The Relationship Between Anthropometry and Body Composition Assessed by Dual-energy X-Ray Absorptiometry in Women 75-80 years old: Are New Skinfold Equations Needed?

by

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Abstract

A link between age-related changes in body composition (BC) and the increased prevalence of disease and disability in old age has been well established (Chumlea & Baumgartner, 1989; Going et al., 1995; Shephard, 1997). Consequently, BC assessment is becoming increasingly important in the evaluation of the health and functional status of the older adult. Individuals 75 years and older comprise one of the fastest growing segments of the population in North America (Canada, 1999; Donatelle & Davis, 1994), yet current BC measurement techniques may not be accurate or reliable in this older age group. The intent of this research was to develop new body fat prediction equations in elderly women based on anthropometry and the criterion method of dual energy X-ray absorptiometry (DEXA), which is considered to be more valid than conventional densitometry among the aging population (Baumgartner et al., 1995; Kohrt, 1998; Visser et al., 1998).

Anthropometry, skinfold (SF) anthropometry, and DEXA (Hologic QDR-4500W) body fat data were initially collected in a sample of 43 women 75-80 years old (m = 77.4yrs) as part of a larger study investigating the effects of strength training on strength, function, bone mineral density (BMD), and BC. Eight BC prediction equations for the elderly were selected from the literature and applied to these data. The correlation between prediction equations and DEXA ranged from 0.76-0.97. However, paired t-tests difference scores (δ) showed that all but one of the equations overestimated DEXA body fat in these older aged women (δ ranged from −3.3kg to 4.0kg and 4.4% to 9.0%; $p<0.001$ in all cases). New equations were derived for FM, %Fat, trunk fat mass (TFM) and percent trunk fat (%TF) using a combination of stepwise and all possible subsets regression procedures, as both total and regional percent fat are important health indicators (Going et al., 1995). The following were entered as predictor variables: weight (WT), height (HT), BMI, hip circumference (HC), waist circumference (WC), SF's of the subscapular (SS), suprailiac (SI), abdominal (ABD), and midaxillary (MA) sites, the SS to triceps skinfold ratio (SSTRI), and the sum of triceps, biceps, SI and SS (SUM4SF); except HC and SUM4SF were not included in the trunk fat regressions.

	New Equations	Adj. R^2	Cp	SEE
FM	= 0.611(WT) - .231(HT) + .143(MA) + 16.462	0.95	4.46	1.53kg
%Fat	= 0.341(WT) – .339(HT) + .285(MA) + 60.122	0.84	4.61	2.12%
TFM	= 0.185(WT) - .008(HT) + .112(MA) + .136(WC) – 2.072	0.90	3.77	1.27kg
%FT	= 0.387(MA) - .227(HT) + .356(WC) + 30.659	0.83	3.9	2.76%

Ultimately, the measure of interest in body composition assessment is the value %Fat and thus supports using the %Fat equation over that for FM. Moreover, %Fat equation was associated with less error ($C.V._{\%Fat} = 5.9\%$; $C.V._{FM} = 6.4\%$). The %TF equation, however, was less precise than the equation for total %Fat and therefore was not considered further in this research. Subsequent analysis showed the %Fat equation to be internally valid using the jackknife method for data splitting. Finally, %fat equations developed in this study sample were tested in two independent samples of elderly women (71.1yrs and 74.5 yrs) and one sample of younger women (33.4 yrs) shared by Baumgartner (1999) and Brodowicz (1999). Both independent studies used DEXA instruments manufactured by Lunar. New equations were

derived for this application using only the variables measured in these independent studies as the predictor variables.

Modified Equations			Adj. R^2	SEE
BROD	%Fat	= 9.819 + .162(SUM4SF) + .652(BMI) - .261(SS)	0.82	2.21
BAUM	%Fat	= 9.198 + .696(BMI) + .295(TRI)	0.80	2.37

The modified prediction equations were reasonably correlated ($r = .73, .81$) with %Fat from DEXA (Lunar) in the elderly women, yet paired t-tests results showed that the new equations significantly underestimated %fat by 6.6% ± 3.9 ($p \leq 0.001$)(BROD), and 5.1% ± 4.5 ($p \leq 0.001$)(BAUM). An unexpected finding was the accurate prediction of %Fat in the younger women ($\delta = -0.7\% \pm 5.4$; $p = 0.45$). The correlation between predicted and measured %Fat was also stronger ($r = .89$). However, the two methods were not interchangeable as a trend in the residuals indicated that %Fat was underpredicted at low body fat and overpredicted at high body fat in the younger women.

