ASSOCIATION OF MEASURES OF FUNCTIONAL STATUS WITH FAT-FREE MASS IN FRAIL ELDERLY WOMEN

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ABSTRACT

Association of Measures of Functional Status With Fat-Free Mass in Frail Elderly Women

The association of functional status with fat-free mass (FFM) was examined cross-sectionally in a sample of 30 frail elderly women (81.5 ± 7 years) to evaluate potential outcome indicators for nutritional interventions. FFM, determined using multi-frequency bioelectrical impedance analysis, was lower in this frail group than in previous reports for "younger" elderly females. All measures of muscle strength (handgrip, biceps, quadriceps) were significantly correlated with FFM ($r \geq 0.45$, $p \leq 0.02$), while the measures of global function (Timed "Up & Go" Test and walking speed) as well as self-perceived health were not. The measures of muscle strength and global function were found to have good reliability based on measurements taken on two occasions separated by one week (ICC ≥ 0.80).

Résumé

Association entre les mesures des capacités fonctionnelles et la masse maigre chez les femmes âgées fragiles

Une étude transversale a été entreprise afin d'examiner l'association entre la capacité fonctionnelle et la masse maigre dans un échantillon de 30 femmes âgées fragiles (81.5 ± 7 ans). La masse maigre de ce groupe de femmes fragiles, déterminée par l'impédancemétrie bioélectrique à fréquence multiple, était inférieure à celle de femmes âgées "plus jeunes" établie lors de recherche antérieures. Toutes les mesures de force musculaire (préhension, biceps, quadriceps) étaient positivement corrélées à la masse maigre ($r \geq 0,45$, $p \leq 0,02$), tandis que les mesures de fonction globale (le test Timed "Up & Go" et la vitesse de marche) et d'autoévaluation de la santé ne l'étaient pas. D'après des évaluations effectuées en deux occasions à une semaine d'intervalle, les mesures de force musculaire et de fonction globale ont démontré une excellente fidélité temporelle (CCI > 0,80).

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LIST OF ABBREVIATIONS

ADL	=	activities of daily living
BF	=	body fat
BIA	=	bioelectrical impedance analysis
BIS	=	bioimpedance spectroscopy
BMI	=	body mass index
C_M	=	cell membrane capacitance
CAD	=	coronary artery disease
Calf Circ.	=	calf circumference
COPD	=	chronic obstructive pulmonary disease
ECF	=	extra-cellular fluid
ECW	=	extra-cellular water
FFM	=	fat-free mass
HHD	=	hand-held dynamometer
ICC	=	intra-class correlation coefficient
ICF	=	intra-cellular fluid
ICW	=	intra-cellular water
IKD	=	isokinetic dynamometer
kHz	=	kilohertz
kPa	=	kilopascal
MAC	=	mid-upper arm circumference
MAMA	=	mid-upper arm muscle area
MHz	=	megahertz
NIDDM	=	non-insulin dependent diabetes mellitus
Nw	=	newton
R	=	resistance
Recf	=	extra-cellular fluid resistance
Ricf	=	intra-cellular fluid resistance

LIST OF ABBREVIATIONS (CONTINUED)

REE	=	resting energy expenditure
SF-36	=	Medical Outcomes Study Short Form 36 questionnaire
SSF	=	subscapular skinfold
TBK	=	total body potassium
TBW	=	total body water
TSF	=	triceps skinfold
TUAG	=	Timed "Up & Go" Test
Xc	=	reactance
Z	=	impedance
Ω	=	ohm
ϕ	=	phase angle
μA	=	microampere

PART I LITERATURE REVIEW

A. Introduction

Leading an independent and active daily life in old age is a goal for every individual. In order to achieve that goal, an individual must be able to meet a variety of physical, psychosocial and economic/environmental demands. If these demands are not met, the risk of frailty increases and functional independence is threatened. The complex interplay between assets (health, resources and caregivers) that help maintain a person's independence in the community and the deficits (ill health, disability, dependence on others, caregiver burden) that threaten it must be recognized when defining the frail elderly (Rockwood et al 1994). These are individuals who, at a certain point in their lives, fall into a state where they need some support to remain on their own. Once this support is given they can continue to function. They are, however, in a precarious balance between the assets they possess and the deficits they are burdened with. If the deficits side of the balance becomes heavier, the person is no longer a frail elder in the community and becomes institutionalized. Premature loss of functional independence in old age has tremendous costs to the individual, his/her family and society as a whole. Adequate nutrition is an important requirement for good health and, is consequently, a vital asset in the maintenance of this autonomy.

The consequences of poor nutritional status include reduced quality of life, reduced functional capacity, significant morbidity and mortality (Kirk 1993, Chandra et al 1991, Rauscher 1993). The processes of aging and age-associated disease limits the rate and efficiency of metabolic, biochemical and physiologic functions and increases the risk of malnutrition. The work of Gray-Donald and colleagues (1994) and Payette et al (1995) has confirmed the heavy burden of nutritional deficiencies in the frail elderly. Undernutrition is difficult to reverse in old age, requiring a higher energy intake to repair a malnourished state (Shizgal et al 1992). Early detection of nutritional deficit and timely intervention is key.

The ability of an elderly individual to perform necessary activities of daily living (basic and/or instrumental) is dependent, in part, on muscle function of various muscle groups. The basic activities of daily living include self-care activities such as eating/drinking, dressing, grooming, washing as well as mobility activities such as transferring, bathing, walking and stair climbing. Instrumental activities of daily living include use of telephone, use of transportation, shopping, meal preparation, housework, management of medication and finances. The major contributors to the decline in muscle function with age include senescent changes in neuromuscular tissue, chronic diseases, medications, atrophy of disuse and malnutrition (Fiatarone et al 1993).

Nutrition interventions have shown some success in improving functional status in specific disease conditions such as chronic obstructive pulmonary disease (Efthimiou et al 1988, Whittaker et al 1990) and post hip fracture (Delmi et al 1990), but this has not been shown in free-living elderly populations despite dietary improvement and weight gain (Gray-Donald et al 1995). There is a paucity of data relating body composition to muscle strength and functional status. Kelly and co-workers (1984) related body composition to respiratory muscle strength in 59 surgical patients. In the study of chronic obstructive pulmonary disease (COPD) respiratory muscle function as well as measures of functional status such as walking speed have been related to fat-free mass (Schols et al 1991).

B. Body Composition in the Elderly

B.1 Body Composition Changes with Aging

Assessment of body composition is an important factor in determining the nutritional status of an individual. Both cross-sectional and longitudinal studies show that body composition changes with age. These complex changes that occur with old age, however, complicate estimations of lean body mass or fat-free mass and percent body fat (Chumlea et al 1993). Aging is characterized by changes in stature and weight, with the former declining one to three centimeters per every twenty years after maturity and the latter increasing until the fifth decade, reaching a plateau or declining thereafter (Heymsfield et al 1994). Fat-free mass (FFM) decreases (Forbes and Reina 1970) while the body fat mass increases (Novak 1972). Losses in muscle, protein and bone mineral contribute to the decline in FFM (Going et al 1995). The concomitant increase in body fat is also characterized by a redistribution of adipose tissue from subcutaneous to internal depots (Reilly et al 1994). Total body water (TBW), which is subdivided into extra-cellular water (ECW) and intra-cellular water (ICW), is also a part of the FFM. TBW is believed to fall with age, as does the ratio of ICW to ECW (Gibson 1990). There is also increased compressibility of skinfolds and loss of elastic recoil of the skin with advancing age (Heymsfield et al 1994).

B.2 Sarcopenia

Loss of muscle mass is the principle component of the decline in FFM seen with aging (Evans 1995a). Rosenberg (1989) was the first to suggest the term "sarcopenia" to describe this deficiency of muscle mass which is believed to be highly prevalent in the elderly population (Roche 1994). In addition to the effects of aging per se, the very old and frail are placed at increased risk of muscle wasting as a result of disuse, acute or chronic disease, certain medication regimens, and undernutrition (Evans 1995b). Occupational and leisure activity decline with age in most individuals and when this is coupled with periods of bedrest or immobility due to acute or chronic illness, limited opportunities for ambulation, fear of falling, and/or dependency in activities of daily living disuse atrophy is common (Fiatarone et al 1993a). Negative nitrogen balance associated with catabolic and chronic illnesses, and long-term use of medications that stimulate protein breakdown and inhibit protein synthesis such as glucocorticosteroids (Truhan and Ahmed 1989, Roubenoff et al 1990) also place older individuals at increased risk. Inadequate protein intake may be an important cause of sarcopenia (Evans 1995a). There is good evidence that the protein requirements in the elderly are higher than the current recommendation of 0.86g/kg body weight/day. The amount of protein needed to achieve nitrogen balance has been reported to be closer to 1.0g/kg body weight/day (Campbell et al 1994). Energy needs may also be higher than once thought (Young 1992). Resting energy expenditure (REE) can also be increased in some conditions (Schols et al 1991b) making it more difficult for some elderly persons to achieve energy balance and maintain weight.

Low protein reserves are an inevitable consequence of reduced muscle mass since skeletal muscle is the largest reserve of protein in the body. Sarcopenia is also a direct cause of the decrease in muscle strength seen with aging (Evans and Campbell 1993) and as such affects functional capacity. It is also closely linked to age-related losses in bone mineral (Evans 1995a), basal metabolic rate (Tzankoff and Norris 1978) and increased body fat content. The shift towards more body fat increases the risk of developing chronic disorders such as non-insulin-dependent diabetes mellitus (NIDDM), coronary artery disease (CAD), hypertension and obesity (Evans and Campbell 1993).

Investigations in the area of sarcopenia are still at a very early stage. Unfortunately, accurate measurement of total muscle mass is difficult and information concerning sarcopenia and health is generally derived from studies of FFM (Baumgartner et al 1995, Chumlea et al 1995), which in addition to muscle, includes bone, vital organs, blood vessels, nerves and connective tissue.

B.3 Body Composition Measurement

The measurement of body composition frequently relies on the two-compartment model. This model subdivides body weight into fat and fat-free mass. Three classic two-compartment methods are based on estimates of TBW using deuterium (^{2}H) tritium (^{3}H) or stable isotope of oxygen (^{18}O), Total Body Potassium (TBK) and body density determined from underwater weighing. Each model is based on one basic assumption developed or validated in a few young male cadavers (Heymsfield et al 1993). These assumptions, however, may not hold true for the elderly. For example, determining TBW from isotope dilution technique assumes the hydration of FFM is constant (73.2%), while measurement of fat content by hydrodensitometry assumes a constant density of FFM (1.100 kg/l) and fat mass (0.900 kg/l). Based on age-related data on bone loss and muscle loss found in the literature, Deurenberg et al (1989) proposed an adjustment to Siri's equation (1961) that is used to convert body density to %BF. Other methods based on the two-compartment model include bioelectrical impedance and skinfold thicknesses or anthropometric measurement. Advances in technology have permitted the construction of models of body composition which define the body in terms of multi-compartments (Heymsfield et al 1989, Chumlea et al 1991). Although these newer models have particular value in the elderly given that they are not potentially confounded by the aging process, the two-compartment methodology will remain for some time due to the practical constraints of the former. The multi-compartment methods may never be widely used because they require cumbersome expensive equipment not functionally accessible for many elderly subjects, highly trained personnel, and can be invasive (Chumlea and Baumgartner 1989, Kehayias 1993). Similarly, the cost and/or degree of subject cooperation required to perform many of the two-compartment methods leaves anthropometric measurements and bioelectrical impedance analysis (BIA) as two techniques available for body composition assessment of the elderly in many field, community and clinical settings (Reilly et al 1994).

B.3-1 Anthropometric Assessment

Numerous equations for predicting body density and body fat content from skinfolds or simple anthropometric measures such as height, weight and body mass index (BMI) exist, but most have been developed in young and middle-aged subjects and are not valid in the elderly. The decrease in stature will affect BMI and thus the predictions based on this weight/height index. The internalization of fat and increased compressibility of skinfolds that is seen in the elderly will underestimate percent body fat and consequently overestimate FFM if age-specific equations are not used. Broekhoff et al (1992) examined the relationship between densitometrically determined FFM and FFM predicted from several age-specific equations based on either BMI or skinfold thicknesses. Compared to the reference method, they found good relative validity, with the equations based on skinfold measurements having slightly less validity.

B.3-2 Bioelectrical Impedance Analysis

The use of electrical impedance to examine human tissues was established approximately 30 years ago (Thomasset 1962, Hoffer et al 1969), but its current application, as a tool for evaluating body composition is fairly recent, having been developed by Lukaski and co-workers (1985). A full report on bioelectrical impedance analysis (BIA) technology has recently been published by the National Institutes of Health (1994). Briefly, the method measures the opposition of the body to the passage of a weak ($< 1 \mu A$), alternating current. The electrical opposition is called impedance and consists of two components: 1) resistance of the tissues and 2) reactance due to capacitance or storage of electric charge by the cell membranes, tissue interfaces and nonionic tissues. The current flows through all conducting material in its path between two pairs of electrodes, that are usually located on the right wrist and ankle. The voltage drop (from which impedance is determined) is detected by the electrodes placed proximal to those carrying the current. Conductivity is highest in fluids containing electrolytes, intermediate in muscle and lowest in bone and fat. Since FFM, including the protein matrix of adipose tissue, contains virtually all the water and conducting electrolytes in the body, conductivity is far greater in the FFM than in the fat mass. Impedance of the body is, therefore, determined largely by the low impedance lean tissues. This measured value is then used to calculate TBW. The next step is the estimation of FFM using population-specific regression equations that were derived from statistical relationships of impedance to TBW or FFM measured by independent techniques.

Impedance measures vary with the frequency of the current. When a single frequency is used it is typically 50kHz, but there is increasing use of bioelectrical impedance analyzers that allow for multifrequencies or frequency spectrums that can differentiate the proportions of intra- and extra-cellular fluid volumes in the body. At low frequencies, there is little conduction through the cell membranes due to high cell membrane capacitance (C_M). Thus the major conduction pathway is through the extra-cellular fluid (ECF). As frequency increases, the C_M decreases allowing more current to conduct through the intra-cellular fluid (ICF). With very high frequencies, the effect of C_M diminishes to insignificant proportions and the current flows uniformly through both water compartments.

B.3-3 Bioelectrical Impedance Analysis in the Elderly

Use of bioelectrical impedance at 50 kHz in the elderly is limited because impedance measures at this frequency cannot accurately differentiate the proportion of ECF in TBW, which could produce overestimation of FFM in the elderly (Chumlea et al

1995). The ratio of an impedance measure at low frequency to a corresponding impedance value at high frequency has been reported to provide good estimate of the proportion of TBW in ECF and serve as a marker for disease (Jenin et al 1975).

