	*1.6399 (0.9983-2.6937)*	*.0497*
Leg strength	410 (319 : 91)	Recent disability / surgery	4.0738 (1.7237-9.6276)	.0018
		Kyphosis	3.2529 (1.6469-6.4249)	.0009
		Cataract	2.3113 (1.2061-4.4292)	.0075
		Anaemia	1.6609 (1.0121-2.7256)	.0435
Psychomotor skill	414 (330 : 84)	Recent disability / surgery	3.0158 (1.2151-7.4850)	.0216
		Kyphosis	2.8322 (1.2151-7.4850)	.0050
		Cataract	2.7471 (1.3637-5.5341)	.0022
		Major morbidity	2.0546 (1.0868-3.8845)	.0306
		Minor morbidity	1.7634 (1.0642-2.9220)	.0273
Manual dexterity	414 (319 : 95)	Kyphosis	2.5206 (1.2969-4.8990)	.0082
		Recent disability / surgery	2.4878 (10.702-5.7831)	.0410
		Kyphosis	*2.3319 (1.1973-4.5419)*	*.0156*
		Underweight (MUAC)	***1.7131 (1.0751-2.7298)***	***.0234***
Flexibility	410 (370 : 40)	TB	4.4282 (1.2521-15.6609)	.0356
		Recent disability / surgery	3.0657 (1.1183-8.4045)	.0439
		Anaemia	1.9817 (0.9932-3.9542)	.0479
Toilet use	414 (244 : 170)	Kyphosis	1.9466 (1.0297-3.6803)	.0396
Dressing	414 (411 : 3)	Recent disability / surgery	33.739 (2.9495-385.941)	.0056
Bathing	410 (403 : 7)	Anaemia	6.4000 (0.7636-53.638)	.0398
Transfer	414 (187 : 227)	Kyphosis	2.0383 (1.0306-4.0313)	.0346
Overall mobility (3 tasks)	410 (272 : 138)	Recent disability / surgery	3.0768 (1.3374-7.0783)	.0075
		Anaemia	1.5367 (1.0130-2.3311)	.0427
≥ 65				
Handgrip strength	114 (54: 60)	**Underweight (BMI)**	**1.6738 (0.8058-3.4770)**	**.1665**
		Underweight (MUAC)	***1.9421 (0.9151-4.1216)***	***.0816***
Leg strength	117 (62 : 55)	Kyphosis	1.8828 (0.8886-3.981)	.0967
Psychomotor skill	117 (62 : 55)	**Underweight (BMI)**	**1.6036 (0.6855-3.7584)**	**.1134**
		Minor morbidity	*1.7500 (0.8251-3.7115)*	*.1428*
Manual dexterity	114 (69 : 45)	Anaemia	2.3776 (1.0369-5.4522)	.0359
Flexibility	117 (77 : 40)	Kyphosis	3.1765 (1.9502-7.0302)	.0038
Toilet use	117 (32 : 85)	Recent disability / surgery	1.9375 (0.2176-17.2549)	.5271
Dressing	115 (108 : 7)	Hypoalbuminaemia	7.1373 (1.4643-34.7888)	.0167
Bathing	115 (104 : 11)	Hypoalbuminaemia	7.1200 (1.9272-26.3043)	.0039
Transfer	117 (21 : 96)	Cataract	0.3182 (0.0873-1.1591)	.0558
Overall mobility	117 (46 : 71)	Kyphosis	2.2045 (0.9971-4.8736)	.0465

Italicised font is used for all those variables that emerged as significant predictors of impairment using the MUAC classification of underweight

Table 7.6 Summary : underweight, and the risk of impaired functional ability and poor performance

	Age group	BMI OR	BMI 95% C.I.	BMI *p-value*	MUAC OR	MUAC 95% C.I.	MUAC *p-value*
MEN							
Poor handgrip strength	50-64	3.79	2.08-6.91	.0000	4.46	2.46-8.11	.0000
	≥ 65				4.17	1.74-9.97	.0009
Impaired mobility	50-64	3.96	1.61-9.69	.0017	3.14	1.37-7.21	.0078
	≥ 65				2.80	1.07-7.31	.0378
Dressing dependence	50-64				7.23	1.26-41.5	.0218
	≥ 65						
Bathing dependence	50-64				7.99	0.82-77.9	.0493
	≥ 65				10.1	1.08-93.9	.0200
WOMEN							
Poor handgrip strength	50-64	2.70	1.67-4.34	.0000	4.17	2.51-6.91	.0000
	≥ 65						
Poor manual dexterity	50-64				1.71	1.07-2.73	.0234
	≥ 65						

7.3 Summary

The results of logistic regression analysis have demonstrated a strong independent association between the presence of underweight and the risk of impairment in some important dimensions of functional ability and of poor physical performance, particularly handgrip strength, in both men and women independent of other factors including age and disease. Not surprisingly, increasing age was a very important factor contributing to the risk of functional ability impairment, but it was not always the overriding one. The presence of kyphosis and anaemia also emerged as important co-contributors to the risk of functional ability impairment. To a large extent, the hypothesis is supported. Irrespective of age and state of health, underweight is a good predictor of impairment in some important dimensions of functional ability and of poor performance in physical tests, but particularly of poor handgrip strength, in these elderly people.

Table 7.7 Summary table of variables associated with poor handgrip strength

	variable	significance test	variable	significance test
Continuous variables		MEN		WOMEN
Higher	Age	Z= 4.67, p=<0.001	Age	Z = 6.35, p=<0.001
Lower	Weight	Z= 7.51 , p=<0.001	Weight	Z = 8.55, p=<0.001
	BMI	Z= 6.40, p=<0.001	BMI	Z = 7.59, p=<0.001
	MUAC	Z= 7.25, p=<0.001	MUAC	Z = 9.37, p=<0.001
	Calf circumf	Z= 7.04, p=<0.001	Calf circumf	Z = 9.93, p=<0.001
	Triceps skinf	Z= 5.00, p=<0.001	Triceps skinfold	Z = 7.51, p=<0.001
	cAMA	Z = 7.32, p=<0.001	cAMA	Z = 9.48, p=<0.001
	Haemoglobin	Z = 2.74, p=0.0061	Haemoglobin	Z = 2.74, p=0.0062
	Serum albumin	-	Serum albumin	Z = 2.74, p=0.0061
Slower	Chair rise time	Z = 3.60, p=<0.001	Chair rise time	Z = 3.69, p= 0.0002
	Plate-tap time	Z = 5.72, p=<0.001	Plate-tap time	Z = 5.22, p= <0.001
	Lock open time	Z = 6.09, p=<0.001	Lock open time	Z = 7.22, p=<0.001
Dichotomous variables				
	> 65 years	χ^2 = 25.23, p=<0.001	> 65 years	χ^2 = 33.98, p=<0.001
Dependence in				
	Dressing	χ^2 = 13.54, p=0.00076	Dressing	χ^2 = 10.30, p=0.0013
	Transfer	χ^2 = 6.46, p=0.01106	Transfer	χ^2 = 10.65, p=0.0011
	Bathing	χ^2 = 13.54, p=0.00076	Bathing	χ^2 = 16.09, p=0.0006
	Self-feeding	χ^2 = 7.77, p=0.01195	Self-feeding	χ^2 = 6.98, p=0.00825
	Toilet use	χ^2 = 13.81, p=0.0002	Toilet use	χ^2 = 21.74, p=<0.001
	IMPADL	χ^2 = 6.62, p=0.0101	IMPADL	χ^2 = 12.47, p=0.0004
	Walking	χ^2 = 49.46, p=<0.001	Walking	χ^2 = 7.83, p=0.00514
	Stairs	χ^2 = 17.50, p=<0.001	Stairs	χ^2 = 8.315, p=0.0039
	Travel	χ^2 = 49.76, p=<0.001	Travel	χ^2 = 23.76, p=<0.001
	IMPMOB	χ^2 = 53.03, p=<0.001	IMPMOB	χ^2 = 23.74, p=<0.001
	Flexibility	χ^2 = 6.67, p=0.00982	Flexibility	χ^2 = 37.08, p=<0.001
Presence of				
	COPD	χ^2 = 3.63, p=0.04686	COPD	-
	Neurological dis	χ^2 = 4.94, p=0.02626	Neurological dis	-
	TB	χ^2 = 5.42, p=0.01990	TB	-
	Musculoskel dis	-	Musculoskel dis	χ^2 = 6.37, p=0.01160
	Anaemia	χ^2 = 7.32, p=0.0068	Anaemia	χ^2 = 8.524, p=0.0035
	Hypoalbuminaemia	-	Hypoalbuminaemia	χ^2 = 10.69, p=0.0011
	Kyphosis	χ^2 = 17.33, p=<0.0003	Kyphosis	χ^2 = 7.91, p=0.0049
	Underweight BMI	χ^2 = 27.55, p=<0.001	Underweight BMI	χ^2 = 38.74, p=<0.001
	Underweight MUAC	χ^2 = 45.44, p=<0.001	Underweight MUAC	χ^2 = 64.81, p=<0.001
Being	Housebound	χ^2 = 24.41, p=<0.001	Housebound	χ^2 =9.599, p= 0.0019
	Recently disabled	-	Recently disabled	χ^2 = 15.44, p=0.0009

CHAPTER 8 : DISCUSSION

The preceding three chapters have described the characteristics of the whole data set, looked at bivariate associations and, using logistic regression models, quantified the risk of being impaired in some important dimensions of functional ability, and of having poor performance in physical tests reflecting aspects of functional ability, in the presence of underweight. This chapter looks at the findings in the light of other data on elderly people particularly in the Asian region. The functional significance of underweight classified both by low BMI and low MUAC is then discussed, with debate focusing on the emerging and potential confounders and the complex relationship between muscle mass and function. Finally, the meanings of risk and prediction are explored, leading to a conclusion as to whether or not the association found in this study between underweight and impaired functional ability could be a causal one.

8.1 Comparison with other studies

Although comparative data are not extensive, this study reveals large differences in levels of nutritional status and functional ability impairment between these older people from Mumbai and other elderly in developed countries, but similarities with other low-income older people from the less developed world. Marked gender differences in the prevalences of underweight, functional disability and disease are consistent with other published studies. In broad terms, the classic pattern of declines of most nutritional, health and functional variables associated with ageing was also demonstrated, attesting to the "universality of the biophysical manifestation of ageing" (Andrews 1988).

8.1.1 Anthropometry and underweight

Table 8.1 presents a summary of differences between anthropometric measurements taken in Mumbai elderly and older adults elsewhere. Many age- and sex- matched mean anthropometric measurements in Mumbai are broadly similar to those found amongst other older adult Asian communities of low socio-economic status, but considerably lower than reference data from the USA, and groups of US and European elderly. For example, the 50th centiles for height in both men and women in the USA mostly fall on or above the 95th centile for Mumbai, and differences in mean weight by age group between the present data set and US reference data[1] are approximately 20-25 kg in both sexes. The lower values in Mumbai will be due to a combination of genetics, health and nutritional differences. This study found an overall correlation coefficient between height (of non-kyphotics) and armspan of 0.82. Even though this would have included people over 50 years in whom some height loss would have occurred even in the absence of overt kyphosis, this figure is comparable to those found amongst Caucasian adults in Europe and America (Steele and Mattox 1987, Kwok and Whitelaw 1991, Reeves *et al* 1996), as well as other Asians (Rabe *et al* 1996), but higher than those found for blacks (McPherson *et al* 1978, Steele and Chenier 1990).

Fat and muscle-related anthropometric characteristics of this study population show a similar pattern. The 50th centile for MUAC in Mumbai men approximates the 25th centile in the UK (Burr and Phillips 1984), and for women it is the 5th centile, whereas Indian reference data from slum areas (NNMB 1984[2], NNMB 1988-90) on MUAC and weight are similar to the present data. Calf circumference values reported in the USA and UK show means 5-7 cms greater (Damon *et al* 1972, Friedlander *et al* 1977, Patrick *et al* 1982, Chumlea *et al* 1986) than those in Mumbai. This pattern is repeated for cAMA values. There is very little comparative data for calf circumference or cAMA from Asian populations, although a recent study on adult men aged 18-64 years living on the streets of Calcutta reported lower values for MUAC, calf circumference and cAMA (Campbell and Ulijaszek 1994) than those found in Mumbai.

[1] In the absence of reference data for elderly people in developing countries, the recent WHO Technical Report on Anthropometry (1995) recommends comparisons with the US National Health and Nutrition Examination Survey (NHANES) III data set which has no upper age limit and oversampled the oldest age-group. However full results from this are still not available so comparisons are still only possible with the NHANES I and II survey data using 5-year age intervals (Frisancho 1990)

[2] pooled data on slum groups from 16 cities (not including Mumbai) from 10 Indian states

Table 8.1 Comparison of anthropometry (means) in community-living older adults

Anthropometry	Lower than Mumbai	Similar to Mumbai	Greater than Mumbai
WEIGHT	Rural Rajhasthan (4) Rural Andra Pradesh (5) Rural Philippines (14) Urban Guatemalans (31)	India slum reference data (2,3) Hyderabad poor (6) Rural Uttar Pradesh (29) Rural China (7) Poor Indonesians (21)	USA reference data (1) USA (8, 27) Holland (9), Italy (25) UK (10, 20) Madras (11) Urban Uttar Pradesh (29) Urban Chinese (7) Rural Malaysian women (12) US Asians (13) Urban Guatemalans (31) Chinese (Taiwan) (32)
HEIGHT	India slum data - men (2) Poor Indonesian men (21) Rural Philippines (14) Rural Chinese women (7)	India slum data - women (2) Poor Indonesian women (21) Hyderabad poor (6) Rural Malaysian women (12) Rural Chinese men (7)	USA reference data (1) USA (8, 27) Holland (9), Italy (25) Madras (11) Urban Chinese (7) Chinese (Taiwan) (32)
ARMSPAN	Rural Malaysia (12) Poor Indonesian men (21)	Mumbai middle class (16) Poor Indonesian women (21)	US whites (17, 18, 22, 28) US blacks (19, 22)
MUAC	India slum data - men (2) Rural Philippines (14) Poor Calcutta men (30)	India slum data - women (2,3) Hyderabad poor (6) Uttar Pradesh women (29) Rural Chinese (7)	USA reference data (1, 26) USA (8, 15, 23, 27) Holland (9), Italy (25) , UK (10) Urban China (7) Rural Malaysian women (12) Urban Guatemalans (31)
CALF CIRCUMFERENCE	Poor Calcutta men (30)	Rural Philippines men (14)	US whites (17,) Philippines women (14) UK (33)
TRICEPS SKINFOLD	India slum data - men (2) Hyderabad poor (6) Rural Philippines women (14) Rural Chinese (7)	Rural Philippines men (14) Urban Guatemalans (31)	USA reference data (1, 26) India slum data-women (2) USA (8, 15, 26, 27) Rural Malaysian women (12) Urban Chinese (7) US Asians (13) Holland (9), Italy (25), UK (10, 20)
cAMA	Poor Calcutta men (30)		USA reference data (1) UK (10) Urban Guatemalans (31)

Key to references

1 Frisancho 1990	2 NNMB 1984	3 NNMB 1988-90
4 Purohit & Sharma 1976	5 Kullah & Ramnath 1985	6 Rao et al 1986
7 Side et al 1991	8 Nelson & Evans 1992	9 Minten et al 1991
10 Burr & Phillips 1984	11 Natarajan et al 1993	12 Yassin & Terry 1991
13 Kim et al 1993	14 Garcia et al 1982	15 Falciglia et al 1988
16 Pathak 1978	17 Friedlander et al 1977	18 Borkan et al 1983
19 McPherson et al 1978	20 Milne 1979	21 Rabe et al 1996
22 Steele & Chenier 1990	23 Chumlea et al 1984 b	24 Bishop et al 1981
25 Lancia et al 1997	26 Cronk & Roche 1982	27 Kubena et al 1991
28 Kelly & Kroemer 1990	29 Mehta 1987	30 Campbell and Ulijaszek 1994
31 Herman et al 1998	32 Liang & Chumlea 1998	33 Patrick et al 1982

The age and gender associations with most anthropometric variables found in this study are in line with those reported previously in the literature. A downward trend in all variables, except height, across the age range is also found in most other studies (Burr and Phillips 1984, Chumlea *et al* 1984 b, Falciglia *et al* 1988, Yassin and Terry 1991, Nelson and Evans 1992), although not in all (Woo *et al* 1988). The lack of an association between height and age reflects the cross-sectional nature of this study with its in-built survivorship resulting from selective mortality.

Comparison with age- and sex- matched US reference data shows that mean **BMI** values for Mumbai in all age groups over 50 years old are 5-6 BMI points lower than for US men and 5-8 BMI points lower than US women (Frisancho 1990). Mean BMIs in Mumbai are also well below those reported for populations of elderly in other developed countries (Burr and Phillips 1984, Norgan 1990, Rolland-Cahera *et al* 1991, EURONUT 1991, Minten *et al* 1991, Nelson and Evans 1992), including those of Asian origin (Netland and Brownstein 1985, Kim *et al* 1993, Launer and Harris 1996).

Table 8.2 shows selected data on BMI from older adults in Asia. This shows that the Mumbai mean BMI of approximately 21, for both sexes, is similar to other low income urban elderly elsewhere in the region. This is in line with reports that most adult groups in the lesser developed world have average BMIs in the range of 19-21 kg/m^2 apart from a few groups with exceptionally long legs[3] (James *et al* 1988). Low BMI is generally characteristic of many Indian populations (Norgan 1990, Naidu and Rao 1994), although there are differences by level of socio-economic status (Rao *et al* 1986, Naidu and Rao 1994).

Pooled European data for 20-65 year olds showed higher BMI means in men than women, and lower BMI means in older age groups (Norgan 1990). An age group difference in mean BMI was seen in this study but a significant gender difference in mean BMI was not, although it was present for all other raw anthropometric variables at the p <0.0001 level.

[3] such as African Dinka, Australian aborigines

Table 8.2 Comparison of BMI (mean, sd) of adult and elderly Asians, and Americans

		MEN				WOMEN				
Country	pop	Age	n	mn	sd	Age	n	mn	sd	Reference
India	Mumbai *	50-54	104	20.4	3.9	50-54	223	21.1	4.2	present study
		55-59	102	20.4	3.8	55-59	159	20.7	4.0	
		60-64	120	20.6	3.8	60-64	117	20.9	4.6	
		65-69	69	20.9	4.0	65-69	63	20.7	4.1	
		> 70	52	19.9	3.1	> 70	67	18.3	4.1	
India	rural	adult	9,447	18.9		adult	11914	19.0		Naidu & Rao 1994
S. India	rural	> 60	58	17.7		> 60	42	18.7		McNeill et al 1988
S. India	urban **	> 49	98	20.5	1.4	> 49	143	20.1	1.0	Rao et al 1986
N. India	urban I	15-54	195	20.2	2.4					Kumar & Vali 1994
Bangladesh	urban *	av 36	199	19.0	2.9	av 26	186	18.8	2.5	Pryer 1993
Thailand	rural	> 60	38	19.5	3.9	> 60	44	17.2	3.8	Pongpaew & Schelp 1997
	urban	> 60	59	21.8		> 60	146	22.4		
Malaysia	rural					55-65	173	24.1	5.1	Yassin & Terry 1991
Java	urban **	55-59	34	19.9	3.6	55-59	29	20.1	3.4	Evans 1990
Indonesia	urban **	60-69	36	21.7	4.7	60-69	33	21.3	4.2	Rabe et al 1996
Sarawak	rural	50-54	36	20.9	3.5	50-54	55	21.2	3.6	Strickland & Ulijaszek 1993
		55-59	24	20.2	2.3	55-59	36	20.8	3.0	
		60-64	35	19.8	2.1	60-64	49	20.1	3.2	
		65-69	36	19.7	1.9	65-69	35	19.2	3.3	
		> 70	35	19.6	3.2	> 70	45	18.2	3.4	
Vietnam	urban @	50-59	368	19.7	2.3	50-59	278	20.0	2.6	Giay & Khoi 1994
		60-69	154	19.0	2.4	60-69	199	19.0	2.6	
		> 70	95	17.9	2.4	> 70	142	18.3	2.7	
	rural	50-59	1341	19.0	1.9	50-59	1691	18.6	2.1	
		60-69	949	18.8	3.4	60-69	1166	18.2	2.2	
		> 70	495	18.1	2.2	> 70	639	17.6	2.3	
China	rural	> 70	83	20.4	2.6	> 70	98	20.6	3.3	Side et al 1991
	urban	> 70	126	23.2	3.3	> 70	134	23.0	4.4	
Hong Kong	urban **	60-64	20	21.9	2.9	60-64	26	24.2	3.5	Woo et al 1988
		65-69	57	21.3	3.2	65-69	80	22.7	4.0	
		70-74	64	22.1	5.1	70-74	95	22.5	4.3	
		> 75	18	21.3	3.4	> 75	42	22.7	3.8	
Taiwan	urban /rural @	65-69	125	23.6	2.7	65-69	77	23.6	3.1	Liang & Chumlea 1998
		70-74	98	23.6	2.9	70-74	60	23.2	3.2	
		75-80	105	23.4	2.7	75-80	73	22.2	3.4	
USA	ref data NHANES I and II	50-54	767	26.0	4.1	50-54	863	25.6	5.1	Frisancho 1990
		55-59	693	26.2	4.1	55-59	756	26.3	5.1	
		60-64	1122	25.8	3.8	60-64	1225	26.5	5.4	
		65-69	1488	25.6	3.9	65-69	1651	26.6	5.4	
		> 70	1057	25.4	3.9	> 70	1262	26.4	5.2	

Key to references
* slums ** low / middle income *** high income I factory workers @ all income groups

Definitions of **"underweight"** vary greatly in the literature making meaningful comparison limited. However, it is clear that there is very much more underweight amongst these poor elderly people in Mumbai than their developed country counterparts, as well as compared to other groups of elderly people in less developed countries.

Pooling data (adults) from a large number of less developed country studies, Pelletier and Rahn (1998) reported that the prevalence of underweight (BMI<18.5) was the highest in India, echoing the findings of Bailey and Ferro-Luzzi (1995) on adult BMI in developing countries. For Indian men from the lowest socio-economic classes the prevalence of underweight was 29%, which is lower than the 35% reported here, but for Indian women it was identical (35%), and three times higher than that reported for women of high socio-economic status (Pelletier and Rahn 1998). National Indian data on rural adults reveals that about half of all adults above 50 suffer from underweight (Naidu and Rao 1994). The prevalence of underweight (BMI<18.5) in male 50-59 year olds was 48%, rising to 53% amongst the over 60s. In women the equivalent figures were 45% and 56% respectively.

In Mumbai, the prevalence of underweight was somewhat lower than this, with approximately one third of men and women suffering from underweight. Amongst poor adults over 50 years old in urban Hyderabad, the prevalence of underweight (BMI<18) was similar for women (roughly 30%) but much lower amongst men (14% in men compared to roughly 25% in the present study) (Rao *et al* 1986). The vast majority (89%) of male (aged 18-64 years) slum dwellers in a Calcutta study had a BMI<18.5, and nearly half (44%) had severe underweight (BMI<16) (Campbell and Ulijaszek 1994), which are much higher rates of underweight than those found in the Mumbai slum dwellers. This may be explained by the fact that the Calcutta men were mostly destitute street dwellers and thus likely to be even more disadvantaged than the Mumbai slum dwellers. The Calcutta men also suffered higher rates of TB (27%) and respiratory infections (34%) than the Mumbai population.

Table 8.3 International comparisons of ADL and mobility impairments in elderly people

			ADL impairment %				Mobility impairment %			
Country	study n	Age and sex	Dress	Transfer	Toilet	Bath	Walk	Stairs	Travel	ref
India Mumbai slums	1,097	50-64 men	3	46	36	2	42	68	11	present study
		50-64 women	1	59	45	2	62	85	46	
		> 65 men	6	49	41	73	56	73	31	
		> 65 women	7	82	72	10	75	91	70	
USA national data	27.9 million	> 65 both sex		6		9	8			1
USA Boston, community	3,812	> 65 men	8	4		10	8	18		2
		> 65 women	9	7		13	12	33		
USA community	2,654	55-64 men	1	0		0	3	2		3
		55-64 women	0	1		1	4	4		
		65-74 men	1	0		1	5	3		
		65-74 women	0	0		1	10	5		
		75-84 men	3	3		3	13	7		
		75-84 women	2	2		5	28	20		
China Hong Kong	2,032	70-79 men	1	1	1	3	3			4
		70-79 women	4	4	4	8	10			
		> 80 men	3	3	3	8	10			
		> 80 women	9	11	11	20	26			
Indonesia rural, urban	580	> 65 women			2					5
Philippines *	927	> 60	< 3	< 3	4	< 3	23			6
Malaysia *	1,000	> 60	< 3	< 3	4	< 3	12			
Fiji *	796	> 60	< 3	< 3	7	< 3	42		7	
Thailand urban slum	703	> 60 men	3	1	3	2	5	9	18	7
		> 60 women	2	1	3	2	8	16	32	
Japan urban Tokyo	238	79-81 men	10		10	10	30			8
		79-81 women	8		10	6	23			
Sweden urban Gothenburg	619	70 men	16	5	4	39				9
		70 women	16	13	2	51				

References

1 Schultz et al 1995
2 Foley et al 1986 (US Institute of Aging, Established Populations for Epidemiologic Studies of the Elderly)
3 Jette and Branch 1981 (Framingham Disability Study)
4 Woo et al 1996
5 Manton et al 1986
6 Andrews et al 1986 (* WHO Asia-Pacific study)
7 Jitapunkul et al 1993
8 Haga et al 1991
9 Gosman-Hedstrom et al 1988

The high prevalences for underweight in Mumbai (ranging from 25-40%) are certainly in striking contrast to the very low prevalence amongst free-living elderly living in Europe of between 5-8% (Department of Health 1972, Guigoz *et al* 1996), an exception being a prevalence of 12% recently recorded for men and women over 60 years old living in three cities besieged during the war in Bosnia-Hercegovina (Vespa and Watson 1995).

8.1.2 Functional ability impairment and poor physical performance

There is still relatively little known about the extent to which elderly people in developing countries experience functional limitations (Manton *et al* 1986, Barker 1989). However, comparison of functional disability between the USA and Europe, the Western Pacific 4-nation study, and several countries in the Caribbean and Latin America, show that there are generally higher levels of impairment in ADL and mobility in elderly living in the less developed countries (Heikkinen *et al* 1996). The lower prevalences of ADL impairments in developed countries is probably partly due to the modern amenities and aids available to elderly individuals there.

With comparison of the extent and severity of **ADL** impairment even within the same country hampered by the use of different definitions and methodologies, the problem is even more apparent when comparisons are attempted between countries (Wiener *et al* 1990, Fillenbaum 1996). The EURONUT Seneca study provides data on the prevalence of ADL impairment amongst elderly Europeans (EURONUT 1996) but uses a broader methodology for ADL assessment[4] than many other studies, including this one, and a large amount of variation in prevalence between the 11 European sites also confuses the picture. Cautious comparison overall shows that ADL and mobility impairment is much higher amongst the Mumbai elderly than amongst elderly studied in Europe (EURONUT 1996, Heikkinen *et al* 1996) and the USA (Foley *et al* 1986, Stone and Murtaugh 1990, Wiener *et al* 1990). Cultural differences in ADL tasks may play some role here. For

[4] based on sum score (for 16 questions and a 4-point ranking of difficulty) over the number of items

example, toilet use in Mumbai requires getting up and down from a squat, and self-feeding refers more to use of fingers than using cutlery. Even though attempts were made to account for this in the way the questions were asked, there may still have been a residue of cultural bias in the protocol.

Data from 4 US national surveys showed that 14% of people aged 65-74 years reported difficulty in walking (Miles *et al* 1993). Similarly, in the Framingham Disability Study, only 12% of women and 5% of men were unable to walk half a mile (Jette and Branch 1981). The equivalent figures for Mumbai were 38% and 19% respectively, and there were similarly very large differences for climbing stairs, and transfer and toilet use ADLs, using a methodology similar to the present one.

This study found that different types of tasks were not equally difficult. Using the toilet was the most common problem in this study, as it was also in the WHO Asia-Pacific study (Andrews *et al* 1986). However, this study also found a high prevalence of impairment in transferring, which the WHO study did not. In Mumbai, the range of frequency of impairments in the different ADLs was very wide, from 2% for self-feeding to 57% for transfer. This is in marked contrast to national data on non-institutionalised elderly from the USA in which the frequency of impairment in different ADL tasks had a very small range, from only 2% (self-feeding) to 7% (for bathing) (Stone and Murtaugh 1990). A study of elderly Hong Kong Chinese found that bathing impairment was the most commonly reported ADL problem (Woo *et al* 1996) whereas for Mumbai elderly the frequency of this ADL impairment was low.

Some international comparative prevalences for ADL and mobility impairments are presented in Table 8.3. Other Indian studies reporting ADL and mobility impairments are largely unavailable. A recent study of 300 rural and urban elderly (over 60 years) living in Bangalore district reported that 44% had mobility problems, and, overall, 20% needed help in ADLs (Prakash 1998). These values are much lower than those for Mumbai but it is difficult to see why this might be without more information

The present finding of high reliability for the ADL scale is consistent with other recent studies (Bowling and Grundy 1997 in the UK, Jitapunkul *et al* 1993 in Thailand, Guralnik and Lacroix 1992, reporting studies from the USA, Reuben *et al* 1995 from the USA). Inter-item correlations are also comparable.

Physical test performance data from older adults in developing countries are scarce (Murray *et al* 1992 b). Any comparison of the prevalence of poor performance is also hampered by major differences in the test and equipment methodologies as well as criteria used to define "poor" or "impairment". Only a few comparisons of actual means for timed tests, and for handgrip strength are possible. For example, in Mumbai, overall mean chair stand times were 4-6 seconds slower than those reported in Europe (EURONUT 1996) and the USA (Seeman *et al* 1994). This may be due to the unfamiliarity with using chairs amongst the elderly people in Mumbai, which even seems to counteract the presumable benefits to leg strength conferred by habitual squatting. Table 8.4 shows that mean values for handgrip strength for these elderly people in Mumbai are much lower than most published for elderly elsewhere, although many studies exclude elderly with certain diseases. Good comparative data from less developed countries are lacking.

The finding that women report higher rates of ADL impairments than men, and that there are similar gender differences for the physical performance tests, are in agreement with many studies (MacLennan *et al* 1980, Jette and Branch 1981, Garcia *et al* 1982, Milne and Maule 1984, Martin *et al* 1985, Csuka and McCarty 1985, Shukla *et al* 1987, Cooper *et al* 1988, Bassey *et al* 1989 b, EURONUT 1991 d and 1996, Frontera *et al* 1991, Rantanen *et al* 1994, Seeman *et al* 1994, Khetarpal and Kumar 1995, Woo *et al* 1996, Bowling and Grundy 1997, Schroll *et al* 1997, Liang and Chumlea 1998), although a few studies have found the reverse to be true (Haga *et al* 1991 in Japan; Herman *et al* 1998 in Guatemala), or no gender difference at all (Gosman-Hedstrom *et al* 1988). A recent Indian study also reports that older women have higher rates of ADL impairment than older men (Prakash 1998). Previous findings that women have more problems with mobility items than men were confirmed in this study (EURONUT 1991 d, Woo *et al* 1996, Herman *et al* 1998).

Table 8.4 Some comparisons of mean handgrip strength values for elderly people

Country	study n	Age, sex	mean kgs	SD	reference
Mumbai slums	1097	50-64 men	23.7	6.5	present study
		50-64 women	14.0	4.4	
		≥ 65 men	20.8	6.0	
		≥ 65 women	11.1	4.2	
UK healthy volunteers	756	> 60 men	39.5	5.4	Anderson & Cowan 1966
		> 60 women	30.3	3.6	
UK healthy home living	270	> 65 men	29		MacLennan et al 1980 (reported in Pearson 1985)
		> 65 women	16		
		> 75 men	24		
		> 75 women	13		
		> 85 men	19		
		> 85 women	10		
UK healthy volunteers	599	55-64 men	42.6		Cooper et al 1988
		55-64 women	23.8		
		65-74 men	33.5		
		65-74 women	20.9		
		75-84 men	25.4		
		75-84 women	17.6		
UK representative sample community-living elderly	350	> 65 men	37.2*	8.1*	Bassey 1998
		> 65 women	21.6*	5.9*	
UK healthy volunteers	100	65-69 men	46.7*	7.9*	Skelton et al 1994
		65-69 men	26.0*	3.0*	
		70-74 men	40.1*	5.0*	
		70-74 women	27.0*	5.0*	
		75-79 men	37.1*	5.0*	
		75-79 women	22.0*	6.0*	
UK hospital/day care	92	65-89 men	32.7*	10.1*	Hyatt et al 1990
		65-89 women	22.0*	8.6*	
Yugoslavia mobile, living in care	100	65-80	48.1 *	3.4*	Suboticanec et al 1989
India patients @	78	20-70 men	18.1	6.8	Shukla et al 1987
		20-70 women	9.7	3.9	
The Philippines rural	100	60-69 men	32	8	Garcia et al 1982
		60-69 women	21	4	
		> 70 men	29	7	
		> 70 women	18	6	
USA twin study	343	59 yrs, men	42.3	7.6	Reed et al 1991
		60-64 men	41.2	8.4	
		65-69 men	38.5	8.6	
USA community , white	9,704	> 65 women	20.6	5.0	Ensrud et al 1994
Norway hospitalised	311	70-94 men	22.2	9.7	Mowe et al 1994
		70-94 women	12.3	5.8	
Norway home living	106	70-94 men	30.8	8.7	
		70-94 women	17.8	5.1	

Key
**converted from Newtons using the conversion 1 N (Newton) = 0.102 kgs*
@ with no post-operative complications

A study designed to test the accuracy of "real" versus self-reported gender differences in functional ability impairments in older people found that higher prevalences of reported impairments in ADL's in women compared to men was probably a reflection of true disability for most disability measures (Merrill *et al* 1997). The assumption that females are socialized to pay attention to, and acknowledge pain and discomfort, which males are more socialized to ignore, may play a role. Women were worse off in terms of lower morale and well-being scores, and had more limited access to health care, and even family care. Previous work has also reported that men live a greater proportion of their lives without disability (Bebbington 1988) but tend to die shortly after losing independence (Brody 1985).

The findings that all dimensions of functional ability were more impaired, and physical test performances lower, in the older than in the younger age group are in agreement with the majority of epidemiological studies from Europe (Milne and Maule 1984, Cooper *et al* 1988, Didier *et al* 1993, Heikkinen *et al* 1996, Bassey 1998), North America (Jette *et al* 1981, Cauley *et al* 1987, Ostwald *et al* 1989) and less developed countries (Garcia *et al* 1982, Andrews *et al* 1986, Woo *et al* 1996, Herman *et al* 1998, Liang and Chumlea 1998, Prakash 1998). For example, in a study of Sri Lankan elderly[5], the ability to perform chair rises and shoulder rotations was significantly less in the very old (over 80 years) than in those aged 60 (Fernando and Seneviratna 1993).

Many bivariate inter-relationships between functional variables demonstrated in the Mumbai population are in agreement with other cross-sectional studies. Examples are the findings that decreasing handgrip was associated with decreased reaction time (Heikkinen *et al* 1993), reduced ADL ability (Gosman-Hedstrom 1988, Hyatt *et al* 1990, Rantanen *et al* 1994), reduced mobility (Bendall *et al* 1989, Rantanen *et al* 1994, Brown *et al* 1995), and reduced manual performance (Hughes *et al* 1997). The strong associations between poor manual dexterity and shoulder flexibility and some ADL and mobility impairments also reflect earlier findings (Bergstrom *et al* 1985, Bassey *et al* 1989 b, Jette *et al* 1990). Modest inter-correlations found between the physical test variables confirms earlier work (Seeman *et al* 1994) which used this as justification for

[5] the poorest and the sickest did not participate

developing a summary measure of physical ability. However, not all self-reported functional ability dimensions were significantly associated with physical test performance, supporting the conclusions of Reuben and others (1995) that these two techniques are not necessarily measuring the same dimensions.