A major finding of this study was that neither existing equations nor the newly derived equations were able to accurately and reliably predict body fat in independent samples of elderly women. Some of the prediction error can be attributed to inter-method differences and differences in DEXA manufacturer, but this lack of agreement also emphasizes the problem of sample specificity with regression equations. Equations will always perform better in the sample from which they were derived and must be interpreted with caution when applied externally. A second major finding of this research was that a single "best" equation did not exist for these data, but rather, several alternative models provided similar equation statistics and regression coefficients. However, the combination of WT, HT (or BMI) and SF's was better than SF's alone.

Nonetheless, this study demonstrated that a strong relationship between anthropometry and DEXA exists among elderly women and that internally valid equations can be proposed for this population. Moreover, it is reasonable to conclude that prediction equations based on DEXA have greater face validity in elderly women than those based on densitometry, as the DEXA model is associated with fewer assumptions. Due to the relatively small sample size, the new %Fat equation cannot be recommended at this time. However, this study shows promise for future use of DEXA and anthropometry in elderly women.

Table of Contents

List of Tables

List of Figures

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To my grandmothers,

Irma Elizabeth Hamilton and Margaret Frances Dalton

1. Introduction

1.1 Rationale

The health and well-being of the rapidly expanding older adult population is becoming a major public health concern in North America as disease and disability become more prevalent with advancing age. Much of the disease and disability affecting the elderly today has been linked to age-related changes in body composition, which in turn, may largely be the result of sedentary lifestyle practices and poor nutrition (Baumgartner, Stauber, McHugh, Koehler, & Garry, 1995; Chumlea & Baumgartner, 1989; Evans & Cyr-Campbell, 1997; Going, Williams, & Lohman, 1995; Shephard, 1997). Consequently, the measurement of body composition is becoming increasingly important in the assessment of health, nutritional and functional status of the older adult population and in monitoring the effectiveness of exercise, diet and medical interventions.

Women over the age of 75 years comprise one of the fastest growing segments of the population (Canada, 1999; Donatelle & Davis, 1994), yet at present, no one method of body composition assessment appears to be both accurate and convenient for use in this more elderly population. Three major problems concern the measurement of body composition in the elderly: 1) assumptions of conventional criterion methods are invalid; 2) indirect methods based on conventional criterion methods will retain errors associated with the criterion methods; and 3) the procedures of conventional criterion methods may be less reliable.

Hydrodensitometry, or underwater weighing (UWW), has been considered the criterion method in body composition against which most indirect and more practical methods are standardized (Lukaski, 1987). Whole body density is measured and converted to percent body fat using the well-known Siri's equation based on the conventional two-compartment (2C) model (Brodie, 1988a; Keys & Brozek, 1953). The 2C model divides the body into fat mass (FM) and fat-free mass (FFM) components and assumes a constant density of 1.1g/ml for the FFM component (Keys & Brozek, 1953; Lukaski, 1987). This model, therefore, does not hold for older adult populations whose FFM density (d_{ffm}) is considerably lower and much more variable due to rapid bone loss associated with aging (Baumgartner, Heymsfield, Lichtman, Wang, & Pierson, 1991; Deurenberg, Weststrate, & van der Kooy, 1989; Going et al., 1995; Lukaski, 1987; Martin & Drinkwater, 1991).