Bioelectrical impedance analysis has practical utility in elderly subjects in terms of safety, convenience to the subject and non-invasiveness. The instrument is portable and relatively inexpensive, adding to its applicability in a variety of settings. The technology is simple to use and takes little time to perform. Numerous validation studies have been conducted on healthy adults. The criterion methods used in most of the studies have been TBW by isotope dilution techniques and body density by the underwater weighing method. BIA has been found to be reliable and valid for assessing body composition in ages seventeen to sixty-five (Segal et al 1985, Lukaski et al 1985, Lukaski et al 1986, Segal et al 1988, Khaled et al 1988). More limited validation data is available on the elderly. Deurenberg and colleagues (1990) regressed estimates of FFM by densitometry on anthropometric and impedance variables in a group of 72 healthy men and women aged 60 to 83 years. Their age-specific prediction equation had a correlation coefficient (r) of 0.94 and a standard error of estimate (SEE) of 3.1 kg. In 32 patients with severe chronic obstructive pulmonary disease, aged 63 ± 9 years, Schols et al (1991) generated a regression model for bioelectrical impedance by using deuterium dilution as the reference method. They found an equally excellent correlation coefficient (r) of 0.93, SEE of 1.9 L between the impedance index ($Height^2$/Resistance) and TBW - $^2H_20$. In another study, body composition was evaluated in 20 elderly men and women (mean age 74.5 ± 8.4) with normal body weight using the tritiated water ($^3H_20$) method (Sergi et al 1992). An excellent relationship between BIA and this reference method for TBW was found (r = 0.98). Recently, Visser and colleagues (1995) found multi-frequency bioelectrical impedance to be useful in assessing TBW and ECW in groups of elderly men and women, aged 63 to 87 years. TBW and ECW were determined using deuterium oxide (D_20) dilution and potassium bromide (KBr) dilution, respectively. Prediction errors for TBW (2.7 kg) and ECW (1.0 kg) were less for women than men.

C. Measures of Functional Status

C.1 Muscle Strength and Functional Status in the Elderly

Strength in upper and lower limb muscle groups, such as hands, elbow flexors or biceps and knee extensors or quadriceps, has been correlated with several measurements of functional status in the elderly (Hyatt et al 1990). Upper limbs play an important role in daily life and strength in this extremity seems to be less affected by aging than in the lower extremity (Sperling 1980). Grip and biceps strength are considered to be the best indicators of upper limb strength in older individuals (Rice et al 1989). Jette and co-workers (1990) showed that diminished hand function, of which grip strength is a component, influenced dependence in personal daily life activities such as hygiene, dressing and feeding, as well as activities necessary for maintaining a dwelling in the community. Similarly, Sonn et al (1995), in their cross-sectional analysis of 602 seventy year olds and a six year follow-up, revealed significantly lower grip strength in dependent subjects as compared to those independent in ADL. Elbow flexion, a movement used, for example, in horizontal pulling, was strongly associated with receipt of domiciliary services (Hyatt 1990). Lower extremity muscle function also has tremendous impact on the day-to-day life of elderly individuals. Strength in leg muscles, particularly quadriceps, is a significant predictor of functional ability as it is related to walking speed, rising from a seated position and a lower susceptibility to falling (Aniansson et al 1980, Young 1986, Bassey et al 1992). Quadriceps strength is considered one of the best indicators of lower limb strength in the elderly (Rice et al 1989).

C.2 Muscle Strength as Functional Indicator of Nutritional Status

Investigations that have examined functional indicators of nutritional status in older individuals have, for the most part, been disease-specific. Goldstein et al (1986) measured skeletal muscle strength in the quadriceps and hamstrings of five elderly (67-81 years old) COPD patients receiving enteral nutrition for approximately 20 days. After two weeks of refeeding, repletion resulted in 11% improvement in quadricep strength and 37% improvement in hamstring strength. After three weeks, a further improvement was observed, for a total improvement of 44 ± 19% in quadricep and 65 ± 18% in hamstring strength. Efthimiou and co-workers (1988) used functional parameters in their randomized, controlled trial investigating the effect of three months of oral supplementation on poorly nourished COPD patients. Significant improvements in body weight, triceps skinfold thickness, mid-arm muscle circumference were reflected in significantly improved respiratory muscle strength, handgrip strength, breathlessness scores and 6 minute walking distance. Lewis et al (1987) conducted a randomized supplementation trial in 21 malnourished elderly (mean age 65) outpatients with COPD. The use of an high energy, high protein supplement for 8 weeks, resulting in a significant increase in protein ($p < 0.05$) and calories ($p < 0.05$) in the fed group, had no significant effect on weight gain, mid-arm muscle circumference, triceps skinfold thickness, as well as the muscle function parameters of respiratory muscle function and handgrip strength. The effect of short-term (16 days) enteral feeding on 10 malnourished COPD patients was studied in a randomized trial (Whittaker et al 1990). The refed group gained significantly more weight which was only reflected in expiratory muscle strength and not inspiratory muscle strength or adductor pollicis muscle function. Recently, Gray-Donald et al (1995) conducted a randomized, controlled trial assessing the impact of 12 weeks of nutritional supplementation on a frail elderly population receiving home care services. Despite significant weight gain in the supplemented group, there was no significant change in the muscle function parameter - handgrip strength. The percentage of subjects reporting falls, however, was significantly lower in the supplemented group as compared to the controls. This trial had sufficient power to detect differences in handgrip strength as low as 1.4 ± 3.8 kg. Although handgrip strength, a measure generally accepted as an index of functional integrity of the upper extremity, has been described as one of the best measures of functional status in some nutrition studies, it may be difficult for frail elderly to manipulate the apparatus. This, in turn, would make detection of changes difficult.

Few investigators have used lower extremity muscle function changes as outcome measures during nutritional repletion in elderly subjects. As mentioned previously, Goldstein and co-workers (1986) used quadriceps and hamstring strength as outcome measures. Fiatarone et al (1994) conducted a randomized, placebo-controlled trial comparing progressive resistance training of knee and hip extensors, multinutrient supplementation, both interventions and neither in 100 frail, nursing home residents. The trial lasted 10 weeks. It was their hypothesis that physical frailty is partially mediated by skeletal muscle disuse and marginal nutritional intake and should, therefore, be reduced by interventions designed to reverse these deficits. Although exercise significantly improved the results of all muscle function tests, the nutritional supplement had neither an independent nor additive effect on these outcomes. In contrast to the COPD subjects, studied by Goldstein et al (1986), whose mean body mass index was 19, the elderly men and women randomized to the supplemented groups in this trial had a mean body mass index of 25 and could not be considered undernourished. Response to supplementation, in a group that is not sufficiently compromised, would not be expected. Earlier, Meredith et al (1992) conducted a 12 week dietary supplement trial with resistance training of knee extensors and flexors in 11 healthy elderly men. Although they found no relationship between gain in dynamic strength and dietary changes, they reported greater mid-thigh hypertrophy in the supplemented group. They concluded that although the functional value of an increase in muscle size is harder to establish, greater lean tissue mass would provide a larger reserve to draw upon in times of need.

C.3 Health-Related Quality of Life Measures as Indicators of Nutritional Status

The growing interest in the measurement of health status from the perspective of the patient has led to the development of numerous health-related quality of life instruments that vary in type (generic versus disease specific), length, preferred mode of administration, and properties (Fitzpatrick et al 1992, Guyatt et al 1993). Health-related quality of life measures have been used as indicators of the functional effect of improved nutritional status in the elderly, both in hospital and community settings (Efthimiou et al

1988, Gray-Donald et al 1994, Gray-Donald et al 1995). The positive nutritional outcomes experienced by the experimental group in the study by Efthimiou and co-workers (1988) were reflected in the significant improvement in scores obtained on an analogue-type rating of general well-being. In their earlier study of elderly subjects receiving home services, Gray-Donald and colleagues (1994) reported significant improvement in mean scores on the General Well-Being Schedule which was strongly correlated with change in energy intake ($r=0.63$, $p=0.014$). In contrast, the same General Well-Being Schedule score and the response to a single question on self-perceived health status did not improve as a result of increased nutritional intake and significant weight gain in their subsequent randomized trial conducted in the same population (Gray-Donald et al (1995). The validity of the General Well-Being Schedule to detect change in this particular frail population was, as a result, questioned. In comparison to longer questionnaires, single item indicators as was used in combination with the General Well-Being Schedule, are less reliable, less sensitive to change and less able to capture complex processes evaluating health status (Weinberger et al 1991).

C.4 Handgrip Strength Measurement

Handgrip strength is an economical and reliable measure that is easy to administer. The most widely used instrument to measure handgrip strength, both in clinical and research settings, is the Jamar™ dynamometer. It was introduced by Bechtol (1954) and consists of a sealed hydraulic system with five adjustable handle positions, measuring maximal or peak force in kilograms or pounds. No perceptible movement is generated when the handle is squeezed, thus quantifying isometric strength as opposed to isotonic or dynamic strength. It is known for its precision, reliability and reproducibility (Mathiowetz et al 1984). Demonstrating the highest calibration accuracy for the measurement of grip strength at ± 3%, this instrument is considered the gold standard to which others are compared (American Society for Surgery of the Hand 1983, ASHT 1981). From a negative perspective, however, its bulkiness, shape rigidity and weight present difficulties not only for persons with musculoskeletal and neurologic problems (Agnew and Maas 1991, Dunn 1993 and Balogun et al 1990), but for healthy elderly persons as well (Milne and Maule 1984, Desrosiers et al 1995).

The Martin vigorimeter and modified sphygmomanometer are two other instruments that are frequently used to evaluate grip strength (Pincus and Callahan 1992, Agnew and Maas 1991, Giles 1984, Jones et al 1991, Desrosiers et al 1995). Unlike the Jamar™ dynamometer, these pneumatic devices 1) rely on compression of air by means of a rubber bulb or bag and, therefore, measure pressure, not force (Dunn 1993, Jones et al 1991) 2) involve isotonic muscular action since movement is required to compress the bulb or bag (Desrosiers et al 1995) and 3) register results in different units. Their soft, compliant surfaces render these instruments particularly advantageous for documenting grip when joints are painful and weakened, as in the case of arthritis and wrist fractures (Jones et al 1991, Balogun et al 1990, Dunn 1993, Melvin 1989, Solgaard et al 1984) - two prevalent conditions in the elderly.

C.4-1 Martin Vigorimeter

The Martin vigorimeter consists of a manometer connected to a compressible rubber bulb which is available in three different sizes (4, 5, or 6 cm diameter) to fit small, medium and large hands, respectively. Air pressure introduced into the system, upon exertion of maximum force, is measured in kilopond (kp)/cm^2 or kiloPascals (kPa). Solgaard et al 1984 compared the Martin vigorimeter with two other instruments. Each was evaluated using a universal testing machine that provided a range of force from 50 to 500 newtons. The vigorimeter, with the medium bulb, gave an almost perfect linear response, indicating sensitivity and reliability. Grip strength measurements, taken with this instrument and based on 100 subjects (aged 20-87 years), demonstrated relatively good reproducibility with coefficients of variation at 6.1% (right hand) and 6.8% (left hand). Jones et al 1991 demonstrated the high test-retest reliability of the vigorimeter. Intraclass correlation coefficients for the mean of three measures and for only one measure (dominant hand) were 0.96 and 0.93, respectively. For the non-dominant hand, the figures were 0.98 and 0.96, respectively. Coefficients of variation, obtained for the mean of three observations, were less than previously reported at 6.0% (dominant) and 4.7% (non-dominant). Recently, a comparison of the Jamar dynamometer and the Martin vigorimeter by Desrosiers et al 1995 revealed a close relationship between the two, with high Pearson product moment correlations of 0.89 (right hand) and 0.90 (left hand).

C.4-2 Modified Sphygmomanometer

The modified sphygmomanometer (blood pressure cuff and gauge) has also been found to be valid, as compared to the criterion method (Jamar™ dynamometer) and highly reproducible. Agnew and Maas (1991) reported strong Pearson product moment correlations of 0.83 (right hand) and 0.84 (left hand) between the two instruments in their sample of 72 female and 16 male Rheumatoid arthritic subjects, aged 26 to 65. Using the non-parametric equivalent or Spearman rank correlation, Hamilton et al (1992) reported a slightly smaller value of 0.75 in their younger study population of 29 female college students. Test-retest reliability was first investigated by Balogun and coworkers in 1990. Their short retest interval of 24 hours found the modified sphygmomanometer to be highly reproducible with a correlation coefficient of 0.99. Extending this interval to one week, Hamilton's group (1992) demonstrated good within-instrument reliability (rho=0.85).

The modified sphygmomanometer has the following additional advantages over the Jamar™ dynamometer vis à vis an elderly population: 1) readily available in any clinic 2) provides a scale with smaller increments and, therefore, potentially more sensitive to small differences in strength.

C.5 Isometric Muscle Strength Measurement

The maximum voluntary isometric strength of the knee extensors and elbow flexors has been measured in healthy elderly people, by standard methods, with repeatability comparable with that found with younger subjects (Greig et al 1994). Manual muscle testing is an inexpensive, relatively quick and convenient method for assessing muscle strength, but can be limited due to subjective grading systems that lack precision and sensitivity to detect strength changes unless relatively large changes in status have occurred. As a consequence, instruments that provide objective and more precise, quantitative measurements have been developed to supplement the information obtained from the manual muscle test and different test protocols have been compared.

C.5-1 Hand-held Dynamometers

Hand-held isometric dynamometers used for muscle strength testing are portable, can provide rapid information in a variety of settings, useful in population-based studies and relatively inexpensive compared to the costly isokinetic dynamometers. The latter are large fixed instruments that measure dynamic strength, believed to be a more physiologic measurement of physical function capacity (Reed et al 1993). The hand-held dynamometers are used following the same procedures as those of manual muscle testing. Work regarding validation is limited. Bohannon (1990) compared measures of knee extension torque obtained with a hand-held dynamometer (HHD) and an isokinetic dynamometer (IKD) as reference. In this sample of women (mean age 29.2 ± 7.0), the HHD was found to be highly reliable (ICC = 0.945). Measures obtained with the two instruments did not differ significantly and had fair inter-instrument reliability (ICC = 0.797). He proposed that these instruments could be used interchangeably and that HHD was a practical alternative. More recently, and in an older population of men and women 60 years and older, Reed and associates (1993) reported very good correlations between hand-held and isokinetic measurements that ranged from 0.74 to 0.85 ($p < 0.05$), depending on the muscle group being tested. Investigations documenting the reliability of hand-held dynamometers for muscle strengths other than grip are also limited. Bohannon (1986) retrospectively analyzed measurement data for 18 extremity muscle groups in 30 neurologically involved patients, aged 17 to 82 years, and found these measurements to be highly reproducible during a single session, with correlation coefficients ranging from $r = 0.84$ to 0.99. On two consecutive days, and in a group of 28 healthy children and children with muscular dystrophy, Stuberg and Metcalf (1988) found no significant difference ($p < 0.05$) between measurements (which included hip and knee extension, elbow flexion and shoulder abduction) taken within and across testing sessions in either group. Test-retest correlation coefficients ranged from 0.83 to 0.99 for the variables tested in the dystophic group and 0.74 to 0.99 in the healthy group.

C.5-1.1 Microfet Hand-Held Dynamometer

The Microfet2™ (Hoggan Health Industries, Draper, Utah) is one such hand-held dynamometer that was demonstrated at a recent conference of the Canadian Association of Gerontology held in Vancouver, B.C. in October 1995. It is a battery operated device that uses a strain gauge transducer and provides a digital readout of peak force, similar to the devices compared by Bohannon in 1993 that were found to be reliable and correlated. No data on reliability and validity for this particular instrument is available at this time.

C.5-1.2 Assessment Techniques Used With Hand-Held Dynamometers

The examiner- and the belt-resisted methods are two clinical techniques for assessing muscle strength using portable and/or hand-held devices. In the former, the examiner alone provides resistance and the stabilization/positioning of the device. In the belt-resisted method, a strap (5 cm wide) is positioned over the limb and around an examining table or chair's arm or leg, to provide some stabilization of the limb being tested. Using the same belt or an additional one, the strength testing device is positioned on the limb so that the imparted force compresses the device. Although Kramer et al 1991 reported both methodologies to be reliable in young and elderly women, they cited the following advantages of the belt-resisted method: 1) For the subject, greater stability, proprioceptive feedback and possibly decreased hesitancy to perform strong contractions, trusting their own resistance over which they have control. 2) For the examiner, there are reduced strength requirements since no active resistance is required when using this method.