8.1.3 Morbidity

There is a heavy burden of both **disease** and disability amongst this population of poor elderly people. Although comparative reliable data for older adult morbidity for developing countries are limited (Hoover and Siegel 1986, Phillips *et al* 1992 a, Jitapunkul *et al* 1993), the patterns of disease in Mumbai appear to be similar to other studies of elderly people in the less developed world. However, the prevalences of the main diseases reported (musculoskeletal and respiratory disease, COPD, cataracts, neurological disease and TB) are higher than those reported for other groups in Mumbai (Desai and Naik 196x, Pathak 1978), elsewhere in India (Raj and Prasad 1970, Purohit and Sharma 1976, Mehrota *et al* 1979, Sengupta and Chakraborty 1982, Natarajan 1991, Ara 1994, Khilnani *et al* 1995[6], Prakash 1998) and from other developing countries (Andrews 1987, Manton *et al* 1987, Barker *et al* 1989, Fernando and Seneviratna 1993). An exception is a population survey conducted amongst people aged over 60 in Thailand which found over 70% of men and women suffered from arthritis, higher than the 47% suffering from musculoskeletal diseases in this study (Jitapunkul *et al* 1993). Men living on the streets of Calcutta suffered much higher rates of TB, leprosy, respiratory infection and gastrointestinal disease, but lesser levels of musculoskeletal disease and diabetes than Mumbai men (Campbell and Ulijaszek 1994).

Some of the gender differences in prevalences of some morbidity conditions found in Mumbai (e.g. more COPD, TB, and respiratory disease in men, more musculoskeletal disease in women) have been reported elsewhere (Woo *et al* 1996). Barker (1989) found that men had higher rates of respiratory problems than women amongst the elderly population on the Polynesian island of Niue, findings which they attributed to differences

[6] with the exception of COPD which was double the rate (15%) of Mumbai (7%)

in occupancy and levels of smoking, which may also be a plausible explanation in this population.

Weight loss and underweight are known to be significantly more common in people with some disease conditions than healthy people of the same age, sex and occupation (Campbell and Ulijaszek 1994). This is certainly supported in this study with significantly lower anthropometric values found amongst those with COPD, TB and neurological disease (men only). The mechanism of underweight in COPD is not clear, but maybe because there is inadequate dietary intake to meet the increased energy expenditure from respiratory work in the presence of respiratory muscle weakness.

In intensive care patients, acute infection and severe disease adversely affects handgrip (Martin *et al* 1985). In this study, despite some expected and strong associations between some disease conditions and functional impairment and poor performance, generally illness does not appear to be fully explaining poor functional ability. American data show that certain types of health conditions such as diabetes, stroke and arthritis/rheumatism are likely to be associated with a large number of ADL impairments and physical test performance, and cognitive status with IADL impairments (Ensrud *et al* 1994, Fillenbaum 1996). A Swedish study of over-70 year olds reported similar results for mobility (Gosman-Hedstrom *et al* 1988). However, in Mumbai, whilst musculoskeletal and neurological diseases do emerge strongly from the multivariate analyses, diabetes does not, with more important disease predictors of impaired function and poor performance being anaemia, hypoalbuminaemia, COPD and TB.

The finding that musculoskeletal problems are negatively associated with some ADL and mobility tasks supports other findings that arthritis and related joint impairment in old people, especially in the knee and lower spine joints, account for significant levels of functional disability and immobility (Gosman-Hedstrom 1988, Jette *et al* 1990, Hughes *et al* 1993, Gibbs *et al* 1993). Moreover, in this study, musculoskeletal disease emerged as a significant independent predictor of impaired ability to use the toilet in both sexes, and in transferring in men. However, the presence of musculoskeletal disease was not always related to functional dimensions requiring considerable joint and muscle action, as reported elsewhere (Csuka and McCarty 1985, Boult *et al* 1994, Brown *et al* 1995). Whilst poor manual dexterity, and to a lesser extent poor shoulder flexibility, was associated with the presence of musculoskeletal impairment, poor chair rise performance and poor handgrip strength were not. This may be due in part to the use of simple assessment methods for physical performance testing used in this field study rather than the more rigorous laboratory techniques mostly used elsewhere. It is somewhat puzzling that TB emerged as a strong independent predictor of impaired function in women (over 65 years) and not in men who suffered much more from this disease. With regard to TB, a final remark needs to be made about diagnostic accuracy. Although chest X-rays and smear and culture positivity were used in this study, the presentation of TB in the elderly is often uncharacteristic (Davies 1996). Thus the actual prevalence of TB may have been even higher than that reported here.

In line with other studies on poor elderly in developing countries, blindness was the commonest form of **disability**, mainly from cataracts and glaucoma. The prevalence of cataracts (72%) was very much higher compared to other groups of elderly in South East Asia (Andrews *et al* 1986, Jitapunkul *et al* 1993) and the Pacific (Barker *et al* 1989). The prevalence of cataracts also exceeds that of other places in India, such as the 18% found in Calcutta (Sengupta and Chakraborty 1982), 24% in New Delhi (Khilnani *et al* 1995), and 40% in rural Jaipur (Purohit and Sharma 1975). In contrast, the prevalence of full deafness in Mumbai (4% in men and 1% in women) appears to be very similar (Purohit and Sharma 1975, Sengupta and Chakraborty 1982). No comparable data from India on the prevalence of recent onset of disability or surgery could be found.

Mean and median haemoglobin values from elderly populations in the USA (whites : Garry *et al* 1983, Yip *et al* 1984, urban low-income blacks : Bailey *et al* 1979) and Europe (Attwood *et al* 1978, EURONUT 1991c, Mowe *et al* 1994, Ortega *et al* 1994,) are all higher than those found in Mumbai. So too are values from elderly "coloureds" of mixed race in South Africa (Charlton *et al* 1997) and even elderly slum dwellers in Kenya (Ethangatta *et al* 1994). In an analysis of Bombay Hospital data from middle class elderly patients (Pathak 1978) mean values of 13.1 g/dl for men and only 11.7 g/dl for women are reported, which are similar to those found in this study.

A series of epidemiological studies in the developed world indicate that anaemia is more prevalent in persons over 60 years old than in younger people (Garry *et al* 1983, Dallman *et al* 1984, Lipschitz 1990a, Russell 1992). The present study confirms this age effect in women. In rural Andra Pradesh, the prevalence of anaemia[7] in women over 60 years was 31%, higher than the 26% prevalence found for women aged 25-45 years (Kullah and Ramnath 1985) but still somewhat lower than the women in this study (52% overall, and 65% for women over 65 years of age). US national prevalence of anaemia for elderly men (65-74 years, all races) has been reported as 3.9%[8] (Dallman *et al* 1984). Very much higher levels were found in this study, as elsewhere in India (Purohit and Sharma 1975). Several studies previously reported high rates of helminthic infection, particularly *Ascaris* and *Trichuris*, amongst poor elderly people in Indian cities (Pathak 1978, Sengupta and Chakraborty 1982), as well as amongst poor elderly in rural Guatemala (King *et al* 1997). This may have been a contributory factor in the high levels of anaemia found in this study (Roche and Layrisse 1966, Finch 1989). The finding that a significant association exists between anaemia and poorer levels of some anthropometric measurements is consistent with previous work (Russell 1992, King *et al* 1997).

In contrast, the levels of **serum albumin** found in this study are not very different from age-and sex-matched values from the literature. For example, mean albumin for men and women in the Boston Nutritional Status Survey of elderly people was 4.2 g/dL (Munro 1992 a), compared to Mumbai means of 4.1 for men and 4.0 for women. Munro (1992 a) also reported that the level of albumin in women was significantly negatively correlated with age in both men and women, a finding only repeated for women in the present study. However, the prevalence of **hypoalbuminaemia** in these Mumbai is much higher than that reported elsewhere. The EURONUT study reported an overall prevalence of only 2% hypoalbuminaemia (Van Staveren *et al* 1995, EURONUT 1991 c), similar to other findings from developed countries (Department of Health 1979, Williams and

[7] this makes the assumption that the standard WHO criteria were used. Unfortunately no details were specified.

[8] this prevalence was based on the percentage of those falling below the 95th percentile reference range from the Second National Health and Nutrition Examination Survey (NHANES II)

Boyce 1989, Salive *et al* 1992, Kuzcmarski 1993, Corti *et al* 1994, Reuben *et al* 1997), and high-income groups elsewhere (Woo *et al* 1988). Compared to these, the finding of a 19% prevalence of hypoalbuminaemia amongst women over 65 years in Mumbai is extremely high. However, it is somewhat expected as even national data from the USA reported that the prevalence of hypolbuminaemia was greater for those below the poverty line than for those at or above it (Kuczmarski 1993), and a study of elderly Navajo Indians in the USA found a much higher prevalence of hypoalbuminaemia amongst women (16%) than amongst men (4%) (Williams and Boyce 1989).

The lack of associations found in Mumbai for **smoking** behaviour with either underweight or impaired function contrasts with recent work (Ensrud *et al* 1994, Parker *et al* 1996 b, Reuben *et al* 1997, Donkin *et al* 1998, Chilima 1998).

8.2 The functional significance of underweight assessed by anthropometry

In a discussion paper for the new journal "Nutrition, Health and Aging" Chumlea and co-authors (1997 a) wrote :

> *"anthropometric measurements are simple predictors of subsequent ill health, functional impairment and mortality."*

In the context of an urban slum in India, evidence of the predictive strength of underweight, based on BMI, and even more strongly on MUAC, in terms of functional ability impairment has been demonstrated. This makes being underweight a constraint on the ability to live an independent life irrespective of the level of age or ill health. The risk varies by sex and age group as well as according to which anthropometric indicators and functional ability dimensions are specified in the multivariate models.

The work of Galanos and others (1994) provided important empirical evidence from American elderly aged over 65 of an important relationship between BMI and the level of functional ability. There was an apparent dose-response relationship between extremes of BMI and functional risk while controlling for 22 potential confounders, such as chronic disease, socio-economic status, medication and vision problems. Functional status was determined by a 26-item battery of self-report responses[9]. This Mumbai study has extended the work of Galanos and his team in the USA by including objective as well as self-reported assessments of functional ability, biochemical variables and diagnoses of ill health. Although the definition of "low" BMI was different (< 21), similarly strong associations between low BMI and impaired function were found. However, the relationships first documented by Galanos and others has held true for low BMI amongst a population of poor elderly people living in an Indian slum.

The trend[10] towards more shoulder flexibility impairment amongst the underweight than the normally nourished in this study is in agreement with Swedish evidence (Bergstrom *et al* 1985). This seems to undermine the hypothesis that impairment in this dimension of functional ability is more adversely related to being fat than being lean (Bassey *et al* 1989 b), although no similar exploration of the data on those over 25 BMI was undertaken. In Mumbai, the prevalence of those encountering difficulty in performing shoulder rotations was less than that reported in studies of elderly in the USA in whom there was also much higher mean BMI's (Jette and Branch 1981, Foley *et al* 1986, Tinetti *et al* 1994 a).

This study looked at underweight defined by a BMI below 18.5, that is including <u>all</u> levels of underweight. What happens if we look only at **severe underweight**, or those with a BMI less than 16 ? A problem encountered in the determination of low BMI as an acceptable predictor of impaired functional ability and poor performance is that there are usually only very small numbers of individuals in any population with a BMI less than 16 (Campbell and Ulijaszek 1994). However, with 49 men (11%) and 100 women (14%) having BMI's below 16, this study provides an opportunity to address this question.

It seems reasonable to assume that using a more severe threshold of underweight will increase the power of underweight to predict functional impairment. Handgrip strength has emerged as the most significant functional outcome variable in the multivariate and bivariate analyses. Using handgrip as the dependent variable, a BMI<16 was entered as

[9] incorporating the Katz ADL, the Rosow-Breslau scale and an Arthritis Scale
[10] only significant amongst women using the MUAC classification

the exposure independent variable, treating both sexes, the dichotomized age group variable, and the other confounders in the same way as the earlier logistic regression models. Results are given in Table 8.5.

Table 8.5 Severe underweight (BMI<16) and the risk of poor handgrip strength

	n (able:unable)	EXPOSURE Indicator/ confounder	ODDS RATIO (95% C.I.)	p-value
MEN	439 (327:112)	BMI < 16	4.6254 (2.4414-8.7634)	.0000
		Kyphosis	2.4587 (1.3242-4.5652)	.0050
		Age > 65 years	2.4511 (1.5057-3.9903)	.0004
WOMEN	620 (453:167)	BMI < 16	3.9482 (2.4674-6.3176)	.0000
		Age > 65 years	3.2953 (2.1396-5.0751)	.0000
		Recent disability/surgery	3.0439 (1.4935-6.2037)	.0026
		Anaemia	1.5055 (1.0199-2.2222)	.0388

Severe underweight greatly increased levels of risk (odds ratios) compared to the higher cut-offs for underweight reported in Chapter 7. The odds ratio increased from 3.04 to 4.63 in men, and in women from 2.43 to 3.95. In men, using the more severe BMI cut-off for underweight led to the reversal of the placings of kyphosis and age group, with kyphosis becoming more important. In women, underweight also replaced older age as the most important independent predictor of poor handgrip strength.

Does using a more severe threshold of wasting, using MUAC, similarly increase the power of underweight to predict functional impairment ? A re-analysis was done using MUAC cut-offs of <19.9 cm for men and <18.9 cm for women to define severe wasting (Ferro-Luzzi and James 1996). Results for logistic regression for handgrip strength as the independent variable are given in Table 8.6. Again, severe underweight defined by MUAC greatly increased levels of risk (odds ratios) compared with the higher cut-off. In men, the odds ratio increased substantially from 4.37 to 7.63, and in women from 3.38 to 5.13. Neurological disease and kyphosis emerged as independent predictor variables for poor handgrip strength in men, whereas, for women, anaemia was removed. The odds ratios for the risk of poor handgrip strength using all levels of underweight, and severe underweight only, were all higher using MUAC than using BMI to define nutritional status.

Table 8.6. Severe wasting (using MUAC) and the risk of poor handgrip strength

	n (able:unable)	EXPOSURE Indicator / confounder	ODDS RATIO (95% C.I.)	p-value
MEN	449 (331:118)	MUAC < 19.9 cms	7.6303 (3.2298-18.023)	.0000
		Neurological disease	2.7698 (1.1818-6.4914)	.0228
		Age > 65 years	2.6088 (1.6085-4.2310)	.0001
		Kyphosis	2.1208 (1.1677-3.8520)	.0148
WOMEN	628 (457:171)	MUAC < 18.9 cms	5.1293 (3.2014-8.2182)	.0000
		Recent disability/surgery	3.4603 (1.7261-6.9370)	.0005
		Age > 65 years	3.2109 (2.0952-4.9207)	.0000

8.2 Linking underweight and poor strength via low muscle mass

In this exploration of the relationship between underweight and impaired functional ability and poor performance, poor handgrip strength emerged as the performance measure most strongly predicted by the presence of underweight, classified by BMI and by MUAC. Impaired mobility was also strongly predicted by underweight classified by BMI and, even more strongly, by the MUAC cut-offs. The levels of mobility and handgrip strength were closely related. This is to be expected as mobility is largely dependent on strength, muscle contractions being the basis for physical movement (Rantanen *et al* 1994). In the light of these findings, certain issues about anthropometric measurements as appropriate indicators of muscle mass, and estimations of muscle mass to reflect muscle strength, need to be addressed.

Consistent with other studies, handgrip strength in Mumbai was significantly related to body weight (Anderson and Cowan 1966, Cauley *et al* 1987) and height (Cauley *et al*

1987). Handgrip strength was also significantly related to BMI, but most strongly to MUAC, calf circumference and cAMA. This supports the hypothesis that limb circumferences and limb muscle areas are much more valid and sensitive predictors of handgrip strength than are other anthropometric measurements more related to fatness, including BMI (Martin *et al* 1985). Although low BMI was uncommon, in both cross-sectional and longitudinal analysis of results from the Nottingham Study of Activity and Ageing (Bassey and Harries 1993) BMI was not associated with a loss of handgrip strength.

The finding that **MUAC** emerged as a more powerful predictor of poor handgrip strength and impaired mobility than BMI is not a surprising finding. Firstly, there are certain limitations with the interpretation of BMI as an indicator of body composition in older adults. Secondly, there is evidence of the close relationship between limb circumferences and limb muscle areas with muscle strength and function which make these measurements more appropriate for our purposes in terms of their functional importance.

BMI has become the anthropometric index of choice in the assessment of the nutritional status of adults because it is highly correlated with body fat content in kg[11], and with fat-free mass, when age and sex are controlled for, as well as being virtually independent of stature (Shetty and James 1994, Norgan 1990, and 1994). Very low BMI will be characterized by low fat mass as well as low fat-free mass (Norgan 1990). However, body compositional studies using direct measurement techniques have shown that BMI has a different relation to fat and muscle mass in elderly people than in younger adulthood (Deurenberg *et al* 1989 b, Micozzi and Harris 1990, WHO 1995). Moreover, the focus of research in this area to date has been determining body fat percentage in obesity, rather than fat-free mass in underweight (Chumlea *et al* 1984, Deurenberg *et al* 1989 b), and almost all research has been on Caucasians only. Thus, the meaning of a low BMI in terms of muscle mass is still not well understood and BMI may not be the most appropriate or specific indicator to use to assess nutritional status or estimate muscle mass amongst elderly people in non-Caucasian populations. At what age or

[11] rather than % body fat

physical condition BMI becomes non-informative in the elderly is unknown, but this needs to be determined (Chumlea *et al* 1995).

It is perhaps more appropriate to look at changes in limb circumferences such as MUAC or calf circumference as measures of declining muscle mass in the extremities than by a decline in BMI which reflects overall lean body mass. Circumference measurements are thought to be more sensitive indirect measures of peripheral wasting of muscle and subcutaneous adipose tissue (James *et al* 1994, Ferro-Luzzi and James 1996) and are now frequently used as indices of total body muscle mass (Friedman *et al* 1985, Chumlea *et al* 1997 b). Certainly, an anthropometric measurement that provides, albeit indirectly, a better reflection of the amount of muscle mass is a more appropriate choice in terms of its functional significance. Moreover, given the problems of obtaining an accurate stature measurement in older people, and the comparatively rapid and simple technique involved in taking circumference measurements compared to the derivation of BMI, MUAC and calf circumferences also appear to be preferable to BMI from a practical point of view.

However, whilst MUAC or calf circumference may better reflect muscle mass than does BMI in older people, there are still significant problems when we come to interpret such data. This is because of several assumptions about the limb being circular in cross-section, about all fat being located subcutaneously and about this fat being distributed around the muscle. Direct laboratory measurements (such as by ultrasonography and computerised axial tomography) of muscle cross-sectional area in humans reveal that these assumptions are not strictly true, particularly in the old age group. Unfortunately, there is no gold standard for assessing body composition either directly or indirectly in the elderly that is not beset with limitations of methodological errors, breaches of universal assumptions and affected by aspects of disease (Chumlea *et al* 1997 a).

How far does such an estimation of muscle mass reflect muscle strength ? At any age, strength is directly determined by the amount of muscle mass (Frontera *et al* 1991, WHO 1995). It is generally accepted that the maximum force which can be generated by a muscle such as biceps brachii is directly proportional to the cross-sectional area of the contractile protein (Pearson 1985). Using ultrasound, Young *et al* (1984) compared the quadriceps strength of 25 elderly (71-81 years) and 25 young women (20-29 years) and found that the 'weakness' of elderly women could largely be explained by their smaller size of muscle. Recent studies suggest that "the fibre composition of aging muscle is more or less constant". However, when there is any atrophy of surviving fibres, "the fall is especially pronounced" in the Type II fibres (Grimby and Saltin 1983).

There are very few cross-sectional, and even less longitudinal, reports or data demonstrating relationships between levels of physical function, assessed either by ADLs or by performance tests, and levels of body composition and sarcopenia in elderly people (Chumlea *et al* 1997a). The amount of muscle mass in the body is an important predictor of survival in acute and chronic illness, possibly operating through weakness in particular muscle groups, such as those involved in respiration (Phillips 1986). There also appears to be a threshold where a loss of muscle mass of greater than 40% is considered critical (Roubenoff and Kehayias 1991). In demonstrating strong associations between low muscle mass measured indirectly through anthropometry and impairments in strength and other dimensions of functional ability, this study supports recent North American work (Ravaglia *et al* 1997, Payette *et al* 1998) but contrasts with others who failed to find similar associations (Visser *et al* 1998) or only a limited beneficial effect of muscle training on functional ability in old people (Skelton *et al* 1995). Further exploration of limb circumferences and arm muscle area as indirect estimates of muscle mass, and functional ability data, are needed, and could be attempted in further analysis of this data set.

Whatever the effects of low muscle mass, strength is a complex phenomenon, influenced by many factors. A measurement of strength is the external effect of the internal muscle effort, modified by the mechanical advantages of the body parts involved, and by psychological factors such as motivation and feedback. It is also influenced by the frequency and intensity of habitual use. Thus the quantitative amount of muscle mass is only one factor. While strength losses are partially explained by declining muscle mass, there remain other yet undetermined factors beyond declining muscle mass to explain some of the loss of strength seen with ageing (Kallman *et al* 1990).

The importance of maintaining strength in later life is increasingly the focus of geriatric research spurred by evidence that physically trained older adults maintain a better capacity to cope with daily environmental hazards, have more physical and spatial confidence, enhanced psychomotor efficiency and control, and a stronger self-image (Spirduso 1980, Frontera *et al* 1988, Fiatarone *et al* 1990, Larsson 1991).

In conclusion, although anthropometric measurements like MUAC can give an indirect estimation of the amount of muscle mass, they will only really be of value if they can tell us something about muscle strength and the functional significance of poor muscle strength to everyday life. Cross-sectional, and some longitudinal, data have revealed that there are various changes in muscle size, type and function as well as overall strength with increasing age and accompanying changes in activity (Harris 1997). However, there is still a great deal to be clarified, and better, more sensitive, anthropometric techniques are needed for assessing muscle loss and function with age (Baumgartner *et al* 1995).

8.4 Major confounders

In this study multivariate analysis revealed four main variables (kyphosis, anaemia, hypoalbuminaemia, and recent disability/surgery), that are significant co-predictors of functional ability impairment and poor performance in physical tests reflecting dimensions of functional ability, after controlling for age, sex and co-morbidity. Representing major confounders in the underweight : function relationship, these variables will now be considered, after a consideration of the role of age itself.

8.4.1 Age

In a discussion on conducting clinical research in geriatric populations, Zimmer and co-authors (1985) stressed that in the consideration of the risk factors for problems of old age, the most powerful predictor in many cases is chronological age itself, even "after every conceivable risk factor has been entered into a multivariate analysis". In this study, age did emerge as a significant predictor of impaired functional ability and poor performance, but it was not the only one. The fact that other variables, particularly underweight, significantly predicted impaired functional ability and poor performance in these Mumbai elderly underlines the heterogeneous nature of the ageing process. While there are indeed age-associated changes in many nutritional, health and functional variables, advancing chronological age alone is not always primarily responsible for the actual onset of problems and rate of declining function, which are neither inevitable nor uniform (Ostwald *et al* 1989, Seeman *et al* 1994). Although the predictor variables emerging differed[12], the present findings mirror those of others (Ensrud *et al* 1994, Galanos *et al* 1994, Hirsch *et al* 1997) who reported that age did not always remain an independent predictor of functional disability when the effects of other confounding factors were considered. Recent analysis of data from the US Cardiovascular Health Study found that, whilst age was significantly correlated with measures of physical performance (e.g. chair rises and handgrip strength), it explained little of the variability in a large sample of mostly functionally able, community dwelling, older people (Hirsch *et al* 1997). It could even be argued that age itself need not be entered into models as it will be having its effect through the other variables that all experience age-related pathological processes.

8.4.2 Kyphosis

The emergence of kyphosis as an important independent predictor of impaired functional ability and poor performance is consistent with the findings of Ryan and co-workers (1997) who stated that kyphosis impacts directly on disability. They reported correlations between the degree of kyphosis[13] and difficulties in daily functioning. Similar findings were reported by Alexander and co-workers (1991) who found that kyphosis is more prevalent amongst older people who had difficulty rising from a chair, that those with kyphosis flexed their trunks more during the rise than those without

[12] for example, cigarette smoking emerged strongly amongst elderly US women (Ensrud *et al* 1994) but not at all in Mumbai men or women

[13] measured quantitatively

kyphosis, and that postural stability and range of motion of the spine are as important as leg muscle strength in performing a chair rise. Both these teams viewed the strong interaction between kyphosis and lower extremity arthritis as the main explanation.

Brown and co-workers (1995) put forward an alternative, or perhaps additional, explanation. They demonstrated how thoracic kyphosis affects the centre of gravity in the body mass which results in a challenge to balance, and thereby functional performance. They also remarked on the common finding of weakness in the scapulo-thoracic musculature being combined with calf muscle weakness. It may be this that is involved in the fear of falling which leads to a restriction of activity and further aggravates loss of muscle tone, mobility and independence (Vellas *et al* 1992 b). Another possible explanation might be that kyphosis causes chronic upper and middle back pain leading to functional ability limitation (Ensrud *et al* 1997). Their study found that women with greater degrees of kyphosis had higher back disability scores and poorer self-reported health status than women with less kyphosis. However, the hypothesis that this will particularly affect women is not supported by this study, which, unlike others (Milne and Lauder 1974, Fon *et al* 1980, Milne and Williamson 1983) did not find that women had significantly higher rates of kyphosis than men. Although COPD was not significantly associated with kyphosis in this study, it has been speculated that the deformation of the thoracic cage secondary to osteoporosis might impair pulmonary function, particularly restricting vital capacity (Leech *et al* 1990). Thus, it has been hypothesised that kyphosis, if combined with co-existing pulmonary disease, may well result in functional impairment.

The finding of increasing prevalence of kyphosis with increasing age is in agreement with previous studies (Fon *et al* 1980, Milne and Williamson 1983, Ensrud *et al* 1997). Although the present Mumbai study did not find significant associations between kyphosis and lowered anthropometric measurements[14], there is other evidence that underweight is associated with the presence of vertebral deformity (Johnell *et al* 1997). In a population based study of vertebral osteoporosis across Europe a negative correlation was found between mean weight and the prevalence of deformity in adults

[14] there was a non-significant trend with height

over 50 years old. Women in the lightest quintile for weight had the greatest prevalence of deformity[15].

Whatever the causal pathway, more attention should be paid to the presence and severity of kyphosis in comprehensive assessments of older people, not only because of the effect on an accurate height, and hence BMI measurement, but also because of its apparently detrimental relationship with some dimensions of functioning. Studies that exclude kyphotics from the data set by recording them as missing values (e.g. EURONUT 1991 b) are introducing a serious selective bias, limiting interpretation of nutritional and functional findings.

8.4.3 Recent disability and surgery

A US study showed that recent hospitalization and/or surgery was one of the significant independent predictors of poor physical functioning (Seeman *et al* 1994). This is supported by this study in which recent onset of disability or recent surgery emerges as a significant predictor of functional ability impairment. A study of 5,000 Americans over 70 years of age found that a combined measure of albumin and disability revealed a strong gradient in mortality risk (Corti *et al* 1994). They recommended that disability together with albumin level could serve as a measure of frailty and other adverse outcomes.

8.4.4 Anaemia

Is there evidence from this study that anaemia represents a serious constraint on the ability to live an independent life in old age ? It appears so, at least for women. Multivariate analysis showed that anaemia was a significant predictor of poor handgrip and leg strength, flexibility, manual dexterity, and of dependence in bathing and overall mobility in women, and similarly of poor handgrip strength and flexibility in older men.

[15] A similar result was seen for low BMI although this relationship will be confounded by the association between vertebral deformity and the measurement of height in BMI.

Although there are no other similar studies using functional ability for comparison, some evidence from the literature points in the same direction. There are a number of studies that have shown decreased physical work capacity in anaemic compared to non-anaemic adults, and increased physical work capacity of anaemic subjects after iron therapy (Gardner *et al* 1977). Suboticanec et al (1989) found associations between low haemoglobin and poor handgrip strength in a study of 100 old Yugoslavs. This effect may be further increased in the presence of multiple pathology.

The very high prevalences of anaemia recorded for older adults, and especially women, in developing countries, confirmed in this study, as well as the emerging documentation of the detrimental functional consequences of anaemia to older people alert us to a serious problem warranting urgent attention. The assumption that anaemia is only a problem amongst women of child-bearing age needs to be challenged (Ania *et al* 1997).

8.4.5 Hypoalbuminaemia

There is evidence that a low serum albumin in elderly people indicates a poor prognosis with greater risk of death and/or disease in adults (Rall *et al* 1995). For example, some studies have found that low albumin levels were associated with increased cancer and cardiovascular mortality rates in elderly people (Phillips *et al* 1989, Corti *et al* 1994). Much less is known about how low albumin might relate to functional performance (Rall *et al* 1995), although a large-scale community-based study in the USA reported that low levels of albumin are strongly related to the inability to perform ADLs, after controlling for confounders such as disease and health-behaviour (Salive *et al* 1992). Using a similar analysis technique, results from the present study support these findings.

8.5 Potential confounders

Whether underweight influences function after considering other potential confounders, or whether impaired function influences nutritional status, or whether both are mediated by a third factor, are questions that need further exploration. There are also a number of other biologically plausible mechanisms which could intervene to undermine the associations found here, and alter the risk of having impaired functional ability and poor performance in the presence of underweight.

This study was unable to evaluate the role of **Human Immunodeficiency Virus (HIV)** and **AIDS.** This omission is unfortunate given the magnitude and explosive nature of the AIDS problem in India. It is estimated that there are 2-5 million HIV infections nationwide (mid-1996) with 50,000 to 100,000 cases of AIDS (UNAIDS 1996). Epidemiological evidence suggests rapid, extensive and uncontrolled spread of HIV in many parts of the country. Mumbai has been described as India's AIDS capital, with heterosexual transmission as the main route of transmission mediated through sexual behaviours such as multiple partners, heavy prostitute visitation[16] and low condom usage (UNAIDS 1996).

The global cumulative number of HIV infections among adults has more than doubled since 1990[17]. Recent data from the USA emphasise the surprisingly substantial number (6,390 in the age group ≥ 50 years)[18], and high rate (9.4 per 100,000 in the age group ≥ 50 years)[19] of older people with HIV infection (Centers for Disease Control CDC, 1998 a). Although older people may not perceive themselves to be at risk for HIV infection, condom use is rare amongst adults of older cohorts, and the frequently long incubation period from HIV infection to AIDS diagnosis (up to 20 years) may mean many older persons have been infected as younger adults. Diagnosis of HIV infection may also be missed in old age as the AIDS-opportunistic illnesses that occur commonly amongst persons over 50 years old (e.g. HIV encephalopathy and wasting syndrome) mimic other diseases associated with ageing (e.g. Alzheimer disease and malignancies) (CDC 1998 a). Evidence suggests that older people suffer more rapid course of HIV, and survive for shorter periods, than younger people, probably due to an increase in co-morbidity (Wallace *et al* 1993, Skiest *et al* 1996).

[16] HIV prevalence has reached the level of 50% in sex workers in Mumbai (UNAIDS 1996)
[17] from 10 million in 1990 to nearly 26 million in 1996 (UNAIDS 1996)
[18] 50,340 in the age group 13-49 years, in the USA in 1996. Estimates are rounded to the nearest tens because they do not represent exact counts of persons with AIDS but are estimates that are within approximately ± 3% of the true value (CDC 1998 a)
[19] 34.9 per 100,000 in the age group 13-49 years, in the USA in 1996

The deadly confounding interconnection between **TB, AIDS and underweight** could also not be addressed in this study. The HIV virus primarily attacks the immune system, making those infected more prone to opportunistic infections such as TB. A person with HIV is up to one hundred times more likely to develop active TB than a person with a healthy immune system (CDC 1998 b), and TB is the cause of death for one out of every three people with AIDS worldwide (UNAIDS 1998). The prevalence of TB is also increasing in areas with epidemics of HIV infection and AIDS (Phillips *et al* 1992 a). An estimated 1-2 million cases of TB occur in India every year. In Mumbai, 10% of the patients presenting with TB are HIV-positive and TB is the presenting symptom of AIDS in over 60% of AIDS cases (UNAIDS 1996). Malnutrition is known to be detrimental to the ability to fight infection from *Mycobacterium Tuberculosis*, and this has been confirmed in India amongst children (Bhaskaram 1996).

Anaemia is also a frequent complication of HIV infection and its incidence is associated with progression of HIV disease, particularly in women (Sullivan *et al* 1998). The high level of anaemia reported amongst these older people in Mumbai could well be associated with undocumented HIV infection. Lastly, another opportunistic group of infections known to be associated with HIV is skin diseases. It could well be that the relatively high prevalence of skin disease diagnosed amongst these Mumbai elders may also be partly indicative of a high rate of HIV infection.

Wasting[20] or weight loss, accompanied by decline in muscle mass, has long been noted in men with AIDS or advanced HIV infection (National Institutes of Health, NIH 1997, Evans *et al* 1998). With older people perhaps accounting for over 10% of the total number of people with AIDS in India (Kun 1998), it is likely that many of the people in the present study were HIV-infected and some of these were suffering wasting malnutrition as a result of AIDS.

Other biologically plausible confounders in the relationship between underweight and impaired functional ability and poor performance may have been missed in this study.

[20] HIV wasting syndrome is diagnosed in HIV-infected people who have unintentionally lost more than 10% of their body weight (NIAID 1997).

For example, a high blood pressure[21] was found to be a significant risk factor for poor physical performance in elderly people in the USA (Seeman *et al* 1994).

Past and present occupation are also potential confounders that need consideration. A number of studies have reported how habitual levels of physical activity relate to overall functional ability in old age (Morgan *et al* 1991, Cauley *et al* 1987, Cooper *et al* 1988, Chilima *et al* 1998). A US study reported that physical performance in tasks such as handgrip strength, shoulder flexibility and a tapping test of psychomotor co-ordination was more highly related to lifelong physical activity than to age (Rikli and Busch 1986). Similarly, a Scandinavian study of joint impairment and disability amongst 79 year olds found that previous sedentary workers were more disabled in ADL function than those with a previous strenuous physical work load (Bergstrom *et al* 1985). Certainly, the relevance of underweight to physical activity is very much influenced by the type of activity (Durnin 1994). In India, poor street and slum dwellers of both sexes whatever their age tend to earn an irregular income through heavy physical work such as cycling rickshaws, operating industrial equipment such as textile looms, digging, shovelling, carrying and pulling loads, and stone splitting, in construction and industrial sites. Durnin argued that although work capacity in most people will only begin to be detrimentally affected when BMIs are 17 or less, for those involved in such heavy physical tasks involving the use of the body mass, even high BMIs (<18.5) will be placed under great stress. The results from this study, showing an increased risk of especially poor upper body strength in the presence of underweight, tend to support this argument. In an older person faced with physical load stress, the decline towards the threshold of functional impairment in the presence of underweight may be very steep. In such a situation, muscle mass is the most pertinent variable (Durnin 1994).

There are also other **non-biologically plausible mechanisms** which could intervene to alter the risk of developing functional impairment in the presence of underweight. Other strong socio-economic predictors of functional ability impairment have been documented, such as the level of social activity in Japanese elderly (Haga *et al* 1991), and lower income and higher education in a US study (Seeman *et al* 1994). In this study,

[21] >140/90mmHg or taking blood pressure medications

more information on the possible role of social and economic correlates of underweight and impaired functional ability and poor performance could have been instructive. In the light of this discussion about other potential confounders, a further series of more complex models may be required.

8.6 Separating cause and effect

This thesis has attempted to predict whether or not being an underweight older person rather than a normally nourished older person living in a Mumbai slum leads to an increased risk of the adverse outcome of being functionally impaired. In this study, risk is taken to mean the pathway to impaired functional ability and whether or not underweight can be the cause. In answer to the question : "is the chance of having impaired functional ability and poor physical performance related to having anthropometrically-defined underweight", the odds ratios presented in this study have given us a measure of that chance in a quantifiable form.