The UWW method is not convenient for field or clinical conditions, and therefore, it has been usual practice to regress more reasonable assessment methods against UWW. Of these, the most common indirect method is anthropometry, which includes the thickness of the skinfold (SF), body girths, height and weight (Brodie, 1988a) (Durnin & Rahaman, 1967; Lohman, 1981). Since the strong correlation between anthropometry and body composition was discovered, numerous general and population specific equations have been derived to predict body composition from anthropometry (Durnin & Womersley, 1974; Martin, Ross, Drinkwater, & Clarys, 1985). Due to concerns for the aging population, several equations have been developed in the elderly over the past decade. However, many of these equations were derived from body density measurements from UWW and will thus retain errors inherent to the 2C model (Baumgartner et al., 1991).

Advances in body composition technology now allow quantification of previously unmeasureable fractions of the FFM by dividing the body into either three compartments (3C) or four (4C) (Heymsfield et al., 1990; Mazess, Barden, Bisek, & Hanson, 1990). Dual-energy X-ray absorptiometry (DEXA) has the capability of dividing the body into 3C: fat mass, non-bone fat-free mass and bone mineral content, and therefore accounts for variation in the FFM component due to bone (Baumgartner et al., 1991). Originally developed for the assessment of bone mineral density, DEXA has demonstrated reasonable accuracy and precision in the measurement of soft-tissue components (Gotfredsen, Baeksgaard, & Hilsted, 1997; Kelly, Berger, & Richardson, 1998b; Kelly, Shepherd, Steiger, & Stein, 1997; Kohrt, 1998; Mazess et al., 1990; Pritchard et al., 1993; Svendsen, Haarbo, Hassager, & Christiansen, 1993). Four-compartment models use a combination of hydrodensitometry, DEXA and total body water methods to assess body composition (Heymsfield et al., 1990). Although DEXA may be less accurate than the 4C methods, there is less error involved with using only one instrument (Guo, Chumlea, & Cockram, 1996). DEXA has a further advantage in that it can be used to assess regional body composition (Baumgartner et al., 1995). In the case of body fatness, excess abdominal adiposity (particularly internal fat) is more strongly linked to health risks than total body fat, and perhaps a more useful measure (Borkan et al., 1983).

Like UWW, these more sophisticated 3C and 4C models are not practical for wide scale use because of equipment costs, the need for a laboratory setting, and the expense of trained technicians. Simple anthropometry equations based on 3C and 4C would be more useful and certainly more valid than 2C equations in the elderly. Research in this area has begun, but due to various limitations, none of the existing equations appear valid for women over the age of 75 (Chapman, Bannerman, Cowen, & MacLennan, 1998; Goran, Toth, & Poehlman, 1997; Svendsen, Haarbo, Heitmann, Gotfredsen, & Christiansen, 1991).

1.2 Purpose

The primary intent of this research was to evaluate the performance of existing body composition prediction equations in a sample of women ages 75 to 80 years and to propose new prediction equations based on DEXA for total and regional body fat for this population. Additionally, requests were made for independent databases of both young and elderly women to test the performance of the newly developed equations and confirm the need for separate assessment techniques among different age cohorts.

2. Review of the Literature

2.1 Health care implications of an aging society

The number of people aged 65 years and older in Canada is expected to nearly double over the next thirty years and comprise more than 20% of the population as a result of the aging "baby boomer" (Canada, 1999). An even more dramatic rise is expected for people 75 years of age and older due to increased life expectancy (Baumgartner et al., 1995; Canada, 1999; Going et al., 1995). Similar increases are predicted for the U.S. and other industrialized nations (Donatelle & Davis, 1994). As disease and disability become more prevalent with age, the aging baby boomers will no doubt place an unprecedented stress on the current health care system (Canada, 1999; Shephard, 1997). U.S. health care statistics for 1992 indicated that 36% of all health care expenditures were spent on the elderly, who at that time comprised only 13% of the total population (Donatelle & Davis, 1994).

There is increasing evidence that the maintenance of desirable body composition in old age has important health and functional implications (Kuczmarski, 1989; Snead, Birge, & Kohrt, 1993). Information related to age-related changes in body composition and the factors influencing these changes will therefore have substantial health care benefits. As a result, the measurement of body composition in the elderly has become an important focus in the growing body of literature on aging, body composition and health (Baumgartner et al., 1995; Chumlea & Baumgartner, 1989; Going et al., 1995; Visser et al., 1998; Visser, Van Den Heuvel, & Deurenberg, 1994).