C.5-2 Types of Tests Used in Assessment of Isometric Strength

There are two types of tests to use in assessing strength. The "make" test is performed by having the body segment impart a maximal voluntary isometric force to some external object, such as the examiner's hand in the case of the manual muscle test or the transducer pad of a hand-held dynamometer. The "break" test requires that the examiner pushes against the subject's limb until the subject's maximal muscular effort is overcome or "breaks" and the joint being tested gives way. Bohannon (1988) compared the forces produced by the elbow flexors during "make" and "break" tests in 27 young women (29.0 ± 5.2 years). Although the force produced during the "break" test was significantly greater, correlation between the forces measured during the two tests was high ($r = 0.81 - 0.87$, $p < .01$) as was the test-retest reliability ($r = 0.91$ for the two "make" tests and 0.92 for the two "break" tests), demonstrating that one is not superior to the other. These findings were later confirmed in a sample of 22 stroke patients, aged 33 to 78 (Bohannon 1990). Manual muscle testing, as well as other methods involving instrumentation, may be performed as either "make" or "break" tests. The "make" test is probably easier to execute, may be better tolerated and is generally preferred when instrumentation is used (Smidt and Rogers 1982). Higher reliability has also been associated with the hand-held dynamometry "make" test compared with the "break" test (Stratford and Balsor 1994).

C.6 Functional Lower Extremity Strength Tests

Practical function tests that are used to assess muscle strength and disability are clinically useful due to their simplicity and reliability. Administration is quick, easy and requires no special equipment or professional expertise. Gait speed (Aniansson et al 1980, Danneskiold-Samsøe et al 1884, Bassey et al 1992, Fiatarone et al 1994, Sonn et al 1995) and the Timed "Up and Go" (Podsiadlo and Richardson 1991) are two such tests that have been standardized with elderly subjects. In the gait speed test, straight distances covered by the subjects range from 6 to 30 meters, depending on space available where testing occurs. For example, 6 meters is appropriate for measurements made during home visits where space may be limited. Gait speed is already known to reflect muscle strength (Bassey et al 1992) and can also reflect function in geriatric patients in regards to their activities of daily living or ADL (Potter et al 1995). The Timed "Up and Go" Test is a modified, timed version of the "Get-Up and Go" Test (Mathias, Nayak and Isaacs 1986). It is a reliable and valid test for quantifying functional mobility in frail elderly persons, aged 60 to 90 years. Basic functional mobility focuses on actions such as getting in and out of a bed and chair, on and off a toilet and walking a few feet. Preliminary evidence suggests that this test may also be useful in following functional change over time. Intraclass correlation coefficients of 0.99 were found for both inter- and intra-rater reliability tests. Good correlations with the Berg Balance Scale (r = -0.72), gait speed (r = -0.55) and Barthel Index of ADL (r = -0.51) have been found.

C.7 Health Related Quality of Life Measurement

It has been suggested that overall health perception in the elderly may be determined by different factors than in young persons (Mangione et al 1993). This means that instruments measuring health that are too global may not capture critically important dimensions. The use of multi-dimensional instruments in the elderly is, therefore, important. The Medical Outcomes Study Short-Form 36 (SF-36) questionnaire is one such measure that evaluates health on eight multi-item dimensions covering functional status, well-being and overall evaluation of health (Ware and Sherbourne 1992). It is a short, 36-item questionnaire. Thirty-five of the items or questions contribute to these eight dimensions or subscales. There is also one item, asking respondents about health change over the past year, that is not used to score any of the above subscales (Appendix I).

C.7-1 Medical Outcomes Short Form SF-36 Health Survey

The SF-36 was designed to monitor ambulatory patients' outcomes in clinical practice and research, as well as for use in health policy evaluations and general population surveys. It was constructed for self-administration, telephone administration or administration during a personal interview. In studies conducted with elderly individuals, the 36 questions have been reported to take 10 to 15 minutes to complete by interview (Weinberger et al 1991, Lyons et al 1994).

Evidence for the reliability and validity of the SF-36 continues to accumulate both in North America and abroad and in various study populations (McHorney et al 1994, Jenkinson et al 1994, Garratt et al 1993, McHorney et al 1993, McHorney et al 1992).

McHorney et al (1992) report reliability estimates between 0.78 and 0.93 for all scales, in a population with either medical (minor or chronic) or psychiatric problems (n=969). Good construct validity was recently reported in the elderly, mean age 73.9 (Weinberger et al 1991). Brazier et al (1992) validated its use in Britain with 1980 patients, aged 16 to 74 years and reported test-retest reliability (at a two week interval) that ranged from 0.60 for the social functioning parameter to 0.81 for the physical functioning parameter.

As part of the International Quality of Life Assessment (IQOLA) project that was launched in 1991 the SF-36 was translated for use in 14 countries, adapted, and tested for cross-cultural applicability (Ware et al 1995). The Canadian version of the SF-36 was adapted from the U.S. form by Sharon Wood-Dauphinée, Ph.D. and colleagues at McGill University. The only alteration that was necessary to change was item 3g which went from "walking more than a mile" to "walking more than a kilometre". This same group was also responsible for the French-Canadian version.

D. OBJECTIVES

The main objective of the study is to determine the association between different functional status measures and FFM in a group of frail, elderly women aged ≥ 65 years. FFM will be assessed using multi-frequency bioelectrical impedance analysis. Functional status will be measured in terms of muscle strength: 1) handgrip strength as measured with a Jamar™ dynamometer; 2) handgrip strength as measured with the Martin vigorimeter; 3) handgrip strength as measured with a modified sphygmomanometer; 4) isometric elbow flexion strength as measured with the Microfet™ hand-held dynamometer; 5) isometric knee extension strength as measured with the same instrument; 6) functional lower extremity strength as measured with the Timed "Up & Go" test and usual walking speed over 15 meters. A second objective of the study is to test the reliability (repeatability) of these measures in this population. The final objective of the study is to determine the association between another measure of functional status, the SF-36 Health Survey, and FFM in these individuals.

The specific objectives among these frail women are as follows:

1. To describe the relationship between the handgrip strength measured with a Jamar™ dynamometer and FFM.
2. To describe the relationship between the handgrip strength measured with the Martin vigorimeter and FFM.
3. To describe the relationship between the handgrip strength measured with a modified sphygmomanometer and FFM.
4. To describe the relationship between elbow flexion (biceps) strength and FFM.
5. To describe the relationship between knee extension (quadriceps) strength and FFM.
6. To describe the relationship between the Timed "Up & Go" test and FFM.
7. To describe the relationship between usual walking speed and FFM.
8. To determine the test-retest reliability of these measures taken on two occasions separated by a one week interval.
9. To describe the relationship between the SF-36 Health Survey score and FFM in this population.

E. Significance of the Study

The proposed cross-sectional study has the potential to determine which measures of functional status best reflect fat-free mass among the frail elderly. The measures of upper and lower body strength were chosen from a broad search of physical and occupational therapy literature and are those that could easily be conducted in a community setting. Relationship with body composition is important when examining measures as indicators of nutritional status. Work in this area of research is at its initial stages and the results will serve as an important step in our search for valid and reliable measures which are badly needed in future studies of the prevention or treatment of undernutrition in the elderly.

PART II MATERIALS AND METHODS

A. Subjects

A.1 Subject Recruitment

The population envisaged was that of frail elderly still living at home. In order to standardize testing, however, it was necessary to recruit people living in group settings or people attending Day Centres. Subjects were recruited from a long-term care facility for retired nuns of the congregation "Les Soeurs de la Presentation de Marie" in Sherbrooke. The remaining subjects were recruited from among the volunteers working at the Hôpital d'Youville in Sherbrooke, Québec, patients admitted for short-term geriatric assessment at this facility, Day Hospital clients, residents of two convent-run nursing homes (one in Sherbrooke and the other in nearby Waterville) and clients attending the Geriatric Day Center at the Royal Victoria Hospital.

A.2 Subject Eligibility

Eligible subjects included those who were frail (depending on others for one or more aspect of their activities of daily living, for example bathing, cleaning, shopping, transportation), female, 65 years and older, ambulatory (with or without assistive device) and who did not have any conditions that would 1) preclude their ability to perform the muscle function tests, such as neuromuscular disease; 2) affect optimal performance as a result of a recent acute illness or unstable condition such as diabetes mellitus, arthritis, COPD, cardiac condition, depression as denoted by a score of > 10 on the Geriatric Depression Scale (Yesavage and Brink 1983) or use of medications such as corticosteroids; 3) invalidate bioelectrical impedance analysis due to the presence of hardware in artificial prostheses or edema, dehydration, hemiplegia that would affect fluid distribution throughout the body or medications that would affect water-mineral homeostasis such as diuretics; 4) preclude the introduction of the weak electrical current used in BIA, such as in individuals with internal pacemakers in place; 5) preclude their ability to understand the nature of the study, follow instructions and complete the SF-36 questionnaire, such as in the case of cognitive impairment as denoted by a score of < 24 on the Folstein Mini-Mental State Examination (Folstein et al 1975).

A total of 30 women met all eligibility criteria and, upon providing signed informed consent, made up this convenience sample. The study was approved by the ethics committees of the Royal Victoria Hospital in Montréal and the Centre de recherche en gérontologie et gériatrie de l'Hôpital d'Youville in Sherbrooke, Québec.

B. Data Collection and Management

B.1 Subject Characteristics Information

In addition to the measures described below, data on age, hospitalizations in the past year, concurrent illness and any major surgical interventions were collected. A copy of the Data Collection Form can be found in Appendix III.

B.2 Body Composition and Functional Status Measurements

All measurements were conducted by one examiner. BIA was the first measurement to be performed, followed by anthropometric measurements. The SF-36 questionnaire was completed during a rest interval provided approximately half way through the initial session. All other measurements were performed in random order, alternating between upper (Jamar™, vigorimeter, sphygmomanometer, biceps) and lower (quadriceps, Timed "Up & Go", gait speed) extremity tests. In the case of the nuns, the initial session was divided into two separate testing periods. The first for BIA measurement only, and the second for completion of the anthropometric and functional status measures. Repeat handgrip strengths, functional lower extremity strength tests and isometric muscle strength tests were conducted at an interval of one week for all subjects.

B.3 Body Composition Measurement

B.3-1 Bioelectrical Impedance Analysis

The assessment of fat-free mass (FFM) was conducted using bioimpedance spectroscopy (BIS). The Bio-Impedance Spectrum Analyzer (Model 4000B, Xitron Technologies, San Diego, CA) was used. Many "multifrequency" analyzers use only two frequencies, one at high and one at low, to predict TBW and ECW, respectively. BIS, however, makes Resistance (R), Reactance (Xc), Impedance (Z) and phase angle (ϕ) measurements throughout the entire frequency range of interest and uses a curve-fitting model to calculate the overall extracellular fluid resistance (Recf) and the intracellular fluid resistance (Ricf). Total body water volume (Litres), extracellular fluid volume (Litres), intracellular fluid volume (Litres), FFM (kg), and fat (kg), can be computed using built-in prediction equations.

Whole body measurements (wrist to ankle) were conducted on the right side of the body, according to standard procedures (NIH 1994). The analyzer was self-calibrated before each measurement session, using a standard resistor (422Ω) supplied by the manufacturer. Measurements were made > 2 hours after eating and within 30 minutes of voiding. Testing was conducted in the morning to control for any diurnal effects, known to play a role in body fluid fluctuations, that may possibly affect BIA measurements (Deurenberg et al 1988). The subject was clothed, with shoes, socks, jewelry and glasses removed, and in a supine position. This position was maintained for 10 minutes prior to testing, to accommodate for the sharp rise in impedance that is known to occur within this time period (NIH 1994). Limbs were adducted at 30° - 45° from the trunk. Disposable gum electrodes (similar to those used for ECG) were arranged according to present convention. Two distal current injection electrodes were placed on the dorsal surfaces of the hand and foot just proximal to the metacarpal and metatarsal phalangeal joints, respectively. Two current detection electrodes were positioned at the pisiform prominence of the wrist and between the medial and lateral malleoli of the ankle. A distance of 3 cm, the minimum distance required for sufficient separation of injection and detection electrodes, was maintained (Walker et al 1990). Resistance (R), reactance (Xc), impedance (Z) and phase angle (ϕ) were measured in a log spectrum of 50 frequencies from 5KHz to 1MHz.

FFM was estimated using two different equations: 1) supplied from the manufacturer and 2) using the following age-specific regression equation developed by Deurenberg et al (1990):

$$\text{FFM (kg)} = (0.671 \times 10^4 \times H^2/R) + 3.1(S) + 3.9$$

where, H^2/R is Height (m^2)/Resistance (ohms), S is gender with females 0; males 1.

B.3-2 Anthropometric Measurements

Height and weight was measured with the women wearing indoor clothing and without shoes, using a level platform with an attached measuring tape and a portable scale (Health-O-Meter electronic digital strain gauge scale, Bridgeview, Illinois 60455), respectively. When measuring height, the subject was asked to stand as straight as possible ensuring that her knees were also straightened. For data collected at the research center, a Detecto beam scale (Webb City, MO) with built-in measuring rod was used. Stature was measured to the nearest 0.2 cm and weight was recorded to the nearest 0.2 kg. Prior to taking these measurements, the subject was asked to report her weight, height and any recent changes in the former. Body Mass Index (BMI) was calculated as measured weight (kg)/measured height (m^2). The value was entered into two different age-specific prediction equations for body fat content (Deurenberg et al 1991) and body density (Visser et al 1994). Equations can be found in Appendix II.

Skinfold thickness measurements were taken at three sites (biceps, subscapular and suprailiac) using an Harpenden skinfold caliper (Bionetics Ltd., St-Laurent, Québec, Canada) and following standard procedures (Lohman et al 1988). All measurements were taken on the left side of the body with the subject standing. Two readings were taken; if the difference was > 1 mm, a third measurement was taken and the mean of the closest pair recorded. The logarithm of the sum of skinfold thicknesses at these three sites was used to calculate body density (Durnin and Womersley 1974) which was then used to calculate FFM (see Appendix II). Mid-upper arm and calf circumferences were measured using a flexible, nonstretch fiberglass tape with the subject standing. Mid-arm muscle area (MAMA) was calculated (see Appendix II) as an index of fat-free mass (Gibson 1990). Calf circumference represents muscle tissue in the lower leg and has been recommended as a more sensitive measure of muscle mass loss in the elderly than mid-arm circumference and mid-arm muscle area (Chumlea et al 1995).

B.4 Functional Status Measurements

B.4-1 Measures of Handgrip Strength

Hand grip strength was measured using three different instruments, namely the Jamar™ adjustable hand dynamometer (Model PC5030J1 - Therapeutic Equipment Corporation, Clifton NJ), Martin Vigorimeter (Elmed, Addison IL) and a modified aneroid adult sphygmomanometer.

For all three instruments, the subject was seated on a standard (46 cm) straight back chair without arm rests. Hips and knees were at right angles. Anthropometric data of both hands were collected (Desrosiers et al 1995). Hand circumference was measured at the thumb commissure following the axis of the head of the metacarpals. Hand length was measured from the distal crease of the wrist to the distal extremity of the middle finger. Circumference and length was recorded in centimeters and used to determine the best handle position (Jamar™ dynamometer) or bulb size (Martin vigorimeter) to use in the assessment of maximal grip. According to the American Society of Hand Therapists (1981) and Mathiowetz et al (1984), upper extremity position was ensured: shoulder adducted and neutrally rotated, elbow flexed at 90°, forearm in neutral position and wrist in light extension (0 to 30°). The examiner demonstrated how to hold the instrument and position the upper extremity, then sat directly opposite the subject. Verbal encouragement was provided throughout the period of effort. Three measurements were taken for each hand, alternating dominant/non-dominant. Hand dominance was reported by the subject. Recommended rest intervals to permit muscular recovery between replicate trials were provided.