However, risk does not necessarily imply causality (Mascie-Taylor 1994). Although the larger the increased risk estimate (here, the odds ratio), the more likely it is that there is a cause-effect relationship between the exposure (underweight) and the outcome (impaired functional ability / poor performance), we cannot be sure (Margetts 1991). There are several fundamentals of the causality principle that dictate caution. This is because, firstly, all potential confounders in this relationship have probably not been considered, and secondly, to infer causality, impaired functional ability and poor performance would need to appear after underweight, something which cannot be determined in a cross-sectional study design.

Once the effects of bias and confounders have been considered, and the final statistical associations of interest presented, the final step is to draw inferences about the nature of any possible cause-effect relationship (Margetts 1991). In the same way that it is common to find independent and vigorous elderly people with long and serious lists of medical problems (Besdine 1990), it should not be assumed that the presence and severity of underweight will necessarily result in losses of functional ability. Longitudinal work is also necessary to show that nutritional interventions, resulting in measurable improvements in nutritional status, would need to be followed by measurable improvements in dimensions of functional ability status. There is already an example of this amongst institutionalised elderly in whom vitamin supplementation was associated with improved physical function, as measured by handgrip strength, in those with the lowest pre-supplementation values (Suboticanec *et al* 1989). However, the work of Fiatarone (1994) and Gray-Donald (1995) and their colleagues reminds us that, even if underweight is predictive of poor muscle strength in old age, nutritional intervention alone may not improve cross-sectional muscle area, strength or functional ability as a whole.

Any causal sequence may not be in one direction only. Whilst underweight may increase the risk of functional impairment, the reverse is also plausible. Impaired functional ability may increase the risk of underweight. A study of elderly people in a suburban area of Java found that the ability to earn a living was the crucial determinant of nutritional status (Evans 1990). This will largely be determined by the degree of functional ability. There are a number of non-nutritional variables that have been shown to be associated with impairments in dimensions of functional ability such as mobility, manual dexterity and feeding. Many such factors are reviewed in the literature and include depression, problems with dentition and swallowing, fear of incontinence, and declining sensory abilities. These will all in turn influence nutritional status through food acquisition, preparation, choice and level of intake, as well as socialisation of eating patterns, and may lead to a tendency to neglect food (Goodwin 1989, Lehmann 1989, Davies and Knutson 1991, Grimby *et al* 1993, Wahlqvist *et al* 1994).

Even if a sequence is not yet proven to be direct and causal, there is enough to alarm us with the associative evidence provided by this study, despite any shortcomings. Let us take a hypothetical scenario. An older person becomes underweight and is more likely to suffer from poor handgrip strength compared to a normally nourished person. This situation may be accentuated by worsening arthritis of the leg and hand joints. Although the minimum amount of strength required to perform a particular task in a particular way is not known, there will come a point when impairment will affect the level of independence, for example, in transferring, dressing and getting around. It also seems plausible to assume that this could lead to lower levels of food intake because of the resultant difficulties in growing, shopping for, or preparing, food without assistance. This in turn may worsen his nutritional status still further, and so on.

It could be argued that proving the exact causal sequence in this scenario is unnecessary. The strong risk associations and the plausible practical outcomes are enough to be going on with. They are suggestive of a causal relationship, make intuitive sense and are more than sufficient justification for ameliorative action. They also represent important prerequisite information for developing effective interventions.

CHAPTER 9 : CONCLUSIONS AND RECOMMENDATIONS

Bringing the thesis to a close, this chapter summarises the study's main findings. This study has tackled a challenging area of research in which the current tools for assessment are far from perfect, many questions still remain unanswered, and there is a lack of reliable data from developing countries. The outlook is promising as the whole area is beginning to attract more attention and it is increasingly acknowledged that there is much to be gained from understanding factors related to the development of poor functional status in later life. Finally, in an attempt to make a contribution to move the field forward, recommendations for future research are proposed.

9.1 The main conclusions of the study

This study set out to quantify the risk of being functionally impaired in the presence of underweight. Although a causal pathway has not been established, the results of this study demonstrate something long suspected : being underweight carries a measurable disadvantage in terms of an older person's ability to live an independent life.

With a mean age of approximately 60 years, 1097 non-oedematous people living in slums and chawls in an administratively-defined area of Mumbai were recruited into a cross-sectional study. The sex ratio of subjects was 42:58 in favour of women, and men were significantly older than women. There was some selective bias away from the working, and underweight, male.

Men were heavier and taller and had larger muscle-related measurements (MUAC and calf circumference, and cAMA) than women, who had larger triceps skinfold, indicating a higher degree of fat. BMI values did not differ significantly by sex or by age. Means of all other anthropometric variables, except height and armspan, showed a downward trend with increasing age. The overall prevalence of **kyphosis** was 15.2%, with a significant positive effect of increasing age.

Using classifications for **underweight** based on BMI cut-offs, the prevalence of underweight (BMI<18.5) was 35% in both men and women, with 14% overall classified as severely underweight (BMI<16). Using the MUAC classification, less men (26%, MUAC<23cm) but more women (41%, MUAC<22cm) were underweight. Approximately 12% overall fell into the severely wasted category (MUAC<19.9cm for men, <18.9cm for women).

In terms of **functional ability impairment**, there was a high level of dependence reported for transferring (57%) and toilet use (45%) activities of daily living, with women reporting more problems than men, but dependence was much less for the other ADLs. Mobility problems were also very common (stair climbing and walking half a mile reached 80% and 57% prevalence respectively), and again women were significantly more affected than men. Levels of dependence in most activities of daily living and mobility tasks were higher amongst the over 65's than amongst those aged 50-64. **Poor performance** (defined as the worst quartile of the sex-specific distribution in each of five physical tests) was significantly associated with older age. Women were significantly slower at timed tests of manual dexterity, psychomotor co-ordination and lower body strength, and had weaker handgrip strength and worse shoulder flexibility than men.

There was a heavy burden of **disease**. The most commonly diagnosed conditions were cataracts (72%), musculoskeletal disease (47%), hypertension (20%), skin diseases (13%), and COPD (7%). TB was diagnosed in 8% of men and 4% of women. The prevalence of anaemia was much higher amongst women (52%), particularly over the age of 65, than amongst men (22%). Hypoalbuminaemia was diagnosed in 7% of men and 10 % of women, in whom there was also a significant effect of older age.

Bivariate analyses revealed that underweight was associated with poorer levels of functional ability and performance. They also showed very close inter-relationships between anthropometric variables, and between functional ability and performance test variables. The presence of some diseases, particularly TB and COPD, was associated with underweight, and the presence of musculoskeletal disease was associated with impaired handgrip strength. Those with kyphosis, especially over 65 years old, were significantly more impaired in most activities of daily living and mobility, were poorer performers in physical tests, and were more likely to suffer musculoskeletal disease, anaemia and hypoalbuminaemia, and be underweight.

Multivariate analyses using logistic regression modelling was conducted on complete-case only data for those with a BMI below 25, that is those who were either underweight or normally nourished. The resultant data set for multivariate analysis did not result in any significant changes from the complete data set in any descriptive and distributional characteristics of any functional, health or demographic variable. Risk estimates (odds ratios) for impairment in each of the self-reported functional ability variables, and for poor performance in physical tests, in the presence of underweight were independent of the effects of age, sensory disability, cognitive status, kyphosis, disease including anaemia and hypolbuminaemia, and smoking and drinking behaviour.

Although no differences between odds ratios were examined for statistical significance, the results suggest the following :

In **men**, having a BMI below 18.5 significantly increased the risk of having poor handgrip strength *(OR 3.04, 95% CI 1.86-4.96, p=0.000)* and poor mobility *(OR 2.00, 95% CI 1.05-3.71, p=0.0337).* Using MUAC the risk estimates were higher (for poor handgrip strength *OR 4.37, 95% CI 2.67-7.15, p=0.000*; for poor mobility *OR 2.57, 95% CI 1.35-4.89, p=0.0044*), and increased risk also emerged for dependence in dressing *(OR 6.45, 95% CI 1.55-26.83, p=0.0079*) and bathing *(OR 11.63, 95% CI 2.33-58.03, p=0.008)*. Underweight was the strongest risk factor in men using both classifications.

In **women**, having a BMI below 18.5 also significantly increased the risk of having poor handgrip strength *(OR 2.43, 95% CI 1.63-3.64, p=0.0000)*, but not for any other poor functional ability or performance measure. Again, using the MUAC classification increased the risk estimate for poor handgrip strength *(OR 3.33, 95% CI 2.20-5.05, p=0.0000)*, as well as introducing risk for poor performance in other variables, namely psychomotor skill *(OR 1.64, 95% CI 1.08-2.47, p=0.0195)* and manual dexterity *(OR 1.78, 95% CI 1.19-2.68, p=0.0050)*. Underweight using MUAC was the strongest risk factor, whereas it took second place below being over 65 years old when using BMI.

Applying more severe cut-offs for underweight using both BMI and MUAC greatly increased the level of risk of poor handgrip strength. Overall, MUAC surpassed BMI as a predictor of impaired functional ability.

The performance measure most consistently demonstrating this detrimental association with underweight was **handgrip strength** in both sexes. Other affected variables were levels of dependence in mobility, and dressing and bathing in men, and poor psychomotor skill and poor manual dexterity in women. The most consistent independent co-predictors of impaired functional ability and poor performance in the presence of underweight were kyphosis, musculoskeletal and neurological disease, TB and hypoalbuminaemia in men, and kyphosis, recent disability/surgery, anaemia, and hypolbuminaemia in women.

The main findings of this study can be summarised as follows :

1. For these poor elderly people in Mumbai, after accounting for the effects of sex, age, disease and other confounders, being underweight carries a significantly increased risk of being impaired in some important dimensions of functional ability, and of having poor performance in physical tests reflecting dimensions of functional ability.

2. Poor handgrip strength emerges as the functional ability dimension most strongly and most consistently predicted by underweight in both men and women. This is followed by poor mobility. Underweight also independently predicts the risk of being dependent in dressing and bathing in men, and of having poor manual dexterity in women.

3. For most functional ability dimensions in which underweight emerged as a significant independent predictor of impairment, defining the presence of underweight according to established cut-offs of MUAC carries a higher risk than does underweight defined by BMI cut-offs. This is probably because MUAC better reflects poor muscle mass in old people than does BMI.

4. The presence of kyphosis, anaemia, hypoalbuminaemia, TB, musculoskeletal disease and neurological disease also emerged as significant independent co-predictors of functional ability impairment.

5. These elderly people in Mumbai suffer from a high level of underweight, functional ability impairment, and a heavy burden of disease.

9.2 Recommendations for further research

Quantifying risk in terms of odds ratios has highlighted the functional importance of underweight in the pathway to impairment in dimensions affecting the ability to live an independent life. The risk factors approach, and the identification of the most strongly and independently associated variables in the relationship between underweight and impaired functional ability and poor performance, can be used to help identify cut-offs and criteria for programme planners and policy makers. All this can provide a powerful voice for advocacy, providing numbers and figures to lobby for more attention and resources aimed at this population group. It adds weight to the argument that there is an urgent need to develop and test appropriate intervention strategies that could result in improved nutritional status, and the postponement of functional ability impairment, amongst this population group. It also highlights the need for the inclusion of nutritional as well as functional ability assessment in the comprehensive assessment of community-living elderly in developing countries. The Government of India proposes to announce a National Policy on Older Persons during 1998 under the Ministry of Social Welfare (Singh 1998). This seems an appropriate practical place to start, but many research questions still remain. The rest of this section discusses potential areas for future research, based on the experiences of this study, recognition of the limitations of the present protocol, and the existing literature.

9.2.1 Improving anthropometric assessment of underweight in elderly people

It is important to know the acceptable lower limit of nutritional status at which bodily functions start to fail, and subsequently cause dysfunction (Garcia and Kennedy 1994).

In 1989, David Macfayden ended a book on Nutrition in the Elderly with a list of priorities for future research. In his list, he asked the following question :

> *"are anthropometric measures, including simple height and weight charts, useful tools for determining nutritional status and health risks in the elderly ?"*

The findings of this study provide some answers. **Low BMI** carries an increased risk of functional ability impairment, which is undoubtedly detrimental to health and overall quality of life. However, BMI based on height is not the best, or only, choice of measurement tool for determining underweight in older people.

Firstly, the measurement of **height** must be used with caution. In this study, the problem of an inaccurate height measurement caused by kyphosis was overcome by measuring armspan as a substitute for height in those people showing any degree of kyphosis. A regression equation to estimate height from armspan was derived from height and armspan in adults 50-54 years old, and the estimated height was then used in place of measured height to derive BMI. However, this was not a perfect solution. The 50-54 year olds had probably already lost some height due to age-related vertebral changes, and a better choice would have been a younger adult population of 20-30 year olds from which to derive the equation. Arguably, however, since these age-related height changes reflect real loss of height and not errors of measurement (as in those with kyphosis or bent legs), BMI of elderly people should be based on actual height (if it can be measured accurately) rather than maximum attained adult height.

Progress is being made on the development of valid anthropometric assessment techniques for older people (WHO 1995), and data on different races from developing countries are beginning to emerge, although much still remains to be done (Launer and Harris 1996). The use and appropriateness of armspan, and other long bone approximates of stature such as knee height, in different age, sex and racial groups, needs to be explored using both cross-sectional and longitudinal studies before they can be recommended as routine procedures. (Yassin and Terry 1991). Ideally, **local data** including percentiles and prediction regression equations should be compiled amongst younger adults in different population groups.

This study has focused on two commonly used **classifications of underweight** using cut-offs of BMI (James *et al* 1988, Ferro-Luzzi *et al* 1992) and MUAC (Ferro-Luzzi *et al* 1996). It is well recognised that the BMI cut-offs were chosen using pragmatic value judgements, and were the outcome of a series of compromises about what is acceptable, or desirable, in term of risk to health, rather than from a large body of hard data (Mascie-Taylor 1994, James and Francois 1994). So far at least, there is no logically defensible single cut-off point for BMI. Moreover, as we have seen, for the elderly, body compositional changes with age and other factors, render BMI a problematic indicator for assessing underweight in older people, and underweight may not necessarily be present at a low BMI (Durnin 1994, Allison *et al* 1997). This leads us on to the consideration of cut-offs of MUAC as a better alternative.

In this study, **low MUAC** led to a greater risk of functional ability impairment (most notably in poor handgrip strength in both sexes, and dependence in mobility in men) than low BMI. Is this because low MUAC is better able to predict those with functional ability impairment than is low BMI ? Possibly so, because it is an independent measure of peripheral tissue wasting more sensitive to age-related changes in muscle mass than BMI and weight (James *et al* 1994). Certainly, the choice of MUAC over BMI as an indicator of underweight in older people has distinct practical advantages. It is a quick and easy measurement to take in the field and it neither requires a decision on whether or not height loss and/or kyphosis is present, nor whether a stature substitute should be measured. Nor does it involve the calculation of a derived variable, as is the case for BMI[1]. However, from a theoretical point of view, these MUAC cut-offs also suffer from a flaw. This is because they were based on rounded off Z-scores from distributions of MUAC around the mean values from an international aggregate data set (Ferro-Luzzi *et al* 1996). Moreover, although the -1SD MUAC value taken from this combined data set readily distinguished those with a BMI<16 from those with a BMI<18.5, intermediate grades of BMI were poorly specified by MUAC values.

Whether BMI or MUAC measurements are chosen, arguably, applying other value judgements could lead to equally valid cut-offs and classifications. For example, above or below 2 SD from the mean of a reference population, or the study population, could be

[1] These same theoretical and practical advantages also apply to calf circumference.

applied to determine what constitutes "underweight". No other published evaluations on other possible anthropometric indicators of underweight in older adults are available, and it seems sensible first to validate the existing criteria and to clarify their relationships with health and function than to simply introduce more criteria. The WHO cautions that BMI cut-offs have not yet been validated for elderly people over 70 years of age (WHO 1995). This study has demonstrated that a BMI below 18.5 carries an increased risk of functional ability impairment, most notably in poor handgrip strength and dependence in mobility, for those aged 50-64 as well as those aged 65 and above. It has also demonstrated that an even lower BMI of below 16 carries an even greater risk, an effect which is repeated using MUAC cut-offs. Thus, despite notes of caution on theoretical grounds, the functional implications of both low BMI and low MUAC have clearly emerged in this population of poor elderly people.

Are there other classifications of underweight using other anthropometric variables besides BMI and MUAC that could surpass both these in terms of their ability to predict functional impairment in elderly people ? As outlined in Chapter 8, the most obvious candidates for this are calf circumference and cAMA. Calf circumference is now considered the most sensitive measurement of muscle mass in the elderly because it reflects changes in fat-free mass as well as decreased activity more than MUAC does (Patrick *et al* 1982, WHO 1995). Neither calf circumference nor cAMA were used as classifications of underweight in this study because accepted cut-offs for underweight do not exist for these measurements as they do for MUAC. For cAMA, there is also the issue of the introduction of additional error from the skinfold thickness measurement that is needed to derive muscle area (James *et al* 1994).

In the 1980s, Friedman and his group recommended the use of arm muscle area cut-offs[2] to "diagnose" malnutrition (Friedman *et al* 1985, Friedman 1986) on the basis of the strength of its predictive ability to identify mortality in hospitalised elderly patients. Although the multivariate analysis in this study did not test cut-offs of cAMA or calf circumferences in terms of their abilities to predict the risk of impaired functional ability, there is reason to suppose that these would perform well. The correlation between cAMA and handgrip in both sexes is marginally higher than those for MUAC and BMI

[2] < 16.0 cms^2 for men and < 16.9 cms^2 for women

(although still only moderate, r=<0.5). In a study of poor men in Calcutta, Campbell and Ulijaszek (1994) found that, whilst BMI was the best overall discriminator of retrospective morbidity in the 18-64 year olds, for men aged 65 and above, weight and calf circumference were more significant discriminators of respiratory infections than was BMI. There are other suggestions that uncorrected arm muscle area may be a better overall index of health than BMI (Strickland and Ulijaszek 1994), supported by the findings that underweight classified by both **cAMA and calf circumference** surpassed BMI in terms of being predictors of physical capacity for work amongst adults in rural Nepal (Tuffrey 1994). Substituting calf circumference and a calf skinfold for MUAC and triceps skinfold to derive a calf muscle area variable has been adopted elsewhere (Pearson *et al* 1985, Strickland and Tuffrey 1997) and may be preferable.

Finally, older adult distributions for BMI, MUAC, calf circumference and cAMA can be affected by many factors. These include the effects of genetic potential, early growth and nutritional status, chronic disease patterns, previous and past occupations and lifestyles and other such factors, as well as differential losses in the sample due to mortality. Thus, using standard deviations from distributions from a few limited and scattered data sources for deriving universal cut-offs is ultimately a flawed procedure (Launer and Harris 1996). Without much more information on all the geographic and ethnic differences, the debate on how well simple anthropometric indicators like MUAC, calf circumference and cAMA can reflect the level of muscle and fat in an older person is also set to continue.

What about any non-anthropometric classifications of underweight ? In this study, mean levels of both haemoglobin and albumin were significantly lower amongst those classified as underweight, using both BMI and MUAC classifications. There was close agreement between those classified as **anaemic and hypoalbuminaemic** and those classified as being underweight using MUAC, but not so much when BMI was used, especially for anaemic women. However, the levels of both haemoglobin or serum albumin will be affected by disease which limits their value as purely nutritional status indicators. A study of hospitalised elderly showed that the levels of haemoglobin and serum albumin levels were not found to be related to nutritional status assessed by anthropometry, but a higher BMI cut-off (24) was used (Lemonnier *et al* 1991).

Finally, a mention needs to be made of the Mini-Nutritional Assessment (Guigoz *et al* 1996), which defines grades of nutritional status according to scoring from measurements and questions in 5 spheres, only one of which is anthropometry. However this was originally designed for use amongst hospitalised elderly, and it may not be practical for assessing underweight amongst community-living elderly people, particularly in developing countries, because of the clinical skills needed to ascertain drug use, and diagnose dementia and psychological stress. Furthermore, its relationship to impaired functional ability has not been documented.

In summary, whilst other ways of classifying underweight are plausible, and may have similarly strong predictive powers in terms of functional ability impairment amongst community-living older people, much more data are needed to confirm this. Until these are available, there is little alternative but to rely on the more widely used methods, being aware of their flaws and limitations. Certainly, given the functional cost demonstrated in this study, any methodological uncertainties are no excuse for inaction.

9.2.2 Improving functional assessment protocols

It is likely that validated, more refined and more easily conducted and communicated mechanisms for functional ability assessment will evolve over the next few decades (Brody 1988). The **cultural inappropriateness** of some aspects of current functional ability protocols, both self-reports and physical tests, is still a major constraint for their use in developing countries (Beall and Eckert 1986). Difficulties encountered with the incontinence part of the Katz ADL, usually attributed to cultural inappropriateness, have been addressed elsewhere (Jitapunkul *et al* 1993, Beall and Eckert 1986). This study encountered problems over the incontinence and self-feeding questions which may have been inappropriate, despite some local adaptation. The self-feeding question assumes the use of feeding utensils : in this population most people ate with their fingers. Another issue that may have led to problems with these two questions, in particular, were their early appearances in the assessment protocol, which had been planned to present the most intrusive part of the protocol (physical tests) last and the least intrusive (the self-report questionnaire) first. This meant that the sensitive and intimate question about incontinence came early in the **assessment sequence**, which may have created discomfort amongst some people and possibly led to less co-operation and effort elsewhere in the assessment (Lemke and Drube 1992). In an attempt to make mobility questions more appropriate to the cultural setting, a study of functional disability in Indonesia collected data on the abilities to fetch water and repair the house (Manton *et al* 1986). These activities are more appropriate and probably imply greater physical capacity than those used in usual ADL and mobility scales. However, different content and phrasing to self-report protocols limits cross-national comparisons and introduces other problems of validation.

The overriding problem with the physical tests is that they cannot differentiate the unmotivated from the incapable people (Reuben and Siu 1990). It is difficult to evaluate the causes of, and the extent to which **motivational,** and other factors, affecting performance in the physical tests undermines the present findings (Lenmarken *et al* 1986). For example, the chair stand test did not prove successful in this study. Possible reasons for this may have been due to its association with being a former punishment in schools, or the fact that for many people the chair was not set at 100% of knee height (Didier *et al* 1993) nor was a choice of different height chairs offered (Brown *et al* 1995). Handgrip is also known to be affected by the volitional problems of subject performance (Chumlea *et al* 1995). The issue of **non-familiarity** affecting performance is also pertinent, with most poor elderly people used to sitting cross-legged on the floor or a bed rather than using chairs, and more familiar with hand, rather than utensil, techniques of self-feeding. These issues need to be addressed urgently if protocols are to be improved and adapted for use in cultures other than the ones in which they were designed.

These issues of cultural and motivational barriers to functional testing are important ones, and should not be glossed over. The social anthropologists, Beall and Eckert (1986) focus on the fundamental differences between the **etic and the emic perspectives** of functional status assessment. Typifying the etic view in his debate over strength thresholds, **Young** argues that age-related morphological and physiological deterioration may ultimately preclude the performance of certain tasks (**1986, 1992**). A time may occur when capacity has declined to a point where some activities are not feasible and an individual may alter his or her activity because it represents an excessive physiological strain. In contrast, the emic view considers only the meaning and importance attached to each particular function dimension by the individual concerned within a particular social context, the social and cultural norms and expectations. In the case of functional ability assessment it may refer to a person's own meaning of "dependency", rather than any scientific definition. Some examples could be that an old person expects to be helped regardless of functional ability level purely by virtue of senior "status", or that he/she "just feels the need to have someone present all the time" (Jitapunkul *et al* 1993). Beall and Eckert (1986) consider that both approaches are needed to achieve a truly biocultural understanding of functional ability. Whilst the etic perspective can quantify the biological processes differentiating levels of functional ability, an emic understanding is necessary for relating these levels of functional ability to social consequences.

Beall and Eckert (1986) further stress that the operationalization and interpretation of functional status assessment measures, whether by ADL self-reports or physical testing, requires a considerable understanding of the cultural context. They recommend that a strategy for devising culturally sensitive tests should begin by exploring local definitions of senility, age-appropriate and age-inappropriate behaviour, and capacity, and should identify locally recognisable and acceptable items to use as props before the protocol is finalised. Whilst this was done to a certain extent in this study (e.g. for memory test, cognitive screen), it possibly did not sufficiently identify the potential problems with chair rises, nor with the ADL questions about incontinence or self-feeding.

As discussed in section 3.14, this study could be criticised because of its **lack of repeatability** of physical performances. This is a common problem, highlighted in a review that found only 5 out of 43 published reports had evaluated test-re-test reliability (Feinstein *et al* 1986). Whilst, theoretically, lack of repeatability in a measure indicates that it is not valid, no standardised methods for handling this have been recommended for the variables used in this study. The main problem is that it is difficult to have exactly the same conditions for the initial and the repeat measure (Margetts 1991). In this study, cross-sectional analysis at least showed there was high internal consistency amongst both the self-reported and performance variables.

In conclusion, none of the methods available for adoption in this study for the assessment of nutritional status or functional ability amongst community-living elderly is flawless. Many limitations still apply to their use and consequent interpretation of the results. Given the importance of both nutrition and function to the everyday life of millions of elderly people worldwide, refinement of such imperfect protocols is urgently required.

Handgrip strength emerged as the dimension of functional ability in which poor performance is most strongly predicted by underweight. Handgrip strength is relatively easy to measure in the field. It is also an important indicator of overall functional status that may help identify people close to functional thresholds and who would benefit from interventions such as muscle strengthening or nutritional supplementation. This highlights the potential usefulness of handgrip strength in both nutritional and geriatric assessment. **Self-reported mobility** also emerged strongly in both bivariate and multivariate analyses and is another easily obtained functional ability dimension that should be universally included into assessment protocols.

9.2.3 Need for more complex multivariate modelling

Driven by the need to account for the undoubted heterogeneity of community living elderly people and the wide variety of multiple confounders, more complex multivariate models could be developed. These might introduce other potential confounders, such as drug use, HIV/AIDS, socio-economic status and past occupation, into the testing of the relationship between underweight and impaired functional ability and poor performance. Further refinement of variables used in the original logistic regression models used in this study might also be informative. Examples of possible refinements follow.

(i) in place of absolute measures of strength, normalizing handgrip strength, and possibly other physical test variables, for :

- body weight and BMI (Anderson and Cowan 1966, Rantanen *et al* 1994, Skelton *et al* 1994, Brown *et al* 1995, Harris 1997)
- skeletal size measures such as height and armspan (Cauley *et al* 1987, Bassey and Harries 1993, Bruce *et al* 1989, Vaz *et al* 1996 , Davis *et al* 1998)

- cAMA as an indicator of muscle bulk (Frontera *et al 1988*, Bruce *et al* 1989, Reed *et al* 1991, Vaz *et al* 1996).

(ii) normalizing mobility and some ADL variables (transfer, bathing) for body weight (Rantanen *et al* 1994).

(iii) including other functional ability variables as potential confounders into models pertaining to a particular functional ability dimension. For example, it may have been advisable to include poor manual dexterity as a potential confounder in every model relating to poor handgrip strength (and vice versa). In a longitudinal study of 485 older Americans, grip strength was a significant predictor of decline in manual performance[3], which in turn was associated with increasing dependency (Hughes *et al* 1997).

(iv) using a different percentile to determine the criteria for poor test performance, instead of the worst quartile used here. Examples could be the 15th and 85th percentiles, or tertiles (Wickham *et al* 1989, Seeman *et al* 1994).

(v) experimenting with different definitions of underweight using calf circumference and cAMA cut-offs, e.g. :

- cAMA <16.0 in men and <16.9 in women (Friedman 1985, Freidman *et al* 1986)
- for cAMA, calculating % of standard using (median) 50th percentiles of NHANES/local data as the denominator, to determine limits of an acceptable range, and then applying a cut-off (e.g. 85% of standard) as the level of nutritional risk (Bistrian 1980, Lewis and Bell 1990)
- for cAMA and calf circumference, calculating -2 SD of a population, or a reference, distribution
- using BMI corrected for cAMA.

Finally, there are admittedly methodological shortcomings in this study which would need to be avoided in future work. The main limitation is that, for various reasons, cases

[3] measured by the Timed Manual Performance Test (Williams *et al* 1984)

were lost at various stages and the logistic regression analysis was performed on complete cases only. People with certain characteristics may have been systematically removed, thus undermining the generality of the results. Nevertheless considerable internal consistency within the data set lends support to the strength of the findings.

9.2.4 Exploring urban - rural differences

Providing valuable data from a developing country setting, this study fills a knowledge gap on the extent, severity and consequences of underweight and the prevalence and associates of functional ability impairment and poor performance amongst poor older people in an urban setting. However, the study could bear repetition in a rural area to allow for an analysis of rural-urban differentials in both nutritional status and functional ability status. Low BMIs are more prevalent amongst adults in rural than urban India (Rao *et al* 1986, Mehta 1987, Norgan 1994), a pattern repeated in other countries in the region (Side *et al* 1991, Pongpaew and Schelp 1997). There is also some indication that the prevalence of ADL impairment is higher amongst rural than amongst urban elderly in less developed countries (Murray *et al* 1992 b, Andrews 1988), including India (Prakash 1998). However, a recent UK study found the reverse to be true, reporting a higher prevalence of underweight and a higher rate of mortality amongst elderly living in urban compared to rural areas of Nottinghamshire (Donkin *et al* 1998).

In rural areas of most of the less developed world, a higher proportion of the total population is elderly compared to urban areas (Hoover and Siegel 1986). This is due to internal mass movements of young adults to cities which leads to an imbalance in the sex and age distributions of both urban and rural populations. These are paralleled by urban-rural differences in public health, medical services and effective sanitation measures which are the primary determinants of differences in morbidity and mortality between urban and rural areas. A rural study could test whether or not the present finding that underweight is strongly predictive of functional ability impairment holds true amongst rural elderly with very different types of daily activities, present and past occupation, patterns of disease, and access to health care and welfare provisions, and how these are changing (Wahlqvist *et al* 1994). Moreover, the best assurance that the findings of this study are valid is to verify the accuracy of the models in a second population (Sullivan and Walls 1994).

9.2.5 Longitudinal studies and interventions

A final point also needs to be made about the differential survival of people enrolled into a cross-sectional study such as this. Generalizing these findings is limited by the fact that data on nutritional status, ill health and functional impairment and the relationships between them represent only the survivors. We cannot be sure that these findings are true for, or represent, the older population living in the slums. Any interpretations of the associations and predictive odds ratios found in this study will be flawed by such limitations. Even the role of age cannot be properly accounted for without recourse to longitudinal analysis. This issue is well-illustrated by Manton (1992). Cross-sectional data show that women tend to have a higher prevalence of disability than men whereas longitudinal data show the incidence of disability is similar in both sexes. The higher prevalence of disability among females apparent from cross-sectional data is due to the greater survival of females after the onset of disability. Thus, the present cross-sectional findings should be interpreted with caution until further international longitudinal studies can provide confirmation. Although the results from this study seem to indicate that, for poor elderly slum dwellers in Mumbai, having underweight, as assessed by anthropometric indicators of BMI and MUAC, has a negative effect on functional ability outcomes, a causal relationship has yet to be established.

In order to prove causality, prospective longitudinal work to determine how far an improvement in nutritional status could lead to the prevention or slowing of functional decline, and a resultant gain in active functional years, would need to be carried out. This could lead on to the development, testing and implementation of nutrition intervention strategies, appropriate to different developing country situations, aimed at attaining that goal. Admittedly, a longitudinal study can be exacting, laborious and expensive, but it should be possible to develop a study design involving a combination of cross-sectional and cohort- and time-sequential research strategies to address elderly nutritional and functional issues (Kua and Ko 1994). Any research design will need to include all the parameters deemed essential, recruit samples of sufficient size to allow for an efficient use of multivariate statistical methods, and to maintain a good response rate within samples despite follow-up intervals (Heikkinen *et al* 1993, Chumlea *et al* 1995).

However, longitudinal work focusing on the effects of nutritional intervention might not be straightforward, despite the plausibility. For example, a US study (Martin *et al* 1985) showed that handgrip strength values did not change in severely anorectic patients, either during nutritional depletion, or during reversion to a depleted state. The authors concluded that that even large changes in nutritional state may not always be accompanied by changes in grip strength. Certainly, growing evidence seems to indicate that unless muscle training also takes place, nutrition support may be of limited value in improving performance (Fiatarone *et al* 1994). The same may be true for other dimensions of functional ability, but the data to argue for or against this are unavailable for the elderly.

Nevertheless, the findings of the present study indicate that interventional work be urgently directed at underweight elderly people because they are at increased risk of functional ability impairment. Implementing interventions aimed at improving nutritional status may be one way of helping old people to maintain reasonable levels of functional ability, rather than waiting to intervene later in the "disabling process" (Seeman *et al* 1994). Attention needs to be paid especially to those with kyphosis, TB, musculoskeletal and neurological disease, anaemia, hypoalbuminaemia, and the recently disabled, as these factors have emerged as important co-predictors in the relationship between underweight and the risk of functional ability impairment.

9.2.6 Anthropological research

An undoubted limitation of this study is the lack of attention paid to potential socio-economic and psychosocial confounders that may have affected the relationship between underweight and impaired functional ability and poor performance found amongst these elderly slum and chawl dwellers in Mumbai. Unfortunately, time and resource constraints, and the sensitive nature of the social and political climate in the study site during the fieldwork period, meant that exploration of these issues was not possible. Although the study sample were all low-income in the broadest sense as they lived in slums and chawls, no detailed exploration of differing income levels, or whether or not differentials existed in pension or welfare payments, was attempted. Nor was any attention paid to different past and present occupations, marital status, lifestyles and education levels. Many of these are known to be associated with nutritional and functional status (Parker *et al* 1996, Ravaglia *et al* 1997, Scott *et al* 1997, Berkman and Gurland 1998) in older people. How patterns of intra-household food distribution affects elderly people and their status within the household are also important, but neglected, areas of anthropological research for the gerontologist. Further exploration of the role of these issues in the relationship between underweight and impaired functional ability in community-living elderly people in the less developed world is recommended.

9.3 Summary of recommendations

1 - Attention should be paid to the presence and severity of kyphosis in any nutritional or functional assessment of older people.

2 - The use of a long bone measurement, such as armspan, as an alternative to height is essential in the assessment of stature of older people who have any degree of kyphosis, or in whom a height measurement would be inaccurate (e.g. bent knees, poor posture).

3 - MUAC (and possibly calf circumference and cAMA, and calf muscle area) is a better indicator of underweight in older people than BMI. This is because MUAC is a better reflection of functionally important changes in muscle mass, and it has a stronger relationship to impaired functional ability than BMI. It is also a simpler measurement to take in the field. However, more international, racially-diverse information is needed to clarify how all simple anthropometric measurements reflect both muscle mass and muscle strength in older people.

4 - The measurement of handgrip strength should be introduced into nutritional and functional initial assessments and monitoring of older people living in the community.

Handgrip strength strongly reflects the level of nutritional status as well as other dimensions of functional ability.

5 - Self-reported mobility should also be assessed as it is a useful indicator of overall functional ability, is closely related to muscle strength, and impairment is strongly predicted by underweight.

6 - More work is urgently needed to address practical and interpretational constraints in the existing functional ability protocols. The main needs are for more culturally appropriate and validated self-report protocols, and simple physical performance measures less influenced by motivational factors.

7 - Generally more and better data on nutritional status and functional ability are needed from developing countries, especially documenting urban-rural differences

8 - Prospective longitudinal studies involving nutritional interventions (or combined therapies such as activity and muscle training) need to be designed and tested to demonstrate that improving nutritional status has a beneficial impact on functional ability and thus quality of life of older people.

9. More anthropological research needs to focus on socio-economic, psychosocial differentials and causes of nutritional vulnerability amongst poor elderly people living in the community, and how these all interact with functional ability decline.