Women continue to outlive their male counterparts and thus make up the majority of seniors over the age of 75 years (Canada, 1999; Donatelle & Davis, 1994; Shephard, 1997).

Consequently, the specific health care needs of elderly women should be the focus of future investigations.

2.2 Study of human body composition

The study of human body composition spans over 100 years and has applications in clinical research, basic science, medicine, nutrition, exercise physiology and in the growing health and fitness industry (Heyward & Stolarczyk, 1996a; Lohman, Roche, & Martorell, 1988). Information related to body composition study can be categorized as biological or technical (Wang, Pierson, & Heymsfield, 1992). Biological research seeks to describe the changes in body components with growth, illness and aging, the factors affecting change, and the resulting effect on health and function (Roubenoff, Kehayias, Dawson-Hughes, & Heymsfield, 1993). Technical research focuses on the methodology involved and aims to improve the assessment of body composition and thus our understanding of the biological information.

Recent investigations on aging and body composition have been primarily technical in nature as practical, accurate and reliable methods, requisite for epidemiological research and furthering our understanding of the aging body and the relationship between body composition and health and function, are currently lacking for elderly women. Conventional methods do not account for the several anatomical and physiological changes in the aging body which must be considered when developing new measurement tools for elderly women (Shephard, 1997).

2.3 Age-related changes in body composition

Several age-related changes in body fat, muscle, bone and water content have been documented in the literature. Consequently, methods used to assess body composition in older adults must take these many changes into account. Furthermore, women do not age in the same way or at the same rate as men and should be considered separately in the research.

Throughout the lifespan, women tend to be fatter than their male counterparts, with a preferential deposit of adipose fat in the limbs and lower body, and more subcutaneously than internally (Vogel & Friedl, 1992). With aging, numerous studies have shown a gradual increase in body fat and body weight (Going et al., 1995; Shephard, 1997). After menopause, the typical gynoid fat patterning is less apparent due to declines in estrogen production, and fat stores tend to "migrate" to the trunk and visceral cavity (Ley, Lees, & Stevenson, 1992; Vogel & Friedl, 1992). The redistribution of fat appears to stabilize after age 65 (Baumgartner et al., 1995). Changes in total body fat beyond age 60 are less clear. Conflicting reports have indicated both steady inclines (Baumgartner et al., 1995; Protho & Rosenbloom, 1995) and declines (Going et al., 1995) for the older age groups.

Excess adiposity has been long associated with an increased risk for several chronic diseases such as coronary heart disease, hypertension, hypercholesterolemia, diabetes, osteoarthritis, obesity and some cancers (Blair et al., 1996; Chumlea & Baumgartner, 1989; Durnin & Womersley, 1974; Seidell, Deurenberg, & Hautvast, 1987; Shephard, 1997). More recently, the risk for heart disease and mortality has been more strongly linked the amount of abdominal and intra-abdominal fat (Borkan, Hults, Gerzof, Robbins, & Silbert, 1983; Vogel & Friedl, 1992). In more extreme cases of over fatness, reduced mobility levels can limit performance in daily routines and have lasting social and emotional effects (Brodie, 1988a).

Extremely low body fat in older age has also been related to an increased risk for morbidity and mortality (Visser et al., 1994).

Muscle, bone and water content remain relatively stable until the fifth or sixth decade in life and then begin to decline (Going et al., 1995). Recent data from a study of elderly people ages 65-85 years indicates that these declines continue into the ninth decade of life and an average of 6-7% of these combined components may be lost over the 20 year span (Baumgartner et al., 1995). Wasting of appendicular skeletal muscle is the primary source of this decline, and accounts for approximately 60% of the lean tissue lost with aging (Baumgartner et al., 1998; Kirkendall & Garrett, 1998). Significant and rapid bone mineral loss associated with post-menopause can contribute an additional 11% to this decline in elderly women (Baumgartner et al., 1995; Vogel & Friedl, 1992).