B.4-1.1 Jamar™ dynamometer

The second handle position was used for all subjects. Central positioning of the hand on the handle was verified. The subject was instructed to squeeze the handle as hard as she could upon the examiner's signal. The dynamometer was lightly held around the readout dial by the examiner to prevent inadvertent dropping. The period of effort did not exceed 10 seconds and a minimum of 20 seconds between two measurements in one hand was ensured by alternating hands being tested (Mathiowetz et al 1985). Results were recorded in kilograms of force.

B.4-1.2 Martin Vigorimeter

The medium-sized bulb was used for all subjects. The bulb was held with the connection tube emerging between the thumb and index finger, while the examiner held the manometer. The subject was instructed to squeeze the bulb as hard as possible. The period of effort did not exceed 6 seconds (Fike and Rousseau 1982). Alternating hands allowed one minute of rest between two consecutive measurements in one hand. Results were recorded in kiloPascals (kPa).

B.4-1.3 Modified Sphygmomanometer

Modification of the sphygmomanometer was conducted according to Helewa et al 1981. The bladder was removed from the cuff, folded into three equal parts and secured in a partially sewn cotton bag (12.5 cm long by 9 cm wide). The valve was tightly closed prior to the system being inflated to 100 millimeters of mercury (Hg). This inflation is needed to remove any wrinkles from the bladder and ensure the air within was evenly distributed. Pressure was then reduced to a baseline of 20 mm Hg to provide some minimal standardized resistance for the subject to work against. This also creates a measurement interval of 20 to 300 mm Hg. The valve was tightly closed again to prevent leakage.

The sphygmomanometer bag was placed vertically in the subject's hand while the examiner held the gauge. The subject was instructed to squeeze as hard as possible. The period of effort did not exceed 5 seconds (Lusardi and Bohannon 1991). Alternating hands allowed for 1 minute between two measurements in one hand. Results were recorded in mm Hg. Since 20 mm Hg is the baseline measurement and corresponds to zero pressure applied, this amount was deducted from all readings.

B.4-2 Isometric Muscle Strength Testing

Maximum voluntary isometric strength of the knee extensors (quadriceps) and elbow flexors (biceps) was tested using the Microfet2™ dynamometer (Hoggan Health Industries, Draper, Utah).

Muscle testing, using the belt-resisted, "make" test, was performed bilaterally for each muscle group. The subject was seated in a straight back arm chair (standard seat height 46 cm) with shoulders adducted and neutrally rotated, hips at right angles. Three maximal contractions were recorded on the dominant side before repeating the procedure for the same muscle group on the opposite side. Prior to testing, the examiner demonstrated the muscle contraction to be performed. All contractions were of 4 seconds duration and completed about 30 seconds apart. Consistent verbal encouragement was given throughout the period of effort. Peak force of each contraction was recorded in newtons. Threshold position of the Microfet2™ dynamometer was maintained on High.

B.4-2.1 Elbow flexion

With the subject's arm resting on the arm of the chair, elbow flexion force was measured with the limb segment and dynamometer positioned as described by Bohannon (1986). The elbow angle was at 90°, next to the torso, with the forearm in complete supination. The resister belt was threaded through the hand strap of the dynamometer which was fitted with the curved transducer pad. The pad of the device was applied perpendicular to the surface of the forearm, just proximal to the radial styloid process. The belt was then secured to the arm of the chair, tight enough to stabilize the forearm but not too tight to create pressure. Additional manual stabilization was provided to the tested extremity. With her other hand, the examiner prevented the dynamometer from shifting position during the period of effort.

B.4-2.2 Knee extension

The subject was seated with the knee at 60° from full extension, foot resting flat on the floor. The resister belt was threaded through the hand strap of the Microfet2™ dynamometer which was fitted with the curved transducer pad. The pad was then applied perpendicular to the anterior surface of the leg, just proximal to the malleoli, as described by Reed et al (1993). The belt was secured to the adjacent leg of the chair. To prevent the belt from slipping, a piece of rubberized material (approximately 13 x 9 x 0.5 cm) was positioned between the surfaces of the resister belt and the leg of the chair.

B.4-3 Functional Lower Extremity Strength Tests

Lower extremity functional strength was measured using the Timed "Up and Go" test and usual gait speed. Both tests were conducted on linoleum floor surfaces.

B.4-3.1 Timed "Up and Go" Test

The subject was seated with her back against a standard (seat height of 46 cm) arm chair (Podsiadlo and Richardson 1991). Arms rested on the arm rests and any usual assistive device (none, cane or walker) remained at hand. On the word "go", the subject was instructed to get up, walk at a comfortable and safe pace to a line 3 meters away, turn, return to the chair and sit down. No physical assistance was given. The subject wore her usual footwear. A stopwatch was used to time the test and results were recorded to the nearest tenth of a second.

B.4-3.2 Gait speed

The subject was requested to walk, using her usual walking speed, for a distance of 15 meters. As in the above test, regular footwear was worn and any customary walking aid was used. The examiner followed the subject as she walked, ensuring that appropriate distance was maintained so as not to alter the subject's usual speed. A regular stopwatch was used to time the performance to the nearest 0.01 second. The speed was calculated in meters per second.

B.4-4 Medical Outcomes Study Short-Form 36 (SF-36)

The SF-36 health survey questionnaire was administered by the examiner. Permission to use the instrument and its French translation had been obtained from the Medical Outcomes Trust and Dr. Sharon Wood-Dauphinée, respectively (see Appendix IV). For each dimension, items were coded, summed and transformed on to a scale from zero (worst health) to 100 (best health).

D. Data Analysis

Data analysis was conducted using the Statistical Analysis System (SAS), DOS version 6.04 software (Cody and Smith 1991). The characteristics of the subjects were described by mean, standard deviation and range for the continuous variables (age, anthropometric and body composition measurements) and by frequencies and percentages for the categorical variables (co-morbidity, surgical interventions, recent hospitalizations, weight changes and ambulation status).

Correlation analysis was used to assess relationships between all functional status indicators and FFM. Scatterplots were used as part of the initial analysis to inspect the pattern of the association between body composition (FFM) and each grip strength measure, isometric muscle strength measure, functional lower extremity strength test and SF-36 subscale score. These graphical displays help detect outliers and identify any non-linear relationships that would be missed if analysis of magnitude and statistical significance of association was conducted directly.

The strength of associations that appeared linear, with no extreme observations or were between two numerical variables that were normally distributed were analyzed using the Pearson product moment correlation coefficient. This analysis was done on the highest score obtained on three trials, from either side of the body and either test session for handgrip, biceps and quadriceps strength. The maximum gait speed from test session one or two and the lowest score from both trials at either test session obtained on the Timed Up & Go test were likewise used. Pearson's correlation coefficients were also calculated between the upper extremity strength measures (handgrips and biceps) as well as between the upper and lower extremity (quadriceps) strength measures.

Spearman's rho or rank correlation was used to describe the relationship between the variables when one or both were not normally distributed or when the assumption of normality was threatened as when the sample was divided into smaller subsets or when there were outlying observations. Relationships involving SF-36 subscales, as well as relationships examined separately according to state of depletion or pain symptoms were described using this nonparametric equivalent.

Subjects were classified by body composition to relate functional status measurements to state of nutritional depletion. This classification was first presented by Schols et al (1993) who concluded that fat-free mass is a better predictor of physical impairment in COPD patients than body weight. Fat-free mass (FFM), as determined from BIA, was expressed as a percentage of ideal body weight to create a new variable called FFMIBW. Ideal body weight was determined as the mid-point of the weight range for a given height and frame size taken from the 1983 Metropolitan Life Tables. Since no frame size determinations were made for this particular sample of elderly women, the mid-point of the medium frame size was used exclusively. Extrapolations were required for the two height categories of 140 and 142 cm that were not represented on the table. Assuming a weight range of 5.45 kg for each category, the extrapolated mid-points were 50.68 and 51.59 kg, respectively (See Appendix VI). Body weight was also expressed as a percentage of ideal body weight (PIBW) as per the same mid-points. Four groups were formed based on a commonly employed definition of normal (≥ 90% ideal body weight) versus below normal body weight (< 90% ideal body weight) and a regression-derived cutoff value (also taken from Schols report) for normal (≥ 63%) versus below normal (<63%) FFMIBW. The following groups were formed:

Group 1. PIBW < 90% and FFMIBW < 63%

Group 2. PIBW < 90% and FFMIBW ≥ 63%

Group 3. PIBW ≥ 90% and FFMIBW < 63%

Group 4. PIBW ≥ 90% and FFMIBW ≥ 63%.

For the purpose of examining relationships according to body composition, Groups 1 and 3 were collapsed into one depleted group, leaving Group 4 as the not depleted group. There were no subjects who met the criteria for Group 2.

To examine the relationship between muscle strength and FFM within the context of pain reported in the SF-36, raw scores for the bodily pain index were used and the sample dichotomized into those with and without pain. The pain index (Appendix IV) is composed of two items or questions. The first (item 7) relates to how much bodily pain was experienced in the past four weeks. Response choices include none, very mild, mild, moderate, severe and very severe. The cut-off used for considering an individual to be suffering from pain was a moderate, severe or very severe response valued at 3.1, 2.2 and 1.0, respectively. It is important to note that the scale is scored positively so that a high score indicates lack of bodily pain. The second item or question included in the pain index (item 8) relates to how much did pain interfere with normal work during the past four weeks. Response choices to this item include not at all, a little bit, moderately, quite a bit and extremely. The arbitrary cut-off for pain, in this case, was set for responses of moderately, quite a bit or extremely valued at 3, 2, and 1, respectively. Individuals, therefore, who obtained a summed raw score on these two items that was less than or equal to 6.1 were classified as having pain while those with greater than 6.1 were classified as not. The lowest and highest possible raw scores for the pain index are 2 and 12, respectively.

A one-way analysis of variance was used to assess whether BMI or FFM differed according to age. Age was divided into three categories; less than 76, $76 \leq$ age <86 and age ≥ 86.

Differences between FFM estimated by BIA and FFM predicted from BMI equations or skinfolds were tested with paired Student's t tests. Percentiles of the individual differences between FFM estimated by BIA and FFM predicted from the BMI equation by Visser et al 1994 were examined. Two subjects, whose differences were above the 95th percentile, were excluded from subsequent analyses involving FFM as it is most likely that the TBW (BIA determined) was not correct (Deurenberg, personal communication with committee member).

The Wilcoxon Rank-Sum test, was used to compare the mean strength values between two different breakdowns of the sample that resulted in very small numbers. The first was between the depleted portion (n=19) of the sample and the not depleted portion (n=9) while the second was between the portion with pain (n=11) and the one without pain (n=19).

Test-Retest Reliability: The intraclass correlation coefficient (Fleiss, 1986) was used to assess the agreement of two separate observations of each grip strength measure, each isometric muscle strength measure and each functional lower extremity strength test, administered one week apart in each subject. The ICC, derived from the analysis of variance model, expresses the relative magnitude of the two components of variability that exists among the two repeat measurements taken in this study. The variability observed is a result of between-subject differences and the random variation or error. As random error decreases, the ICC approaches its maximum value of one. Conversely, as the random error increases, the ICC approaches its minimum value of zero. Unlike the Pearson's correlation coefficient, the ICC can be directly interpretable as the portion of variance of a measurement that is due to between-subject variability in error-free scores (Fleiss, 1986). The highest score obtained at each of the test sessions was used for this analysis. The practice of taking the highest score is commonly used in clinical practice, appearing more valid since it corresponds to the real potential maximum strength of the subject (Desrosiers et al 1995a). A 95% confidence interval (Bravo and Potvin, 1991) was calculated for each measurement. The confidence interval serves two purposes: 1) to provide a test of the hypothesis that the underlying value of the ICC is zero (meaning the measurement is so unreliable that the similarities between subjects at two points in time are due to chance alone) and 2) to indicate the limits of uncertainty concerning the degree of reliability present in these measurements. The Student's t test for mean differences $[|T_1 - T_2| = 0]$, $p<0,05$ was used to indicate the presence of any systematic bias and is interpreted as a learning effect if there was an improvement over time.

PART III RESULTS

A. Subject Characteristics

The study population consisted of thirty frail elderly women with a mean age of 81.5 ± 7.0 years. All subjects were Caucasian and born in the province of Québec, Canada. Sixteen women were retired nuns living in a nursing home, eight were nursing home residents from two other convent-run facilities, three attended the Day Hospital of the Hôpital d'Youville, one was undergoing a three week geriatric assessment at the hospital and two of the subjects were hospital volunteers. No subjects were recruited from the Royal Victoria Hospital.

The medical history of these women is summarized in Table 1. Two subjects, both in their 80's, reported having no medical problems. Twenty-two (73.3%) subjects, however, reported having more than one medical condition. Seventy percent suffered from arthritis. Gastrointestinal disorders (ulcers, liver, gallbladder or other digestive problems) were cited by half the sample. The most commonly reported medical conditions thereafter were heart disease (40 %), hypertension (36.7%) and peripheral vascular disease (36.7%). Sixteen women (53.3 %) had undergone major surgery with hysterectomy, mastectomy and cholecystectomy the most frequent reasons provided. The frequency of hospitalization in the last year was 26.7%. Nine subjects had reported weight loss during the last 12 months. This was the result of a voluntary effort in only one of the women. Six had reported losses in excess of 10% of usual weight. Using the guidelines of Blackburn et al (1977) this percentage weight loss would be classified as severe in the case of four of these subjects.

All subjects were ambulatory. Ten (33%) used assistive devices to maintain their mobility, specifically seven (23%) used a cane and three (10%) used a walker. Three women (10%) required the use of a cane only when walking outdoors.

B. Body Composition

B.1 Anthropometric Status

The mean body mass index (26.0 ± 4.7 kg/m^2) in our study sample was consistent with values (24 - 29 kg/m^2) associated with the lowest morbidity, mortality and functional dependency among the elderly (Galanos et al 1994, Cornoni-Huntley et al 1991, Kubena et al 1991, Zeman 1991, Harris et al 1988). Following these criteria, nine (30%) and seven (23%) of the frail elderly subjects were at high risk of low or high body weight, respectively.

Table 2 shows the mean anthropometric measurements of this sample. For each individual the height, weight, body mass index (BMI), mid-upper arm circumference (MAC), triceps skinfold thickness (TSF) and suprailiac skinfold thickness were also compared to reference percentile data for women aged 58 to 100 years (Kubena et al 1991). Subscapular skinfold thickness (SSF) and calf circumference measurements were compared to data reported by Chumlea et al (1985) for women 65 to 90 years old. Mid-upper arm muscle area (MAMA) was likewise compared to percentile norms developed by Falciglia et al (1988) for women aged 60 to 89 years. The use of three different standards was required since no one set provided percentile distributions for comparison of all the parameters measured in this study. Figure 1 shows the frequency distribution of these measurements for less than the 5^{th}, the 5^{th} to 50^{th}, the 51^{st} to 95^{th} and greater than the 95^{th} percentiles. Despite the limited sensitivity and usefulness of some anthropometric indices of body fat, fat distribution and muscle mass in the elderly (Baumgartner et al 1995), this comparison of individual anthropometric values to existing standards provides the following description of this sample. Sixteen women were ranked at or below the 50^{th} percentile for weight and nearly all (n=29) were within this category for height. The BMI, for the greater proportion of the sample, was categorized within the 51^{st} to 95^{th} percentile grouping. In regards to the indirect measures of body fat, namely the skinfold thicknesses, a greater number of the subjects were considered above average, that is, within the 51^{st} to 95^{th} percentile. The converse was seen in reference to the indices of lean tissue or muscle mass, namely calf circumference and mid-upper arm muscle area, as a greater number of these frail women (n=16) were at or below average.