9.4 And finally ...

Being poor, old and malnourished carries a measurable detrimental risk in terms of the ability to live an independent life. Thus, the hypothesis that nutritional status is a potentially important source of correctable or postponeable functional ability impairment is plausible. Certainly, unless we can postpone the onset of functional impairment and disability, rather than just disease, then there will be an ever-increasing cost and burden to the ageing individual, their carers and the society and economy at large. From what is known about the active roles that older people play in their families and communities in developing countries, the findings of this study carry some serious practical implications.

This research has tried to untangle the strands of the relationship between underweight and functional impairment. However, these strands form part of a wider multi-weaved tapestry. It is increasingly accepted that quality of life is not just the absence of disease or disability but something positive as well. The definition of "quality of life" for the older person needs to move beyond the body to include personal and social well-being (Butler 1992).

A broader definition of quality of life might include :

- maintaining good nutritional status and appetite
- having intellectual capacity
- having the capacity to perform activities of daily living (functional ability)
- freedom from pain and suffering
- preservation of senses and sensuality
- a social support system
- an adequate financial base
- mastery over one's life: independence, autonomy and choice
- a purpose outside of oneself, a sense of usefulness
- some degree of happiness and morale

Thus, despite the demonstration that underweight carries an increased risk of functional ability impairment in older people, and the plausible assumption that underweight is a modifiable predictor that can postpone functional decline, this will only ever be one piece of the puzzle.

REFERENCES

Akhtar AJ (1972). Refusal to participate in a survey of the elderly. *Gerontologia Clinica* 14 : 205-11

Alexander NB, Schultz AB and Warwick DN (1991). Rising from a chair : effects of age and functional ability on performance biomechanics. *Journal of Gerontology* 46 (3) : M91-8

Alexander NB, Ulbrich J, Raheja A, Channer D (1997). Rising from the floor in older adults. *Journal of the American Geriatrics Society* 45 (5) : 564-9

Allen SC (1989). The relationship between height, armspan and forced expiratory volume in elderly women. *Age and Ageing* 18 (2) : 113-6

Allison DB, Faith MS, Heo M, and Kotler DP (1997). Hypothesis concerning the U-Shaped relationship between Body Mass Index and mortality. *American Journal of Epidemiology* 146 (4) : 339-49

Altman DG (1991). Practical statistics for medical research. Chapman and Hall, London

Anderson WF and Cowan NR (1966). Hand grip pressure in older people. *British Journal of Preventive and Social Medicine* 20 : 141-7

Andrews GR, Esterman AJ, Braunack-Mayer AJ, Rungie CM (1986). Aging in the Western Pacific. WHO Regional Office for the Western Pacific, Manila

Andrews GR (1987). Ageing in Asia and the Pacific : a multidimensional cross-national study in 4 countries. *Comprehensive Gerontology C* 1 : 24-32

Andrews GR (1988). Health and ageing in the developing world. In : *Research and the Ageing Population*. Eds. Evered D and Whelan J. CIBA Foundation Symposium 134. John Wiley and Sons, Chichester

Ania BJ, Suman VJ, Fairbanks VF, Raedmacher DM and Melton LJ (1997). Incidence of anaemia in older people : an epidemiologic study in a well-defined population. *Journal of the American Geriatrics Society* 45 (7) : 825-31

Anklesaria PS (1995). Comprehensive biomedical assessment of the urban elderly people. Ph.D. Thesis. University of Bombay

Appollonia I, Fra Hola L, Caracbellesse C and Trabucchi M (1989). The eyes and ears of the world of function. *Journal of the American Geriatrics Society* 37 (11) : 1099-1102

Ara S (1994). Old age among slum dwellers. South Asian Publishers, New Delhi (for HelpAge India)

Atkinson SJ (1992). Food for the cities : urban nutrition policy in developing countries. LSHTM , PHP Department Publication, no. 5

Attwood EC, Robey E, Kramer JJ, Ovenden N, Snape S, Ross J, and Bradley F (1978). A survey of the haemotological, nutritional, and biochemical state of the elderly with particular reference to vitamin C. *Age and Ageing* 7 (1) : 46-56

Badley EM, Wagstaff S and Wood PHN (1984). Measures of functional ability (disability) in arthritis in relation to impairment of range of joint motion. *Annals of the Rheumatic Diseases* 43 (4) : 563-9

Bailey LB, Wagner PA, Christakis GJ, Appledorf H, Davis CG, Araujo PE, Masteryanmi J and Dinning JS (1979). Folacin and iron status and haemotological findings in predominantly black elderly persons from urban low-income households. *American Journal of Clinical Nutrition* 32 (11) : 2346-53

Bailey KV and Ferro-Luzzi A (1995). Use of body mass index in assessing individual and community nutritional status. *Bulletin of the World Health Organisation* 73 (5) : 673-680

Barker JC (1989). Health and functional status of the elderly in a Polynesian population. *Journal of Cross-Cultural Gerontology* 4 : 163-94

Bassey EJ (1986). Demispan as a measure of skeletal size. *Annals of Human Biology* 13 (5) : 499-502

Bassey EJ, Ebrahim SBJ, Dallosso HM and Morgan K (1989 a). Normal values for range of shoulder abduction in men and women aged over 65 years. *Annals of Human Biology* 16 (3) : 249-57

Bassey EJ, Morgan K, Dallosso H and Ebrahim SB (1989 b). Flexibility of the shoulder joint measured as range of abduction in a large representative sample of men and women over 65 years of age. *European Journal of Applied Physiology* 58 (4) : 353-60

Bassey EJ (1990 a). Tests of muscle strength. In : *Handbook of Methods for the Measurement of Work Performance, Physical Fitness and Energy Expenditure in Tropical Populations*. Ed. Collins KJ. International Union of Biological Sciences, Medical Research Council and London School of Hygiene and Tropical Medicine, London

Bassey EJ (1990 b). Simple performance tests. In : *Handbook of Methods for the Measurement of Work Performance, Physical Fitness and Energy Expenditure in Tropical Populations*. Ed. Collins KJ. International Union of Biological Sciences, Medical Research Council and London School of Hygiene and Tropical Medicine, London

Bassey EJ, Fiatarone MA, O'Neill EF, Kelly M, Evans WJ and Lipsitz LA (1992). Leg extensor power and functional performance in very old men and women. *Clinical Science* 82 (3) : 321-7

Bassey EJ and Harries UJ (1993). Normal values for handgrip strength in 920 men and women aged over 65 years, and longitudinal changes over 4 years in 620 survivors. *Clinical Science* 84 (3) : 331-7

Bassey EJ (1998). Longitudinal changes in selected physical capabilities : muscle strength, flexibility and body size. *Age and Ageing* 27 (S3) : 12-6

Bastow MD, Rawlings J, and Allison SP (1983). Undernutrition, hypothermia and injury in elderly women with fractured femur : an injury response to altered metabolism ? *Lancet* Jan 22 : 143-6

Baumgartner RN, Rhyne RL, Troup C, Wayne S, and Garry PJ (1992). Appendicular skeletal muscle areas assessed by magnetic resonance imaging in older persons. *Journal of Gerontology* 47 (3) : M67-72

Baumgartner RN, Stauber PM, McHugh D, Koehler KM and Garry PJ (1995). Cross-sectional age differences in body composition in persons 60+ years of age. Journals of Gerontology 50A (6) : M307-M316

Beall CM and Goldstein MC (1982). Work, aging and dependency in a Sherpa population in Nepal. *Social Science and Medicine* 16 (2) : 141-7

Beall CM and Eckert JK (1986). Measuring functional status cross-culturally. In : *New Methods for Old Age Research : A strategy for studying diversity*. Eds. Fry CL and Keith J. Bergin and Garvey Publishers, Southharvy, MA

Bebbington AC (1988). The expectation of life without disabilities in England and Wales. *Social Science and Medicine* 27 (4) : 321-6

Bemben MG, Massey BH, Bemben DA, Bolleau RA and Misner JE (1998). Age-related variability in body composition methods for assessment of percent fat and fat-free mass in men aged 20-74 years. *Age and Ageing* 27 (2) : 147-53

Bendall MJ, Bassey EJ and Pearson MB (1989). Factors affecting walking speed of elderly people. *Age and Ageing* 18 (5) : 327-32

Bergstrom G, Aniansson A, Bjelle A, Grimby G, Lundgren-Lindquist B, and Svanborg A (1985). Functional consequences of joint impairment at age 79. *Scandinavian Journal of Rehabilitative Medicine* 17 (4) : 183-90

Berkman CS and Gurland BJ (1998). The relationship among income, other socioeconomic indicators on functional level in older people. *Journal of Aging and Health* 10 : 81-98

Besdine RW (1990). Functional assessment in the elderly. In : *Geriatric Medicine*. Eds. Rowe JL and Besdine RW, 2nd edition. Little, Brown and Co. Inc., Boston

Bess FH, Lichenstein MJ, Logan MJ, Burger MC and Nelson E (1989). Hearing impairment as a determinant of function in the elderly. *Journal of the American Geriatrics Society* 37 (2) : 123-8

Beutler E (1988). The common anaemias. *Journal of the American Medical Association* 259 (16) : 2433-7

Bhaskaram P (1996). Malnutrition - a critical determination of progressive forms of tuberculosis. *Nutrition News* (National Institute of Nutrition, India) 17 (1) : 1-4

Bishop CW, Bowen PE and Ritchey SJ (1981). Norms for nutritional assessment of American adults by upper arm anthropometry. *American Journal of Clinical Nutrition* 34 (11) 2530-9

Bistrian BR (1980). Anthropometric norms used in assessment of hospitalized patients. *American Journal of Clinical Nutrition* 33 : 2211-4

Borkan GA, Hults DE and Glyn RJ (1983). Role of longitudinal change and secular trend in age difference in male body dimensions. *Human Biology* 55 (3) : 629-41

Boult C, Kane RL, Louis TA, Boult L and McCaffrey D (1994). Chronic conditions that lead to functional limitation in the elderly. *Journal of Gerontology* 49 (1) : M28-36

Bowling A and Grundy E (1997). Activities of daily living : changes in functional ability in 3 samples of elderly and very elderly people. *Age and Ageing* 26 (2) : 107-14

Bowman BB and Rosenberg IH (1982). Assessment of the nutritional status of the elderly. *American Journal of Clinical Nutrition* 35 (Suppl 5) : 1142-51

Branch LG and Meyers AR (1987). Assessing physical function in the elderly. *Clinics in Geriatric Medicine* 3 (1) : 29-51

Brody JA (1985). Prospects for an ageing population. *Nature* : 315 (6019) : 463-6

Brody JA (1988). Changing health needs of the ageing population. In : *Research and the Ageing population*. Eds. Evered D and Whelan J. CIBA Foundation Symposium 134. John Wiley and Sons, Chichester

Brown M, Sinacore DR and Host (1995). The relationship of strength to function in the older adult. *Journal of Gerontology* 50 (special) : 55-9

Brown OT and Wigzell FW (1964). The significance of span as a clinical measurement. Conference on medical and surgical aspects of aging. In : *Current Achievements in Geriatrics*. Eds. Anderson WF and Isaacs B. Cassell, London

Bruce SA, Newton D, and Woldege RC (1989). Effect of subnutrition on normalized muscle force and relaxation rate in human subjects using voluntary contraction. *Clinical Science* 76 (6) : 637-41

Bryman A and Cramer D (1990). Quantitative data analysis for social scientists. Routledge, New York

Burr ML and Phillips KM (1984). Anthropometric norms in the elderly. *British Journal of Nutrition* 51 (2) : 165-9

Butler RN (1992). Quality of life : can it be an endpoint ? How can it be measured ? *American Journal of Clinical Nutrition* 55 (Suppl 6) : 1267S -70S

Campbell AJ (1986). Measures to improve the response rate in community based studies of elderly people. *Journal of Clinical Experimental Gerontology* 8 (1/2) : 41-50

Campbell AJ, Spears GF, Brown JS, Busby WJ, and Borrie MJ (1990). Anthropometric measurements as predictors of mortality in a community population aged 70 years and over. *Age and Ageing* 19 (2) : 131-5

Campbell P and Ulijaszek SJ (1994). Relationships between anthropometry and retrospective morbidity in poor men in Calcutta. *European Journal of Clinical Nutrition* 48 (7) : 507-12

Carter JS, Williams HG and Macera CA (1993). Relationships between physical activity habits and functional neuromuscular capacities in healthy older adults. *The Journal of Applied Gerontology* 12 (2) : 283-93

Carter LT, Oliveira DO,Duponte J, and Lynch SV (1988). The relationship of cognitive skills performance to activities of daily living in stroke patients. *The American Journal of Occupational Therapy* 42 (7) : 449-55

Cauley JA, Petrini AM, LaPorte RE, Sandler RB, Bayles CM, Robertson RJ and Slemenda CW (1987). The decline of grip strength in the menopause : relationship to physical activity, estrogen use and anthropometric factors. *Journal of Chronic Diseases* 40 (2) : 115-20

Centers for Disease Control and Prevention, CDC (1998 a). AIDS amongst persons aged ≥ 50 years, United States 1991-1996. *Morbidity and Mortality Weekly Report*, January 23rd

Centers for Disease Control and Prevention, CDC (1998 b). The deadly intersection between TB and HIV. Bulletin : June

Chandler PJ and Bock RD (1991). Age changes in adult stature : trend estimation from mixed longitudinal data. *Annals of Human Biology* 198 (5) : 433-40

Charlton KE, Kruger M, Labadarios D, Wolmarans P and Aronson I (1997). Iron, folate and vitamin B12 status of an elderly South African population. *European Journal of Clinical Nutrition* : 51 (7) : 424-30

Chilima DM (1998). Nutritional status and functional ability of older people in rural Malawi. Ph.D. Thesis, University of London

Chumlea WC, Roche AF and Rogers E (1984 a). Replicability for anthropometry in the elderly. *Human Biology* 56 (2) : 329-37

Chumlea WC, Roche AF and Webb P (1984 b). Body size, subcutaneous fatness and total fat in the elderly. *International Journal of Obesity* 8 (4) : 311-8

Chumlea WC, Roche AF and Mukherjee D (1986). Some anthropometric indices of body composition in elderly adults. *Journal of Gerontology* 41 (1) : 36-9

Chumlea WC, Roche AF and Mukherjee D (1987). Nutritional assessment in the elderly through anthropometry. Ross Laboratories, Columbus Ohio

Chumlea, W.C. and Baumgartner RN (1989). Status of anthropometry and body composition data in elderly subjects. *American Journal of Clinical Nutrition* 50 (Suppl 5) : 1158-66

Chumlea WC, Roche AF and Steinbaugh ML (1989). Anthropometric approaches to the nutritional assessment of the elderly. In : *Nutrition, ageing and the elderly*. Eds. Munro HN and Danford DE. Plenum Press, New York

Chumlea WC, Guo S, Kuczmarski RJ, Johnson CL, and Leahy CK (1990). Reliability for anthropometric measurements in the Hispanic Health and Nutrition Examination Survey (HHANES 1982-1984). *American Journal of Clinical Nutrition* 51 : 902S-7S

Chumlea WC, Baumgartner RN and Vellas BP (1991). Anthropometry and body composition in the perspectives of nutritional status in the elderly. *Nutrition* 7 (1); 57-60

Chumlea WC and Guo S (1992). Equations for predicting stature in white and black elderly individuals. *Journal of Gerontology* 47 (6) : M197-203

Chumlea WC, Guo SS, Vellas BJ and Guigoz Y (1995). Techniques of assessing muscle mass and function (sarcopenia) for epidemiological studies of the elderly. *Journal of Gerontology* 50A : 45-51

Chumlea WC, Guo SS, Glaser RM and Vellas BJ (1997 a). Sarcopenia, function and health. *Journal of Nutrition, Health and Aging* 1 (1) : 7-12

Chumlea WM, Guo SS, Vellas B and Guigoz Y (1997 b). Assessing body composition and sarcopenia with anthropometry. In : *Nutrition personnes agees* (Colloque Internationale sous le Haut Patronage du Ministere de la Sante, Paris - La Defense) CERIN Symposium , Paris, 6-7 December 1996

Clark C, Czaja SU, and Weber RA (1990). Older adults and daily living task profiles. *Human Factors* 32 (5) : 537-49

Cline MG, Meredith KE, Boyer JT and Burrows B (1989). Decline of height with age in adults in a general population sample : estimating maximum height and distinguishing birth cohort effects from actual loss of stature with aging. *Human Biology* 61 (3) : 415-25

Cohen L and Holliday M (1982). Statistics for social scientists. Harper and Row, London

Collin C, Wade DT, Davies S, and Home V (1988). The Barthel ADL Index : a reliability study. *International Disability Studies* 10 (2) : 61-3

Cook JD and Finch CA (1979). Assessing iron status of a population *American Journal of Clinical Nutrition* 32 (10) : 2115-19

Cooper C, Barker DJP and Wickham C (1988). Physical activity, muscle strength and calcium intake in fracture of the proximal femur in Britain. *British Medical Journal* 297 (Dec 3) : 1443-6

Corey-Bloom J, Wiederholt WC, Edelstein S, Salmon DP, Cahn D, and Barrett-Connor E (1996). Cognitive and functional status of the oldest old. *Journal of the American Geriatrics Society* 44 (6) : 671-4

Corti M-C, Guralnik JM, Salive ME and Sorkin JD (1994). Serum albumin level and physical disability as predictors of mortality in older persons. *Journal of the American Medical Association* 272 (13) : 1036-42

Cronk CE and Roche AF (1982). Race- and sex- specific reference data for triceps and subscapular skinfolds and weight/stature 2. *American Journal of Clinical Nutrition* 35 (2) : 347-54

Crook N and Dyson T (1982). Urbanization in India : results of the 1981 census. *Population and Development Review* 8 (1) : 145-55

Csuka M and McCarty DJ (1985). Simple method for measurement of lower extremity muscle strength. *American Journal of Medicine* 78 (1) : 77-81

Dallal GE (1988). Logistic : A logistic regression program for the IBM PC. *American Statistician* 42 : 272

Dallman PR, Yip R and Johnson C (1984). Prevalence and causes of anaemia in the United States, 1976 to 1980. *American Journal of Clinical Nutrition* 39 (3) : 437-45

Damon A, Seltzer CC, Stoudt HW and Bell B (1972). Age and physique in healthy white veterans at Boston. *Journal of Gerontology* 27 (2) : 202-8

Davies LS and Knutson KC (1991). Warning signals for malnutrition in the elderly. *Journal of the American Dietetic Association* 91 (11) : 1413-7

Davies PD (1996). Tuberculosis in the elderly : epidemiology and optimal management. *Drugs and Aging* 8 (6) : 436-44

Davis JW, Preston SD, Nevitt MC and Wasnich RD (1998). Strength, physical activity and body mass index : relationship to performance-based measures and activities of daily living among older Japanese women in Hawaii. *Journal of the American Geriatrics Society* 46 : 274-9

DeMaeyer EM, Dallman P, Gurbey JM, Hallberg, Sood SK and Srikantia SG (1989). Preventing and controlling iron deficiency anaemia through primary health care : A guide for health administrators and programme managers. WHO, Geneva

De Onis M, Yip R, and Mei Z (1997). The development of MUAC-for-age reference data recommended by a WHO Expert Committee. *Bulletin of the World Health Organisation* 75 (1) : 11-8

Department of Health UK (1993). The Nutrition of Elderly People. Report on Health and Social Subjects no.43. London: H.M. Stationery Office

Department of Health and Social Security (DHSS), UK (1972). A nutrition survey of the elderly. Report on Health and Social Subjects, no. 3. HMSO, London

Department of Health and Social Security (DHSS), UK (1979). Nutrition and health in old age. Report on Health and Social Subjects, no. 16. HMSO, London

Dequeker JV, Baeyens JP and Claessens J (1969). The significance of stature as a clinical measurement of aging. *Journal of the American Geriatrics Society* 17 (2) : 169-79

Desai KG and Naik RD (196x , undated). Problems of retired people in Greater Bombay. Tata Institute of Social Sciences, series no. 27. Bombay

Deurenberg P, Westrate JA and Van der Kooy K (1989 a). Is an adaption of Siri's formula for the calculation of body fat percentage from body density in the elderly necessary ? *European Journal of Clinical Nutrition* 43 (4) : 559-68

Deurenberg P, van der Kooy K, Hulshof T and Evers P (1989 b). Body mass index as a measure of body fatness in the elderly. *European Journal of Clinical Nutrition* 43 (4) : 231-6

Didier JP, Mourey F, Brondel L, Marcer I, Milan C, Casillas JM, Verges B, and Winsland JK (1993). The energetic cost of some daily activities : a comparison in a young and old population. *Age and Ageing* 22 (2) : 90-6

Donkin AJM, Johnson AE, Morgan K, Neale RJ and Lilley JM (1998). The interaction of physical, psychosocial, socio-economic and sociodemographic variables on the Body Mass Index (Mindex) of the community-living elderly. *Journal of Nutrition, Health and Aging* 2 (3) : 143-8

Durnin JV (1989). Anthropometric methods of assessing nutritional status. In : *Nutrition in the elderly*. Eds. Horwitz A, Macfadyen DM, Munro HN, Scrimshaw NS, Steen B and Williams TF. Oxford University Press, Oxford

Durnin JV and Womersley J (1974). Body fat assessment from total body density and its estimation from skinfold thickness measurements on 481 men and women aged 16 to 72 years. *British Journal of Nutrition* 32 (1) : 77-97

Durnin JV (1994). Low body mass index, physical work capacity and physical activity levels. *European Journal of Clinical Nutrition* 48 (suppl 3) : S39-S44

Dutta C (1997). Significance of sarcopenia in the elderly. *Journal of Nutrition* 127 (5) : 992S-993S

Ebrahim S, Nouri F and Barer D (1985). Measuring disability after a stroke. *Journal of Epidemiology and Community Health* 39 (1) : 86-9

Engstrom FM, Roche AF, and Mukherjee D (1981). Differences between armspan and stature in white children. *Journal of Adolescent Health* 2 (1) : 19-22

Ensrud KE, Nevitt MC, Yunis C, Cauley JA, Seeley DG, Fox, KM and Cummings SR (1994). Correlates of impaired function in older women. *Journal of the American Geriatrics Society* 42 (5) : 481-9

Ensrud KE, Black DM, Ettinger B, Cummings SR (1997). Correlates of kyphosis in older women. The Fracture Intervention Trial Research Group. *Journal of the American Geriatrics Society* 45 (6) : 682-7

Ethangatta LK, Basu TK, Gee MI and Hawrysh ZJ (1994). Biochemical status of protein and iron status in low income elderly women living in Nairobi City, East Africa. *International Journal of Food Sciences and Nutrition* 45 : 249-53

Ettinger WH, Davis MA, Neuhaus JM and Mallon KP (1994). Long-term physical functioning in persons with knee osteoporosis from NHANES I - effects of co-morbid medical conditions. *Journal of Clinical Epidemiology* 47 (7) : 809-15

Euronut SENECA investigators (1991 a). Nutritional status : anthropometry. In : *Euronut-SENECA : Nutrition and the elderly in Europe*. Eds. de Groot LCPGM, van Staveren WA, and Hautvast JGAJ. *European Journal of Clinical Nutrition* 45 (suppl 3) : 31-42

Euronut SENECA investigators (1991 b). Design, methods and participation. In : *Euronut-SENECA : Nutrition and the elderly in Europe*. Eds. de Groot LCPGM, van Staveren WA, and Hautvast JGAJ. *European Journal of Clinical Nutrition* 45 (suppl 3) : 5-22

Euronut SENECA investigators (1991 c). Nutritional status : haematology and albumin . In : *Euronut-SENECA : Nutrition and the elderly in Europe*. Eds. de Groot LCPGM, van Staveren WA and Hautvast JGAJ. *European Journal of Clinical Nutrition* 45 (suppl 3) : 43-52

Euronut SENECA investigators (1991 d). Life-style : physical activities and activities of daily living. In : *Euronut-SENECA : Nutrition and the elderly in Europe*. Eds. de Groot LCPGM, van Staveren WA, and Hautvast JGAJ. *European Journal of Clinical Nutrition* 45 (suppl 3) : 139-51

Euronut SENECA investigators (1996). Health and physical performance of elderly Europeans. *European Journal of Clinical Nutrition* 50 (suppl 2) : S105-S111

Evans J (1990). The economic status of older men and women in the Javanese household and the influence of this upon their nutritional level. *Journal of Cross-Cultural Gerontology* 5 : 217-42

Evans PH (1994). Nutrient and toxin interactions in neurodegenerative disease. *Proceedings of the Nutrition Society* 53 (2) : 431-42

Evans WJ and Campbell WW (1993). Sarcopenia and age-related changes in body composition and functional capacity. *Journal of Nutrition* 123 (suppl 2) : 465-8

Evans WJ, Roubenoff R and Shevitz A (1998). Exercise and the treatment of wasting : aging and human immunodeficiency virus infection. *Seminars in Oncology* 25 (suppl 6) : 112-22

Exton-Smith AN (1982). Epidemiological studies in the elderly : methodological considerations. *American Journal of Clinical Nutrition* 35 : 1273-9

Falciglia G, O'Connor J and Gedling E (1988). Upper arm anthropometric norms in elderly white subjects. *Journal of the American Dietetics Association* 88 (5) : 569-74

Fanelli MT (1987). The ABC's of nutritional assessment in older adults. *Journal of Nutrition for the Elderly* 6 (3) : 33-45

Feinstein AR, Josephy BR and Wells CK (1986). Scientific and clinical problems in indexes of functional disability. *Annals of Internal Medicine* 105 (3) : 413-20

Fernando DN and Seneviratna R de A (1993). Physical health and functional ability of an elderly population in Sri Lanka. *The Ceylon Journal of Medical Science* 36 (1) : 9-16

Ferro-Luzzi A, Sette M, Franklin M and James WPT (1992). A simplified approach of assessing adult chronic energy deficiency. *European Journal of Clinical Nutrition* 46 (3) : 173-86

Ferro-Luzzi A and James WPT (1996). Adult malnutrition : simple assessment techniques for use in emergencies. *British Journal of Nutrition* 75 (1) : 3-10

Fiatarone MA, Marles EC, Ryan ND, Meredith CN, Lipsitz LA and Evans WJ (1990). High intensity strength training in nonagenarians : effects on skeletal muscle. *Journal of the American Medical Association* 263 (22) : 3029-34

Fiatarone MA, O'Neill EF, Ryan ND, Doyle RN, Clements KM, Solares GR, Nelson ME, Roberts SB, Kehayias JJ, Lipsitz LA and Evans WJ (1994). Exercise training and nutritional supplementation for physical frailty in very elderly people. *New England Journal of Medicine* 330 (25) : 1769-75

Fillenbaum GG (1984). The well-being of the Elderly : approaches to multidimensional assessment. WHO Offset Publication no. 84. WHO, Geneva

Fillenbaum GG (1990). Assessment of health and functional status : an international comparison. In : *Improving the Health of Older People. A World View.* Eds. Kane RL, Grimley Evans J and Macfadyen D. Oxford University Press and WHO, New York

Fillenbaum GG (1996). Functional ability. In : *Epidemiology of Old Age*. Eds. Ebrahim S and Kalache A. BMJ Publishing Group/WHO London

Finch CA (1989). Nutritional anaemia. In : *Nutrition in the elderly.* Eds. Horwitz A, Macfadyen DM, Munro H, Scrimshaw NS, Steen B and Williams TF. Oxford University Press (for WHO), New York

Fisher NM, Pendergast DR, and Calkins E (1991). Muscle rehabilitation in impaired elderly nursing home residents. *Archives of Physical Medicine and Rehabilitation* 72 (3) : 181-5

Fitzgerald JF, Smith DM, Martin DK, Freedman JA and Wolinsky FD (1993). Replication of the multidimensionality of activities of daily living. *Journal of Gerontology* 48 (1) : S28-S31

Foley DJ, Berkman LF, Branch LG, Farmer HE, and Wallace RB (1986). Physical functioning. In : *Established populations for epidemiologic studies of the elderly : a resource data book.* Eds. Cornoni-Huntley J, Brock DB, Ostfield AM, Taylor JO and Wallace RB. US National Institutes of Health, US Department of Health and Human Services, Bethesda, Maryland. NIH Pub. No. 86-2443

Folstein MF, Folstein SE, and McHugh PR (1975). Mini-Mental State : a practical method for grading the cognitive state of patients for the clinician. *Journal of Psychiatric Research* 12 (3) : 189-98

Folstein M, Anthony JC, Parhad I, Duffy B and Gruenberg EM (1985). The meaning of cognitive impairment in the elderly. *Journal of American Geriatrics Society* 33 (4) : 228-35

Fon GT, Pitt MJ and Thies AC (1980). Thoracic kyphosis : range in normal subjects. *American Journal of Radiology* 134 (2) : 979-83

Forbes GB, Brown MR and Griffiths HJ (1988). Arm muscle plus bone area : anthropometry and CAT scan compared. *American Journal of Clinical Nutrition* 47 (6) : 929-31

Fozard JL, Vercryssen M, Reynolds SL, Hancock PA, and Quilter RE (1994). Age differences and changes in reaction time : the Baltimore Longitudinal Study of Aging. *Journal of Gerontology* 49 (4) : P179-89

Friedlander JS, Costa PT, Bosse R, Ellis E, Rhoads JG, and Stoudt HW (1977). Longitudinal physique changes among healthy white veterans at Boston. *Human Biology* 49 (4) : 541-58

Friedman PJ, Campbell AJ and Caradoc-Davies TH (1985). Prospective trial of a new diagnostic criterion for severe wasting malnutrition in the elderly. *Age and Ageing* 14 (3) : 149-54

Friedman PJ (1986). A prospective comparison of methods to identify lethal wasting malnutrition. *Nutrition Research* 6 : 139-46

Friedman PJ (1987). Arm muscle mass and malnutrition. *Journal of the American Geriatrics Society* 35 (3) : 272-3 (Letters to Editor)

Frisancho AR (1990). Anthropometric standards for the assessment of growth and nutritional status. The University of Michigan Press, Ann Arbor, USA

Frontera WR, Meredith CN, O'Reilly KP, Knuttgen HG, and Evans WJ (1988). Strength conditioning in older men : skeletal muscle hypertrophy and improved function. *Journal of Applied Physiology* 64 (3) : 1038-44

Frontera WR, Huges VA, Lutz KJ, and Evans WJ (1991). A cross-sectional study of muscle strength and mass in 45 - 78 year old men and women. *Journal of Applied Physiology* 71 (2) : 644-50

Galanos AN, Pieper CF, Cornoni-Huntley JC, Bales CW and Fillenbaum GG (1994). Nutrition and function : is there a relationship between BMI and functional capabilities of community-dwelling elderly ? *Journal of the American Geriatrics Society* 42 (4) : 368-73

Gallagher D, Visser M, De Meersman RE, Sepulveda D, Baumgartner RN, Pierson RN, Harris T and Heymsfield SB (1997). Appendicular skeletal muscle mass : effects of age, gender and ethnicity. *Journal of Applied Physiology* 83 (1) : 229-39

Garcia M and Kennedy E (1994). Assessing the linkages between low body mass index and morbidity in adults : evidence from 4 developing countries. *European Journal of Clinical Nutrition* 48 (suppl 3) : S90-S97

Garcia PA, Luther T, Serrano FJ, and Tan AG (1982). Nutrition and health of rural elderly in five selected baranguays in the Philippines. *Nutrition Research* 2 : 545-60

Gardner GW, Edgerton VR, Senewiratne B, Barnard RJ and Ohira Y (1977). Physical work capacity and metabolic stress in subjects with iron deficiency anaemia. *American Journal of Clinical Nutrition* 30 (6) : 910-7

Garg BS and Singh JV (1983). Nutritional status of aged in an urban area. *Indian Journal of Nutrition and Dietetics* 20 (1) : 316-22

Garry PJ, Goodwin JS and Hunt WC (1983). Iron status and anemia in the elderly : new findings and a review of previous studies. *Journal of the American Geriatrics Society* 31 (7) : 389-99

Garry PJ, Hunt WC, VanderJagt DJ, and Rhyne RL (1989). Clinical chemistry reference intervals for healthy elderly subjects. *American Journal of Clinical Nutrition* 50 (Suppl 5) : 1219-30

Giay T and Khoi HH (1994). Use of body mass index in the assessment of adult nutritional status in Vietnam. *European Journal of Clinical Nutrition* 48 (suppl 3) : S124-S130

Gibbs J, Hughes S, Dunlop D, Edelman P, Singer R and Chang R, 1993. Joint impairment and ambulation in the elderly. *Journal of the American Geriatrics Society* 41 (11) : 1205-11

Gibson RS (1990). Principles of Nutritional Assessment. Oxford University Press, New York

Gill TM, Williams CS and Tinetti ME (1995). Assessing risk for the onset of functional dependence among older adults. *Journal of the American Geriatrics Society* 43 (6) : 603-9

Gill TM, Williams CS, Mendes de Leon CF and Tinetti ME (1997). The role of change in physical performance in determining risk for dependence in activities of daily living among non-disabled community-living elderly persons. *Journal of Clinical Epidemiology* 50 (7) : 765-72

Golden MH (1996). Severe malnutrition. In : *Oxford Textbook of Medicine*. Eds. Weaterall DG, Ledingham JCG and Warrel DA. Oxford Medical Publications, Oxford (3rd edition , vol 1)

Goldstein MC, Schuler S and Ross JL (1983). Social and economic forces affecting the intergenerational relations in extended families in a Third World country : a cautionary tale. *Journal of Gerontology* 38 (6) : 716-24

Goodwin JS, Goodwin JM and Garry PJ (1983). Association between nutritional status and cognitive functioning in a healthy elderly population. *Journal of the American Medical Association* 249 (21) : 2917-21

Goodwin JS (1989). Social, psychological and physical factors affecting the nutritional status of the elderly : separating cause and effect. *American Journal of Clinical Nutrition:* 50 (suppl 5) : 1201-9

Gopalan C (1992). Nutrition in development transition in South East Asia. World Health Organisation Regional Office for South East Asia, New Delhi

Gopalan C (1998). Demographic and developmental transition in India : its impact on nutrition-related disease. In : *Diet, nutrition and chronic disease : an Asian perspective*. Eds. Shetty P and Gopalan C. Smith-Gordon/Nishimura, London

Gordon CC, Chumlea WC and Roche AF (1988). Stature, recumbent lengths and weight. In : *Anthropometric standardization reference manual.* Eds. Lohman TG, Roche AF, Martorell R. Human Kinetics Books, Champaign, Illinois

Gosman-Hedstrom G, Aniansson A, and Persson G-B (1988). ADL-reduction and need for technical aids among 70 year-olds from the population study of 70 year olds in Goteborg. *Comprehensive Gerontology B* 2 : 16-23

Gray-Donald K, Payette H, Boutier V (1995). Randomized clinical trial of nutritional supplementation shows little effect on functional status among free-living frail elderly. *Journal of Nutrition* 125 (12) : 2965-71

Grimby A, Milsom I, Molander U, Wiklund I and Ekelund P (1993). The influence of urinary incontinence on quality of life of elderly women. *Age and Ageing* 22 (2) : 82-9

Grimby G and Saltin B (1983). The ageing muscle. *Clinical in Physics and Physiological Measurement* 3 (3) : 209-18

Grimley Evans J (1988). Ageing and disease. In : *Research and the Ageing Population.* (CIBA Foundation Symposium 134). John Wiley and Sons, Chichester

Gross R and Monteiro CA (1989). Urban nutrition in developing countries : some lessons to learn. *Food and Nutrition Bulletin* 9 (2) : 37-42

Guccione AA, Felson DT, Anderson JJ, Anthony JM, Zhang Y, Wilson PW, Kelly-Hayes M, Wolf PA, Kreger BE and Kannel WB (1994). The effects of specific medical conditions on the functional limitations of elders in the Framingham study. *American Journal of Public Health* 84 (3) : 351-8

Guigoz Y, Vellas B and Garry PJ (1996). Assessing the nutritional status of the elderly : the Mini-Nutritional Assessment as part of the geriatric evaluation. *Nutrition Reviews* 54 (10) : S59-S65