Disability among the elderly has been linked to age-related declines in both muscle and bone. Muscle wasting has been associated with decreased muscle strength, endurance and mobility which, in turn, can limit performance in activities of daily living and threaten the independence of the elderly (Evans & Cyr-Campbell, 1997). Significant bone mineral loss may result in osteoporosis and an increased susceptibility for fractures (Kelley, 1998; Kuczmarski, 1989).

A dehydrating effect has also been observed with aging. Total body water (TBW) decreases from 50% of total body weight in early adulthood to 45% in middle age (Going et al., 1995), and a possible total loss of 4-6 litres by old age. At present, it is unclear whether the aqueous fraction of the fat-free tissue is effected by the loss in TBW. Several studies indicate no change in the water content of fat-free tissue due to proportional losses in both water and muscle

(Deurenberg et al., 1989; Going et al., 1995), while others report small increases in the hydration level of fat-free tissue with aging (Baumgartner et al., 1991).

Together, these unfavourable changes in body composition greatly impact health and functioning in old age. Although several biological and environmental factors likely interact to influence the age-related changes, current research suggests that chronic inactivity and poor nutrition play a major role (Evans & Cyr-Campbell, 1997; Going et al., 1995; Shephard, 1997). This has led scientists, health and fitness professionals to believe that the risk for disease and functional decline in older age could be greatly reduced through regular exercise and proper nutrition. Consequently, the measurement of body composition has become increasingly important in the assessment and management of disease and disability among the elderly.

2.4 Conventional methods in body composition assessment

The only true direct measures of body fat or other body constituents is through cadaver analysis (Brodie, 1988a; Clarys, Martin, & Drinkwater, 1984); thus, human body composition assessment relies on methods of indirect measure. Assessment techniques are commonly categorized as either criterion methods (which are actually indirect methods) or indirect methods (which are essentially doubly indirect).

(i) densitometry

Research on conventional methodology dates back to the 1940's and the lab of Albert Behnke whose primary interest was in the measurement of body fatness (Lukaski, 1987). Early criterion methods of densitometry were based on a two-compartment (2C) chemical model which partitions the body into fat mass (FM) and fat-free mass (FFM), based on the premise that FM is considerably less dense than all other components of the body (Heymsfield et al., 1989; Keys &

Brozek, 1953). The FM component contains all lipids in the body, both essential and non-essential, and the FFM includes everything else (mineral, protein, water, and all other body constituents other than lipid) (Going et al., 1995). A measure of whole body density (D_b) is therefore dependent on the relative contribution of FM and FFM, and is inversely related to percent body fat.

Hydrodensitometry, or underwater weighing (UWW) has been considered the "gold standard" in body composition against which most other methods are compared to (Brodie, 1988a; Clarys et al., 1984; Jebb & Elia, 1993; Lukaski, 1987). Using the principle of Archimedes and UWW, D_b can be calculated from body volume, by subtracting body weight in water from body weight in air, and then converted to percent body fat using Siri's equation ($\%Fat = 495/D_b - 450$) or other similar formulae (Brodie, 1988a). This model, however, relies on assumptions that the consistencies of the FM and FFM are unchanging and are of constant density, with values of 0.9g/ml and 1.1g/ml, respectively (Brodie, 1988a; Keys & Brozek, 1953). Other 2C models include total body potassium and total body water (TBW) (Heymsfield et al., 1989).

UWW is not practical for large-scale epidemiological studies or many private clinics because of the equipment required (Brodie, 1988a; Brodie, 1988b; Guo et al., 1996; Jebb & Elia, 1993; Lohman, 1981; Lukaski, 1987; Shephard, 1997). Thus, extensive efforts have been made to describe body composition, particularly body fat, using simpler, yet more indirect methods.

(ii) anthropometry

The most common indirect method to assess body composition is anthropometry. Anthropometry includes the measurements of the skinfold thickness (SF), body circumferences, breadths, height (HT), weight (WT) and body mass index (BMI) (Durnin & Rahaman, 1967; Durnin & Womersley, 1974; Heyward & Stolarczyk, 1996a; Keys & Brozek, 1953; Lohman, 1981; Martin & Drinkwater, 1991). Anthropometry methods are the most widely used because the equipment involved is relatively simple, inexpensive, highly portable and non-invasive (Lohman et al., 1988).