B.2 Fat-Free Mass Determinations

Table 3 presents the body composition of these frail women. Shown are the BIA-determined values estimated from the built-in equations of the Xitron 4000B, as well as values for FFM estimated from three different predictive equations utilizing anthropometric data. Two of these equations (Deurenberg et al 1991, Visser et al 1994) predict percent body fat using body mass index while the third (Durnin and Womersley

1974) predicts body density using the logarithm of three skinfold thicknesses, namely triceps, subscapular and suprailiac. Fat-free mass is then derived from two other equations (See Appendix II for all of these equations). The fat-free mass, estimated from multi-frequency bioelectrical impedance, was highly correlated with the fat-free mass estimated from all three of the predictive equations. Pearson's correlation coefficient (r) ranged from 0.80, p=0.001 (Deurenberg et al 1991), to 0.83, p=0.001 (Durnin and Womersley 1974) to 0.86, p=0.001 (Visser et al 1994). A paired t-test analysis revealed, however, significant discrepancies between the BIA-determined FFM and the values predicted from all the equations except the Visser method. The BIA and the Visser method estimations of FFM were similar, with a mean difference of 0.90 ± 0.45 kg (p=0.06). The individual differences between these two methods, however, tended to increase as total body water, estimated from impedance, increased. Two subjects, with differences between the two methods of fat-free mass estimation that were above the 95^{th} percentile of their distribution, were excluded from subsequent analyses involving fat-free mass. BIA-determined FFM was higher than that determined by the Visser equation in both of these subjects.

The regression equation for calculating FFM from body impedance developed by Deurenberg et al (1990) could not be used with this elderly sample, despite the fact that the equation was derived from data collected on an older population. The estimation of TBW provided by the multi-frequency Xitron 4000B analyzer includes both ICF and ECF. Reactance was not measured in Deurenberg's subjects and the equation, therefore, uses only ECF volume as TBW. Applying the equation to this data set would presume that the hydration of fat-free mass in our sample was on average 91.2% as opposed to 73% if the built-in equation of the Xitron 4000B was used.

Table 4 shows body composition data calculated from bioelectrical impedance for these frail elderly women compared to data from three previous studies using the same method in slightly younger apparently healthy elderly women who were living autonomously (Ferry et al 1990, Blanchard et al 1990, Broekhoff et al 1992). Despite a similar body mass index between these subjects and those in the Broekhoff study, the amount of fat-free mass was lower in the frail as compared to autonomous elderly women. As a result, the proportion (%) of total body fat is greater in our sample of frail women. Although some of this difference in FFM is due to the older mean age of our subjects, it is doubtful that any of these other studies had any frail women in their sample. Within our sample no statistically significant differences by age were found in body mass index (F-value 0.42; df=2, p=0.66) or fat-free mass (F-value 0.04; df=2, p=0.96). The age groupings used in this one way analysis of variance were: < 76 (n = 5), $76 \leq$ age < 86 (n = 17), and age ≥ 86 (n = 6).

Age-related differences in body composition are quite pronounced when a much younger sample is used for the purpose of comparison. Blanchard et al (1990) estimated the percent body fat and fat-free mass in females aged 20 to 29 whose mean BMI was 22.04 ± 2.73. BIA-determined %BF and FFM (kg) were 24.7 ± 4.8% and 43.8 ± 3.2 kg, respectively. This comparison of two cross-sectional views is consistent with the significant changes in body composition that are known to occur with age during adulthood, specifically, the amount of fat in the body increases while the size of the lean components decrease (Novak 1972, Forbes and Reina 1970).

B.3 Group Classification by Body Composition

B.3-1 Classification Based on BIA-determined FFM

Since no data are available on ideal FFM, FFM was indexed to ideal body weight (Schols et al 1993). FFM, as determined from BIA, was expressed as a percentage of ideal body weight to create the new variable FFMIBW. Ideal body weight was determined as the midpoint of the medium frame range for a given height from the 1983 Metropolitan Life Insurance tables.(See Appendix VI). Indexing FFM this way circumvents the problem of reporting a lower percent fat-free mass, or conversely a high percent total body fat in overweight subjects. It also adjusts for the fact that taller women have higher percent FFM. Table 5 shows the classification according to body composition, with body weight also expressed as a percentage of ideal body weight (PIBW). Four groups were formed based on a commonly employed definition of normal (≥ 90% ideal body weight) versus below normal (< 90% IBW) body weight and a regression-derived cutoff value from Schols and colleagues (1993) for normal (≥ 63%) versus below normal (< 63%) fat-free mass. Five women (17.9%) were classified as below normal in both weight and FFM. The mean %FFM in this group was only 51.3 ± 5.7%. The remaining twenty-three women (82.1%) were classified as having normal weight, but within this category, the majority (61.9%) had below normal fat-free mass (mean value 59.1 ± 2.6%). Women in the Group 4 categorization (normal weight, normal FFM) had a mean FFMIBW well above the other two groups (70.5 ± 3.1%). The overall mean PIBW (108.8 ± 19.8%) and the overall mean FFMIBW (61.38 ± 7.78%) are also illustrative of the fact that even in relation to desirable body weight, the fat-free mass was very low in this group. Sarcopenia, defined as age-related loss in skeletal muscle mass, thus appears to be more prevalent within this frail elderly population as compared to a healthy elderly group. Although a number of our subjects appeared to be well nourished by body weight measurements, their body composition measurements indicated very low values for fat-free mass.

B.3-2 Classification Based on BMI-determined FFM

FFM, as determined by the Visser equation (Appendix II), was indexed in the same fashion to determine if these groupings by body composition could be reproduced using only anthropometry. The mean BMI-determined FFM expressed as a percentage of IBW (FFMIBW) was 60.49 ± 5.65% (n=28). Subsequent groupings were identical for all but three (10.7%) subjects. Two of these individuals, formerly categorized as normal weight, below normal FFM (Group 3), became classified as normal weight, normal FFM (Group 4). The third subject conversely went from a Group 4 categorization to Group 3. All subjects formerly classified as below normal weight, below normal FFM (Group 1) remained classified in this group.

C. Functional Status

The maximal strength result, specifically, the highest score on three trials, from either side of the body and either test session, was used for all subsequent analysis in regards to handgrip, biceps and quadriceps strength. Maximal gait speed from test session 1 or 2 and minimal time taken to complete the Timed "Up & Go" (lowest score from both tries at either test session) was likewise used. Mean values for each measure are presented in Table 6.

D. Association of Measures of Functional Status with FFM

D.1 Association of FFM with Muscle Strength and Functional Strength

An analysis of muscle strength measures in relation to fat-free mass indicated that all measures of strength were significantly correlated with fat-free mass estimated by BIA or anthropometry (Table 7). Pearson's correlation coefficients were higher with BIA predicted fat-free mass (FFM^1). Handgrip strength, when measured using the Jamar dynamometer, had the highest correlation with fat-free mass while quadriceps strength had the lowest. In contrast to the measures of muscle strength, the Timed "Up & Go" and gait speed, both measures of global function, were not associated with fat-free mass. All measures of upper extremity strength (handgrip and biceps) were strongly inter-correlated ($r \geq 0.63$, $p \leq 0.0002$). Upper and lower extremity strength measures were also correlated, with handgrip (Jamar) and biceps having the strongest association with quadriceps ($r = 0.62$, $p=0.0003$ and $r = 0.66$, $p=0.0001$, respectively).

D.1-1 Associations Stratified by Body Composition Groupings

Mean values for muscle strength in relation to body composition are shown in Table 8. Groups 1 and 3 from the previous categorization were collapsed into one depleted group for the purpose of this comparison. Group 4 is represented as the not depleted group. Elbow flexion (biceps) strength ($p=0.01$) and knee extension (quadriceps) strength ($p = 0.049$) were the only strength measures significantly different between the two groups. From the significance levels obtained for the other measurements, it appears that this comparison was most likely hampered by insufficient power. In fact, handgrip strength would have been significant if a one-tailed test had been chosen. Correlation analysis, Pearson's (r) and Spearman's (rho), revealed that within the depleted group only handgrip strengths ($r \geq 0.61$, $p \leq 0.005$; rho ≥ 0.47, $p \leq 0.04$)) were correlated with FFM. The rank correlation was calculated in addition to the Pearson's correlation coefficient since the assumption of normality was threatened due to small numbers in these groups. Although biceps strength is lower in the depleted women, within this group the degree of depletion was not related to biceps strength. In the not depleted group, none of the muscle strength measures were associated with FFM. Correlations between all upper extremity (handgrips and biceps) strength measures ($r \geq 0.54$, $p \leq 0.017$; rho ≥ 0.59, $p \leq 0.008$) and between all upper and lower extremity strength measures (rho ≥ 0.51, $p \leq 0.03$) held up in the depleted group only. In general, these results yield evidence that the relationship between FFM and muscle strength is not linear over all levels of body composition. The problem of a small number of subjects in the not depleted group must also be taken into consideration.

D.1-2 Associations Stratified by Level of Pain

Another issue that may be clouding the relationship between muscle strength and FFM in an elderly sample is one of pain. Arthritis is a prevalent condition among aging individuals and painful joints can interfere with day-to-day functioning. To examine this issue in this particular group of which 70% suffered from arthritis, the sample was dichotomized based on raw bodily pain scores obtained on items seven and eight of the SF-36 questionnaire. An obvious cut-off to use in regards to the presence of pain was a response of "moderate" or worse for the questions concerned with how much pain was experienced in the past four weeks and how much pain interfered with normal work. Individuals with a summed raw score of less than and equal to 6.1 were classified as having pain ($n = 11$) while those with greater than 6.1 were classified as not ($n = 19$). All muscle strength and functional strength measures were significantly different ($p < 0.04$) between the groups, with the exception of quadriceps strength ($p=0.08$). Correlation analysis ($r \geq 0.50$, $p \leq 0.05$; $rho \geq 0.42$, $p \leq 0.07$) revealed that all muscle strength measures, except quadriceps, were correlated with FFM, but only within the group reporting no pain. Timed "Up & Go" and gait speed were not correlated with FFM in either group. These results demonstrate that, in this frail elderly sample, pain appeared to be modifying the relationship between muscle strength and FFM.

D.2 Association of FFM with SF-36 Subscales

The SF-36 Health Survey contains 36 items or questions that measure physical and mental functioning, social and role disability, bodily pain, vitality and general health perceptions. These 36 items are summed into eight subscales that have two to ten items each and a single item measure of reported health transition that is not used to score any of the other scales. The subscales include: physical functioning, role limitations due to physical health or role-physical, bodily pain, general health perceptions, vitality, social functioning, role limitations due to emotional problems or role-emotional, and mental health. FFM was not correlated with any of the SF-36 subscales ($n=28$).

E. Association of Muscle and Functional Strengths with SF-36 Subscales

The relationship of these measures of muscle strength and physical function (Timed "Up & Go" and walking speed) to perceived functional capacities and well-being, as measured by the SF-36 health survey, provide a measure of how important strength and function is to health from the subjects' perspective. Table 9 shows the Spearman rank correlations of these measures and the SF-36 subscales in all 30 subjects. The Timed "Up & Go" and walking speed were each correlated with a minimum of five subscales. The strongest correlations were between Timed "Up & Go" and Social Functioning (rho = -0.66, p = 0.0001) and gait speed and Physical Functioning (rho = 0.70, p = 0.0001). Correlations for the Timed "Up & Go" were negative, showing the inverse relationship between the variables, that is, a shorter time taken to complete the Timed "Up & Go" test reflects better function and a higher score on the SF-36 items and scales indicates a better health state. Since a higher score or faster speed is required for better function, it follows that the correlations for gait speed were positive.

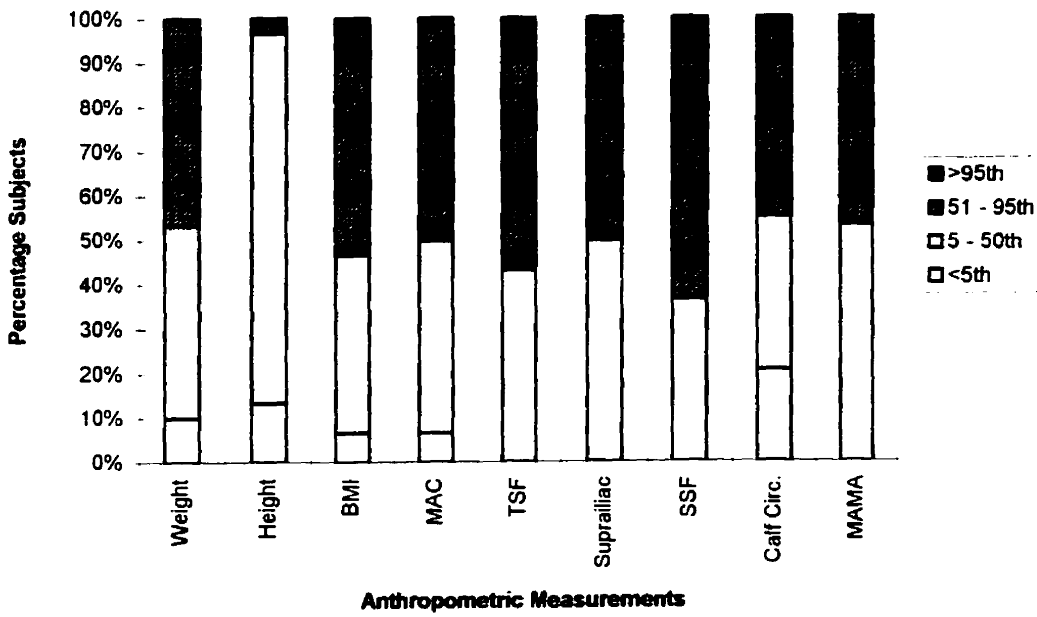
The muscle strength measure having the strongest association with the SF-36 was biceps strength. Significant associations were found between this measure and the role physical subscale (rho = 0.49, p=0.006), vitality (rho = 0.55, p=0.001), and pain (rho = 0.56, p=0.001). Handgrip strength, as measured with the vigorimeter and modified sphygmomanometer, was also related to the SF-36, but only to the pain subscale. Quadriceps strength was not related to the SF-36.

F. Test-Retest Reliability of Muscle and Functional Strengths Measurements

Results of the test-retest reliability are shown in Table 10. Intra-class correlation coefficients were greater than 0.90 for the functional indicators and ranged from 0.80 to 0.93 for strength measures with the exception of right knee extension strength indicating very good temporal stability of these measures. The only measure to have a systematic bias in the measures repeated one week apart was handgrip strength measured by the Jamar dynamometer, where a small but statistically significant improvement over the two time periods suggested a learning effect.

Figure 1. Frequency distribution of anthropometric measurements* by percentile grouping in frail elderly women.

	<5th	5 - 50th	51 - 95th	>95th
Weight	3	13	14	0
Height	4	25	1	0
BMI	2	12	16	0
MAC	2	13	15	0
TSF	0	13	16	1
Suprailiac	0	13	13	0
SSF	0	11	17	2
Calf Circ.	6	10	12	1
MAMA	0	16	14	0



*Abbreviations used: **BMI** (Body Mass Index), **MAC** (Mid-arm circumference), **TSF** (Triceps Skinfold), **SSF** (Subscapular Skinfold), **Calf Circ.** (Calf Circumference), **MAMA** (Mid-Upper Arm Muscle Area).