Guo CB, Zhang W, Ma DQ, Zhang KH and Huang JQ (1996). Handgrip strength : an indicator of nutritional state and the mix of postoperative complications in patients with oral and maxillofacial cancers. *British Journal of Oral and Maxillofacial Surgery* 34 (4) : 325-7

Guralnik JM, Branch LG, Cummings SR and Curb JD (1989). Physical performance measures in aging research. *Journal of Gerontology* 44 (5) : M141-146

Guralnik JM and AZ Lacroix (1992). Assessing physical function in older populations. In : *The Epidemiologic Study of old age*. Eds. Wallace RW, Woolson RF. Oxford University Press, New York

Guralnik JM, Ferrucci L, Simonsick EM, Salive ME and Wallace RB (1995). Lower-extremity function in persons over the age of 70 years as a predictor of subsequent disability. *New England Journal of Medicine* 332 (19) : 556-61

Haboudi NY, Hudson PR and Pathy MS (1990). Measurement of height in the elderly. *Journal of the American Geriatrics Society* 38 (9) : 1008-10

Haga H, Shibata H, Keno M, Nagai H, Suyama Y, Matsuzaki T, Yasumura S, Koyano W, Hatano S (1991). Factors contributing to longitudinal changes in activities of daily living (ADL) : the Koganei Study. *Journal of Cross-Cultural Gerontology* 6 : 91-9

Hall JC, O'Quigley J, Giles GR, Appleton N and Stocks H (1980). Upper limb anthropometry : the value of measurement variance studies. *American Journal of Clinical Nutrition* 33 (8) : 1846-51

Harpham T, Vaughan P and Rifkin S (1985). Health and the urban poor in developing countries. A review and selected annotated bibliography. Evaluation and Planning Centre for Health Care, London School of Hygiene and Tropical Medicine, London EPC Pub. No. 5

Harris T, Woteki C, Briefel RR and Kleinman JC (1989). NHANES III for older persons : nutrition content and methodological considerations. *American Journal of Clinical Nutrition* 50 (Suppl 5) : 1145-9

Harris TB and Feldman JJ (1991). Implications of health status in analysis of risk in older persons. *Journal of Aging and Health* 3 : 262-84

Harris T (1997). Muscle mass and strength : relation to function in population studies. *Journal of Nutrition* 127 (Suppl 5) : 1004S-1006S

Harrison GA, Weiner JS, Tanner JM, Barnicot NA and Reynolds V (1977). Human Biology : an introduction to human evolution, variation, growth and ecology. Oxford University Press, Oxford

Hashimoto A, Kendig HL and Coppard L (1992). Family support to the elderly in international perspective. In : *Family support for the elderly : the international experience*. Eds. Kendig HL, Hashimoto A and Coppard LC. Oxford University Press, on behalf of WHO, Oxford

Heikkinen E, Waters WE, and Brzezinski ZJ (1983). The elderly in 11 Countries. A Sociomedical survey. Public Health in Europe, No. 21. WHO Regional Office for Europe, Copenhagen

Heikkinen E, Era P, Jokela J, Jylha M, Lyyra A and Pohjolainen AP (1993). Socioeconomic and lifestyle factors as modulators of health and functional capacity with age. In : *Ageing, Health and Competence*. Ed. Schroots J. Elsevier Science Publications, Amsterdam

Heikkinen E, Jokela J, and Jylha M (1996). Disability and functional status among elderly people : cross-national comparisons. In : *Health and mortality among elderly populations*. Eds. Caselli G and Lopez AD. Clarendon Press, Oxford

Henry CJ (1990). BMI and the limits to human survival. *European Journal of Clinical Nutrition* 44 (suppl 1) : 79-84

Herman DR, Solomons NW, Mendoza I, Gonzales C, and Qureshi AK (1998). Anthropometric measures and indices of body composition among Guatemalan elderly : relationship with self-reated health and activities of daily living and comparison with other sites in the "Food Habits in Later Life" multicentre study. *Asia Pacific Journal of Clinical Nutrition* 7 (1) : 55-64

Hermann FR, Safran AL, Levkoff SE and Misaker KL (1992). Serum albumin level on admission as a predictor of death, length of stay and readmission. *Archives of Internal Medicine* 152 : 125-30

Heymsfield SB, McManus C, Smith J, Stevens V and Nixon DW (1982 a). Anthropometric measurement of muscle mass : revised equations for calculating bone-free arm muscle area. *American Journal of Clinical Nutrition* 36 (4) : 680-90

Heymsfield SB, McManus C, Stevens V and Smith J (1982 b). Muscle mass : reliable indicator of protein-energy malnutrition severity and outcome. *American Journal of Clinical Nutrition* 35 : 1192-9

Hibbert ME, Lanigan A, Raven J, and Phelan PD (1988). Relation of armspan to height and the prediction of lung function. *Thorax* 43 (8) : 657-9

Himes JH, Roche AF, Siervogel RM (1979). Compressibility of skinfolds and the measurement of subcutaneous fatness. *American Journal of Clinical Nutrition* 32 (8) : 1734-40

Hirsch CH, Fried LP, Harris T, Fitzpatrick A, Enright P and Shulz R (1997). Correlates of performance-based measures of muscle function in the elderly : the Cardiovascular Health Study. *Journal of Gerontology* 52 (4) : M192-200

Hoe A, Atha J and Murray-Leslie C (1994). Stature loss from sustained gentle body loading. *Annals of Human Biology* 21 (2) : 171-8

Hoeymans N, Feskens EJ, van Den Bos GA and Kromhout D (1998). Non-response bias in a study of cardiovascular diseases, functional status and self-rated health among elderly men. *Age and Ageing* 27 (1) : 35-40

Hoover SL and Siegel JS (1986). International demographic trends and perspectives on aging. *Journal of Cross-Cultural Gerontology* 1 : 5-30

Hughes S, Gibbs J, Edelman P, Singer R and Chang RW (1992). Joint impairment and hand function in the elderly. *Journal of the American Geriatrics Society* 40 (9) : 871-7

Hughes SL, Edelman PL, Singer RH and Chang RW (1993). Joint impairment and self-reported disability in elderly persons. *Journal of Gerontology* 48 (2) : S84-S92

Hughes SL, Gibbs J, Dunlop D, Edelman P, Singer R and Chang RW (1997). Predictors of decline in manual performance in older adults. *Journal of the American Geriatrics Society* 45 (8) : 905-10

Hurley MV, Rees J and Newham DJ (1998). Quadriceps function, proprioceptive acuity and functional performance in healthy young, middle-aged and elderly subjects. *Age and Ageing* 27 (1) : 55-62

Hyatt RH, Whitelaw MN, Bhat A, Scott S, and Maxwell JD (1990). Association of muscle strength with functional status of elderly people. *Age and Ageing* 19 (5) : 330-6

Institute of Medicine, USA (1990). The second fifty years : promoting health and preventing disability. Division of Health Promotion and Disease. National Academy Press, Washington DC

James WPT, Ferro-Luzzi A and Waterlow JC (1988). Definition of chronic energy deficiency in adults. Report of a working party of the International Dietary Energy Consultative Group. Discussion Paper. *European Journal of Clinical Nutrition* 42 : 969-81

James WPT and Ralph A (Eds) (1994). The functional significance of low body mass index. Proceedings of an IDECG workshop held in Rome, Italy Nov 4-6 1992. *European Journal of Clinical Nutrition* 48 : supplement 3

James WPT, Mascie-Taylor GCN, Norgan NG, Bistrian BR, Shetty PS and Ferro-Luzzi A (1994). The value of arm circumference measurements in assessing chronic energy deficiency in Third World adults. *European Journal of Clinical Nutrition* 48 (12) : 883-94

James WPT (1994). Introduction : the challenge of adult chronic energy deficiency. *European Journal of Clinical Nutrition* 48 (supplement 3) : S1-S9

James WPT and Francois PJ (1994). The choice of cut-off point for distinguishing normal body weights from underweight or chronic energy deficiency in adults. *European Journal of Clinical Nutrition* 48 (suppl 3) : S179-S184

Jarzem PF and Gledhill RB (1993). Predicting height from armspan measurements. *Journal of Pediatric Orthopaedics* 13 (6) : 761-5

Jette AM and Branch LG (1981). The Framingham Disability Study : II. Physical disability among the aging. *American Journal of Public Health* 71 (11) : 1211-5

Jette AM, Branch LG, and Berlin J (1990). Musculoskeletal impairments and physical disablement among the aged. *Journal of Gerontology* 45 (6) : M203-208

Jitapunkul S, Bunnang S and Ebrahim S (1993). Health care for elderly people in developing countries : a case study of Thailand. *Age and Ageing* 22 (5) : 377-81

Jitapunkul S, Kamolratanakul P, and Ebrahim S (1994). The meaning of activities of daily living in a Thai elderly population : development of a new index. *Age and Ageing* 23 (2) : 97-101

Johnell O, O'Neill T, Felsenberg D, Kanis J, Cooper C and Silman AJ (1997). Anthropometric measurements and vertebral deformities. The European Vertebral Osteoporosis Study (EVOS) Group. American *Journal of Epidemiology* 146 (4) : 287-93

Joseph JA (eds) (1988). Central determinants of age-related declines in motor function. *Annals of the New York Academy of Sciences* 515 : 1-429

Joslin D and Brouard A (1995). The prevalence of grandmothers as primary care givers in a poor pediatric population. *Journal of Community Health* 20 (5) : 383-401

Judge JO, Schechtman K, and Cress E (1996). The relationship between physical performance measures and independence in instrumental activities of daily living. The FICSIT group. *Journal of the American Geriatrics Society* 44 (11) : 1332-41

Kalache A (1991). Ageing in developing countries. In : *Principles and Practices of Geriatric Medicine*. Ed. Pathy MSJ. John Wiley and Sons Ltd, Chichester

Kallman, DA, Plato CC and Tobin JD (1990). The role of muscle loss in the age-related decline of grip strength : cross sectional and longitudinal perspectives. *Journal of Gerontology* 45 (3) : M82-M88

Kane RA and Kane RL (1981). Assessing the Elderly : A Practical Guide to Measurement. Lexington Books, Lexington, Mass.

Kaplan GM, Wurtele SK and Gillis D (1996). Maximal effort during functional capacity evaluations : an examination of psychological factors. *Archives of Physical Medicine and Rehabilitation* 77 : 161-4

Katz SC, Ford AB, Moskowitz RW, Jackson BA and Jaffe MW (1963). Studies of illness in the aged. The index of ADL : A standardized measure of biological and psychosocial function. *Journal of the American Medical Association* 185 : 914-9

Katz S, Downs TD, Cash HR and Grotz RC (1970). Progress in the development of the Index of ADL. *The Gerontologist* 1 : 20-37

Katz S (1983). Assessing self-maintenance : activities of daily living, mobility and instrumental activities of daily living. *Journal of the American Geriatrics Society* 31 (12) : 721-7

Katz S and Stroud MW (1989). Functional assessment in geriatrics : a review of progress and directions. *Journal of the American Geriatrics Society* 37 (3) : 267-71

Kearney MT, Wanklyn PD, Goldman JM, Pearson SB, and Teale C (1994). Tuberculosis and urban deprivation in the elderly *Age and Ageing* 23 (suppl 1) : 28-9 (abstract)

Kelly PL and Kroemer KH (1990). Anthropometry of the elderly : status and recommendations. *Human Factors* 32 (5) : 571-595

Kempen GI and Suurmeijer TP (1990). The development of hierarchical polychotomous ADL-IADL for non-institutionalised elderly. *The Gerontologist* 30 (4) : 497-502

Kempen GI, van Heuvelen MJ, van den Brink RH, Kooijman AC, Klein M, Houx PJ and Ormel J (1996). Factors affecting contrasting results between self-reported and performance-based levels of physical limitations. *Age and Ageing* 25 (6) : 458-64

Kemper HCG and Binkhorst RA (1993). Exercise and the physiogical consequences of aging. In : *Aging, health and competence.* Ed. Schroots JJ. Elsevier Science Publishers PV, Amsterdam

Khetarpal K and Kumar V (1995). Locomotor disabilities in the urban elderly. *Journal of the Association of Physicians of India* 43 (12) : 959 (abstract)

Khilnani GC, Dey AB, Nagarkar KM, Soneja S and Kumar V (1995). Symptom analysis of geriatric outpatients. *Journal of the Association of Physicians of India* 43 (12) : 885 (abstract)

Kim KK, Yu ES, Liu WT, Kim J, and Kohrs MB (1993). Nutritional status of Chinese-, Korean- and Japanese-American elderly. *Journal of the American Dietetic Association* 93 (12) : 1416-22

King JE, Mazariegos M, Valdez C, Castaneda C, and Solomons NW (1997). Nutritional status indicators and their interaction in rural Guatemalan elderly : a study in San Pedro Ayampuc. *American Journal of Clinical Nutrition* 66 (4) : 795-802

Kinsella K and Suzman R (1992). Demographic dimensions of population aging in developing countries. *American Journal of Human Biology* 4 : 3-8

Klidjian AM, Foster KJ, Kammerling RM, Cooper A and Karran SJ (1980). Relation of anthropometric and dynamometric variables to serious postoperative complications. *British Medical Journal* 281 Oct 4 (6245) : 899-901

Klidjian AM, Archer TJ, Foster KJ and Karran SJ (1982). Detection of dangerous malnutrition. *Journal of Parenteral and Enteral Nutrition* 6 (2) : 119-21

Kua EH and Ko SM (1994). The ageing of elderly people. *Singapore Medical Journal* 35 (4) : 386-9

Kubena KS, McIntosh WA, Georghiades MB, and Landmann WA (1991). Anthropometry and health in the elderly. *Journal of the American Dietetic Association* 91 (11) : 1402-7

Kuczmarski RJ (1989). Need for body composition information in elderly subjects. *American Journal of Clinical Nutrition* 50 (suppl 5) : 1150-7

Kuczmarski MF (1993). Nutritional status of older adults. In : *Nutrition in aging*. Ed. Schlenker E. Mosby-Year Book Inc., Missouri

Kullah KM and Ramnath T (1985). Nutritional status of the aged in rural areas of Andra Pradesh. *Indian Journal of Nutrition and Dietetics* 22 (11) : 330-6

Kumar AR and Vali S (1994). Anthropometric and clinical nutritional status of workers in some Indian factories. *Asia Pacific Journal of Clinical Nutrition* 3 : 179-84

Kun CK (1998). The impact of HIV/AIDS on older persons. *INIANET : Bulletin of the International Institute on Ageing* (UN, Malta) (May) : 6-7

Kwok T and Whitelaw MN (1989). A new nutritional indicator. *Journal of the American Geriatrics Society* 37 (11) : 1100-1

Kwok T and Whitelaw MN (1991). The use of armspan in nutritional assessment of the elderly. *Journal of the American Geriatrics Society* 39 (5) : 492-6

Lachenbruch PA (1992). Utility of logistic regression in epidemiologic studies of the elderly. In : *The Epidemiologic study of the elderly.* Eds. Wallace RB and Woolson RF. Oxford University Press New York

Lampl M (1992). Further observations in diurnal variation in standing height. *Annals of Human Biology* 19 (1) : 87-90

Lancia B, Tedesco M, Sergio G and Tenna M (1997). Anthropometric and nutritional assessment in Italian elderly subjects. *The Journal of Nutrition, Health and Aging* 1 (3) : 174-80

Langlois JA, Maggi S, Harris T, Simonsick EM, Ferrucci L, Pavan M, Sartori L and Enzi G (1996). Self-report of difficulty in performing functional activities identifies a broad range of disability in old age. *Journal of the American Geriatrics Society* 44 (12) : 1421-8

Larsson EB (1991). Exercise, functional decline and frailty. *Journal of the American Geriatrics Society*: 39 96) : 635-6

Laukkanen P, Heikkinen E and Kauppinen M (1995). Muscle strength and mobility as predictors of survival in 75-84 year old people. *Age and Ageing* 24 (6) : 468-73

Launer LJ and Harris T (1996). Weight, height and Body Mass Index distributions in geographically and ethnically diverse samples of older persons. *Age and Ageing* 25 (4) : 300-6

Launer LJ, Harris T, Runpel C and Madans J (1994). Body mass index, weight change and risk of mobility disability in middle-old and older women. The epidemiologic follow up study of NHANES. *Journal of the American Geriatrics Society* 271 (14) : 1093-8

Law M and Letts L (1989). A critical review of scales of activities of daily living. *American Journal of Occupational Therapy* 43 (8) : 522-8

Lawton MP and Brody EM (1969). Assessment of older people : self-maintaining and instrumental activities of daily living. *The Gerontologist* 9 (3) : 179-86

Leech JA, Dulberg C, Kellie S, Pattee L and Gay J (1990). Relationship of lung function to severity of osteoporosis in women. *American Review of Respiratory Disease* 141 (1) : 68-71

Lehmann AB (1989). Review : undernutrition in elderly people. *Age and Ageing* 18 (5) : 339-53

Lehmann AB, Bassey EJ, Morgan K and Dallosso HM (1991). Normal values for weight, skeletal size and body mass indices in 890 men and women aged over 65 years. *Clinical Nutrition* 10 : 18-22

Lemke JH and Drube GA (1992). Issues in handling incomplete data in surveys of the elderly. In : *The epidemiologic study of aging*. Eds. Wallace RB and Woolson RF. Oxford University Press, New York

Lemonnier DS, Acher S, Boukaiba N, Flament C, Doucet C, Piau A and Chappuis P (1991). Discrepancy between anthropometry and biochemistry in the assessment of the nutritional status of the elderly. *European Journal of Clinical Nutrition* 45 : 281-6

Lenmarken C, Sandtedt S, Schenck HV and Larsson J (1986). The effect of starvation on skeletal muscle function in men. *Clinical Nutrition* 5 : 99-103

Lewis EJ and Bell SJ (1990). Nutritional assessment in the elderly. In : *Geriatric Nutrition*. Eds. Morley JE, Glick Z and Rubenstein LZ. Raven Press, New York

Liang MH and Jette AM (1981). Measuring functional ability in chronic arthritis: a critical review. *Arthritis and Rheumatism* 24 (1) : 80-6

Liang MT and Chumlea WM (1998). Balance and strength of elderly Chinese men and women. *The Journal of Nutrition, Aging and Health* 2 (1) : 21-9

Little A, Hemsley D, Bergmann K., Volans J, and Levy R (1987). Comparison of the sensitivity of three instruments for the detection of cognitive decline in elderly living at home. *British Journal of Psychiatry* 150 (June) : 808-14

Lipschitz DA (1990 a). Nutritional anaemias in the elderly. In : *Geriatric Nutrition.* Eds. Morley JE, Glick Z and Rubenstein LZ. Raven Press Ltd, New York

Lipschitz DA (1990 b). The anaemia of chronic disease. *Journal of the American Geriatric Society* 38 (11) : 1258-64

Loebl WY (1967). Measurement of spinal posture and spinal movement. *Annals of Physical Medicine* 9 (3) : 103-10

Lohman TG (1981). Skinfolds and body density and their relation to body fatness : a review. *Human Biology* 53 (2) : 181-225

Lohman TG, Roche AF and Martorell R (eds) (1988). Anthropometric standardization reference manual. Human Kinetics Books, Champaign, Illinois

Lohman TG (1991). Anthropometric assessment of fat-free body mass. In : *Anthropometric assessment of nutritional status.* Ed. Himes JH. Wiley-Liss Inc, New York

Lynch SR, Finch CA, Monsen ER and Cook JD (1982). Iron status of elderly Americans. *American Journal of Clinical Nutrition* 36 (suppl 5) : 1032-45

Macfadyen DM, 1989. Priorities for nutritional research. In : *Nutrition in the elderly.* Eds. Horwitz A, Macfadyen DM, Munro HN, Scrimshaw NS, Steen B and Williams TF. Oxford University Press, Oxford

Macfadyen DM (1992). The developing world. In : *Oxford Textbook of Geriatric Medicine.* Eds. Grimley Evans J and Franklin Wiliams T. Oxford University Press, Oxford

MacLennan WJ, Hall MR, Timothy JI and Robinson M (1980). Is weakness in old age due to muscle wasting ? *Age and Ageing* 9 (3) : 188-92

Mansell PI, Rawlings J, Allison SP, Bendall MJ, Pearson M, Bassey EJ and Bastow MD (1990). Low anthropometric indices in elderly females with fractured neck of femur. *Clinical Nutrition* 9 : 190-4

Manton KG, Dowd JE and Woodbury MA (1986). Conceptual and measurement issues in assessing disability cross-nationally : analysis of a WHO-sponsored survey of the disablement process in Indonesia. *Journal of Cross-Cultural Gerontology* 1 : 339-62

Manton KG, Myers GC and Andrews GR (1987). Morbidity and disability patterns in four developing nations : their implications for social and economic integration of the elderly. *Journal of Cross-Cultural Gerontology* 2 : 115-29

Manton KG (1992). The dynamics of aging : measurement and interventions issues for health and function. *Journal of Cross-Cultural Gerontology* 7 : 185-201

Margetts BM (1991). Basic issues in designing and interpreting epidemiological research. In : *Design concepts in nutritional epidemiology.* Eds. Margetts BM and Nelson M. Oxford University Press, New York

Martin AD, Lindsay Carter JE, Hendy KC and Malina RM (1988). Segment lengths. In : *Anthropometric standardization reference manual.* Lohmann TG, Roche AF, and Martorell R. Human Kinetics Books, Champaign, Illinois

Martin LG (1988) The aging of Asia. *Journal of Gerontology* 43 (4) : S99-S113

Martin LG (1990). The status of South Asia's growing elderly population. *Journal of Cross-Cultural Gerontology* 5 : 93-117

Martin S, Neale G and Elia M (1985). Factors affecting maximal momentary grip strength. *Human Nutrition : Clinical Nutrition* 39 (2) : 137-47

Mascie-Taylor CGN (1993). Research designs and sampling strategies. In : *Research strategies in human biology : field and survey studies.* Eds. Lasker GW and Mascie-Taylor CGN. Cambridge University Press, Cambridge (Cambridge Studies in Biological Anthropology 13).

Mascie-Taylor CGN (1994). Analysing cross-sectional anthropometric data. *European Journal of Clinical Nutrition* 48 (suppl 3) : S190-S202

McMahon M and Bistrian BR (1991). Anthropometric assessment of nutritional status in hospitalised patients. In : *Anthropometry of nutritional status.* Ed. Himes JH. Wiley-Loss, New York

McNeill G, Payne P and Rivers J (1988). Patterns of adult energy nutrition in a South Indian village. London School of Hygiene and Tropical Medicine, Nutrition Unit, Occasional Paper no. 11

McPherson DR, Lancaster DR, and Carroll JC (1978). Stature changes with aging in black Americans. *Journal of Gerontology* 33 (1) : 20-5

Mehrotra SK, Pandey DN and Dabral SB (1979). Urban aged population - a social study. *Indian Journal of Public Health* 23 (2) : 71-5

Mehta A (1987). Rural urban differences in household food consumption pattern and nutritional status of elderly women of Uttar Pradesh. M.Sc. Dissertation. Lady Irwin College, University of Delhi

Merrill SS, Seeman TE, Kasl SV and Berkman LF (1997). Gender differences in the comparison of self-reported disability and performance measures. *Journal of Gerontology* 52A (1) : M19-M26

Miall WE, Ashcroft MT, Lovell HG and Moore F (1967). A longitudinal study of the decline of adult height with age in 2 Welsh communities. *Human Biology* 39 (4) : 445-54

Micozzi MS and Harris T (1990). Age variations in the relation of BMI to estimates of body fat and muscle mass. *American Journal of Physical Anthropology* 81 (3) : 375-9

Miles TP, Flegal K, and Harris T (1993). Muscoloskeletal disorders : time trends, comorbid conditions, self-assessed health and associated activity limitations. *Vital Health Statistics* 3 (27 Jan) : 275-88

Milne JS, Maule MM, and Williamson J (1971). Method of sampling in a study of older people with a comparison of respondents and non-respondents. *British Journal of Preventive and Social Medicine* 25 (1) : 37-41

Milne JS and Lauder IJ (1974). Age effects in kyphosis and lordosis in adults. *Annals of Human Biology* 1 (3) : 327-37

Milne JS (1979). Longitudinal studies of body weight and skinfold thickness in older people. *Journal of Clinical Experimental Gerontology* 1 (1) : 101-22

Milne JS and Williamson J (1983). A longitudinal study of kyphosis in older people. *Age and Ageing* 12 (3) : 225-33

Milne JS and Maule MM (1984). A longitudinal study of handgrip and dementia in older people. *Age and Ageing* 13 (1) : 42-8

Minten VK, Lowik MRH, Deurenberg P, and Kok FJ (1991). Inconsistent associations among anthropometric measurements in elderly Dutch men and women. *Journal of the American Dietetic Association* 91 (11) : 1408-12

Mitchell CO and Lipschitz DA (1982 a). Arm length measurements as an alternative to height in nutritional assessment of the elderly. *Journal of Parenteral and Enteral Nutrition* 6 (3) : 226-9

Mitchell CO and Lipschitz DA (1982 b). The effect of age and sex on the routinely used measurements to assess the nutritional status of hospitalised patients. *American Journal of Clinical Nutrition* 36 (2) : 340-9

Morgan K, Dallosso H, Bassey EJ, Ebrahim S, Fenten PH and Arie THD (1991). Customary physical activity, psychological well-being and successful ageing. *Ageing and Society* 11 : 399-415

Mowat EA, Thomas S, Hyatt R, Maxwell JD and Whitelaw MN (1992). A comparison of nutritional intake, functional status and muscle strength between elderly day hospital and day centre attenders in South London. *Journal of Human Nutrition and Dietetics* 5 : 35-51

Mowè M, Bohmer T and Kindt E (1994). Reduced nutritional status in an elderly population is probable before disease and possibly contributes to the development of disease. *American Journal of Clinical Nutrition* 59 (2) : 317-24

Mueller WH and Martorell R (1988). Reliability and accuracy of measurement. In : *Anthropometric standardization reference manual.* Eds. Lohman TG, Roche AF and Martorell R. Human Kinetics Books, Champaign, Il., USA

Muhlethaler R, Stuck AE, Minder CE and Frey BM (1995). The prognostic significance of protein-energy malnutrition in geriatric patients. *Age and Ageing* 24 (3) : 193-7

Municipal Coorporation of Greater Bombay (1989). Annual Report of the Executive Health Office, Public Health Department, Bombay

Municipal Corporation of Greater Bombay (1991). Civic Health Bulletin. Information, Education and Communication Cell, Public Health Department

Munro HN (1992 a). Protein. In : *Nutrition in the elderly : the Boston Nutritional Status Survey.* Eds. Hartz SC, Russell RM and Rosenberg IH. Smith-Gordon/Nishimura, London

Munro HN (1992 b). Iron. In : *Nutrition in the elderly : the Boston Nutritional Status Survey.* Eds. Hartz SC, Russell RM and Rosenberg IH. Smith-Gordon/Nishimura, London

Murray CJ, Yong G and Qiao X (1992 a). Adult mortality : levels, patterns and causes. In : *The Health of Adults in the Developing World.* Eds. Feachem RG, Kjellstrom T, Murray CJ, Over M and Phillips MA. Oxford University Press (for the World Bank), Washington CD

Murray CJ, Feachem RG, Phillips MA and Willis C (1992 b). Adult morbidity : limited data and methodological uncertainty. In : *The Health of Adults in the Developing World.* Eds. Feachem RG, Kjellstrom T, Murray CJ, Over M and Phillips MA. OxfordUniversity Press (for the World Bank), Washington DC

Naidu AN and Rao NP (1994). Body mass index : a measure of the nutritional status in Indian populations. *European Journal of Clinical Nutrition* 48 (suppl 3) : S131-S140

National Institutes of Health NIH, USA (1997). HIV wasting syndrome. National Institute of Allergy and Infectious Diseases, Press release

National Institutes of Health NIH, USA (1990). National Health and Nutrition and Examination Survey III : Physical Function Examination Manual. Bethesda, Maryland

National Nutrition Monitoring Bureau NNMB, India (1984). Report on diet and nturitional status of specific groups of urban population (1975-79). National Institute of Nutrition, Hyderabad

National Nutrition Monitoring Bureau NNMB, India (1988-90). Report of NNMB. Annex II. National Institute of Nutrition, Hyderabad

Nelson ME and Evans WJ (1992). Macronutrients and anthropometrics. In : *Nutrition in the elderly : the Boston Nutritional Status Survey.* Eds Hartz SC, Russell RM and Rosenberg IH. Smith-Gordon/Nishimura, London

Nesher G, Moore TL and Zuckner J (1991). Rheumatoid arthritis in the elderly. *Journal of the American Geriatrics Society* 39 (3) : 284-94

Netland PA and Brownstein H (1985). Anthropometric measurements for Asian and Caucasian elderly. *Journal of the American Dietetic Association* 85 (2) : 221-3

Nevitt MC, Cummings SR, Kidd S, and Black D (1989). Risk factors for recurrent nonsyncopal falls : a prospective study. *Journal of the American Medical Association* 261 (18) : 2663-8

Norgan NG (1990). Body mass index and body energy stores in developing countries. *European Journal of Clinical Nutrition* 44 (suppl 1) : 79-84

Norgan NG (1994). Population differences in body composition in relation to the body mass index. *European Journal of Clinical Nutrition* 48 (suppl 3) : S10-S27

Norgan NG and Ferro-Luzzi A (1982). Weight-height indices as estimators of fatness in men. *Human Nutrition : Clinical Nutrition* 36 (5) : 363-72

Norusis MJ /SPSS/PC (1990). The SPSS guide to data analysis for SPSS/PC+, 2nd edition. SPSS Inc., Chicago

Ohira Y, Edgerton VR, Gardner GW, Gunawardena KA, Senewiratne B, and Ikawa S (1981). Work capacity after iron treatment as a function of haemoglobin and iron deficiency. *Journal of Nutritional Science and Vitaminology* 27 (2) : 87-96

Oppenheimer S and Hendrickse R (1983). The clinical effects of iron deficiency and iron supplementation. *Nutrition Abstracts and Reviews* 53 (7) : 585-98

Ortega RM, Turrero E, Andres P, Moreiras O and Gasper MJ (1994). Nutritional assessment of the iron status in a group of institutionalised elderly people in Madrid (Spain). *Journal of Human Nutrition and Dietetics* 7 : 215-3

Osler M and Schroll M (1992). Differences between participants and non-participants in a population study on nutrition and health in the elderly. *European Journal of Clinical Nutrition* 46 (4) : 289-95

Ostwald SK, Snowdon DA, Rysavy DM, Keenan NL and Kane RL (1989). Manual dexterity as a correlate of dependency in the elderly. *Journal of the American Geriatrics Society* 37 (10) : 963-9

Pahor M and Kritchevsky S (1998). Research hypothesis on muscle wasting, aging, loss of function and disability. *Journal of Nutrition, Health and Aging* 2 (2) : 97-100

Panton LB, Graves JE, Pollock ML, Hagberg JM and Chen W (1990). Effect of aerobic and resistance training on fractionated reaction time and speed of movement. *Journal of Gerontology* 45 (1) : M26-M31

Parker JM, Dillard TA, and Phillips Y (1996 a). Armspan-height relationships in patients referred for spirometry. *American Journal of Respiratory and Critical Care Medicine* 154 : 533-6

Parker MG, Thorslund M, Lundberg O, and Kareholt I (1996 b). Predictors of physical function amongst the oldest old : a comparison of three outcome variables in a 24-year follow-up. *Journal of Aging and Health* 8 (3) : 444-60

Pathak JD (1978). Our elderly : some effects of ageing in Indian subjects. Bombay Hospital Trust Medical Research Centre

Patrick JM, Bassey EJ and Fentem PH (1982). Changes in body fat and muscle in manual workers at and after retirement. *European Journal of Applied Physiology and Occupational Physiology* 49 (2) : 187-96

Payette H (1994). Nutritional status of community-residing elderly with functional limitations. *Age and Nutrition* 5 : 4-7

Payette H, Hanusaik N, Boutier V, Morais JA and Gray-Donald K (1998). Muscle strength and functional mobility in relation to lean body mass in free-living frail elderly women. *European Journal of Clinical Nutrition* 52 (1) : 45-53

Pearson MB (1985). Muscle strength, body composition and activity in the elderly. M.Phil Dissertation, University of Notttingham

Pearson MB, Bassey EJ and Bendall MJ (1985). The effects of age on muscle strength and anthropometric indices within a group of elderly men and women. *Age and Ageing* 14 (4) : 230-4

Pelletier DL and Rahn M (1998). Trends in body mass index in developing countries. *Food and Nutrition Bulletin* 19 (3) : 223-39

Pfeiffer E (1975). A short portable mental status questionnaire for the assessment of organic brain deficits in elderly patients. *Journal of the American Geriatrics Society* 23 (10) : 433-41

Phillips P (1986). Grip strength, mental performance and nutritional status as indicators of mortality risk among female geriatric patients. *Age and Ageing* 15 (1) : 53-6

Phillips A, Shaper AG, and Whincup PH (1989). Association between serum albumin and mortaility from cardiovascular disease, cancer, and other causes. *Lancet (*Dec 16) : 1434-6

Phillips MA, Feachem RGA and Koplan JP (1992 a). The emerging agenda for adult health . In : *The Health of Adults in the Developing World.* Eds. Feachem RG, Kjellstrom T, Murray CJ, Over M, and Phillips MA. Oxford University Press (for the World Bank), Washington DC

Phillips SK, Bruce SA, Newton D, and Woledge RC (1992). The weakness of old age is not due to failure of muscle activation. *Journal of Gerontology* 47 (2) : M45-49

Pinholt EM, Kroenke K, Hanley JF, Kussman MJ, Twymann PL and Carpenter JL (1987). Functional assessment of the elderly : a comparison of standard instruments with clinical judgement. *Archives of Internal Medicine* 147 (3) : 484-8

Plato CC, Fox KM and Tobin JD (1994). Skeletal changes in human aging : In : *Biological anthropology and aging : perpectives on human variation over the life span.* Eds. Crew DE and Garruto RM. Oxford University Press, New York

Podsiadlo D and Richardson S (1991). The timed "up and go" : a test of basic functional mobility for frail elderly persons. *Journal of the American Geriatrics Society* 39 (2) : 142-8

Pongpaew P and Schelp F-P (1997). Elderly in a country going through epidemiological health transition - the example of Thailand. *Journal of Nutrition, Health and Aging* 1 : 45-9

Prakash IJ (1998). Maintenance of competence in daily living and well-being of elderly. *HelpAge India Research and Development Journal* 4 : 2-3

Pryer J and Crook T (1988). Cities of hunger : urban malnutrition in developing countries. Oxfam UK, Oxford

Pryer JA (1993). Body mass index and work-disabling morbidity : results from a Bangladeshi case study. *European Journal of Clinical Nutrition* 47 (9) : 653-7

Purohit CK and Sharma RA (1975). A study of nutritional status of persons 60 years and above. *Indian Journal of Medical Science* 29 (4-5) : 99-103

Quigley M and Myatt M (1994). Don't panic : a guide to statistical methods for outbreak investigation. Brixton Books, London

Rabe B, Thamrin MH, Gross R, Solomons NW, and Schultink W (1996). Body Mass Index of the elderly derived from height and from armspan. *Asia Pacific Journal of Clinical Nutrition* 5 : 79-83

Raj B and Prasad BG (1970). Health status of the aged in India : a study in 3 villages. *Geriatrics* 25 (6) : 142-85

Rall LC, Roubenoff R, and Harris TB (1995). Albumin as a marker of nutritional and health status. In : *Nutritional Assessment of elderly populations : Measure and function.* Ed. Rosenberg IH. Raven Press, New York

Rantanen T, Era P and Heikkinen E (1994). Maximal isometric strength and mobility among 75 year old men and women. *Age and Ageing* 23 (2) : 132-7

Rantanen T, Guralnik JM, Izmirlian G, Williamson JD, Simonsick EM, Ferrucci L and Fried LP (1998). Association of muscle strength with maximum walking speed in disabled older women. *American Journal of Physical and Medical Rehabilitation* 77 (4) : 299-305