The SF has been studied extensively in the body composition literature because of the strong relationship between the subcutaneous layer of adipose tissue, body density and percent body fat (Durnin & Womersley, 1974; Lohman, 1981). Using spring-loaded calipers, the thickness of one or several SF sites (which contains two layers of skin as well as adipose tissue) are measured and compared to criterion body fat, usually measured by densitometry (Lohman et al., 1988). Numerous general and population specific equations have been developed to predict body fat measured by UWW from anthropometry (Lohman et al., 1988).

Various regression techniques have been used to determine the best predictors of body composition in specific populations, and subsequently, the best equation to describe the relationship between anthropometry and criterion body fat (Guo et al., 1996). Height, WT, BMI and trunk or limb circumferences are often added in combination with SF anthropometry in order to improve the prediction equation (Baumgartner et al., 1991; Dupler, 1997; Goran et al., 1997; Williams, Going, Milliken, Hall, & Lohman, 1995). Anthropometric predictors of body fat must have strong statistical and biological support for their selection. Finally, equations specific to elderly women must reflect the uniqueness of the aging female body in the choice of predictor variables.

The prediction of body composition from SF anthropometry is also based on certain assumptions. First, a constant proportion between subcutaneous fat and internal fat deposits is assumed and second, the fat content of adipose tissue is presumed constant. Additionally, skin thickness and SF compressibility are assumed constant within and between individuals at various anatomical sites (Keys & Brozek, 1953; Martin et al., 1985).

2.5 Limitations of conventional methods

When UWW and anthropometry are used to measure body composition in the elderly population, biological variations in the assumptions of the 2C model, and technical error are both sources of potential error (Going et al., 1995; Heymsfield et al., 1989; Lohman et al., 1988; Martin & Drinkwater, 1991). Densitometry and Siri's conversion to percent fat, require the density of FFM (d_{ffm}), to be unchanging. This is true among young and middle-age adults, but not the case for older adults whose muscle, bone and water fractions all change with aging.

Of these, the density of the bone mineral content is the greatest, and therefore, variations in this fraction will have the largest impact on the measurement of d_{ffm}. Significant bone mineral loss associated with aging lowers the overall density of the FFM, and thus, violates the assumptions of constant d_{ffm} and value of 1.1g/ml (Going et al., 1995; Shephard, 1997). As a result, body fatness is overestimated in the elderly when Siri's formula is applied (Martin & Drinkwater, 1991). This error is likely more drastic in elderly women who experience more rapid and significant bone demineralization (Vogel & Friedl, 1992). Several researchers have accounted for this by modifying Siri's equation (Deurenberg et al., 1989); however, others have shown this to be unacceptable (Baumgartner et al., 1991; Williams et al., 1995). Williams et al. (1995) have demonstrated that adjusted two-component models under and overestimate percentage body fat measured by a multi-component model by 6% and 14%, respectively.

An additional concern is the UWW procedure itself. The process of maximally expelling air from the lungs and breathholding while remaining still underwater may be too stressful and difficult for elderly subjects to perform successfully, and could result in further erroneous measurements of total body density (Baumgartner et al., 1991; Brodie, 1988b; Jebb & Elia, 1993; Shephard, 1997).

Measurement techniques and assumptions of the SF method may introduce further error. Many experts have questioned the reliability of the SF measurement in elderly populations as several studies have demonstrated greater error in the prediction of body fat from skinfold anthropometry with increasing age (Baumgartner et al., 1995; Williams et al., 1995). Others suggest that age-related changes in the hydration affect the elasticity and compressibility of the subcutaneous adipose layer may alter the relationship between the skinfold thickness and body fat content (Chumlea & Baumgartner, 1989). Changes in the elasticity and compressibility of the SF as a result of dehydration and reduced muscle tone have been implicated (Chumlea & Baumgartner, 1989). Finally, the inability of the SF to detect internal fat stores could result in an undersampling of total body fat and thus alter the relationship between anthropometry and body composition.