Table 1. Medical history of frail elderly women (n=30)

Characteristics	n	%
Weight loss reported during last 12 months	9	30.0
Weight loss > 10%[1]	6	20.0
Hospitalization in the last year	8	26.7
Major surgery	16	53.3
Medical problems[2]		
anemia	3	10.0
arthritis	21	70.0
cancer	1	3.3
cerebrovascular disease (e.g. stroke, cerebral hemorrhage, TIA's)	3	10.0
disease of urinary system	6	20.0
diabetes mellitus	1	3.3
gastrointestinal disorders (e.g. ulcers, liver, gallbladder or digestive problems)	15	50.0
glaucoma	1	3.3
heart disease (e.g. angina, MI, congestive heart failure)	12	40.0
hypertension	11	36.7
peripheral vascular disease	11	36.7
pulmonary disorders (e.g. asthma, chronic bronchitis or emphysema)	3	10.0
skin disorders	3	10.0
thyroid disorders	4	13.3
tuberculosis	1	3.3
other (vertigo)	2	6.7

[1]Percentage weight loss = (usual weight - actual weight)/usual weight × 100%

[2]22 subjects reported having more than 1 condition

Table 2. Anthropometric measurements in frail elderly women n=30

Variable	Mean	S.D.	Range
Age (years)	81.5	7.0	65 - 94
Weight (kg)	60.4	10.7	37.2 - 80.6
Height (cm)	152.3	4.3	141 - 160
BMI (kg/m^2)	26.0	4.7	17.5 - 34.4
Mid-upper arm Circumference (mm)	27.5	3.8	19.0 - 35.8
MAMA (mm^2)	3604	839	1892 - 5275
Triceps skinfold (mm)	20.3	7.1	8.8 - 40.6
Suprailiac skinfold (mm)*	18.5	8.0	6.8 - 37.4
Subscapular skinfold (mm)	16.9	6.8	6.4 - 39.4
Waist circumference (cm)	86.7	11.0	71.0 - 108.3
Hip circumference (cm)**	99.8	10.1	81 - 118
Waist-to-Hip Ratio**	0.9	0.1	0.8 - 1.3
Calf Circumference (cm)**	33.6	4.0	23.7 - 41.4

*n = 26; **n = 29

Table 3. **Body composition in free-living frail elderly women (n=30)**

	TBW (liters)[¶]	% TBW	Ratio ECF/ICF[§]	FFM[1] (kg)	FFM[2] (kg)	FFM[3] (kg)	FFM[4] (kg)
Mean	25.1	42.1	1.36	34.5[a]	32.9[b]	33.6[a]	38.2[b]
(S.D.)	(3.5)	(4.4)	(0.17)	(4.7)	(3.5)	(3.4)	(4.7)
Range	17.2 - 31.8	34 - 53	0.93 - 1.73	23.6 - 42.9	24.2 - 38.9	24.4 - 38.2	29.0 - 47.6

[¶] Total body water estimated from multi-frequency impedance

[§] Ratio of extracellular to intracellular water content

FFM[1] Estimated from multi-frequency BIA equation (Xitron 4000B) with the frequencies (n=50) randomly selected from 5Khz to 1Mhz

FFM[2] Deurenberg et al., 1991 (See Appendix II)

FFM[3] Visser et al., 1994 (See Appendix II)

FFM[4] Durnin and Womersley, 1974 (See Appendix II)

[a,b] Superscript differing from BIA-determined FFM[1] denotes statistically significant mean difference

Table 4. Body composition of free-living elderly women *

	AUTONOMOUS			FRAIL
	Ferry et al 1990 n = 53	Blanchard et al 1990 n = 14	Broekhoff et al 1992 n = 28	(current study) n = 28
Age (yrs) (range)	73.1 ± 1.8 (70.5-76)	68.2 ± 2.6 (65-72)	72.0 ± 4.0 (67-78)	81.5 ± 7.0 (65-94)
Weight (kg)	61.1 ± 11.4	60.2 ± 10.1	68.4 ± 9.9	60.4 ± 10.9
Height (m)	1.55 ± 0.07	1.58 ± 0.05	1.61 ± 0.07	1.52 ± 0.04
BMI (kg/m^2)	---	24.2 ± 3.2	26.3 ±3.4	26.1 ± 4.8
Fat-Free Mass (kg)**	38.0 ± 7.7	36.3 ± 4.4	40.6 ± 4.4	34.1 ± 4.6
Total Body Fat (%)**	37.9 ± 2.5	39.3 ± 3.7	40.0 ± 6.5	42.9 ± 5.4

* Mean ± S.D.

** Estimated from bioelectrical impedance using multi-frequency (Ferry et al, 1990; present study) or single frequency (50 kHz) (Blanchard et al, 1990; Broekhoff et al, 1992) methodology.

Table 5 Classification of Study Group by Body Composition (n=28)

Group No.	Classification	N	FFM(kg)*	%Body Fat	FFMIBW(%)	BMI**
1	PIBW < 90% and FFMIBW < 63%	5	28.5 ± 4.5	36.6 ± 2.4	51.3 ± 5.7	19.4
2	PIBW < 90% and FFMIBW ≥ 63%	0	—	—	—	—
3	PIBW ≥ 90% and FFMIBW < 63%	14	32.7 ± 1.8	43.5 ± 5.3	59.1 ± 2.6	24.4
4	PIBW ≥ 90% and FFMIBW ≥ 63%	9	39.3 ± 1.3	45.4 ± 4.1	70.5 ± 3.1	31.8

* Mean ± Standard Deviation

** Median

Table 6 Muscle and functional strength in frail elderly women (n=30)

Measurement	Mean (S.D.)	Range
Handgrip Strength		
Jamar™ dynamometer (kg)	18.87 (4.78)	8.0 - 30.0
Martin vigorimeter (kPa)	55.93 (14.64)	30.0 - 88.0
Modified sphygmomanometer (mm Hg)	148.33 (39.75)	60.0 - 230.0
Isometric Muscle Strength		
Elbow flexion (Nw)	98.3 (40.05)	31.0 - 204.0
Knee extension (Nw)	145.27 (47.34)	60.0 - 235.0
Lower Extremity Functional Strength		
Timed Up & Go (sec)	12.8 (5.4)	6.0 - 25.5
Gait speed (m/sec)	1.03 (0.33)	0.43 - 1.55

Table 7. Pearson correlation coefficient (r) between FFM and functional status indicators in frail elderly women (n=28)

	Handgrip Strength			**Isometric elbow flexion muscle strength**	**Isometric Knee extension muscle strength**	**Timed Up&Go**	**Gait speed**
	Jamar ™ dynamometer	Martin vigorimeter	Modified sphygmomanometer	Microfet2™ Hand Held Dynamometer			
FFM[1]	0.62 (p = 0.0005)	0.53 (p = 0.004)	0.54 (p = 0.003)	0.58 (p = 0.001)	0.45 (p = 0.017)	0.16 NS	0.19 NS
FFM[2]	0.55 (p = 0.002)	0.44 (p = 0.02)	0.51 (p = 0.006)	0.44 (p = 0.02)	0.42 (p = 0.03)	-0.01 NS	0.10 NS

[1] Xitron 4000B multi-frequency BIA equation

[2] Visser et al (1994) equation

Table 8. Comparison of muscle strength by body composition group

Muscle Strength Measure	Depleted (n = 19)	Not Depleted (n = 9)	P value
Handgrip Strength:*			
Jamar™ dynamometer (kg)	17.89 ± 4.59	21.56 ± 4.33	0.07
Martin vigorimeter (kPa)	54.63 ± 14.95	61.78 ± 12.14	0.32
Modified Sphygmomanometer (mm Hg)	143.79 ± 40.66	165.78 ± 35.54	0.15
Isometric Muscle Strength:*			
Elbow Flexion (Nw)	85.79 ± 34.80	128.89 ± 31.45	0.01
Knee Extension (Nw)	136.63 ± 47.32	172.22 ± 39.20	0.049
Lower Extremity Functional Strength:**			
Timed Up & Go (sec)	11.67 ± 4.49	14.60 ± 6.19	0.30
Gait Speed (m/sec)	1.09 ± 0.30	0.95 ± 0.36	0.24

*Maximum strength (highest score for all repetitions, right or left side, either test session)

**Minimum time

Table 9. Spearman rank correlations of functional status measures and SF-36 subscales (n=30)

	Handgrip Strength			Isometric Muscle Strength		Physical Function	
SF-36 Subscale	Jamar	Vigorimeter	Sphygmo-manometer	Biceps	Quadriceps	TUAG*	Gait Speed
Pain Index	0.41 (0.026)	0.54 (0.002)	0.53 (0.002)	0.56 (0.001)	0.32 (0.089)	-0.37 (0.042)	0.51 (0.004)
General Health Perceptions	0.12 (0.515)	0.27 (0.154)	0.27 (0.148)	0.40 (0.03)	0.23 (0.216)	-0.53 (0.003)	0.59 (0.0007)
Mental Health Index	0.01 (0.976)	0.28 (0.132)	0.24 (0.203)	0.29 (0.124)	0.17 (0.383)	-0.37 (0.043)	0.42 (0.02)
Physical Functioning	0.24 (0.20)	0.37 (0.045)	0.39 (0.031)	0.39 (0.032)	0.18 (0.353)	-0.62 (0.0002)	0.70 (0.0001)
Role-Emotional	0.08 (0.657)	0.21 (0.267)	0.17 (0.363)	0.21 (0.276)	-0.05 (0.814)	-0.36 (0.054)	0.26 (0.169)
Social Functioning	0.26 (0.17)	0.44 (0.016)	0.43 (0.018)	0.40 (0.030)	0.33 (0.078)	-0.66 (0.0001)	0.60 (0.0004)
Vitality	0.24 (0.205)	0.41 (0.026)	0.37 (0.044)	0.55 (0.002)	0.40 (0.028)	-0.61 (0.0003)	0.57 (0.001)
Role-Physical	0.39 (0.032)	0.28 (0.136)	0.31 (0.10)	0.49 (0.006)	0.29 (0.124)	-0.56 (0.001)	0.52 (0.003)

*Timed "Up & Go"

Table 10. Test-retest reliability of indicators of functional status in frail elderly women (n = 30)

	Highest score on 3 trials - T_1,T_2	ICC*	95% CI**	Pearson's (r)	Δ (T_1 - T_2)
Handgrip strength					
Jamar™ dynamometer (kg)					
Left	16.7 ± 4.2	0.83	0.73 - 0.90	0.85	-1.2[•]
Right	18.4 ± 5.1	0.89	0.81 - 0.94	0.90	-1.1
Martin vigorimeter (kPa)					
Left	49.9 ± 13.5	0.91	0.85 - 0.94	0.91	1.7
Right	53.9 ± 16.0	0.93	0.88 - 0.95	0.93	0.1
Sphygmomanometer (mmHg)					
Left	140.7 ± 40.2	0.87	0.79 - 0.92	0.88	-6.7
Right	141.3 ± 42.3	0.93	0.89 - 0.96	0.94	-2.3
Isometric muscle Strength					
Elbow flexion (Nw)					
Left	89.3 ± 40.1	0.86	0.78 - 0.92	0.86	-1.5
Right	89.9 ± 41.7	0.81	0.69 - 0.88	0.82	-6.8
Knee extension (Nw)					
Left	124.9 ± 52.2	0.80	0.68 - 0.87	0.80	-4.9
Right	134.6 ± 48.5	0.76	0.62 - 0.85	0.76	-8.3
Timed Up & Go (sec)	12.8 ± 5.4	0.90	0.84 - 0.94	0.90	0.12
Gait speed (m/sec)	1.03 ± 0.33	0.95	0.91 - 0.97	0.96	0.02

* ICC: Intraclass correlation coefficient (Fleiss, 1986)
** 95% CI: 95% confidence interval around the ICC (Bravo and Potvin, 1991)
• Pr > |T|: Probability associated with Student t-test statistics for mean differences [$|T_1 - T_2| \neq 0$], $p < 0{,}05$

PART IV DISCUSSION AND CONCLUSION

Sample Recruitment

Sample recruitment began initially at the geriatric day hospitals of the Royal Victoria Hospital in Montréal and the Hôpital d'Youville in Sherbrooke, Québec. The intent was to recruit independent-living frail women who could be tested in a group setting, thus reducing transportation of the various pieces of equipment needed to assess their body composition and functional status. The final sample, however, included only three day hospital clients. The elderly attending these special units, in general, do so because of the rehabilitation services provided and as a result suffer from many of the health conditions listed in our exclusion criteria. The remainder of our sample, therefore, consisted of frail elderly, who were relatively well, ambulatory and living either at home or in an assisted-living situation. The retired nuns, living in the nursing home attached to the convent, could technically still be classified as living at "home" since they have not left this cloistered existence and were not requiring important health services that could not be provided at home. It was possible, therefore, to conduct assessments at only three different locations, thereby keeping transportation of equipment to a minimum.

The frail elderly are difficult to recruit. These are not the same types of individuals seen participating in many of the large studies on aging. Unlike those healthy, relatively young elderly, the frail elderly are less likely to volunteer to be included in a study (Gray Donald 1995). Not only can they be less inclined to have strangers come into their homes, they are also less likely to leave their homes to be assessed.

Body Composition

This study is the first report of body composition of the free-living frail elderly. The mean age (81.5 years) of the individuals who participated is also noteworthy in that few investigations have managed to recruit subjects with a mean age greater than 75. The fat-free mass of these women was lower than previous reports (Ferry et al 1990, Blanchard et al 1990, Broekhoff et al 1992, Reed et al 1991) for well elderly females and indicates that even among women with a seemingly good weight for height, many have very low fat-free mass with a greater than expected percentage of body fat. Using bioelectrical impedance, Schols and colleagues (1993) have shown that among elderly patients with chronic obstructive pulmonary disease (COPD), depletion of fat-free mass can occur despite a normal body weight for height. Those patients with a low fat-free mass suffered from physical impairment to a greater degree than underweight patients with a relative preservation of fat-free mass. Their results indicate that somatic wasting has detrimental effects on respiratory muscle function and decreased exercise performance. Following the same method of classification by body composition, no subjects in this sample could be classified as underweight with normal FFM. We found all muscle strength measurements were lower in the depleted group but only reached statistical significance in regards to biceps muscle strength and quadriceps strength.

The FFM cut-off, used by Schols et al (1993) to create their body composition groupings, is the only one available in the literature. It can be argued, however, that because this value of 63% was derived in younger subjects (mean age 62 ± 9 years) it should not be applied to our older population. It may be too high, not reflecting the lower relative amount of FFM that would be present in a much older sample such as ours. We are, however, not comparing healthy "old" to healthy "young" elderly. The COPD subjects due to their chronic disease state are biologically older than their chronological age and may, therefore, serve as a reasonable comparison. Reducing this cut-off to even 60% would provide a very different picture of our sample and illustrates the difficulty in choosing a definite point to define two populations (depleted versus not depleted). Regardless of the cut-off used, there will always be individuals who are marginal and care must be taken when interpreting individual results.

Validation of BMI Prediction Equation for FFM

This study also provides the first cross-validation of the prediction equation for the estimation of body composition in the elderly using BMI (Visser et al 1994). The reference method used by Visser and colleagues to develop the equation was hydrodensitometry. Their resulting equation for body density, can be used in the adjusted or unadjusted Siri's formula to calculate body fat content. Siri's formula (Siri, 1961) in Appendix II assumes the value of the density of FFM to be 1.1000 kg/l, but with advancing age, the density of FFM may decrease due to demineralization of the bone and changes in body water. Deurenberg et al (1989) suggested adjustments to this equation stating that using the density value of 1.1000 kg/l could result in an overestimation of body fat in the elderly. The unadjusted formula, however, was used in the present study.