Rao KV, Rau P and Thimmayamma BVS (1986). Nutritional anthropometry of Indian adults. *Indian Journal of Nutrition and Dietetics* 23 (8) : 239-256

Rao PT, Gowrinath SJ and Vijayarghansan K (1974). Nutritional status of children in urban slums around Hyderabad city. *Indian Journal of Medical Research* 62 : 1492-8

Ravaglia G, Forti P, Maioli F, Boschi F, Cicognani A, Bernardi M, Pratelli L, Pizzoferrato Am Percu S and Gasbarrini G (1997). Determinants of functional status in healthy nonagenarians and centarians : a comprehensive functional assessment by the instruments of geriatric practice. *Journal of the American Geriatrics Society* 45 (10) : 1196-202

Rea IM, Gillen S and Clarke E (1997). Anthropometric measurements from a cross-sectional survey of community dwelling subjects aged over 90 years of age. *European Journal of Clinical Nutrition* 51 (2) : 102-6

Reddy V (1991). Body mass index and mortality rates. *Nutrition News* (National Institute of Nutrition, Hyderabad) 12 : 1

Reed T, Fabsitz RR, Selby JV and Carmelli D (1991). Genetic influences and grip strength norms in the NHLB twin study of males aged 59-69. *Annals of Human Biology* 18 (5) : 425-32

Reeves SL, Varakamin C and Henry CJ (1996). The relationship between armspan and height with special reference to gender and ethnicity. *European Journal of Clinical Nutrition* 50 (6) : 398-400

Reilly JJ, Murray LA, Wilson J and Durnin JV (1994). Prediciton of body density from skinfold thickness in elderly subjects : are the existing equations valid ? *Annals of Human Biology* 21 (6) : 613-6

Reuben DB and Siu AL (1990). An objective measure of physical function of elderly outpatients : The Physical Performance Test. *Journal of the American Geriatrics Society* 38 (10) : 1105-12

Reuben DB, Siu AL and Kimpau S (1992). The predictive validity of self-report and performance-based measures of function and health. *Journal of Gerontology* 47 : M106-110

Reuben DB, Valle LA, Hays RD and Siu AL (1995). Measuring physical function in community-dwelling older persons : a comparison of self-administered, interviewer-administered and performance-based measures. *Journal of the American Geriatrics Society* 43 (1) : 17-23

Reuben DB, Moore AA, Damesyn M, Keeler E, Harrison GG and Greendale GA (1997). Correlates of hypoalbuminaemia in community-dwelling older persons. *American Journal of Clinical Nutrition* 66 (1) : 38-45

Rikli R and Busch S (1986). Motor performance of women as a function of age and physical activity level. *Journal of Gerontology* 41 (5) : 645-9

Roche M and Layrisse M (1966). The nature and causes of hookworm anaemia. *American Journal of Tropical Medicine and Hygiene* 15 (6) : 1029-102

Rockwood K, Stolee P, Robertson D and Shillington ER (1989). Response bias in a health status survey of elderly people. *Age and Ageing* 18 (3) : 177-82

Rodgers WL and Herzog AR (1987). Interviewing older adults : the accuracy of factual information. *Journal of Gerontology* 42 (4) : 387-94

Roe DA (1986). Nutritional assessment of the elderly. *World Review of Nutrition and Dietetics* 48 : 85-113

Rolland-Cachera MF, Cole TJ, Semper M, Tichet J, Rossignol C, and Charraud A (1991). Body mass index variations : centiles from birth to 87 years. *European Journal of Clinical Nutrition* 45 (1) : 13-21

Rosenberg IH and Miller JW (1992). Nutritional factors in physical and cognitive functions of elderly people. *American Journal of Clinical Nutrition* 55 (6) : 1237S-43S

Rosenberg IH (1997). Sarcopenia : origins and clinical relevance. *Journal of Nutrition* 127 (suppl 5) : 990S-991S

Rosow I and Breslau N (1966). A Guttman health scale for the aged. *Journal of Gerontology* 21 (4) : 556-9

Rossman I (1979). The anatomy of aging. In : *Clinical geriatrics*. Ed. Rossman I. (2nd edition). JB Lippincott Co., Philadelphia

Roubenoff R and Kehayias JJ (1991). The meaning and measurement of lean body mass. *Nutrition Reviews* 49 (6) : 163-75

Roubenoff R and Wilson PW (1993). Advantage of knee height over height as an index of stature in the expressions of body composition in adults. *American Journal of Clinical Nutrition* 57 (5) : 609-3

Roubenoff R and Harris TB (1997). Failure to thrive, sarcopenia and functional decline in the elderly. *Clinics in Geriatric Medicine* 13 (4) : 613-22

Russell DM, Prendergast PJ, Darby PL, Garfinkel PE, Whitwell J, and Jeejeebhoy KN (1983). A comparison between muscle function and body composition in anorexia nervosa : the effect of refeeding. *American Journal of Clinical Nutrition* 38 (2) : 229-37

Russell RM (1992). Anaemia. In : *Nutrition in the elderly : The Boston Nutrition Status Survey.* Eds. Hartz SC, Russell RM and Rosenberg IH. Smith-Gordon/Nishimura, London

Rutherford OM and Jones DA (1992). The relationship of muscle and bone loss and activity levels with age in women. *Age and Ageing* 21 (4) : 286-93

Ryan SD and Fried LP (1997). The impact of kyphosis on daily functioning. *Journal of the American Geriatrics Society* 45 (12) : 1479-86

Salive ME, Cornoni-Huntley J, Phillips CL, Guralnik JM, Cohen HJ, Ostfield AM and Wallace RB (1992). Serum albumin in older persons : relationship with age and health status. *Journal of Clinical Epidemiology* 45 (3) : 213-21

Satanarayana K, Ventakarama Y and Rao SM (1989). Nutrition and work performance studies carried out in India. *Proceedings of the XIV International Congress of Nutrition, Book of Abstracts* (Seoul, Korea) : 98-9

Schade B and Apt N (1986). Aging in developing countries. In : *Aging in the eighties and beyond : highlights in the Twelfth International Congress of Gerontology.* Eds. Bergener M, Lohr U, Lang E and Scherzer RS. Springer Publisher Co., New York

Schroll M, Avlund K, Era P, Gause-Nilsson I, and Davidsen M (1997). Chronic disease and functional ability in 3 Nordic localities (NORA 75). In : *Functional status, health and aging : The NORA study.* Eds. Heikkinen E, Berg S, Schroll M, Steen B and Viidik A. Serdi Publishing Co., Paris

Schultz AB (1995). Muscle function and mobility mechanics in the elderly : an overview of some recent research. *Journal of Gerontology* 50 (special) : 60-3

Scott WK, Macera CA, Cornman CB and Sharpe PA (1997). Functional health status as a predictor of mortality in men and women over 65. *Journal of Clinical Epidemiology* 50 (3) : 291-6

Seeman TE, Charpentier PA, Berkman LF, Tinetti ME, Guralnik JM, Albert M, Blazer D and Rowe JW (1994). Predicting changes in physical performance in a high-functioning elderly cohort : MacArthur Studies of successful aging. *Journal of Gerontology* 49 (3) : M97-M108

Sengupta DK and Chakraborty AK (1982). Health status of males aged 55 and above in a slum area of Calcutta. *India Journal of Public Health* 27 (2) : 112-7

Shah S, Vanclay F and Cooper B (1989). Improving the sensitivity of the Barthel Index for stroke rehabilitation. *Journal of Clinical Epidemiology* 42 (8) : 703-9

Sharma SP and Xenos P (1992). Ageing in India : demographic background and analysis based on census materials. Office of the Registrar General and Census Commissioner, Ministry of Home Affairs, New Delhi. Occasional Paper 2.

Shetty PS (1992). City studies in nutrition : Bangalore, India. *South East Asian Journal of Tropical Medicine and Public Health* 23 (suppl 3) : 54-8

Shetty PS and James WPT (1994). Body Mass Index : a measure of chronic energy deficiency in adults. UN Food and Agriculture Organisation, Nutrition Paper 56, Rome

Shizgall HM, Vasilevsky CA, Gardiner PF, Wang WZ, Tuitt DA and Brabant GV (1986). Nutritional assessment and skeletal muscle function. *American Journal of Clinical Nutrition* 44 (6) : 761-1

Shukla HS, Ahmad MI, Shukla PK and Panda BK (1987). Preoperative nutritional assessment by handgrip dynamometry. *Indian Journal of Medical Research* 86 (Sept) : 321-8

Side X, Mingtang S, Shuquan Z, Zhaomei M, Yinzhi X, Yujun L, Jun W and Kui J (1991). Anthropometric and dietary survey of elderly Chinese. *British Journal of Nutrition* 66 (3) : 355-62

Singh RR (1998). Approach to national policy formation on ageing. *HelpAge India Research and Development Journal* 4 (2/3) : 3-9

Sinoff G and Ore L (1997). The Barthel Activities of Daily Living Index : self-reporting versus actual performance in the old-old (> 75). *Journal of the American Geriatrics Society* 45 (7) : 832-6

Siu AL, Hays RD, Ouslander JG, Osterwell D, Valdez RB, Krynski M and Gross A (1993). Measuring functioning and health in the very old. *Journal of Gerontology* 48 (1) : M10-14

Skelton DA, Greig CA, Davies JM and Young A (1994). Strength, power and related functional ability of healthy people aged 65-89 years. *Age and Ageing* 23 (5) : 371-7

Skelton DA, Young A, Greig CA, and Malbut KE (1995). Effects of resistance training on strength, power and selected functional abilities of women aged 75 and older. *Journal of the American Geriatrics Society* 43 (10) : 1081-7

Skiest DJ, Rubinstein E, Carley N, Gioilella L, and Lyons R (1996). The importance of co-morbidity in HIV infected patients over 55 : a retrospective case-control study. *American Journal of Medicine* 101 (6) : 605-11

Smith LA, Branch LG, Scherr PA, Wetle T, Evans DA, Hebert L and Taylor JO (1990). Short - term variability of measures of physical function in older people. *Journal of American Geriatrics Society* 38 (9) : 993-8

Solomons NW (1992). Nutrition and aging : potentials and problems for research in developing countries. *Nutrition Reviews* 50 (8) : 224-9

Solomons NW, Mazariegos M and Mendoza I (1993). Uses of anthropometry in the elderly in the field setting with notes on screening in developing countries. *Asia Pacific Journal of Clinical Nutrition* 2 : 15-23

Spector WD, Katz S, Murphy JB, and Fulton JP (1987). The hierarchical relationship between activities of daily living and instrumental activities of daily living. *Journal of Chronic Diseases* 40 (6) : 481-9

Spirduso WW (1980). Physical fitness, aging and psychomotor speed : a review. *Journal of Gerontology* 35 (6) : 850-65

Spitzer WO (1987). State of science 1986 : Quality of life and functional status as target variables for research. *Journal of Chronic Diseases* 40 (6) : 465-71

SPSS (1987). SPSS Inc., Chicago, USA

Spurr GB (1987). Effects of chronic energy deficiency on stature, work capacity and productivity. In : *Chronic energy deficiency : consequences and related issues*. Eds. Schurch B and Scrimshaw NS. International Dietary Energy Consultancy Group, Lausanne, Switzerland

Steele MF and Mattox JW (1987). Correlation of armspan and height in young women of two races. *Annals of Human Biology* 14 (5) : 445-7

Steele MF and Chenier TC (1990). Armspan, height and age in black and white women. *Annals of Human Biology* 17 (6) : 533-41

Steen B (1989). Body composition In : *Nutrition in the Elderly*. Eds Horwitz A, Macfadyen DM, Munro H, Scrimshaw NS, Steen B, and Williams TF. Oxford University Press/World Health Organisation, Oxford

Stone RI and Murtaugh CM (1990). The elderly population with chronic functional disability : implications for home care eligibility. *The Gerontologist* 30 (4) : 491-6

Strickland SS and Ulijaszek SJ (1993). Body mass index, ageing and differential reported morbidity in rural Sarawak. *European Journal of Clinical Nutrition* 47 (1) : 9-19

Strickland SS and Ulijaszek SJ (1994). Body mass index and illness in rural Sarawak. *European Journal of Clinical Nutrition* 48 (suppl 3) : S98 - 109

Strickland SS, Tuffrey VR, Gurung GM and Uljaszek SJ (1997). Form and Function : a study of nutrition, adaptation and social inequality in three Gurung villages of the Nepal Himalayas. Smith-Gordon and Company Ltd., London

Suboticanec K, Stavljenic A, Bilic-Pesic L, Gorajscan M, Gorajscan D, Brubacher G and Buzina R (1989). Nutritional status, grip-strength and immune function in institutionalized elderly. *International Journal for Vitamin and Nutrition Research* 59 (1) : 20-8

Sullivan DH, Patch GA, Baden AL and Lipschitz DA (1989). An approach to assessing the reliability of anthropometrics in elderly patients. *Journal of the American Geriatrics Society* 37 (7) : 607-13

Sullivan DH, Patch GA, Walls RC and Lipschitz DA (1990). Impact of nutritional status on morbidity and mortality in a select population of geriatric rehabilitation patients. *American Journal of Clinical Nutrition* 51 (5) : 749-58

Sullivan DH and Walls RC (1994). Impact of nutritional status on morbidity in a population of geriatric rehabilitation patients. *Journal of the American Geriatrics Society* 42 (5) : 471-7

Sullivan PS, Hanson DL, Chu SY, Jones JL, Ward JW and the Adult/Adolsecent Spectrum of Disease group (1998). Epidemiology of anaemia in Human Immunodeficiency Virus (HIV)-infected persons : results from the multistate adult and adolescent spectrum of HIV Disease Surveillance Project. *Blood* 91 (1) : 301-8

Syryani LK, Adnjana AK, Thong D, Manik IR, Putra DKW, Widjaja W, Tama DW and Jensen GD (1988). The physical and mental health of elderly in a Balinese village. *Journal of Cross-Cultural Gerontology* 3 : 105-20

Tabibzadeh I, Rossi-Espagnet A, and Maxwell R (1989). Spotlight on the cities - improving urban health in developing countries. World Health Organisation, Geneva

Tanner JM (1981). A history of the study of human growth. Cambridge University Press, Cambridge

Tinetti ME (1986). Performance-orientated assessment of mobility problems in elderly patients. *Journal of the American Geriatrics Society* 34 (2) : 119-26

Tinetti ME, Baker DI, McAvay G, Claus EB, Garrett P, Gottschalk M, Koch ML, Trainor K and Horwitz RI (1994 a). A multifactorial intervention to reduce the risk of falling among elderly people living in the community. *New England Journal of Medicine* 331 (13) : 821-7

Tinetti M, Mendes de Leon CF, Doucette JT and Baker DI (1994 b). Fear of falling and fall-related efficacy in relationship to functioning among community-living elders. *Journal of Gerontology* 49 (3) : M140-147

Tout K (1989). Ageing in developing countries. Oxford University Press for HelpAge International. Oxford

Trotter M and Glesser GS (1951). The effect of ageing on stature. *American Journal of Physical Anthropology* 9 : 311-24

Trotter M and Glesser GS (1958). A re-evaluation of estimation of stature based on measurements of stature taken during life and longbones after death. *American Journal of Physical Anthropology* 16 : 79-124

Tuffrey V (1994). Seasonality, anthropometric status and household welfare in rural Nepal. Ph.D. Thesis, University of London

Ulijaszek S and Lourie A (1994). Intra- and inter- observer error in anthropometric measurement. In : *Anthropometry : the individual and the population*. Eds. by Uljaszek SJ and Mascie-Taylor CGN. Cambridge University Press, Cambridge

United Nations (1979). The aging in slums and squatter settlements. New York

United Nations (1991). The world ageing situation. Centre for Social Development and Humanitarian Affairs. Vienna, New York

United Nations (1992). Second report of the world nutrition situation. Eds. Garcia PA and Mason J. UN Administrative Committee on Coordination / Subcommittee on Nutrition

UNAIDS (1996). The status and trends of the global HIV/AIDS pandemic. Satellite Symposium July 5-6 1996. UNAIDS/AIDSCAP/Francois-Xavier Bagnond Center for Health and Human Rights of the Harvard School of Public Health. Geneva

UNAIDS (1998). HIV threatens progress against worsening global tuberculosis epidemic. Press Release. Geneva : March 23

Vandervoort AA, Kramer JF, and Wharram ER (1990). Eccentric knee strength of elderly females. *Journal of Gerontology* 45 (4) : B125-128

Van Staveren WA, Van der Wielen RPJ, Dirren H, and Burema J (1995). Serum albumin and dietary protein in the Euronut SENECA project. In : *Nutritional assessment of elderly populations : Measure and function.* : Ed. Rosenberg IH. Raven Press, New York

Vaz M, Thangam S, Prabhu A and PS Shetty (1996). Maximal voluntary contraction as a functional indicator of adult chronic undernutrition. *British Journal of Nutrition* 76 (1) : 9-15

Vellas BJ, Garry PJ and Abarede JL (1992 a). Diseases and aging : patterns of morbidity with age, relationships between aging and age-associated diseases. *American Journal of Clinical Nutrition* 55 (suppl 6) : 1225S-1230S

Vellas BJ, Baumgartner RN, Wayne SJ, Conceico J, Lafont C, Albarede JL, and Garry PJ (1992 b). Relationship between malnutrition and falls in the elderly. *Nutrition* 8 (2) : 105-8

Vespa J and Watson F (1995). Who is nutritionally vulnerable in Bosnia-Hercegovina ? *British Medical Journal* 311 (Sept 9) : 652-4

Visser M, van den Heuvel and Deurenberg P (1994). Prediction equations for the estimation of body composition in the elderly using anthropometric data. *British Journal of Nutrition* 71 (6) : 823-33

Visser M, Harris TB, Langlois J, Hannan MT, Roubenoff R, Felson DT, Wilson DT, and Kiel DP (1998). Body fat and skeletal muscle mass in relation to physical disability in very old men and women of the Framingham Heart Study. *Journal of Gerontology* 53 (3) : 1214-21

Wahlqvist ML, Lukito W and Hsu-Hage B.H-H (1994). Nutrition and ageing in development. In : *Nutrition in the Nineties : Policy Issues*. Eds. Biswas MR and Gabr M. Oxford University Press and World Health Organisation, New Delhi

Wallace RB and Rohrer JE (1990). Aging, quantitative health status assessment and the effectiveness of medical care. In : *Improving the Health of Older People : A World View* Eds. Kane RL, Grimley Evans J and Macfadyen D. Oxford University Press and World Heath Organisation, New York

Wallace JI, Paauw DS and Spach DH (1993). HIV infection in older patients : when to expect the unexpected. *Geriatrics* 48 (6) : 69-70

Webb AR, Newman LA, Taylor M, and Keogh JB (1989). Hand grip dynamometry as a predictor of postoperative complications reappraisal using age standardized grip strengths. *Journal of Parenteral and Enteral Nutrition* 13 (1) : 30-3

Weinberg CR (1993). Toward a clearer definition of confounding. *American Journal of Epidemiology* 137 (1) : 1-8

Weiner JS and Lourie JA (1981). Human Biology : a guide to field methods. International Biological programme. IBP Handbook no. 9. Blackwell Scientific Publications, Oxford-Edinburgh

Wiener JM, Hanley RJ, Clark R and van Nostrand JF (1990). Measuring activities of daily living : comparisons across national surveys. *Journal of Gerontology* 45 (6) : S229-237

Wickham C, Cooper C, Margetts BM and Barker DJP (1989). Muscle strength, activity, housing and the risk of falls in elderly people. *Age and Ageing* 18 (1) : 47-51

Wigzell FW, Alam AK, Maclennan WJ and Hamilton JC (1981). Osteomalacia and kyphosis. *Journal of Clinical and Experimental Gerontology* 3 (2) : 161-73

Williams ME, Hadler NM and Earp JAL (1982). Manual ability as a marker of dependency in geriatric women. *Journal of Chronic Diseases* 35 (2) : 115-22

Williams ME and Hornberger JC (1984). A quantitative method of identifying older persons at risk for increasing long term care services. *Journal of Chronic Diseases* 37 (9/10) : 705-11

Williams ME, Gaylord SA and Gerritty MS (1994). The timed manual performance test as a predictor of hospitalization and death in a community-based elderly population. *Journal of American Geriatrics Society* 42 (1) : 21-7

Williams R and Boyce WT (1989). Protein malnutrition in elderly Navajo patients. *Journal of the American Geriatric Society* 37 (5) : 397-406

Williams TF (1992). Serum albumin, aging and disease. *Journal of Clinical Epidemiology* 45 (3) : 205-6

Wolfson L (1992). Gait and mobility. In : *Oxford Textbook of Geriatric Medicine*. Eds. Grimley Evans J and Franklin Williams T. Oxford University Press, Oxford

Wolfson L, Judge J, Whipple R and King M (1995). Strength is a major factor in balance, gait and the occurrence of falls. *Journal of Gerontology* 50 (A) : 64-7

Woo J, Ho SC, Donnan SP and Swaminathan R (1988). Nutritional status of healthy, active Chinese elderly. *British Journal of Nutrition* 60 (1) : 21-8

Woo J, Ho SC, Yuen YK, Yu LM and Lau J (1996). An estimation of the functional disability burden in elderly Chinese aged 70 years and over. *Disability and Rehabilitation* 18 (12) : 609-12

World Bank (1994). Averting the old age crisis. Oxford University Press Inc., New York

World Health Organisation, WHO (1972). Nutritional anaemia. Technical Report Series 3, Geneva

World Health Organisation, WHO (1980). International classification of impairments, disabilities and handicaps (ICIDH). Geneva

World Health Organisation, WHO (1995). Physical status : the use and interpretation of anthropometry. Technical Report Series 854, Geneva

Yassin Z and Terry RD (1991). Anthropometric characteristics of rural elderly females in Malaysia. *Ecology of Food and Nutrition* 26 : 109-17

Yates FE, Benton LA and Beck JC (1993). Risk assessment and early detection of functional declines. In : *Aging, health and competence*. Ed. Schroots JJ. Elsevier Science Publishers, Amsterdam

Yesudian CA (1988). Utilization of health services by the urban poor (a study of the Naigaum Maternity Home Health Post area). Tata Institute of Social Sciences/WHO, Bombay

Yip R, Johnson C, and Dallman PR (1984). Age-related changes in laboratory values used in the diagnosis of anemia and iron deficiency. *American Journal of Clinical Nutrition* 39 (3) : 427-36

Young A, Stokes M and Crowe M (1984). Size and strength of quadriceps muscles of young and old women. *European Journal of Clinical Investigation* 14 : 282-7

Young A (1986). Exercise physiology in geriatric practice. *Acta Medica Scandinavica* : 711 (suppl) : 227-32

Young A (1992). Strength and power. In : *Oxford Textbook of Geriatric Medicine*. Eds. Grimley Evans J and Franklin-Williams T. Oxford University Press, Oxford

Young A and Skelton DA (1994). Applied physiology of strength and power in old age. *International Journal of Sports Medicine* 15 : 149-51

Zimmer AW, Calkins E, Hadley E, Ostfield AM, Kaye JM and Kaye D (1985). Conducting clinical research in geriatric populations. *Annals of Internal Medicine* 103 (2) : 276-83

APPENDICES

APPENDIX 1 (a) Ethical permission documentation from the LSHTM

LONDON SCHOOL OF HYGIENE AND TROPICAL MEDICINE

LONDON SCHOOL OF HYGIENE & TROPICAL MEDICINE

Application Number ..223..
(To be added by the Secretary)

FORM A

ETHICS COMMITTEE
APPLICATION TO CONDUCT A STUDY INVOLVING HUMAN SUBJECTS

This form should be completed, signed by the Principal Investigator and Head of Department, and returned to Phoebe Roome, Personal Assistant to the Dean, LSHTM, Keppel Street, London WC1E 7HT.

Name of Principal Investigator ....DR SURAIYA ISMAIL........

Appointment held ...SENIOR LECTURER........ Date ..Feb. 5, 1993........

Other Personnel involved ....MARY MARLOW/RESEARCH FELLOW/PROJECT COORDINATOR......

Title of project ......"ASSESSING ELDERLY MALNUTRITION"........

........(A COLLABORATIVE PROJECT WITH HELP THE AGED UK)........

....

I approve this project scientifically and ethically.

...............[signature]...............
(Signature of Head of Department)

Date ......8/2/93..............

==

I have read the attached application and assign it to category I II (III)

...............[signature]...............
(Signature of Chairman or designate)

Date ....12.2.93........

APPENDIX 1 (b) Ethical permission documentation from the KEM Hospital

BIOMEDICAL GERONTOLOGY CENTRE OF HELPAGE INDIA

BGCHI

QUTAB INSTITUTIONAL AREA NEW DELHI-110 016 INDIA PHONES 6865675, 6867697, 6868323 FAX 011-91-11-6852916 (9-17 THRS IST)
MENT OF PHARMACOLOGY SETH G.S MEDICAL COLLEGE PAREL, BOMBAY-400 012 PHONE 4136051 to 59 EXTN 14 GRAM GOSUMEC

B.G.C.H.I/8/93
23-3-93

Date : 23/3/93

Chair person,
Ethics Committee
Seth G.S.Medical College
& K.E.M. Hospital,
BOMBAY- 400 012.

Sub : Biomedical Gerontology Project of Helpage India.

Madam,

This is to inform you that the B.G.C.H.I. has been conducting studies in elderly subjects for which the permission of the ethics committe was obtained in July 1991.

It is now proposed to study the nutritional aspect of the elderly in the same group of subjects who are being monitored by the B.G.C.H.I., where various Physical anthropometric measurements Viz. height, weight, skinfold thickness, armspan, knee height, arm & calf circumferences etc. will be carried out on the elderly in the community.

Pharmac/96/93
29-3-93

Forwarded to Chairperson
Ethics Committee.
- Gupta
23/3/93

Mrs. P.S.Anklesaria.
PROJECT CO- ORDINATOR

29393

APPENDIX II

PROJECT PROTOCOL

English version : Marathi language translation used in the field

1. Introduction and Informed Consent
2. Background questionnaire and coding
3. ADL and mobility questionnaire and coding
4. Instructions and coding for physical performance tests

Procedural instructions and coding for field staff are given in italicised font

NUTRITION PROJECT
BIOMEDICAL GERONTOLOGY CENTRE OF HELPAGE INDIA (BGCHI)
Department of Pharmacology
Seth G.S. Medical College and K.E.M. Hospital, Parel, Bombay

1. INTRODUCTION AND INFORMED CONSENT

"Thank you for coming here and spending some of your time with us.

We are Field Workers from the BGCHI at KEM Hospital. The BGCHI has been working in this community for over a year, conducting health examinations and referring people to the hospital for follow-up care and treatment. We are now adding nutritional assessment and taking some physical measurements.

This examination will take about 30 minutes. We will start by asking you some general questions about general health, memory and daily activities and then do some easy physical tests which assess your strength, mobility, flexibility, balance and coordination. Then lastly we will take some measurements of your body size, fat and muscle to assess your nutritional status.

Before we begin, we would like you to tell us whether or not you understand why we are here and that you agree to take part in the BGCHI Nutrition Project.

Do you understand what we are doing and do we have your consent to continue ?"

Ask for signature/thumb print on Informed Consent Form

1. Name

2. BGCHI Identification Number

3. Address

4. Age

1 ...... Self reported age

2 ...... Age at Independence / dock explosion / riots

3 ...... Age at marriage

4 ...... Age of eldest survivingchild

5 ...... Age at birth of first child

2. BACKGROUND QUESTIONNAIRE AND CODING

Cognitive screen

5. Can you tell me what day it is today ?

1	*Incorrect or confused, don't know*	*2*	*Eventual correct response*
3	*First correct response*	*9*	*Refuse to answer, no answer*

6. Can you tell me what month it is now ?

1	*Incorrect or confused, don't know*	*2*	*Eventual correct response*
3	*First correct response*	*9*	*Refuse to answer, no answer*

7. Can you tell me who is the Prime Minister of India now ?

1	*Incorrect or confused, don't know*	*2*	*Eventual correct response*
3	*First correct response*	*9*	*Refuse to answer, no answer*

8. Who was the Prime Minister before him ?

1	*Incorrect or confused, don't know*	*2*	*Eventual correct response*
3	*First correct response*	*9*	*Refuse to answer, no answer*

Self-reported Health

9. How healthy are you ?

1	*Very poor health*	*2*	*Moderately healthy, not very ill*
3	*Very healthy*	*9*	*Refuse to answer, no answer*

Disability Screen

10. Have you had any surgery or an injury, or disability onset within the last 6 months ? Have you recently had any other health problem that is preventing you from standing up from a chair or walking ?

1	*Yes, major, severely affects functional ability, cannot perform tests*
2	*Yes, but minor, not severely affecting functional ability, or ability to perform tests*
3	*No*
9	*Refuse to answer, no answer*

3. ADL AND MOBILITY QUESTIONNAIRE AND CODING

"Now we are going to ask you some questions about your ability to do basic daily activities in and around your home during the last week. We need to know whether you are able to perform a task by youself, requiring a little help to do a task, requiring a lot of help to do a task, or need constant help. Independence means without supervision, direction, or active personal assistance".

Remember these are used as a record of what a person DOES, not a record of what a patient COULD DO. The main aim is to establish a degree of independence from any help, however minor and for whatever reason. The need for supervision means that a person in NOT independent.. Middle category 2 implies that the person supplies over 50% of the effort.

11. Continence

Can you control your defecation ? Can you control your urination ? Do you find that you are unable to get to the toilet in time or that you have been leaking ?

1 *Total incontinence in urination and defecation*
2 *Partial or occasional incontinence in urination and/or defecation*
3 *Urination and defecation entirely self-controlled*

12. Ability to use the toilet independently

In the last week, have you been able to get from your home to the toilet independently, by yourself without a helper ? To get to the toilet do you use any support such as a walking stick, crutches or wheelchair ? (At night this may be management of bedpan by self) Do you require assistance, such as a member of your family to help you ? Can you undress sufficiently yourself, get down to squat and up again, clean yourself afterwards, and return ? Or do you always use a bedpan (potty, bucket, bowl etc) for all your toileting ?

1 *Cannot reach the toilet unless assisted, cannot undress, squat down, clean self unassisted, rise up and the and leave toilet. If does not go out of the home, cannot use home toilet (pan, bowl, bucket) unassisted.*
2 *Receives some assistance in some of the tasks, either getting to and from, undressing, squatting, cleaning self. Can do some things alone or only needs help sometimes*
3 *Independent, can perform all tasks by self*
9 *Refuse to answer/did not co-operate*

13. Feeding

In the last week, have you been able to eat normal food, not just soft or liquid food ? (This can be food cooked and served by others but not cut up). Has someone put food into your mouth for you? Or have you been able to do take food from your plate by yourself ?

1	*Assistance in all aspects of feeding, cutting up and putting in mouth, wiping etc., does not eat or uses feeding by tube*
2	*Some assistance in feeding, cutting up but not all the time and not for all foods*
3	*Totally able to feed self and eat normal food*
9	*Refuse to answer/did not co-operate*

14. Transfer

Do you usually manage to get up and down from the floor on your own ? Do you find it easy or difficult to do this on your own ? In the last week, have you been able to move around the house i.e. from floor to standing, to bed or chair, by yourself or has someone been helping you ? If you need help, normally how many people help you ? Who are they ? Are you able to sit without support ?

1	*Person needs total assistance in moving in and out of bed/floor and/or chair, cannot move by self without being lifted or held by one or two people, and cannot sit unsupported*
2	*Person needs some assistance in moving in and out/off floor/bed to chair, may be guided or supported for safety but is not totally lifted, can sit unsupported*
3	*Can move between floor, bed, chair totally independently and sit unsupported*
9	*Refuse to answer/did not cooperate*

15. Dressing

In the last week, have you been able to dress yourself (e.g wrapping sari, pulling on blouse, tying strings of petticoat, fastening buttons, pulling vest/ganjifrock/banyan on and off etc), independently or do you require assistance ? If you require assistance is this for all your dressing or for about half ? Do you select your own clothes ? Are all your clothes normal or have you made any adaptations to them to make dressing easier ?

1	*Cannot dress self at all, may remain partially undressed*
2	*Needs assistance with some aspects of dressing, help with buttons, laces but can put some garments on alone*
3	*Independent, can choose all clothes by self, take on and off by self and perform all details*
9	*Refuse to answer/did not co-operate*

16. Bathing

Where do you go to wash ? (outside tap or in the home). In the last week, have you been able to wash your body fully and without assistance ? Or are you only able to wash a part of your body without help ? If you had assistance, who helped you and what did they do ?

1 *Requires direct assistance and supervision of all bathing activities*
2 *Can perform some aspects without assistance but for safety is often directly assisted, or can only wash part of body by self and not full body*
3 *Can bathe completely alone*
9 *Refuse to answer/did not co-operate*

SELF REPORTED GROSS MOBILITY

17. Stairs

Can you get up and down stairs ? By yourself ? Easily ?

1 *No, not at all*
2 *Yes, but with difficulty/slowly/with helper/only infrequently*
3 *Yes, easily, frequently, (can use a walking aid)*
9 *Refuse to answer/did not co-operate*

18. Walk half a mile

Can you walk about half a mile ? I kilometre ?

1 *No*
2 *Yes, but only with difficulty/slowly/with helper/only infrequently*
3 *Yes, easily, frequently (can use a walking aid)*
9 *Refuse to answer/did not co-operate*

19. Ability to travel

Can you get to places outside of walkking distance ? If so, how do you travel ? Bus, train, tempo, lorry, bicycle ? Can you travel alone ?

1 *Unable to travel unless emergency arrangements are made*
2 *Only with help such as an assistant/slowly/only infrequently or if really necessary*
3 *Yes, easily, frequently, can travel alone if necessary (can use a stick)*
9 *Refuse to answer/did not co-operate*

OBSERVED GROSS MOBILITY

20. Observation of movements during interview and tests *(don't need to ask questions)*

Is the patient immobile and bedridden, not able to move around at all ? Or does the patient walk very slowly and with difficulty, with or without an aid or helper ? Or can the patient walk easily and without either aid or helper ?

1 *Unable to move (note main cause as disability/amputation/stroke/severe injury/recent illness. Bedridden, cannot stand or walk without constant supervision or assistance*

2 *Can stand and walk but sometimes needs assistance for some manoeuvres. Movement is slow, stiff and apparently painful. Uses walking aid such as stick or crutches used all the time and other support such as wall used*

3 *Is fully mobile with no apparent restrictions*

4. INSTRUCTIONS AND CODING FOR PHYSICAL PERFORMANCE TESTS

"As you know, certain movements of your body become more difficult to do as you grow older. We would now like you to try to do several different movements of your body that involve your fingers, arms and your legs. I will first describe each movement to you. Then either I or my assistant will demonstrate it to you. Then we would like you to try and do it too. If you cannot do a particular movement or you feel it would be unsafe to try to do it, then tell me and we will move on to the next test instead. We would like you to try each exercise if you can. But we don't want you to try to do anything that might make you feel unsafe, in pain or uncomfortable. Do you understand ? This first exercise is a test of your memory."

21. Object Recall Test (Short-term Memory)

Present the tray covered with 15 objects. Make sure they are all present and in a neat arrangement (larger objects at the back of the tray) and that you always place the objects in the same position. Make sure you have the list of objects ready for recall later.

"Please look carefully at the 15 objects on this tray and try and remember them. The objects are all every day objects that should be very familiar to you. You can pick them up or name them out loud if that helps you to remember them. I do not want you to recall them straight away but only after some time. Later on we will ask you to recall them for us. We will give you 1 minute, starting from now".

Time for 1 minute. Then cover tray and keep tray out of sight

Code result as either :

.... Number of objects recalled

8 Could not perform (e.g. visual handicap)
9 Refused/did not co-operate

22. Lock and Key Test (Manual Dexterity)

"Next we will be looking at your hand function by asking you to pick up a key and open a lock. Show me which hand you would normally use to hold a key to open a lock. You may use your other hand to steady the lock but not to hold the key or help you turn the lock. I will hold the lock like this. I want you to pick up the key and put it in the lock, like this"

Demonstrate procedure

"Although I will be timing you, I would like you to move carefully and smoothly, trying not to drop the key. Do you have any questions ? Good. When I say start, please begin."