The FFM predicted from BMI and the estimate obtained using BIA were found to be similar. These findings confer with those of Deurenberg et al (1991). When FFM estimates obtained from the Visser equation were used, subjects were categorized by body composition in an almost identical fashion to bioelectrical impedance. This has exciting implications from a clinical perspective. Weight/height measurements and the calculation of BMI are easy to complete in most settings. Bioelectrical impedance technology, on the other hand, although relatively easy to use, is not widely available and cannot be applied to all elderly individuals. Common conditions in the elderly that preclude the use of BIA include: the presence of edema/dehydration or hemiplegia following a stroke that would affect fluid distribution throughout the body, the use of diuretic medications, the presence of internal pacemakers or orthopedic hardware as a result of joint replacements and any amputations. Individuals who meet current standards for IBW and whose BMI is within the recommended range are not those who are usually targeted for interventions regarding depleted FFM. Calculating FFM from BMI values and subsequently classifying these patients by body composition allows clinicians to identify those elderly persons who are at risk for poor outcomes re: medical, nutritional, or rehabilitation interventions due to masked low FFM. The application of energy restricted diets in elderly individuals with depleted FFM is one such situation that could be avoided.

Body Mass Index

This stratification by body composition provides additional support for the current recommended BMI range for the elderly. Bray (1987) recommended that the normal range should change with age, increasing by 1 kg/m^2 for each decade of life after 25 - 34 years. This would translate to a normal range of 24 to 29 for individuals greater than 65 years of age. Numerous studies (Galanos et al 1994, Kubena et al 1991, and Harris et al 1988) conducted in the elderly confirmed that this range is associated with the lowest mortality, morbidity and functional decline. Other examinations of the relationship between BMI and mortality (Tayback et al 1990, Cornoni-Huntley et al 1991) have extended the lower limit of this range to 22.

There is little documentation relating BMI to direct measurements of body composition in the elderly, especially at very old ages. Chumlea et al (1995) examined several anthropometric measurements in relation to levels of wasting in samples of both healthy and ill elderly French men and women. The mean value of BMI in the healthy women (n=329) was 25 while the value decreased to 19.1 and 20.9 in the malnourished (n=150) and ill (n=66), respectively. Similarly, in the well nourished portion of our sample, there was no individual whose BMI was under 25 and in the clearly depleted group, individuals with low body weight for height and low FFM, the median BMI was 19.4, with none of the women reaching a BMI of 22. The BMI values in the group with good weight and low FFM, were not as informative, ranging from 21.4 to 31.4 and having a median value of 24.4. This demonstrates the inability of this index to distinguish between adiposity and muscularity (Galanos et al 1994) except at low values when only small amounts of adipose tissue are present (Roche 1994) and its limitations, therefore, as a standard measure of overall nutrition in many clinical settings.

Associations of Functional Status with FFM

The relationship of strength measures to fat-free mass was very evident in this homogeneous sample. Although one can improve muscle strength through high, intensity, progressive resistance exercise training in the very elderly without weight gain or change in fat-free mass (Fiatarone et al 1994) it is important to recognize that many frail elderly have reduced fat-free mass and associated with this loss, there is a substantially reduced muscle strength (Castaneda et al 1995). Strength in upper and lower limb muscle groups play an important role in daily life. Reduced muscle strength, therefore, has tremendous potential implications on the ability of these frail elderly to perform activities of daily living necessary to maintain their independence in the community.

The frail elderly who have reduced muscle mass also have reduced protein stores since skeletal muscle is the largest reserve of protein in the body. Sarcopenia places these individuals at increased risk of protein depletion during times of metabolic stress. Many frail elderly admitted to hospitals are poorly nourished right from the start (Mowé et al 1994, Nelson et al 1993). If appropriate nutrition services and monitoring are not promptly provided upon admission, further losses could be incurred with devastating consequences. The rate of repair by nutritional intervention is often slow in relation to the rate at which depletion develops. Furthermore, the amount of energy required to repair a malnourished state has been shown to increase significantly with age (Shizgal et al 1992). Two recent short term studies have shown that weight gain, following nutritional intervention, is associated predominantly with expansion of fat mass and no significant increase in fat-free mass (Donahoe et al 1994, Schols et al 1995). Preservation of muscle mass and prevention of sarcopenia is, therefore, an important goal for older individuals.

Interestingly, FFM was not related to functional capacity as measured by walking speed and the Timed "Up & Go" test. It was also not related to perceived health as measured with the SF-36 questionnaire. These findings are not entirely surprising given that physical functional capacity is determined by a combination of many factors -

strength, endurance, motivation, flexibility, balance and coordination (Dutta and Hadley 1995) and because a low body weight can confer some advantage in these functional tests as less work is required. There are also a number of variables that affect an individual's perception of health and well-being especially when she is in a fragile state of health (Gray-Donald et al 1994).

Despite the weak relationship between FFM and functional strength, the relationships between both measures of functional strength and several of the dimensions of perceived health as measured with the SF-36 were strong. These measures were strongly correlated with five of the eight dimensions, namely physical functioning, role physical, general health perceptions, vitality and social functioning. Of all the muscle strength measures, biceps strength had the strongest relationship to perceived health. This relationship, however, was not as strong as that between the functional strength measures.

Outcome measures for use in the evaluation of the effectiveness of nutrition interventions conducted in the elderly are greatly needed. (Gray-Donald et al 1994, 1995) Whether the evaluation occurs in a long-term care setting, private clinic or as part of a community-based effort of ameliorating nutritional status, these indicators must be uncomplicated, reproducible and sensitive to changes in body composition. To date, functional status indicators that have been used to measure the effectiveness of nutritional intervention in the elderly have included: handgrip strength as measured with the Jamar™ dynamometer (Efthimiou et al 1988, Lewis et al 1987, Gray-Donald et al 1994), quadriceps strength (Goldstein et al 1986) and various health-related quality of life instruments (Efthimiou et al 1988, Gray-Donald et al 1994). Response, in the wake of significant improvements to nutritional status, has been conflicting in terms of handgrip and quality of life measures. In this study, other instruments for testing grip, more ergonomically suitable for use in the elderly, were examined in relation to body composition, as was testing of another muscle group, namely the biceps. From a methodological stand point, the sphygmomanometer, although easy to modify for the purpose of grip strength measurement, proved difficult to work with. Having no indicator needle that remains in position until reset by the examiner, a feature present in both the Jamar™ and Martin vigorimeter, reading results was frequently challenging. For this reason, use of the modified sphygmomanometer would not be recommended. Although hand-held dynamometers are frequently used to test muscle strength, this was the first time the Microfet™ was used in an elderly population and the first time with the belt-resisted "make" test method. Biceps strength measurement was easily conducted. This was not the case, however, when quadriceps strength was tested. While easy to immobilize the forearm of the subject to the arm of the chair for biceps testing, the only way to immobilize the subject's leg was attaching the belt to the adjacent leg of the chair, thus affecting the angle of movement in a negative fashion. For this reason, despite the fact that this method measures strength in a large proximal muscle, the results were somewhat disappointing in that quadriceps strength showed the lowest correlation with FFM of all the muscle strength measures. The methodology has since been standardized by researchers at the Centre de recherche en gérontologie et gériatrie, Hôpital d'Youville de Sherbrooke and a portable device, allowing appropriate stabilization of the limb to any standard height chair, has been devised. Future studies utilizing this technique are consequently warranted before recommendations can be made.

To date, most investigations involving the SF-36 in elderly subjects, have been concerned with its feasibility of use (Weinberger et al 1991) or validation (Brazier et al 1992, Lyons et al 1994). Constructed for self-administration, or administration by telephone or interview, we chose to use the latter method. Although resource intensive, the interviewer mode of administrating health related quality of life measures ensures compliance, decreases errors and decreases missing items (Guyatt et al 1993). This was certainly our experience having no missing responses to any of the items of the questionnaire. Self-administration of the SF-36 has been found to be clearly more difficult in people aged 75 years and older (Hayes et al 1995) and is recommended as suitable for this type of administration only if modifications to certain questions are considered. These researchers found that those questions that emphasized work or vigorous activities were frequently omitted by their elderly respondents who regarded these questions as not applicable at this stage in their life. Although scoring guidelines for the questionnaire (Medical Outcomes Trust 1994) allow for missed responses, this becomes problematic when respondents repeatedly miss questions. The ease with which the survey was administered to the elderly women in our sample would support, therefore, continued use of the interview method for SF-36 administration in frail individuals.

The relationships among variables can have different associations depending upon the health and nutritional status of the subjects (Chumlea et al 1995). We found the relationships between strength measures and FFM to have different statistical associations depending on the level of pain and relative preservation of lean tissue. The fact that the strongest relationships were among the depleted individuals could suggest that the relationship is not linear over all levels of body composition. Pain was definitely creating noise in the relationships between muscle strength and FFM. This is worrisome given the prevalence of arthritis in the elderly. Chumlea and colleagues (1995) have also highlighted the volitional problem of subject performance stating it may affect results and may be compounded by arthritis or other degenerative diseases or conditions that limit function in the limb being tested.

In this cross-sectional study we were only able to consider the discriminative abilities of these functional status measures in relation to FFM or the variability that exists between frail individuals at one point in time. All these measures, with the exception of quadriceps strength and handgrip measured with the Jamar, were found to be very reliable in this population, an important criteria for use as outcome indicators. The relatively poorer performance of the quadriceps strength was most likely due to the difficulty experienced in properly immobilizing the leg. There was evidence of a practice or motor learning effect in the case of Jamar™-tested handgrip strength since maximal scores improved over the two test sessions. This has not been previously reported (Mathiowetz 1990a, Desrosiers et al 1995a) although this is the first test-retest conducted in frail elderly women.

Because of the inherent limitations of the cross-sectional study design, there is a need to examine these relationships longitudinally to assess the evaluative abilities of these measures or variability within individuals during a period of time. Responsiveness refers to an instrument's ability to detect change. If a treatment results in an important difference, investigators want to be able to detect that difference, even if it is small. The selection of the cohort to be followed should take into consideration various categories of elderly: healthy, sick, very old, etc. since the relationships can be different depending on the health of the subjects. By following individuals prospectively we would be able to determine the extent to which decreases in FFM lead to decreases in muscle strength and functional activities or vice versa. Although not amenable to epidemiological research, it is also important to assess these measures in relation to direct measures of FFM such as Computed Tomography, Magnetic Resonance Imaging and Dual Energy X-ray Absorptiometry (Lukaski et al 1993) to establish biological relationships and corresponding changes with age.

Conclusion

The frail elderly have a very reduced fat-free mass. This is more reduced in thinner women, but many women who appear to be well nourished have a very low FFM as well. The maintenance of adequate FFM is an important aspect of preventive health in this frail elderly population. The relationships between the functional status measures and FFM were different depending on relative FFM preservation. Strength measures were strongly correlated with FFM but only in the individuals who were depleted. The functional status measures examined and tested show promise but require a longitudinal study design to fully explore their abilities to measure change in nutritional interventions involving frail elderly.

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APPENDICES

Appendix I Components of the SF-36™ Health Survey

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Appendix VI 1. Ideal Body Weights Based on Metropolitan Life Table (1983)

2. SAS® Statements: - Calculation of new variables FFMIBW and PIBW

- Body Composition Groupings

Appendix I

Components of the SF-36™ Health Survey

Components of the SF-36™ Health Survey: Number of Items and Summary of Content For Each Dimension Including The Health Transition Item[1]

Dimensions	No. of Items	Summary of Content
Physical Functioning	10	Extent to which health limits physical activities such as self-care, walking, climbing stairs, bending, lifting, and moderate and vigorous exercises
Role Functioning-Physical	4	Extent to which physical health interferes with work or other daily activities, including accomplishing less than wanted, limitations in the kind of activities, or difficulty in performing activities
Bodily Pain	2	Intensity of pain and effect of pain on normal work, both inside and outside the home
General Health	5	Personal evaluation of health, including current health, health outlook, and resistance to illness
Vitality	4	Feeling energetic and full of pep versus feeling tired and worn out
Social Functioning	2	Extent to which physical health or emotional problems interfere with normal social activities
Role Functioning-Emotional	3	Extent to which emotional problems interfere with work or other daily activities, including decreased time spent on activities, accomplishing less, and not working as carefully as usual
Mental Health	5	General mental health, including depression, anxiety, behavioral-emotional control, general positive affect
Reported Health Transition	1	Evaluation of current health compared to one year ago

[1] Adapted from Medical Outcomes Trust. SF-36 Health Survey Scoring Manual for English-Language Adaptations. Sept 1994 p.3.

Appendix II

Body Composition Formulae

Body Composition Formulae

I Prediction of FFM from Body Mass Index (Deurenberg et al 1991)

Percentage body fat (%BF) was derived using the following age specific equation:

$$\%BF = (1.2\ BMI) + (0.23\ AGE) - 5.4 \qquad (1)$$

%BF was converted to Total body fat (TBF) using the equation

$$TBF\ (kg) = (\text{body weight}\ (kg) \times \%BF) \div 100 \qquad (2)$$

TBF was converted to FFM using the equation

$$FFM\ (kg) = \text{body weight}\ (kg) - TBF \qquad (3)$$

II Prediction of FFM from Body Mass Index (Visser et al 1994)

Body Density was derived using the following equation:

$$D = 1.0605 + (-0.0022\ BMI) \qquad (4)$$

%BF was obtained from Siri's equation (1961)

$$\%BF = [(4.95 \div D) - 4.50] \times 100 \qquad (5)$$

FFM was then derived using equations (2) then (3).

III Prediction of FFM from 3 Skinfolds (Durnin and Womersley 1974)

Body Density was derived using the following equation:

$$D = 1.1298 - [0.065 \times \log(\text{Triceps} + \text{Subscapular} + \text{Suprailiac})] \quad (6)$$

%BF was obtained using equation (5)

FFM was derived using equations (2) then (3).

IV Calculation of Mid-Upper Arm Muscle Circumference (MAMA)

MAMA was calculated using the following equation (Gibson 1990):

$$\frac{[\text{MAC} - (\pi \times \text{TSF})]^2}{4\pi} \quad (7)$$

where, MAC is the mid-upper arm circumference
TSF is the triceps skinfold thickness

Consistent units (millimeters) were used throughout.

Appendix III

Data Collection Form

ID: _______

1. Sexe: 1 homme 2 femme
2. Âge: _______ans
3. Poids mémoire: _______kg
4. Poids: _______kg
5. Taille mémoire: _______kg
6. Taille mesurée: _______m
7. Hauteur du genou: _______cm
8. IMC mesuré: _______(kg/m^2)
9. Circonférence brachiale: _______
10. Triceps: _______
11. Sous-scap: _______
12. Suprailiaque: _______
13. Circonférence mollet: _______
14. Circonférence hanche: _______
15. Circonférence taille: _______
16. Ratio T/H: _______
17. Perte de poids récente: 1. oui 0. non
    17.1 si oui, combien? _______kg
    17.2 si oui, depuis combien de temps? _______mois
18. % perte de poids: _______
19. Perte de poids volontaire? 1. oui 0. non
    19.1 si oui, raison: ____________________

ID: ____

20. Hospitalisation durant la dernière année 1. oui 0. non
20.1 si oui, raison: ______________________________

21. Histoire médicale: 1. oui 0. non

arthrite ou rhumatisme	21.1 [ ]
glaucome	21.2 [ ]
asthme	21.3 [ ]
emphysème, bronchite chronique	21.4 [ ]
tuberculose	21.5 [ ]
haute pression	21.6 [ ]
troubles cardiaques	21.7 [ ]
troubles circulatoires (bras, phlébite)	21.8 [ ]
diabète	21.9 [ ]
ulcères d'estomac	21.10[ ]
autres troubles digestifs	21.11[ ]
maladie foie et vésicule biliaire	21.12[ ]
maladie du reins	21.13[ ]
problèmes urinaires	21.14[ ]
cancer ou leucémie	21.15[ ]
anémie	21.16[ ]
thrombose, hémorragie cérébrale, ACV	21.17[ ]
maladie de parkinson	21.18[ ]
épilepsie	21.19[ ]
paralysie cérébrale	21.20[ ]
sclérose en plaques	21.21[ ]
dystrophie musculaire	21.22[ ]
thyröide et troubles de la glande	21.23[ ]
maladie de la peau	21.24[ ]
trouble de la parole	21.25[ ]

22. Opération majeure 1. oui 0. non
22.1 si oui, raison: ____________________

23. Mobilité:
1. sans aide 2. canne 3. marchette 4. fauteuil roulant

24. Échelle de dépression gériatrique: ________

ID: ____

25. 2MS: ________

26. Anthropométrie de la main droite:
    26.1 circonférence: ________
    26.2 longueur: ________

27. Anthropométrie de la main gauche:
    27.1 circonférence: ________
    27.2 longueur: ________

28. Force de préhension Jamar:

Sem 1:	D: ________	G: ________
	D: ________	G: ________
	D: ________	G: ________
Sem 2:	D: ________	G: ________
	D: ________	G: ________
	D: ________	G: ________

29. Force de préhension Vigorimètre:

Sem 1:	D: ________	G: ________
	D: ________	G: ________
	D: ________	G: ________
Sem 2:	D: ________	G: ________
	D: ________	G: ________
	D: ________	G: ________

30. Force de préhension Sphygmomanomètre:

Sem 1:	D: ________	G: ________
	D: ________	G: ________
	D: ________	G: ________
Sem 2:	D: ________	G: ________
	D: ________	G: ________
	D: ________	G: ________

31. Marche de 15m:
    Sem 1: ________sec; ________m/s
    Sem 2: ________sec; ________m/s

ID: _____

32. Timed Up & Go:

Sem 1: ________sec

________sec

Sem 2: ________sec

________sec

33. Quadriceps:

Sem 1:	D: ________	G: ________
	D: ________	G: ________
	D: ________	G: ________
Sem 2:	D: ________	G: ________
	D: ________	G: ________
	D: ________	G: ________

34. Force de biceps:

Sem 1:	D: ________	G: ________
	D: ________	G: ________
	D: ________	G: ________
Sem 2:	D: ________	G: ________
	D: ________	G: ________
	D: ________	G: ________

35. Mains tendues en extension au dessus de la tête:

1. oui 0. non

Appendix IV

English-Canadian SF-36™ Health Survey

ENGLISH (CANADA)

SF-36

7/94

IQOLA SF-36 English (Canada)
Acute Version 1.0

SF-36 HEALTH SURVEY

INSTRUCTIONS: This survey asks for your views about your health. This information will help keep track of how you feel and how well you are able to do your usual activities.

Answer every question by marking the answer as indicated. If you are unsure about how to answer a question, please give the best answer you can.

1. In general, would you say your health is:

(circle one)

Excellent 1

Very good 2

Good 3

Fair 4

Poor 5

2. Compared to one year ago, how would you rate your health in general now?

(circle one)

Much better now than one year ago 1

Somewhat better now than one year ago 2

About the same as one year ago 3

Somewhat worse now than one year ago 4

Much worse now than one year ago 5

3. The following items are about activities you might do during a typical day. Does your health now limit you in these activities? If so, how much?

(circle one number on each line)

ACTIVITIES	Yes, Limited A Lot	Yes, Limited A Little	No, Not Limited At All
a. **Vigorous activities**, such as running, lifting heavy objects, participating in strenuous sports	1	2	3
b. **Moderate activities**, such as moving a table, pushing a vacuum cleaner, bowling, or playing golf	1	2	3
c. Lifting or carrying groceries	1	2	3
d. Climbing **several** flights of stairs	1	2	3
e. Climbing **one** flight of stairs	1	2	3
f. Bending, kneeling, or stooping	1	2	3
g. Walking **more than a kilometre**	1	2	3
h. Walking **several blocks**	1	2	3
i. Walking **one block**	1	2	3
j. Bathing or dressing yourself	1	2	3

4. During the past 4 weeks, have you had any of the following problems with your work or other regular daily activities as a result of your physical health?

(circle one number on each line)

	YES	NO
a. Cut down on the **amount of time** you spent on work or other activities	1	2
b. **Accomplished less** than you would like	1	2
c. Were limited in the **kind** of work or other activities	1	2
d. Had **difficulty** performing the work or other activities (for example, it took extra effort)	1	2

5. During the past 4 weeks, have you had any of the following problems with your work or other regular daily activities as a result of any emotional problems (such as feeling depressed or anxious)?

(circle one number on each line)

	YES	NO
a. Cut down the **amount of time** you spent on work or other activities	1	2
b. **Accomplished less** than you would like	1	2
c. Didn't do work or other activities as **carefully** as usual	1	2

6. During the past 4 weeks, to what extent has your physical health or emotional problems interfered with your normal social activities with family, friends, neighbors, or groups?

(circle one)

Not at all 1

Slightly 2

Moderately 3

Quite a bit 4

Extremely 5

7. How much bodily pain have you had during the past 4 weeks?

(circle one)

None 1

Very mild 2

Mild 3

Moderate 4

Severe 5

Very severe 6

8. During the past 4 weeks, how much did pain interfere with your normal work (including both work outside the home and housework)?

(circle one)

Not at all 1

A little bit 2

Moderately 3

Quite a bit 4

Extremely 5

9. These questions are about how you feel and how things have been with you during the past 4 weeks. For each question, please give the one answer that comes closest to the way you have been feeling. How much of the time during the past 4 weeks -

(circle one number on each line)

	All of the Time	Most of the Time	A Good Bit of the Time	Some of the Time	A Little of the Time	None of the Time
a. Did you feel full of pep?	1	2	3	4	5	6
b. Have you been a very nervous person?	1	2	3	4	5	6
c. Have you felt so down in the dumps that nothing could cheer you up?	1	2	3	4	5	6
d. Have you felt calm and peaceful?	1	2	3	4	5	6
e. Did you have a lot of energy?	1	2	3	4	5	6
f. Have you felt downhearted and blue?	1	2	3	4	5	6
g. Did you feel worn out?	1	2	3	4	5	6
h. Have you been a happy person?	1	2	3	4	5	6
i. Did you feel tired?	1	2	3	4	5	6

10. During the past 4 weeks, how much of the time has your physical health or emotional problems interfered with your social activities (like visiting with friends, relatives, etc.)?

(circle one)

All of the time 1

Most of the time 2

Some of the time 3

A little of the time 4

None of the time 5

11. How TRUE or FALSE is each of the following statements for you?

(circle one number on each line)

	Definitely True	Mostly True	Don't Know	Mostly False	Definitely False
a. I seem to get sick a little easier than other people	1	2	3	4	5
b. I am as healthy as anybody I know	1	2	3	4	5
c. I expect my health to get worse	1	2	3	4	5
d. My health is excellent	1	2	3	4	5

Appendix V

Consent Form

N° du participant [ ][ ][ ][ ]

FORMULAIRE DE CONSENTEMENT

INDICATEURS DE L'ÉTAT NUTRITIONNEL CHEZ LES PERSONNES ÂGÉES

Le Centre de recherche en gérontologie et gériatrie de l'Hôpital d'Youville réalise présentement un projet de recherche pour étudier l'état nutritionnel des personnes âgées de 65 ans et plus. Ces informations permettront une meilleure compréhension des besoins nutritionnels des personnes vieillissantes et, par conséquent, aideront à la planification de services appropriés sur le plan de votre alimentation.

Cette étude comporte d'abord les mesures suivantes : le poids, la taille et la hauteur du genou. Ces mesures sont réalisées avec un pèse-personne (poids), un mètre à ruban (taille) et un compas (hauteur du genoux).

Dans un deuxième temps, de façon à mieux comprendre l'importance et la répartition des muscles et de la graisse dans le corps, une autre mesure est faite avec un appareil d'impédancemétrie. Pour cette mesure, 4 électrodes reliées à l'appareil sont positionnées sur le dos de la main et sur la cheville. Un courant de faible intensité (250 µA RMS) est appliqué pendant 10 secondes. Cette mesure ne cause aucune douleur et ne représente **AUCUN DANGER**; l'appareil est, de plus, muni des mécanismes de sécurité approuvés. Nous tenons à préciser que vous ne devez pas vous soumettre à cette mesure d'impédance si vous êtes porteur d'un «pacemaker» ou d'un appareil conduisant au coeur ou à des vaisseaux sanguins principaux, de clous, vis ou prothèses articulaires métalliques ou d'agrafes métalliques.

Finalement, nous vous demanderons de répondre à un questionnaire portant sur votre état de santé général et d'exécuter quelques tests pour mesurer la force de vos mains et de vos jambes. Ces derniers tests seront répétés une fois à une semaine d'intervalle.

La première rencontre durera environ 45 minutes et la seconde seulement 15 à 20 minutes.

...2/

Les résultats de toutes les mesures effectuées seront traités confidentiellement par le Centre de recherche. En ce qui concerne les membres de l'équipe de recherche, l'anonymat sera entièrement respecté en remplaçant, sur tous les documents, le nom des participants par un numéro.

Nous tenons à préciser que vous pouvez refuser de participer à cette étude et que ce refus n'entraînera **AUCUN** changement dans les services et les soins que vous recevez présentement.

Je considère qu'on a répondu à toutes mes questions concernant ce projet de recherche; si d'autres questions survenaient, je pourrai communiquer avec Véronique Boutier (poste 2023) ou Hélène Payette (poste 2214) du Centre de recherche (829-7131).

Je, soussigné(e)______________________________ déclare avoir compris les objectifs de la présente étude, le rôle que j'aurai à y jouer ainsi que les bénéfices potentiels qui s'y rattachent. J'accepte librement et volontairement d'y participer en permettant à l'assistante de recherche d'effectuer les mesures décrites ci-haut. Je consens à ce que l'équipe de recherche consulte mon dossier médical pour obtenir des informations qu'elles jugent pertinentes à leur étude.

Je me réserve le droit de me retirer du projet à n'importe quel moment sans compromettre la qualité des soins et des services auxquels j'ai droit. J'autorise que les informations recueillies dans le cadre de ce projet soit utilisées à des fins de comparaisons statistiques.

Signature du sujet	Signature du témoin	Date

Signature de la responsable du projet	Date

Appendix VI

1. Ideal Body Weights Based on Metropolitan Life Table 1983

IDEAL BODY WEIGHTS BASED ON METROPOLITAN LIFE TABLE

Ht (in)[1]	Ht (cm)	Ideal Wt (kg)[2]	Range (lb.)[3]	Accept (in)	Accept (cm)
55	140	50.68	12	54.6 - 55.5	140, 141
56	142	51.59	12	55.6 - 56.5	142, 143
57	145	52.27	12	56.6 - 57.5	144, 145, 146
58	147	53.18	12	57.6 - 58.5	147, 148
59	150	54.32	13	58.6 - 59.5	149, 150, 151
60	152	55.45	14	59.6 - 60.5	152, 153
61	155	56.82	14	60.6 - 61.5	154, 155, 156
62	157.5	58.18	14	61.6 - 62.5	157, 158
63	160	59.54	14	62.6 - 63.5	159, 160, 161

[1]Minimum height presented on the table for women is 58" with heels, therefore, 57" without. Extrapolations for mid-point of weight range were made, assuming a weight range of 12 lb. or 5.45 kg for each of the height categories of 56 and 55".

[2]Mid-point of weight range for medium frame

[3]Weight range for medium frame of height category

2. SAS® Statements

```
options ps=60;
libname sav 'c:';
data FFMgrp;set sav.max4;
if id=9 or id=11 then delete;
if m=1.41 then FFMIBWm=(FFMp/50.68)*100;
if m=1.43 then FFMIBWm=(FFMp/51.59)*100;
if m=1.45 then FFMIBWm=(FFMp/52.27)*100;
if m=1.46 then FFMIBWm=(FFMp/52.27)*100;
if m=1.50 or m=1.51 then FFMIBWm=(FFMp/54.32)*100;
if m=1.52 or m=1.53 then FFMIBWm=(FFMp/55.45)*100;
if m=1.54 or m=1.55 then FFMIBWm=(FFMp/56.82)*100;
if m=1.56 then FFMIBWm=(FFMp/56.82)*100;
if m=1.57 then FFMIBWm=(FFMp/58.18)*100;
if m=1.60 then FFMIBWm=(FFMp/59.54)*100;
if m=1.41 then pIBWm=(kg/50.68)*100;
if m=1.43 then pIBWm=(kg/51.59)*100;
if m=1.45 then pIBWm=(kg/52.27)*100;
if m=1.46 then pIBWm=(kg/52.27)*100;
if m=1.50 then pIBWm=(kg/54.32)*100;
if m=1.51 then pIBWm=(kg/54.32)*100;
if m=1.52 then pIBWm=(kg/55.45)*100;
if m=1.53 then pIBWm=(kg/55.45)*100;
if m=1.54 then pIBWm=(kg/56.82)*100;
if m=1.55 then pIBWm=(kg/56.82)*100;
if m=1.56 then pIBWm=(kg/56.82)*100;
if m=1.57 then pIBWm=(kg/58.18)*100;
if m=1.60 then pIBWm=(kg/59.54)*100;
if pIBWm<90 and FFMIBWm<63 then group2=1;
if pIBWm<90 and FFMIBWm>=63 then group2=2;
if pIBWm>=90 and FFMIBWm<63 then group2=3;
if pIBWm>=90 and FFMIBWm>=63 then group2=4;
if m=1.41 then FFMvIBWm=(vissffm2/50.68)*100;
if m=1.43 then FFMvIBWm=(vissffm2/51.59)*100;
if m=1.45 then FFMvIBWm=(vissffm2/52.27)*100;
if m=1.46 then FFMvIBWm=(vissffm2/52.27)*100;
if m=1.50 then FFMvIBWm=(vissffm2/54.32)*100;
if m=1.51 then FFMvIBWm=(vissffm2/54.32)*100;
if m=1.52 then FFMvIBWm=(vissffm2/55.45)*100;
if m=1.53 then FFMvIBWm=(vissffm2/55.45)*100;
if m=1.54 then FFMvIBWm=(vissffm2/56.82)*100;
if m=1.55 then FFMvIBWm=(vissffm2/56.82)*100;
if m=1.56 then FFMvIBWm=(vissffm2/56.82)*100;
if m=1.57 then FFMvIBWm=(vissffm2/58.18)*100;
if m=1.60 then FFMvIBWm=(vissffm2/59.54)*100;
if pIBWm<90 and FFMvIBWm<63 then group4=1;
if pIBWm<90 and FFMvIBWm>=63 then group4=2;
if pIBWm>=90 and FFMvIBWm<63 then group4=3;
if pIBWm>=90 and FFMvIBWm>=63 then group4=4;
run;
```

IMAGE EVALUATION TEST TARGET (QA-3)

150mm

6"

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