Time the subject : from picking up the key to opening the lock.. Begin timing as soon as the subject moves hand towads the key. End timing when the key has been turned to lock the padlock. If first attempt is not satisfactory, then repeat.

Code result as either :

.... Time to open lock in seconds *(record time as 0 for those unable to perform due to disability/ amputation/ painful arthritis)*
9 *Refused/did not co-operate*

23. Internal and External Shoulder Rotations (Flexibility)

"Next, I would like to see how strong and flexible your shoulders and arms are. But first do you have pain at night and stiffness in the morning ? Do you have difficulty, because of pain and stiffness, with combining the hair or with scratching your back ? Now I want you to watch my partner do two exercises and then could you try and copy them"

Demonstrate both first and then repeat each with the subject

(a) External shoulder rotation :

"I'd like you to put both hands behind your neck at the level of your ears. Keep your arms parallel to the floor and point your elbows out to the side"

CHECK : Subject should be standing. Head erect. Each hand placed behind the neck at ear level, fingers touching or overlapping ; forearms straight and parallel to the floor and elbows pointing out away from ears.

Code result as either :

1 *Unable (note cause as disability/ amputation/ painful arthritis). Cannot perform any of the components of the movement*
2 *Partially able. Fingers do not touch together, foreams not parallel to the floor or elbows not pointing out to the side, or hand not held behind neck*
3 *Fully able*
9 *Refused/did not cooperate*

(b) Internal shoulder rotation :

"Next I'd like you to move your arms behind your back and touch your fingers together behind your back"

CHECK : Subject should be standing. Each hand is placed behind the back at waist level or higher (in the small of the back) with fingers touching in the middle of the back near the spine.

Code result as either :

1 *Unable Cannot reach past the side of the body*
2 *Partially able. Arms moved round to the back of the trunk but fingers cannot touch at waist level, or unable to reach sufficiently around to back of trunk so that hand is placed in the middle of the back near the spine*
3 *Fully able*
9 *Refused/did not cooperate*

24. Repeated Chair Stands (Lower Body Strength)

"The next test measures the strength in your legs"

Place the back of the chair against a wall if possible to steady it. Stand next to the subject to provide assistance if he/she loses her balance. Subject should be seated so that feet touch the floor if possible.

"First would you please sit down and fold your arms across your chest. Move forward in the chair without using your arms so that you are sitting about half-way toward the front of the seat. Now stand up once if you can without using your arms to push you up."

Subject performs Single Chair Stand. Walking aids such as canes and crutches should not be used.

"Did you have any problems with doing that ? Did it hurt your knees or legs at all ? Do you think you could do five of these for me, one after the other, and as fast as you can ? I will be timing you but you just do as many stands as you can. Remember that if you feel unsafe or in any pain then you stop whenever you like and we will go on to the next test. Please sit down again with your arms folded ane come halfway up the chair. Ready...Go"

Start timer on the word GO. Count out the numbers for the subject. Stop the timer when he/she sits down after five stands. Allow subject to rest a little.

Code result as either

.... *Time in seconds (record time as 0 for those unable to perform due to disability/ amputation/ painful arthritis)*
9 *Refused/did not cooperate*

25. Plate-Tapping Test (Psychomotor Skill and Co-ordination)

If possible, adjust the table legs / top so that the table top is just below the umbilical level.

"Stand in front of the table in front of the middle shape with your feet slightly apart. Place your non-preferred hand on the rectangle in the middle and keep it there all the time. Place your preferred hand on one of the circles. You will move your preferred hand back and forward between the two outside circles as quickly as possible. You must pass each time over the hand staying still in the centre. Be sure to touch the middle of the outer circles properly each time. If you miss the middle of these, we will not count that lap.

When I say READY, move your preferred hand to one of the circles and when I say GO move your preferred hand back and forth as quickly as possible 25 times. Do not stop until I say STOP. Try and keep going till you have done 25, even if this is slow. You do not need to count. I will shout out the numbers for you. You will do this test once now and once a little later. Your faster time will be your score. OK. READY. START."

Start the stopwatch at the signal "ready...start". Assuming the subject starts on disc A, the stopwatch is stopped when he/she touches this disc for the twenty fifth time. Thus the total number of taps on disc A and disc B amounts to 50 taps, or 25 cycles between A and B.

"Remember that the hand on the rectangular plate has to stay there during the entire test".

Take two trials and allow a rest in between (Hand Dynamometry). The better result is the score. The score is the time needed to touch the disc a total of 25 times, recorded in tenths of seconds. If the subject fails to touch a disc, an extra tap is added in order to reach the required 25 cycles.

Record Plate-Tapping time(fastest of two attempts, second one after handgrip test)

Code result as either

.... *Time in seconds (record time as 0 for those unable to perform due to disability/ amputation/ painful arthritis)*
9 *Refused/did not cooperate*

26. Handgrip Dynamometry (Handgrip Strength)

We will measure both the dominant or preferred hand (the one the subject normally uses), and the non-dominant non-preferred hand and repeat the test three times on each. This allows the technique to become familiar and the subject to be given several chances to improve the reading. One last attempt on the preferred hand is also given.

"This test is going to measure your grip strength. First, bend your arm so that the forearm is resting across your stomach in a relaxed position. Then place your hand in the machine to make sure it is the right size for your hand. Does that feel comfortable ?"

Subject should be sitting. Sit opposite the subject and first explain what the instrument is and what it measures. Demonstrate the holding position and how to grip. Place the loop over the subject's head and arm and hand in correct position lying across the lap and against the trunk. the wrist should be in about 15 degrees of extension. Place hand in the instrument and adjust for size. The second joint of the forefinger should be approximately at a right angle.

"Now you are to squeeze the handle as hard as you can just for a few seconds. You must try your very best by concentrating on squeezing with all your strength. We will repeat this three times on both hands and then let you have one last try on your preferred hand."

Take — *3 readings on the dominant hand*
3 readings on the non-dominant hand
1 last reading on the dominant hand (this is usually the highest)

Give a lot of verbal encouragement to the subject (calling, clapping, shouting etc.). Let the subject see their results on the dial before you move the pointer back to 0 each time.

Record all results

Enter result

.... *Largest kgs (record as 0 for those unable to perform due to disability/ amputation/ painful arthritis)*
9 *Refused/did not cooperate*

Repeat plate-tapping (second try)

"Now we would like you to repeat the tapping test again for us. We are sure you can do it faster than the last one so let's see you really speeding it up. But remember to keep this hand in the middle and only the other hand crosses over as fast as possible. Be sure to touch the two red circles clearly. Twenty five times again. Are you ready (SET TIMER). GO"

Object memory recall

"A few minutes ago, we showed you a tray with 15 everyday objects. We gave you a minute to look at these and asked you to remember what objects were on the tray. Do you remember this ? Now we want you to see how many of the objects that you saw you can remember. Just call them out to me when I ask you to start. Again we are going to give you 1 minute to recall the objects on the tray. Are you ready ?"

> *This is the end of the functional ability tests. Put the equipment away and prepare for the anthropometric measurements. Make sure that all your anthropometric equipment is ready and that you have the right data form before beginning.*

APPENDIX III : Reliability statistics for anthropometric measurements
(for period mid-way through fieldwork)

Inter-observer	MEN			WOMEN		
	Mean	TEM	R	Mean	TEM	R
Weight (kg)	37.4	0.1	1	45.7	0.1	0.99
Height (cm)	162.0	0.2	0.99	154.5	0.3	0.99
Armspan (cm)	171.8	0.4	0.99	161.3	0.3	0.97
MUAC (cm)	23.9	0.3	0.99	22.3	0.1	0.98
Calf circumf (cm)	31.7	0.2	0.99	24.2	0.2	0.98
Triceps skinfold (mm)	9.6	0.3	0.97	11.1	0.4	0.91

Intra-observer	MEN			WOMEN		
	Mean	TEM	R	Mean	TEM	R
Weight (kg)	54.6	0.1	0.99	48.8	0.0	1
Height (cm)	158.7	0.1	0.99	150.4	0.2	0.99
Armspan (cm)	168.7	0.2	0.99	157.0	0.3	0.99
MUAC (cm)	22.6	0.2	0.99	19.5	0.3	0.98
Calf circumf (cm)	30.4	0.1	0.99	26.9	0.3	0.97
Triceps skinfold (mm)	8.4	0.4	0.93	11.0	0.4	0.93

TEM = Technical Error of Measurement
R = Coefficient of Reliability

APPENDIX IV

LOGISTIC REGRESSION MODELLING RESULTS

USING AGE AS A CONTINUOUS VARIABLE

APPENDIX IV (a)

Logistic regression results using age as a continous variable - MEN

OUTCOME Functional ability dimension	n (able : unable)	EXPOSURE Nutrition indicator / confounder	ODDS RATIO (95% C.I.)	p-value
Handgrip strength	387 (281 : 106)	**Undernutrition (BMI)**	**3.4024 (2.0996-5.5136)**	**.0000**
		Age	1.0774 (1.0454-1.1114)	.0000
		Undernutrition (MUAC)	***4.3518 (2.6568-7.1281)***	***.0000***
		Age	*1.0692 (1.0365-1.1029)*	*.0000*
Leg strength	387 (285 : 102)	Hypoalbuminaemia	2.5234 (1.1627-5.4763)	.0217
		Kyphosis	1.8820 (0.9859-3.5926)	.0490
		Age	1.0400 (1.0081-1.0729)	.0133
Psychomotor skill	387 (284 : 103)	Neurological disease	4.6187 (1.8928-11.2704)	.0008
		Kyphosis	3.1036 (1.6265-5.9220)	.0007
		Age	1.0387 (1.0063-1.0722)	.0182
Manual dexterity	393 (292 : 101)	Age	1.0463 (1.0162-1.0772)	.0024
Flexibility	393 (365 : 28)	Hypoalbuminaemia	3.0455 (1.0629-8.7258)	.0582
Toilet use	393 (251 : 142)	Neurological disease	3.7914 (1.5297-9.3971)	.0030
		Kyphosis	3.1799 (1.7106-5.9113)	.0002
		Musculoskel disease	2.1609 (1.3887-3.3625)	.0006
Dressing	393 (384 : 9)	Minor morbidity	4.4297 (0.8711-22.5265)	.0476
		Age	1.1195 (1.0434-1.2011)	.0025
		Undernutrition (MUAC)	***5.6033 (1.3070-24.0209)***	***.0165***
		Minor morbidity	*4.8828 (0.9541-24.9887)*	*.0361*
		Age	*1.1115(1.0331-1.1957)*	*.0051*
Bathing	393 (384 : 9)	Minor morbidity	6.1288 (1.0827-34.6921)	.0222
		Undernutrition (BMI)	**5.9635 (1.2029-29.5640)**	**.0198**
		Age	1.1851 (1.0895-1.2890)	.0000
		Undernutrition (MUAC)	***10.7737 (2.001-58.0324)***	***.0020***
		Minor morbidity	*5.4587 (0.9963-29.9078)*	*.0316*
		Age	*1.1586 (1.0691-1.2557)*	*.0002*
Transfer	393 (216 : 177)	Kyphosis	2.7370 (1.4617-5.1251)	.0013
		Neurological disease	2.5041 (1.0159-6.1726)	.0405
		Musculoskel disease	2.2452 (1.4637-3.4441)	.0002
ADL's (6 tasks)	393 (361-32)	Age	1.0809 (1.0369-1.1268)	.0003

- ctd -

APPENDIX IV (a) continued

Logistic regression results using age as a continous variable - MEN

OUTCOME Functional ability dimension	n (able : unable)	EXPOSURE Nutrition indicator / confounder	ODDS RATIO (95% C.I.)	p-value
Walk half mile	393 (215 : 178)	Kyphosis	3.1383 (1.5734-6.2596)	.0008
		COPD	2.5639 (1.3216-4.9742)	.0046
		Hypoalbuminaemia	2.3340 (1.0378-5.2493)	.0373
		Drinking alcohol	1.9606 (1.2450-3.0873)	.0034
		Age	1.0429 (1.0115-1.0753)	.0064
		Kyphosis	*2.7226 (1.3450-5.5111)*	*.0042*
		COPD	*2.3246 (1.1966-4.5159)*	*.0114*
		Drink	*1.8387 (1.1712-2.8868)*	*.0078*
		Undernutrition (MUAC)	***1.6653 (1.0276-2.6987)***	***.0386***
		Age	*1.0458 (1.0146-1.0780)*	*.0032*
Climb stairs	393 (121 : 272)	Kyphosis	5.9459 (2.0851-16.9555)	.0000
		Major morbidity	1.9896 (1.1298-3.5037)	.0135
Travel	388 (328-60)	Kyphosis	3.3001 (1.6185-6.7286)	.0015
		Anaemia	2.0822 (1.090-3.9743)	.0294
		Age	1.0829 (1.0421-1.1252)	.0000
	393 (332-61)	***Undernutrition (MUAC)***	***2.6571 (1.4184-4.9779)***	***.0026***
		Kyphosis	*2.6277 (1.2518-5.5159)*	*.0128*
		Age	*1.0890 (1.0479-1.1317)*	*.0000*
Mobility (3 tasks)	393 (337 : 56)	Kyphosis	2.9980 (1.4348-6.2645)	.0045
		Undernutrition (BMI)	**2.1879 (1.1481-4.1692)**	**.0168**
		Age	1.1003 (1.0568-1.1456)	.0000
		Undernutrition (MUAC)	***2.7375 (1.4241-5.2624)***	***.0028***
		Kyphosis	*2.6235 (1.2252-5.6177)*	*.0156*
		Age	*1.0958 (1.0530-1.1404)*	*.0000*

APPENDIX IV (b)

Logistic regression results using age as a continous variable - WOMEN

OUTCOME Functional ability dimension	n (able : unable)	EXPOSURE Nutrition indicator / confounder	ODDS RATIO (95% C.I.)	p-value
Handgrip strength	523 (367:156)	**Undernutrition (BMI)**	**2.3734** (1.5851-3.5538)	.0000
		Recent disabil/surgery	2.2526 (1.0384-4.8864)	.0411
		Anaemia	1.5418 (1.0211-2.3281)	.0388
		Age	1.0752 (1.1472-1.1038)	.0000
		Undernutrition (MUAC)	*3.3800 (2.2360-5.1093)*	*.0000*
		Recent disabil/surgery	*2.4907 (1.1815-5.6807)*	*.0182*
		Age	*1.0732 (1.0455-1.1017)*	*.0000*
Leg strength	524 (380:144)	Recent disabil/surgery	2.8491 (1.3281-6.1117)	.0083
		Kyphosis	2.2943 (1.3687-3.8459)	.0018
		Anaemia	1.6014 (1.0520-2.4379)	.0273
		Age	1.0592 (1.0306-1.0886)	.0000
Psychomotor skill	531 (392:139)	*Minor morbidity*	*1.8013 (1.1837-2.7412)*	*.0058*
		Undernutrition (MUAC)	*1.5576 (1.0234-2.3707)*	*.0384*
		Age	*1.0958 (1.0666-1.1258)*	*.0000*
Manual dexterity	524 (385:139)	*Kyphosis*	*1.7913 (1.0659-3.0106)*	*.0294*
		Undernutrition (MUAC)	*1.6619 (1.1011-2.5085)*	*.0154*
		Anaemia	*1.6281 (1.0706-2.4759)*	*.0219*
		Age	*1.0434 (1.0156-1.0720)*	*.0020*
Flexibility	531 (451:80)	TB	3.5501 (1.1834-10.6500)	.0331
		Kyphosis	2.1679 (1.2078-3.8914)	.0112
		Age	1.0862 (1.0527-1.1208)	.0000
Toilet use	531 (276: 255)	Age	1.1002 (1.0713-1.1298)	.0000
Dressing	525 (515 : 10)	Hypoalbuminaemia	7.3945 (1.9648-27.8291)	.0051
		Age	1.1249 (1.0514-1.2037)	.0008
Bathing	525 (507 : 18)	Hypoalbuminaemia	6.5399 (2.3724-18.0285)	0007
		Age	1.0984 (1.0428-1.1571)	.0006
Transfer	531 (208 : 323)	COPD	3.0765 (1.1601-8.1585)	.0161
		Musculoskel disease	1.9694 (1.3495-2.8740)	.0004
		Age	1.1023 (1.0704-1.1352)	.0000
ADL (6 tasks)	524 (455 : 69)	Anaemia	1.8149 (1.0232-3.2190)	.0379
		Age	1.1017 (1.0676-1.1369)	.0000

- ctd -

APPENDIX IV (b) continued

Logistic regression results using age as a continous variable - WOMEN

OUTCOME Functional ability dimension	n (able : unable)	EXPOSURE Nutrition indicator / confounder	ODDS RATIO (95% C.I.)	p-value
Walk half mile	524 (195 : 329)	COPD	3.5398 (1.1952-10.4834)	.0100
		Recent disabi/surgery	2.6106 (1.0440-6.5282)	.0267
		Anaemia	1.4747 (1.0178-2.1367)	.0399
		Age	1.0390 (1.0126-1.0661)	.0027
Climb stairs	531 (78 : 453)	Musculoskel disease	1.8475 (1.1044-3.0906)	.0188
		Age	1.0493 (1.0115-1.0885)	.0063
Travel	524 (195 : 329)	Recent disabil/surgery	2.4704 (0.9883-6.1750)	.0373
		Anaemia	1.5133 (1.0483-2.1847)	.0268
		Age	1.0393 (1.0132-1.0662)	.0022
Mobility (3 tasks)	531 (319 : 212)	Recent disabil/surgery	2.9078 (1.3435-6.2934)	.0055
		Age	1.0771 (1.0510-1.1039)	.0000

APPENDIX V

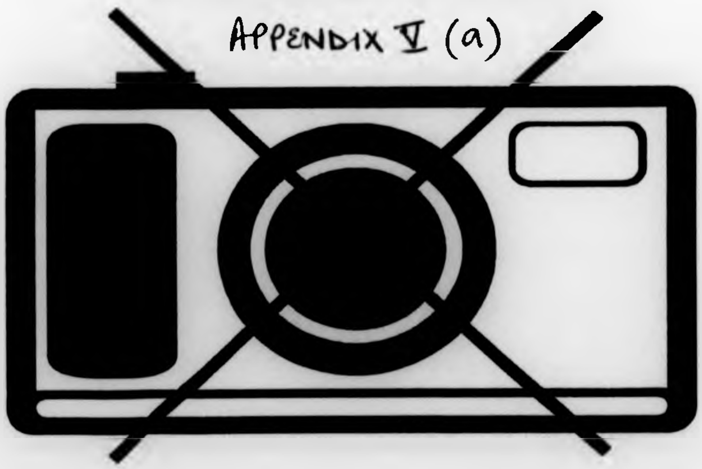
RELATED PUBLISHED PAPERS

(a) Manandhar MC, Anklesaria PS and Ismail SJ, 1997
Weight, skinfolds and circumference characteristics of poor elderly people in Mumbai, India.
Asia Pacific Journal of Clinical Nutrition 6 (3) : 191-9

(b) Manandhar MC, 1995
Functional ability and nutritional status of free-living elderly people.
Proceedings of the Nutrition Society 54 : 677-91

Published Papers Not filmed for Copyright reasons

APPENDIX V (a)



Proceedings of the Nutrition Society (1995), **54**, 677–691 677

Functional ability and nutritional status of free-living elderly people

BY MARY C. MANANDHAR
Human Nutrition Unit, London School of Hygiene and Tropical Medicine, 2 Taviton Street, London WC1H 0BT

HEALTH AND FUNCTION IN AN AGEING WORLD

In 1990 almost half a billion people in the world were over 60 years old (World Bank, 1994). In only 40 years time this number will nearly triple. By the end of those same 40 years three-quarters of the world's elderly population will be living in developing countries (Kinsella & Suzman, 1992). The challenge for the next century is to alter focus accordingly.

Living longer comes at a price. Extra years will not necessarily be years of good health. In the complicated context of ageing biology, transitions from disease to disability rather than disease to death take on prime importance for older people. For many chronic diseases that can never be completely cured, delaying the onset of functional decline, or minimizing the impact of lost independent function on daily life, in effect approximates a 'cure' of the condition for those concerned (Besdine, 1990). Moreover, the presence of illness as measured by objective clinical data does not necessarily determine the presence or severity of dependency. And of course for many elderly people in developing countries the luxury of access to such knowledge is often unavailable. With risk of death increasingly likely, and both the long- and short-term effects of disease, diet and life style hard to disentangle, the traditional health measures of life expectancy and morbidity begin to appear inadequate outcomes against which to measure any health or nutritional indicator in older people, or evaluate preventive strategies. To what then should we turn?

The present paper addresses the following questions: Is functional ability an appropriate outcome indicator of health and nutritional status in free-living people in developing countries? What is functional ability and how can it be assessed? Is there any evidence of a relationship between functional ability and nutritional status in free-living elderly people? I will focus on the community as the site in which functional impairment first appears most often and my bias is towards malnutrition in developing countries. At times, I will refer to our own recent fieldwork experience amongst elderly slum dwellers in Bombay, but no data will be presented. The present paper aims to serve as an introduction to a new issue of growing practical importance in both nutritional gerontology and nutrition in the Third World.

FUNCTIONAL ABILITY AS AN OUTCOME INDICATOR OF HEALTH IN OLD AGE

Functional ability is the ability to perform basic activities of daily life without support, which is the key to overall independence and quality of life. We must be able to identify and measure factors limiting functional ability. We need to find ways of identifying people most at risk of losing these abilities (Skelton *et al.* 1994).

The terms independence and quality of life may not mean the same, or have the same value in all cultures. Nevertheless, preserving functional ability is of particular importance for elderly people and their families in developing countries, where they often make a significant contribution to family welfare and income by their involvement in tasks such as child care, thus freeing younger adults for wage-earning. Many also continue to contribute to the family income well into old age. Continued participation of elderly people in the daily life of the household will depend on their level of functional ability. It may well also affect the way they are treated and respected. There is evidence that in many developing countries, especially in the growing urban areas, the extended family and traditional coping systems for older people are beginning to show signs of strain (Hashimoto *et al.* 1992). Thus, understanding the mechanisms behind the maintenance of functional ability, and devising strategies to preserve it for as long as possible, will have a beneficial impact on millions of elderly people and their families in a number of physical, economic, social and emotional ways.

The passage from a state of independence to that of dependence is characterized by the inability to perform activities of daily living such as getting out of bed, dressing, personal hygiene, eating and walking. Functional ability refers only to that part of functional capacity which is related to essential activities of daily life. Functional ability impairment means a decreased ability to meet one's own daily needs (Besdine, 1990).

Functional ability assessment summarizes the net impact of pathobiological processes and morbid conditions, many of which are still incompletely understood in old age (Wallace & Rohrer, 1990). It can be applied at both individual and population levels to obtain needs assessment information and assist in some subsequent course of action, such as assigning goals and monitoring progress. Functional ability assessment has long been the cornerstone of rehabilitation. With population ageing, we might argue that it should soon become the cornerstone of public health. Many instruments for functional ability assessment have been developed, none of which are particularly refined, easily conducted or the results interpreted. They have been extensively reviewed (Kane & Kane, 1981; Branch & Meyers, 1987), and are not discussed in detail here. Instead, the emphasis is placed on two main types of assessment techniques, and the dimensions they claim to measure.

ASSESSING FUNCTIONAL ABILITY BY SELF-REPORT: ACTIVITIES OF DAILY LIVING (ADL) AND INSTRUMENTAL ADL (IADL)

Self-reporting is the most prevalent type of functional ability assessment in geriatric programmes and research, with a long history and wide applications (Liang & Jette, 1981). It involves merely asking subjects (or family member and/or carer in proxy reporting) whether they are capable of performing a task by themselves or with assistance. Two main types of self-report instruments have been developed. First, an ADL self-report questionnaire assesses basic mobility and essential self-maintenance skills. About 30 years ago, Katz *et al.* (1963) demonstrated that the sequence of recovery of six 'basic' activities of daily living among disabled elderly (i.e. bathing, dressing, toileting, transferring, continence and feeding) resembled the sequence of development of these same functions in child development across the spectrum of human societies (Katz & Stroud, 1989). In developing and testing their index of ADL, the team not only first facilitated the measurement of functional ability, but also channelled our minds to the importance of this outcome in the context of daily life (Spitzer, 1987). Their original work has now been expanded and developed so much that for any research or programme involving the elderly the ability to perform ADL has become a standard variable in the analyses (Weiner *et al.* 1990). The second type is the IADL self-report questionnaire which assesses housekeeping, shopping, handling money and wider mobility such as using public transport. Developed a few years after the Katz *et al.* (1963) ADL by Lawton & Brody (1969), the IADL instrument deals with more complex activities relevant to a minimally adequate social life. IADL are more sensitive in detecting modest functional loss than ADL, and have since also been modified and revised. Later research suggested that a hierarchical relationship exists between some ADL and IADL items, and a combined scale with high discriminant and predictive validity was recommended (Spector *et al.* 1987).

There are over 200 published indices that assess ADL and IADL, the majority of which have not been adequately evaluated (Shah *et al.* 1989). The assumptions and constraints of ADL and IADL have been addressed by a number of authors (Kane & Kane, 1981; Liang & Jette, 1981; Fillenbaum, 1984; Feinstein *et al.* 1986; Guralnik *et al.* 1989; Law & Letts, 1989). They include insensitivity to changes in health status, the assumption 'if you can you will' which is not necessarily true in all cases, the subjectivity of many responses and potential inaccuracy for reasons of language, comprehension, hearing, intellectual capacity, level of motivation and cooperation, or even pride (Rodgers & Herzog, 1987). But the biggest problem is lack of adequate validation. However, the general consensus on self-reports is that they are deemed to give a reasonable approximation, obtained relatively quickly. There is even evidence that they identify more accurately levels of functional impairments in elderly people than do clinical or nursing judgements (Pinholt *et al.* 1987).

ASSESSING FUNCTIONAL ABILITY BY PHYSICAL PERFORMANCE TESTS

Acknowledgement of the constraints in these self-report instruments has led to the development of physical tests which represent more objective and quantifiable performance measures. These are thought to add more appropriate information on overall functional ability as they simulate some physical attributes essential to the satisfactory performance of activities of daily living, and offer the potential to overcome some of the limitations of self-reports (Guralnik *et al.* 1989; Reuben & Siu, 1990). Functional ability has numerous dimensions or components and its assessment must be similarly constructed (Branch & Meyers, 1987). Thus, physical performance tests can be described according to these different dimensions, i.e.: mobility, manual ability, flexibility, muscular strength, psychomotor and cognitive function. Evidence of correlations between these dimensions, as well as with other variables, can be found in the literature and will not be discussed here.

Mobility

The ability to get around in one's environment is a basic human function necessary for independence and activities of daily life (Wolfson, 1992). Loss of mobility is a principal cause of a limited quality of life and increased dependence in elderly people, especially for women. Descriptions of mobility performance tests in elderly people can be found in the reports of Tinetti (1986) and Podsiadlo & Richardson (1991). Lower body dysfunction will affect mobility, and have an impact on other factors such as anxiety, fear of falls, and balance (Tinetti *et al.* 1994).

Mobility impairment can affect nutritional status by impeding participation in food production, acquisition, and preparation as well as in socialization of eating patterns. Conversely, nutritional factors have been implicated in motor and gait disorders (vitamin B_{12} deficiency), osteoporosis (longstanding Ca deficiency, and possibly vitamin D deficiency) and in precipitating fractures in subjects with a low bone-mineral density (Calkins, 1992; Department of Health, 1993), which in turn influence mobility, balance and proneness to falls (Vellas *et al.* 1992). Mansell *et al.* (1990) reported that low body weight and mid-arm circumference measurements were significantly associated with an increased risk of fractured neck of femur and of vertebral collapse in three groups of elderly women, including those living in the community. Bastow *et al.* (1983) highlighted the importance of the increased risk of hypothermia in thin undernourished elderly people because of its impact on lack of coordination, accident and mobility.

Manual ability

The ability to use one's hands proficiently in everyday activities is required for the majority of ADL skills. A decrement in hand function appears to be a significant musculoskeletal mechanism causing disablement in basic ADL and may be one of the earliest markers of impending functional decline (Jette *et al.* 1990). Several versions of a simple timed manual performance test have been developed by Williams *et al.* (1982, 1994), which have proved to be highly correlative and predictive markers of functional dependency, both in the institutional setting and in the community (Ostwald *et al.* 1989; Mowat *et al.* 1992). The test battery involves the performance of commonplace tasks such as opening fasteners, simulating eating, picking up small objects and copying a simple sentence. However, some of these may be inappropriate for use in other cultures. In the Bombay slums, the elderly population is largely illiterate, and the wide variety of fasteners unfamiliar, so we used only a simple lock and key test in our study. Older people suffering from rheumatoid arthritis may find fine neuromuscular control and coordination so reduced that it is difficult to hold or use utensils, procure food, prepare it safely or even self-feed. Such people frequently have a thin emaciated appearance, attributed in part to these manual problems but also to difficulties in chewing or swallowing because of arthritis affecting the jaw, and to chronic gastritis secondary to medication (Calkins, 1992).

Flexibility and range of motion

Decreases in flexibility also typically occur with advancing age, mainly because joints become stiff and painful, articulating surfaces are damaged, range of motion is reduced and there is accompanying gradual lack of use (Badley *et al.* 1984; Bassey *et al.* 1989). The individual's ability to undertake daily activities is consequently reduced. Simple, reliable and socially acceptable performance tests, such as the earlobe test (Bergstrom *et al.* 1985), posterior reach (Rikli & Busch, 1986) and shoulder abduction (Bassey, 1990*b*; used in Bombay), can assess flexibility and range of motion in elderly people living in the community. These tests have functional relevance as they simulate important movements in activities of daily life, such as dressing and grooming, hanging out washing, and using shelves, hooks or supporting rails. Deterioration in this dimension has been linked to reduced independence (Jette *et al.* 1990).

There is some evidence to suggest a relationship between nutritional status and range of motion in elderly people, but it is inconsistent. A Swedish study found that so-called 'lean' subjects reported more shoulder problems, more restricted range of motion and increased ADL assistance than so-called 'non-lean' individuals (Bergstrom *et al.* 1985). However, Bassey *et al.* (1989) reported that BMI was significantly negatively related to shoulder range in women. They hypothesized that compression of fatty tissue will affect stiffness of joints and limit joint range, particularly in the presence of low muscle strength.

Muscular strength

By age 70 years it is estimated that muscle strength is about 35–45% lower than its peak value in youth, although the decline varies according to muscle group and sex (Grimby & Saltin, 1983).

Physical performance tests of the muscular strength dimension of functional ability in older adults have concentrated mainly on isometric tests of handgrip and quadriceps muscle (knee extension and flexion). These have all been found in young Caucasian adult males to relate well to aggregate measures of muscle strength (Bassey, 1990*a*). The power grip of the hand requires the combined action of a number of muscles in both the hand and forearm, and is a familiar action of functional importance for many activities of daily life (transferring tasks, holding onto supports, opening containers, using tools, dressing). As our Bombay experience showed, it can be measured easily in the field setting, preferably using a strain-gauge dynamometer (Bassey, 1990*a*). Low handgrip strength implies considerable functional disadvantages (Kallman *et al.* 1990; Bassey & Harries, 1993). Handgrip strength is more sensitive than body composition measurements to predict post-operative complications and mortality (Klidjian *et al.* 1980; Webb *et al.* 1989).

Quadriceps muscle strength is also of great functional significance in daily activities, but progressively decreases from the third decade onwards (Rutherford & Jones, 1992; Skelton *et al.* 1994). Lack of strength in this muscle will affect most weight-bearing activities, general locomotion and mobility, independence in transferring (Bergstrom *et al.* 1985) and proneness to falls and fractures (Bastow *et al.* 1983; Nevitt *et al.* 1989; Wickham *et al.* 1989). Whilst laboratory-based studies use fixed power-rigs or chair dynamometers to measure quadriceps strength, community studies can use the ability (time taken) to rise repeatedly from a chair without the use of hands. This was developed as a simple standardized test relevant to activities of daily life that can indicate the level of lower body strength and which correlates strongly with the rig or chair methods (Csuka & McCarty, 1985; Alexander *et al.* 1991; Bassey *et al.* 1992). Chair stands may not be such an appropriate test for populations who use neither chairs nor beds in daily life, but who sit and sleep on the floor. In Bombay, we struck an additional complication. As chair rises were used as a punishment in schools, some subjects were not initially keen to perform them.

What effect does this loss of muscular strength have on the functional ability of community-living elderly people? Professor Archie Young (1986, 1992) introduced the concept of threshold, and the narrowing of safety margins between normality and abnormality of function. As one grows older there comes a time when maximal strength in a particular action is the same as the minimum required to perform an everyday activity. A gradual loss of strength may not be apparent until the person is suddenly unable to perform a crucial function, or is at least so dependent on aerobic metabolism as to render it unpleasant to perform. Assuming a rise time of less than 3 s, Young (1986, 1992) speculated that a healthy 80-year-old woman is at, or very near to, the threshold value of quadriceps strength for rising from a low armless chair or lavatory seat. We might infer that an unhealthy, malnourished old woman may experience this threshold some years earlier. A recent paper by Skelton *et al.* (1994) represents the first major analysis of muscle strength and power and their relationship to functional ability in old age. The authors caution that the relationship between even laboratory measures of physical performance and functional ability is still poorly understood. Associations between functional ability and strength and power have been demonstrated in the presence of pathology, but more research is needed in this area, especially with regard to those performance tests suitable for use in the community. Muscular strength presumably affects nutritional status by its impact on mobility, physical activity level and energy expenditure, as well as basic functional ability tasks such as transferring (Rantanen *et al.* 1994). More will be said a little later about the impact of nutritional status on this muscular strength dimension of functional ability.

Psychomotor and cognitive function

The ability of an individual to process, and react to, specific external information is considered an important indicator of overall cerebral status (Panton *et al.* 1990). Decline in psychomotor function is age-related (Fozard *et al.* 1994). Deterioration of this dimension of functional ability will jeopardize capacity to cope with independence in ADL and IADL, although most research has focused on indirect cross-sectional investigations on age, physical fitness and psychomotor speed (Spirduso, 1980; Rikli & Busch, 1986). Simple and choice reaction times, tapping speed and a plate-tapping test (Bassey, 1990*b*; used successfully in Bombay) can be used to measure the speed and coordination skills of this dimension in elderly people in community studies. Evidence of a nutritional association with psychomotor function in elderly people has not been established.

Some assessment of mental status and cognitive function is necessary in any multidimensional assessment of functional ability to act as a screen in identifying those individuals incapable of understanding test instructions and whose responses about ADL and IADL may also be suspect. Instruments for assessing cognitive aspects of mental function in the aged vary greatly in content, detail and administration time (Little *et al.* 1987), although probably the most well-recognized and validated is the Folstein *et al.* (1975) mini-mental state examination, a scored series of eleven questions concerned with orientation, memory, attention and the ability to follow verbal and written commands. It has a high reliability, is significantly correlated with more sophisticated tests of neuropathology, and distinguishes between people with or without cognitive disturbances (Folstein *et al.* 1975, 1985).

As there are behavioural components to all determinants of diet and nutritional status, it follows that for elderly people cognitive status plays a crucial role in nutritional status, which in turn will affect physical activity and behaviour. Conversely, the role of proper nutrition on cognitive function may also be very important. Whilst this is well appreciated in early brain development, evidence of nutritional influences on later cognitive function and mental performance in older adults is more controversial (Evans, 1994). Some work is suggestive of a relationship between nutritional status and cognition in elderly people. Epidemiological investigations have linked malnutrition with an increased risk of Alzheimer's disease, and some dietary deficiencies of vitamins (C, B_{12}, thiamin, folate and riboflavin), and malabsorption of vitamin B_{12} have all been implicated in cognitive dysfunction, especially in association with infection and other stresses (Goodwin, 1989). However, it is not clear whether sharper elderly people eat better, or better nutrition aids cognition, or some other undetermined factor is responsible for both (Roe, 1986). Poor cognition was significantly associated with low BMI and weight loss in studies of elderly nursing home residents in seven American states (C. S. Blaum, B. E. Fries and M. A. Fiatarone, unpublished results). Despite the limitations of correlational data, the hypothesis that poor nutritional status can contribute to neurocognitive decline in otherwise healthy individuals is intriguing (Evans, 1994).

Constraints of physical performance tests of functional ability

Constraints of these tests include space, time, staff and props requirements, motivational skills of the examiner, and motivation, comprehension and compliance of the subject (Martin *et al.* 1985; Shizgall *et al.* 1986; Bassey & Harries, 1993). Pain, stiffness, fatigue, intimidational and other psychosocial factors might influence test performance in elderly people. Physical risks may also be involved, such as falling or angina (Wallace & Rohrer, 1990). Large variation between normal individuals has been found in some tasks, such as handgrip strength. Attributes of reliability, validity and sensitivity are undocumented for many tests, and the ability of most to predict functional decline is unproven (Reuben & Siu, 1990). Results of such tests should probably still be interpreted with caution until there is better understanding of relationships between performance and self-reports, and they have been used in other populations (Guralnik *et al.* 1989).

COMBINING PERFORMANCE TESTS AND SELF-REPORTS

Despite these constraints, performance tests are already routinely combined into batteries of tests for use in the clinical setting as part of physical and occupational therapy. However, they are still not widely incorporated into the assessment of free-living elderly, or for population-based research. Batteries of simple performance tests are now being utilized in some surveys in Europe (Bassey, 1990*b*), Scandinavia (Heikkinen *et al.* 1993) and the USA including the US National Health and Nutrition Examination Survey III. Branch & Meyers (1987) and Guralnik *et al.* (1989) reviewed various instruments involving performance-based ADL. In a longitudinal study of elderly people in different situations, significant independent predictive effects for ADL, gait score and seven-item physical performance test on death and nursing home placement were found (Reuben & Siu, 1990). Recently, Ensrud *et al.* (1994) explored factors associated with impaired function in community-living older women by utilizing both ADL and IADL, and some physical performance tests as well as health, anthropometry, sensory status and habits such as alcohol drinking and smoking. The rationale for their study was that the association between impaired function and modifiable risk factors had not been adequately studied.

The wider use of objective measures of functional ability to supplement the traditional self-report measures in parallel with classic disease-orientated techniques is recommended (Guralnik *et al.* 1989; Besdine, 1990; Reuben *et al.* 1992). However, there is as yet no 'gold standard' for overall functional ability. Although Siu *et al.* (1993) used their physical performance test and other instruments to test the validity of self-reports, they acknowledged that the performance measures do not themselves form any sort of gold standard for the dimensions involved. Branch & Meyers (1987) likened the search for the right functional ability assessment instrument to the search for the holy grail, but remain optimistic: 'Slow progress notwithstanding, the search will continue for a reliable and valid all-purpose instrument, one that summarises physical functioning status into a simple page and can be summarised further into a single score, and that will be useful in just about all health care contexts'. We must ensure that this includes community use in developing countries.

FUNCTIONAL ABILITY AND NUTRITIONAL STATUS: ARE THEY RELATED?

Calls for research on the establishment of associations between physical functional ability and other indicators have been increasing in recent years (Branch & Meyers, 1987; Guralnik *et al.* 1989; Katz & Stroud, 1989; Rosenberg & Miller, 1992). We might begin by asking to what extent nutritional status influences functional dependence in elderly people? In the institutional setting there is evidence that proper evaluation of an elderly patient's nutritional status is important. A significant correlation between measures of nutritional status and risk of developing major complications as well as mortality were found in a study of elderly admissions to a geriatric hospital (Sullivan *et al.* 1990). The nutritional impact on outcome was also found to be independent of all the other non-nutritional variables known to modulate morbidity and mortality. Non-nutritional factors of importance included functional status.

But what about elderly people still living in the community? Unfortunately, evidence of nutritional effects on functional ability, or *vice versa*, for community-living elderly people, are largely unavailable (Institute of Medicine, 1990; Department of Health, 1993; Payette, 1994).

Some major studies on nutrition in the elderly either did not include any functional ability assessments (e.g. Boston Nutritional Status Survey (Hartz, 1992)) or only included self-reports but no physical performance measures (e.g. EURONUT SENECA (De Groot & Van Staveren, 1988)). The International Union of Nutritional Sciences is currently conducting studies on food habits and health status with a protocol that includes self-reported ADL and mental status assessment but no tests of physical performance of functional ability (Wahlqvist *et al.* 1994). The mini-nutritional assessment for elderly people being developed in Toulouse incorporates some physical performance measures such as grip strength, but full results are not yet available (Guigoz *et al.* 1993). The UK nationwide survey on elderly people being conducted by the Ministry of Agriculture, Fisheries and Food, and the Ministry of Health (Hughes *et al.* 1995) includes grip strength but no other physical performance tests of functional ability. Many surveys of functional ability in the elderly have included health but not nutritional assessments (Heikkinen *et al.* 1983). More thorough means of assessing ADL and IADL with special attention to nutrition are needed. Work on questionnaires to assess aspects of functional status that are associated with nutritional risk is apparently under way (Institute of Medicine, 1990).

Does nutritional status influence the muscular strength dimension of functional ability for elderly people? Malnutrition can certainly predispose to impairment of the muscular strength dimension of functional ability if weight loss reflects the effects of loss of lean body mass. Mowé *et al.* (1994) found that handgrip strength was significantly lower in a recently hospitalized and malnourished group of elderly, compared with a normally-nourished home group. Studies on another muscle, the *adductor pollicis* muscle of the hand, may throw some light on the question of muscle strength and nutritional status. Shizgall *et al.* (1986) found that in malnourished (non-elderly) patients the muscle generated less force, fatigued faster and recovered slower than in normally-nourished patients, and concluded that the key factor is probably the availability of energy stores within the muscle and the ability to regenerate them from available substrate. Working with elderly subjects, Phillips *et al.* (1992) concluded that muscle atrophy and reduced force per cross-sectional area mean that older subjects have to use a higher proportion of their muscle maximal voluntary force to produce the same force as a younger subject. Roe (1986) recommended mid-arm circumference and triceps skinfold to calculate arm muscle area and detect wasting in elderly people, and believed that circumference measurements can be used to indicate loss of muscle mass and its functional consequences. Other nutritional factors relating to muscular strength have been documented, such as correlations between dietary Mg and muscle capacity, and circulating vitamin D and muscle strength (Institute of Medicine, 1990).

In a lecture recently delivered at the London School of Hygiene and Tropical Medicine, Professor Nevin Scrimshaw stated that 'almost any indicator of function correlated with BMI shows those with low BMI to be worse off'. But there is no evidence that this holds true for community-living elderly people in terms of their functional ability outcomes. Indeed, there is evidence to the contrary, although this probably reflects the lack of data on nutritional status and functional ability for elderly populations where low BMI are more prevalent. A high BMI was a strong independent risk factor for impaired function (reported difficulty in performing three or more ADL) in a large study of ambulatory old women in the USA (Ensrud *et al.* 1994), and was also found to be strongly associated with physical performance tests in a recent analysis of three large community-based studies of elderly in the USA (Seeman *et al.* 1994). However, it is important to remember that BMI should be used and interpreted with caution in any nutritional assessment of elderly people (James *et al.* 1988).

The Framingham Disability Study raised important questions relating to functional ability and nutritional status. For example, does relative weight have an influence on elderly people's ability to perform basic life activities (Jette & Branch, 1981)? An analysis of the American Longitudinal Study of Aging found that cerebrovascular disease, arthritis and possibly coronary artery disease increased the likelihood of functional limitations (as measured by ADL and IADL), but not abnormally high weights (Boult *et al.* 1994). But what about free-living populations where low weights are more prevalent? The data are not available. A group in the USA found a strong association between feeding dependency and poor intake and both low BMI and weight loss but only in nursing home residents (C. E. Blaum, B. E. Fries and M. A. Fiatarone, unpublished results). Underweight older subjects certainly have decreased reserve capacity and can develop serious nutritional problems both rapidly and with only minor stress. Malnutrition is probably responsible for many non-specific symptoms observed in elderly people, such as chronic fatigue, general feeling of ill-health and loss of appetite, which will eventually lead to more pronounced malnutrition. In the USA there is substantial evidence of specific nutritional deficiencies in independent elderly (based on intakes falling below recommended daily allowances; Goodwin, 1989), but it is not at all clear how functionally important such findings are. So although it thus seems sensible to conclude that malnutrition in elderly people can lead to problems related to independent functional ability and social integration, a large body of quantifiable evidence still eludes us.

A number of other variables affect mobility, manual dexterity and degree of socialization, and can thus be expected to have an impact on both nutritional status and functional ability in elderly people living in the community. Many such factors are reviewed in the literature (Goodwin, 1989; Lehmann, 1989; Davies & Knutson, 1991; Grimby *et al.* 1993) and include social isolation, depression, problems with dentition and swallowing, fear of incontinence, and declining sensory abilities. These all influence food acquisition, preparation, choice and level of intake, as well as socialization of eating patterns, and may lead to a tendency to neglect food.

THE STATE OF THE ART: RESEARCH PRIORITIES

I have failed to find any published study that directly assesses nutritional status and functional ability of free-living elderly in a developing country, and few papers that covered even one of these aspects. What can be done to address this? In general, we need more research on anthropometric and body composition indicators of nutritional status and their interactions and associations with functional ability in elderly people. A number of reviews on nutritional assessment of the elderly outline the undoubted theoretical and practical problems involved especially with regard to anthropometry and body composition (Roe, 1986; Chumlea & Baumgartner, 1989; Lehmann, 1989; Kelly & Kroemer, 1990; World Health Organization Subcommittee on Anthropometry in the Elderly, unpublished results). However, such problems are no excuse for inaction. More research is also needed in relation to vitamin and mineral status indicators and functional ability outcomes.

In the Western world the elderly are probably the largest population group at risk of undernutrition. In the developing world the risk will increase as surely as the numbers will grow. But there is an alarming lack of data on the nutritional status of free-living elderly people from developing countries. The childhood bias in nutritional research has much to answer for, as we face a situation where the least knowledge exists for that very section of the world's population projected to increase the most and where institutional care is largely unfamiliar, but where traditional systems of elderly care and support are increasingly under threat.

A similarly poor situation exists for functional ability. Protocols incorporating functional ability assessments are only just beginning to be assembled in developing countries. There have been very few published applications of performance-based measures of physical function in developing countries, although a number of efforts are either under way or being planned (Guralnik *et al.* 1989; Fillenbaum, 1990). The World

Health Organization has been increasingly active in this field, especially through its Special Program on Aging, of which a community study in Sri Lanka is a recent example (Fernando & Seneviratna, 1993).

We urgently need validations of functional ability assessment techniques (both self-report and physical performance tests) from developing countries. The appropriateness of some existing instruments of functional ability assessment to non-Western cultures may be questionable. In our own study of elderly people in Bombay slums we found, as have others, that an elderly person's cultural environment may not encourage or expect a certain behaviour (covered in an ADL or IADL question, or physical performance test), according to norms of social and economic status, age, sex and prestige (Syryani *et al.* 1988; Barker, 1989). Existing instruments for IADL are especially problematic, and often gender-specific. Many ADL tasks are performed in quite different ways in non-Western cultures (Jitapunkul *et al.* 1994). Barker (1989) remarked especially on the problem of such populations simply being unused to answering direct probing questions about their lives. Conducting physical performance tests of functional ability in our Bombay slums study we found adaptations were necessary due to constraints of space, light and locally-available equipment. However, elderly subjects cooperated in all tests, many enjoying the activities as a change from their normal daily routine. Our experience confirms that functional ability assessments, including performance tests, can be implemented in the field, although their interpretation should probably still be undertaken with some caution (Solomons, 1992).

CONCLUSION

For all age-groups, including the elderly, tackling the causes of malnutrition must be our ultimate goal. However, being able to measure and monitor nutritional status in relation to a functional outcome of practical importance is imperative. Consequently, nutritional assessment for the elderly must be orientated towards providing useful information on the transitions to functional ability impairment. We must begin by identifying in more precise ways the manner in which nutritional status contributes to the preservation or deterioration of functional abilities in older people, and *vice versa*. Some evidence suggests that nutritional status is important for the maintenance of functional ability and independence for an older adult. We may not have convincing evidence of the relationship, but that does not mean the question is unimportant, rather that more information is needed. It could suggest possible ways in which intervention might restore either in the elderly. Whilst some progress is being made in Western countries, the collection of even basic data on nutrition and functional ability amongst free-living elderly people in developing countries has hardly begun. Given the emerging demographic phenomenon of ageing predominantly facing those countries, there is little time to waste.

The author is funded by HelpAge International. The collaboration of Dr Suraiya Ismail (London) and Mrs P. S. Anklesaria (Bombay), and the support of colleagues at HelpAge International, HelpAge India, and the Seth GS Medical College and King Edward VII Memorial Hospital in Bombay are gratefully acknowledged.

REFERENCES

Alexander, N. B., Schultz, A. B. & Warwick, D. N. (1991). Rising from a chair: effects of age and functional ability on performance biomechanics. *Journal of Gerontology* **46**, M91–M98.

Badley, E. M., Wagstaff, S. & Wood, P. H. N. (1984). Measures of functional ability (disability) in arthritis in relation to impairment of range of joint motion. *Journal of Gerontology* **43**, 563–569.

Barker, J. C. (1989). Health and functional status of the elderly in a Polynesian population. *Journal of Cross-Cultural Gerontology* **4**, 163–194.

Bassey, E. J. (1990*a*). Tests of muscle strength. In *Handbook of Methods for the Measurement of Work Performance, Physical Fitness and Energy Expenditure in Tropical Populations*, pp. 59–65 [K. J. Collins, editor]. London: International Union of Biological Sciences, Medical Research Council and London School of Hygiene and Tropical Medicine.

Bassey, E. J. (1990*b*). Simple performance tests. In *Handbook of Methods for the Measurement of Work Performance, Physical Fitness and Energy Expenditure in Tropical Populations*, pp. 67–79 [K. J. Collins, editor]. London: International Union of Biological Sciences, Medical Research Council and London School of Hygiene and Tropical Medicine.

Bassey, E. J., Fiatarone, M. A., O'Neill, E. F., Kelly, M., Evans, W. J. & Lipschitz, L. A. (1992). Leg extensor power and functional performance in very old men and women. *Clinical Science* **82**, 321–327.

Bassey, E. J. & Harries, U. J. (1993). Normal values for handgrip strength in 920 men and women aged over 65 years, and longitudinal changes over 4 years in 620 survivors. *Clinical Science* **84**, 331–337.

Bassey, E. J., Morgan, K., Dallosso, H. M. & Ebrahim, S. B. J. (1989). Flexibility of the shoulder joint measured as range of abduction in a large representative sample of men and women over 65 years of age. *European Journal of Applied Physiology* **58**, 353–360.

Bastow, M. D., Rawlings, J. & Allison, S. P. (1983). Undernutrition, hypothermia and injury in elderly women with fractured femur: an injury response to altered metabolism? *Lancet* **i**, 143–146.

Bergstrom, G., Aniansson, A., Bjelle, A., Grimby, G., Lundgren-Linquist, B. & Svanborg, A. (1985). Functional consequences of joint impairment at age 79. *Scandinavian Journal of Rehabilitative Medicine* **17**, 183–190.

Besdine, R. W. (1990). Functional assessment in the elderly. In *Geriatric Medicine*, 2nd ed., pp. 37–51 [J. L. Rowe and R. W. Besdine, editors]. Boston: Little, Brown and Co. Inc.

Boult, C., Kane, R. L., Louis, T. A., Boult, L. & McCaffrey, D. (1994). Chronic conditions that lead to functional limitation in the elderly. *Journal of Gerontology* **49**, M28–M36.

Branch, L. G. & Meyers, A. R. (1987). Assessing physical function in the elderly. *Clinics in Geriatric Medicine* **3**, 29–51.

Calkins, E. (1992). Management of rheumatoid arthritis in the elderly patient. In *Oxford Textbook of Geriatric Medicine*, pp. 356–362 [J. Grimley Evans and T. Franklin Williams, editors]. Oxford: Oxford University Press.

Chumlea, W. C. & Baumgartner, R. N. (1989). Status of anthropometry and body composition data in elderly subjects. *American Journal of Clinical Nutrition* **50**, 1158–1166.

Csuka, M. & McCarty, D. J. (1985). Simple method for measurement of lower extremity muscle strength. *American Journal of Medicine* **78**, 77–81.

Davies, L. S. & Knutson, K. C. (1991). Warning signals for malnutrition in the elderly. *Journal of the American Dietetic Association* **91**, 1413–1417.

Department of Health (1993). *The Nutrition of Elderly People. Report on Health and Social Subjects* no. 43. London: H.M. Stationery Office.

Ensrud, K. E., Nevitt, M. C., Yunis, C., Cauley, J. A., Seeley, D. G., Fox, K. M. & Cummings, S. R. (1994). Correlates of impaired function in older women. *Journal of the American Geriatrics Society* **42**, 481–489.

Evans, P. H. (1994). Nutrient and toxin interactions in neurodegenerative disease. *Proceedings of the Nutrition Society* **53**, 431–442.

Feinstein, A. R., Josephy, B. R. & Wells, C. K. (1986). Scientific and clinical problems in indexes of functional disability. *Annals of Internal Medicine* **105**, 413–420.

Fernando, D. N. & Seneviratne, R. de A. (1993). Physical health and functional ability of an elderly population in Sri Lanka. *Ceylon Journal of Medical Sciences* **36**, 9–16.

Fillenbaum, G. G. (1984). *The Well-being of the Elderly: Approaches to Multidimensional Assessment. WHO Offset Publication* no. 84. Geneva: WHO.

Fillenbaum, G. G. (1990). Assessment of health and functional status: an international comparison. In *Improving the Health of Older People. A World View*, pp. 69–90 [R. L. Kane, J. Grimley Evans and D. Macfayden, editors]. New York: Oxford University Press and WHO.

Folstein, M., Anthony, J. C., Parhad, I., Duffy, B. & Gruenberg, E. M. (1985). The meaning of cognitive impairment in the elderly. *Journal of the American Geriatrics Society* **33**, 228–235.

Folstein, M. F., Folstein, S. E. & McHugh, P. R. (1975). Mini-Mental State: a practical method for grading the cognitive state of patients for the clinician. *Journal of Psychiatric Research* **12**, 189–198.

Fozard, J. L., Vercruyssen, M., Reynolds, S. L., Hancock, P. A. & Quilter, R. E. (1994). Age differences and changes in reaction time: the Baltimore Longitudinal Study of Aging. *Journal of Gerontology* **49**, P179–P189.

Goodwin, J. S. (1989). Social, psychological and physical factors affecting the nutritional status of elderly subjects: separating cause and effect. *American Journal of Clinical Nutrition* **50**, 1201–1209.

Grimby, A., Milsom, I., Molander, U., Wiklund, I. & Ekelund, P. (1993). The influence of urinary incontinence on quality of life of elderly women. *Age and Ageing* **22**, 82–89.

Grimby, G. & Saltin, B. (1983). The ageing muscle. *Clinical Physiology* **3**, 209–218.

De Groot, C. P. G. M. & Van Staveren, W. A. (1988). *Nutrition and the Elderly: Manual of Operations, Euronut report 11*. Wageningen, The Netherlands: Euronut.

Guigoz, Y., Vellas, B. & Garry, P. J. (1993). The Mini-Nutritional Assessment: a practical assessment tool for grading the nutritional status of elderly patients. *Facts and Research in Gerontology*, Suppl. 2.

Guralnik, J. M., Branch, L. G., Cummings, S. R. & Curb, J. D. (1989). Physical performance measures in aging research. *Journal of Gerontology* **44**, M141–M146.

Hartz, S. C. (1992). Nutritional status survey: design and methodology. In *Nutrition in the Elderly: The Boston Nutritional Status Survey*, pp. 17–25 [S. C. Hartz, R. M. Russell and I. H. Rosenberg, editors]. London: Smith-Gordon/Nishimura.

Hashimoto, A., Kendig, H. L. & Coppard, L. C. (1992). Family support to the elderly in international perspective. In *Family Support for the Elderly*, pp. 293–308 [H. L. Kendig, A. Hashimoto and L. C. Coppard, editors]. New York: Oxford University Press and WHO.

Heikkinen, E., Era, P., Jokela, J., Jylha, M., Lyyra, A. & Pohjolainen, P. (1993). Socioeconomic and lifestyle factors as modulators of health and functional capacity with age. In *Ageing, Health and Competence*, pp. 65–86 [J. Schroots, editor]. Amsterdam: Elsevier Science Publications.

Heikkinen, E., Waters, W. E. & Brzezinski, Z. J. (1983). *The Elderly in 11 Countries. A Sociomedical Survey. Public Health in Europe* no. 21. Copenhagen: WHO Regional Office for Europe.

Hughes, J. M., Smithers, G., Gay, C., Clarke, P. C., Smith, P., Lowe, C., Prentice, A., Bates, C., Whitelaw, M. & Bingham, S. (1995). The British National Diet and Nutrition Survey of people aged 65 years or over: protocol and feasibility study. *Proceedings of the Nutrition Society* **54**, 631–643.

Institute of Medicine (1990). *The Second Fifty Years: Promoting Health and Preventing Disability*. Washington DC: National Academy Press.

James, W. P. T., Ferro-Luzzi, A. & Waterlow, J. C. (1988). Definition of chronic energy deficiency in adults. *European Journal of Clinical Nutrition* **42**, 969–981.

Jette, A. M. & Branch, L. G. (1981). The Framingham Disability Study: II. Physical disability among the aging. *American Journal of Public Health* **71**, 1211–1215.

Jette, A. M., Branch, L. G. & Berlin, J. (1990). Musculoskeletal impairments and physical disablement among the aged. *Journal of Gerontology* **45**, M203–M208.

Jitapunkul, S., Kamolratanakul, P. & Ebrahim, S. (1994). The meaning of activities of daily living in a Thai elderly population: development of a new index. *Age and Ageing* **23**, 97–101.

Kallman, D. A., Plato, C. C. & Tobin, J. D. (1990). The role of muscle loss in the age-related decline of grip strength: cross sectional and longitudinal perspectives. *Journal of Gerontology* **45**, M82–M88.

Kane, R. A. & Kane, R. L. (1981). *Assessing the Elderly: A Practical Guide to Measurement*. Lexington, Mass: Lexington Books.

Katz, S. C., Ford, A. B., Moskowitz, R. W., Jackson, B. A. & Jaffe, M. W. (1963). Studies of illness in the aged. The index of ADL: A standardized measure of biological and psychosocial function. *Journal of the American Medical Association* **185**, 914–919.

Katz, S. & Stroud, M. W. (1989). Functional assessment in geriatrics: a review of progress and directions. *Journal of the American Geriatrics Society* **37**, 267–271.

Kelly, P. L. & Kroemer, K. H. E. (1990). Anthropometry of elderly: status and recommendations. *Human Factors* **32**, 571–595.

Kinsella, K. & Suzman, R. (1992). Demographic dimensions of population aging in developing countries. *American Journal of Human Biology* **4**, 3–8.

Klidjian, J., Foster, K. J., Kammerling, R. M., Cooper, A. & Karran, S. J. (1980). Relation of anthropometric and dynamometric variables to serious postoperative complications. *British Medical Journal* **281**, 899–901.

Law, M. & Letts, L. (1989). A critical review of scales of activities of daily living. *American Journal of Occupational Therapy* **43**, 522–528.

Lawton, M. P. & Brody, E. M. (1969). Assessment of older people: self-maintaining and instrumental activities of daily living. *The Gerontologist* **9**, 179–186.

Lehmann, A. B. (1989). Review: undernutrition in elderly people. *Age and Ageing* **18**, 339–353.

Liang, M. H. & Jette, A. M. (1981). Measuring functional ability in chronic arthritis: a critical review. *Arthritis and Rheumatism* **24**, 80–86.

Little, A., Hemsley, D., Bergmann, K., Volans, J. & Levy, R. (1987). Comparison of the sensitivity of three instruments for the detection of cognitive decline in elderly living at home. *British Journal of Psychiatry* **150**, 808–814.

Mansell, P. I., Rawlings, J., Allison, S. P., Bendall, M. J., Pearson, J., Bassey, E. J. & Bastow, M. D. (1990). Low anthropometric indices in elderly females with fractured neck of femur. *Clinical Nutrition* **9**, 190–194.

Martin, S., Neale, G. & Elia, M. (1985). Factors affecting maximal momentary grip strength. *Human Nutrition: Clinical Nutrition* **39C**, 137–147.

Mowat, E. A., Thomas, S., Hyatt, R., Maxwell, J. D. & Whitelaw, M. N. (1992). A comparison of nutritional intake, functional status and muscle strength between elderly day hospital and day centre attenders in South London. *Journal of Human Nutrition and Dietetics* **5**, 35–51.

Mowé, M., Bohmer, T. & Kindt, E. (1994). Reduced nutritional status in an elderly population is probable before disease and possibly contributes to the development of disease. *American Journal of Clinical Nutrition* **59**, 317–324.

Nevitt, M. C., Cummings, S. R., Kidd, S. & Black, D. (1989). Risk factors for recurrent nonsyncopal falls: a prospective study. *Journal of the American Medical Association* **261**, 2663–2668.

Ostwald, S. K., Snowdon, D. A., Rysavy, S. D. M., Keenan, N. L. & Kane, R. L. (1989). Manual dexterity as a correlate of dependency in the elderly. *Journal of the American Geriatrics Society* **37**, 963–969.

Panton, L. B., Graves, J. E., Pollock, M. L., Hagberg, J. M. & Chen, W. (1990). Effect of aerobic and resistance training on fractionated reaction time and speed of movement. *Journal of Gerontology* **45**, M26–M31.

Payette, H. (1994). Nutritional status of community-residing elderly with functional limitations. *Age and Nutrition* **5**, 4–7.

Phillips, S. K., Bruce, S. A., Newton, D. & Woledge, R. C. (1992). The weakness of old age is not due to failure of muscle activation. *Journal of Gerontology* **47**, M45–M49.

Pinholt, E. M., Kroenke, K., Hanley, J. F., Kussman, M. J., Twyman, P. L. & Carpenter, J. L. (1987). Functional assessment of the elderly: a comparison of standard instruments with clinical judgement. *Archives of Internal Medicine* **147**, 484–488.

Podsiadlo, D. & Richardson, S. (1991). The timed 'up and go': a test of basic functional mobility for frail elderly persons. *Journal of the American Geriatrics Society* **39**, 142–148.

Rantanen, T., Era, P. & Heikkinen, E. (1994). Maximal isometric strength and mobility among 75 year old men and women. *Age and Ageing* **23**, 132–137.

Reuben, D. B. & Siu, A. L. (1990). An objective measure of physical function of elderly outpatients: the physical performance test. *Journal of the American Geriatrics Society* **38**, 1105–1112.

Reuben, D. B., Siu, A. L. & Kimpau, S. (1992). The predictive validity of self-report and performance-based measures of function and health. *Journal of Gerontology* **47**, M106–M110.

Rikli, R. & Busch, S. (1986). Motor performance of women as a function of age and physical activity level. *Journal of Gerontology* **41**, 645–649.

Rodgers, W. L. & Herzog, A. R. (1987). Interviewing older adults: the accuracy of factual information. *Journal of Gerontology* **42**, 387–394.

Roe, D. A. (1986). Nutritional assessment of the elderly. *World Review of Nutrition and Dietetics* **48**, 85–113.

Rosenberg, I. H. & Miller, J. W. (1992). Nutritional factors in physical and cognitive functions of elderly people. *American Journal of Clinical Nutrition* **55**, 1237S–1243S.

Rutherford, O. M. & Jones, D. A. (1992). The relationship of muscle and bone loss and activity levels with age in women. *Age and Ageing* **21**, 286–293.

Seeman, T. E., Charpentier, P. A., Berkman, L. F., Tinetti, M. E., Guralnik, J. M., Albert, M., Blazer, D. & Rowe, J. W. (1994). Predicting changes in physical performance in a high-functioning elderly cohort: MacArthur Studies of successful aging. *Journal of Gerontology* **49**, M97–M108.

Shah, S., Vanclay, F. & Cooper, B. (1989). Improving the sensitivity of the Barthel Index for stroke rehabilitation. *Journal of Clinical Epidemiology* **42**, 703–709.

Shizgall, H. M., Vasilevsky, C. A., Gardiner, P. F., Wang, W., Tuitt, D. A. Q. & Brabant, G. V. (1986). Nutritional assessment and skeletal muscle function. *American Journal of Clinical Nutrition* **44**, 761–771.

Siu, A. L., Hays, R. D., Ouslander, J. G., Osterwell, D., Valdez, R. B., Krynski, M. & Gross, A. (1993). Measuring functioning and health in the very old. *Journal of Gerontology* **48**, M10–M14.

Skelton, D. A., Greig, C. A., Davies, J. M. & Young, A. (1994). Strength, power and related functional ability of healthy people aged 65–89 years. *Age and Ageing* **23**, 371–377.

Solomons, N. W. (1992). Nutrition and aging: potentials and problems for research in developing countries. *Nutrition Reviews* **50**, 224–229.

Spector, W. D., Katz, S., Murphy, J. B. & Fulton, J. P. (1987). The hierarchical relationship between activities of daily living and instrumental activities of daily living. *Journal of Chronic Diseases* **40**, 481–489.

Spirduso, W. W. (1980). Physical fitness, aging and psychomotor speed: a review. *Journal of Gerontology* **35**, 850–865.

Spitzer, W. D. (1987). State of science 1986: Quality of life and functional status as target variables for research. *Journal of Chronic Disease* **40**, 465–471.

Sullivan, D. H., Patch, G. A., Walls, R. C. & Lipschitz, D. A. (1990). Impact of nutritional status on morbidity and mortality in a select population of geriatric rehabilitation patients. *American Journal of Clinical Nutrition* **51**, 749–758.

Syryani, L. K., Adnjana, A. K., Thong, D., Manik, I. R., Putra, D. K. W., Widjaja, W., Tama, D. W. & Jensen, G. D. (1988). The physical and mental health of elderly in a Balinese village. *Journal of Cross-Cultural Gerontology* **3**, 105–120.

Tinetti, M. E. (1986). Performance-orientated assessment of mobility problems in elderly patients. *Journal of the American Geriatrics Society* **34**, 119–126.

Tinetti, M. E., Baker, D. I., McAvay, G., Claus, E. B., Garrett, P., Gottschalk, M., Koch, M. L., Trainor, K. & Horwitz, R. I. (1994). A multifactorial intervention to reduce the risk of falling among elderly people living in the community. *New England Journal of Medicine* **331**, 821–827.

Vellas, B. J., Garry, P. J. & Abarede, J. L. (1992). Diseases and aging: patterns of morbidity with age, relationships between aging and age-associated diseases. *American Journal of Clinical Nutrition* **55**, 1225S–1230S.

Wahlqvist, M. L., Lukito, W. & Hsu-Hage, B. H.-H. (1994). Nutrition and ageing in development. In *Nutrition in the Nineties: Policy Issues*, pp. 82–108 [M. R. Biswas and M. Gabr, editors]. New Delhi: Oxford University Press and WHO.

Wallace, R. B. & Rohrer, J. E. (1990). Aging, quantitative health status assessment and the effectiveness of medical care. In *Improving the Health of Older People: A World View*, pp. 91–106 [R. L. Kane, J. Grimley Evans and D. Macfayden, editors]. New York: Oxford University Press and WHO.

Webb, A. R., Newman, L. A., Taylor, M. & Keogh, J. B. (1989). Hand grip dynamometry as a predictor of postoperative complications reappraisal using age standardized grip strengths. *Journal of Parenteral and Enteral Nutrition* **13**, 30–33.

Weiner, J. M., Hanley, R. J., Clark, R. & van Nostrand, J. F. (1990). Measuring activities of daily living: comparisons across national surveys. *Journal of Gerontology* **45**, S229–S237.

Wickham, C., Cooper, C., Margetts, B. M. & Barker, D. J. P. (1989). Muscle strength, activity, housing and the risk of falls in elderly people. *Age and Ageing* **18**, 47–51.

Williams, M. E., Gaylord, S. A. & Gerrity, M. S. (1994). The timed manual performance test as a predictor of hospitalization and death in a community-based elderly population. *Journal of the American Geriatrics Society* **42**, 21–27.

Williams, M. E., Hadler, N. M. & Earp, J. A. L. (1982). Manual ability as a marker of dependency in geriatric women. *Journal of Chronic Diseases* **35**, 115–122.

Wolfson, L. I. (1992). Gait and mobility. In *Oxford Textbook of Geriatric Medicine*, pp. 585–593 [J. Grimley Evans and T. Franklin Williams, editors]. Oxford: Oxford University Press.

World Bank (1994). *Averting the Old Age Crisis*. New York: Oxford University Press, Inc.

Young, A. (1986). Exercise physiology in geriatric practice. *Acta Medica Scandinavica* **711**, 227–232.

Young, A. (1992). Strength and power. In *Oxford Textbook of Geriatric Medicine*, pp. 597–604 [J. Grimley Evans and T. Franklin-Williams, editors]. Oxford: Oxford University Press.

Printed in Great Britain

APPENDIX VI

LIST OF ABBREVIATIONS

ADL	Activities of Daily Living
AIDS	Acquired Immunodeficiency Syndrome
AMA	Arm Muscle Area
ANOVA	Analysis of variance
BGCHI	Biomedical Gerontology Centre of HelpAge India
BMI	Body Mass Index
BMIHT	Body Mass Index, derived from height
BMIHTAS	Body Mass Index, derived from height estimated from armspan
cAMA	Corrected Arm Muscle Area
CATARACTS	Bilateral or unilateral cataracts
χ	Chi squared statistic
CI	Confidence Interval
COPD	Chronic Obstructive Pulmonary Disease
CV	Cardiovascular disease
EPI-INFO	Statistical analysis software package
EURONUT	European multi-centre Nutrition Study on the elderly : SENECA
HIV	Human Immunodeficiency Virus
TB	Tuberculosis
GI	Gastrointestinal disease
HB	Haemoglobin (gm/dL)
HTAS	Height derived from armspan using regression equation from the sample (50-54 year olds)
HYPERTEN	Hypertension
IADL	Instrumental Activities of Daily Living
IMPADL	Difficulty in performing three or more ADL tasks
IMPMOB	Difficulty in performing two out of three mobility tasks
KEM	King Edward VII Memorial Hospital, Mumbai

LEM	Liver, endocrinological and metabolic disease
LOGISTIC	Logistic Regression software package
LSHTM	London School of Hygiene and Tropical Medicine
MUAC	Mid-Upper Arm Circumference
MAJMORB	Any major morbidity condition (Table 3.3)
MENTAL	Composite cognitive status variable
MINMORB	Any minor morbidity condition (Table 3.3)
MUSCSKEL	Musculoskeletal disease
MVC	Maximal Voluntary Contraction
NEURO	Neurological disease
NHANES	National Health and Nutrition Examination Survey (USA)
NIH	National Institutes of Health (USA)
NNMB	National Nutrition Monitoring Bureau (India)
OR	Odds Ratio
OPD	Out-Patient's Department
POORADL	Number of ADL tasks impaired
PSYCHO	Psychological disease
R	Coefficient of Reliability
r	Pearson's product moment correlation coefficient
SD	Standard Deviation
SKIN	Skin disease
SPSS	Statistical Package for Social Scientists
TEM	Technical Error of Measurement
TWOAGES	Dichomotous age group variable (50-64 years; 60 and above)
UN	United Nations
UNBMI	Undernutrition, classified by BMI cut-offs
UNMUAC	Undernutrition, classified by MUAC cut-offs
UROGEN	Urogenitary infection
URTI	Upper respiratory tract infection
WHO	World Health Organisation
chawl	Government-owned tenement housing block in Mumbai

BIOMEDICAL GERONTOLOGY CENTRE OF HELPAGE INDIA

BGCHI

HELPAGE INTERNATIONAL