In the cadaver study, Martin et al. (1992) showed just as much variation in SF compressibility among and within elderly subjects as others attribute to aging. The variability in compressibility among 13 cadaver subjects (ages 55-94 years) resulted in a 2.4% deviation in percent body fat for both men and women when estimated by the Jackson & Pollock equation (Martin, Drinkwater, Clarys, Daniel, & Ross, 1992). This was the first investigation to examine the effect of compressibility on body fat predictions, and as all the subjects were older in age, it is difficult to say whether variations in compressibility are age-related or due to individual differences.

The effect of skin thickness on the prediction of body fatness was also examined in this study. It was proposed that in lean subjects a thicker layer of skin would lead to greater measurement error. Women have larger skinfolds than men and were found to have thinner skin thickness as well. The potential problem associated with skin thickness is therefore much less in women. Furthermore, in both men and women, the skin thickness at the subscapular site was greater than any other anatomical site and therefore may be less reliable in the prediction of body fat (Martin et al., 1992). Again, subjects were elderly, and hence, the independent factor of age on skin thickness was not clear.

Finally, less reliable prediction of body fat in the elderly from anthropometric methods could be attributed to poor inter-method agreement. Measurement errors in body composition will be propagated from one level of directness to the next, and consequently, prediction equations derived from UWW will retain the systematic errors inherent to the 2C model (Baumgartner et al., 1991). (Heymsfield et al., 1989).

2.6 Advances in body composition technology

Advances in body composition technology now allow for quantification of previously unmeasureable tissue *in vivo*. With the development of dual-photon absorptiometry (DPA), and then dual-energy X-ray absorptiometry (DEXA), bone mineral mass and density can be assessed with high precision and accuracy; thus, resolving limitations associated with densitometry and the 2C model (Heymsfield et al., 1989; Mazess et al., 1990).

Both DPA and DEXA have been used in combination with other criterion methods to measure body composition using a four-compartment model (4C). Typically densitometry, TBW and neutron activation have been among the other methods. This model separates the body into fat (F), fat-free mineral (M), fat-free protein (P), and aqueous (A) fractions (Heymsfield et al., 1990), and therefore, has the advantage of being able to detect differences in hydration. This model is now considered the most valid model to assess human body composition in vivo. However, expensive instrumentation, complicated procedures, moderate levels of radiation and time involved all limit its use to research and laboratory settings (Going et al., 1995; Goran et al., 1997; Heymsfield et al., 1990). Furthermore, the gains in accuracy may be offset by a loss in precision due to the accumulation of error associated with the use of multiple assessment methods (Guo et al., 1996).

The most promising method to replace UWW as the gold standard is DEXA as it is based on a three-compartment model (3C) (Kohrt, 1995). Originally designed to measure bone, DEXA has the ability to accurately and precisely assess soft tissue components by dividing the body into fat mass, fat-free bone mineral content (BMC), and fat-free bone-free mass (Kelly et al., 1997; Kohrt, 1998; Mazess et al., 1990). Several investigations have shown DEXA to be more accurate and precise than UWW when compared to 4C measurements of body composition (Prior et al., 1997; Pritchard et al., 1993). Moreover, DEXA has distinct advantages over the multi-method approach as DEXA is safe (< 1rem dose of radiation for a whole body scan) and convenient for the subject, requires minimal time (~ 5-15 minutes for a whole body scan) and is of moderate cost (Gotfredsen et al., 1997; Kelly et al., 1997; Mazess et al., 1990; Roubenoff et al., 1993). A more detailed discussion of DEXA follows.

2.7 Support for DEXA as the criterion method for body composition assessment

The principle mechanism underlying DEXA is the differential tissue attenuation of photons from two energy levels emitted from an X-ray source (Jebb & Elia, 1993; Mazess et al., 1990; Svendsen et al., 1993; Wellens et al., 1994). Thus, DEXA can only discriminate two substances in a given system (or pixel). First, it distinguishes bone-mineral (high attenuation) from soft-tissue (low attenuation) then energy levels are reset to allow for distinction of the FM and FFM components of soft-tissue. The mass attenuation coefficients of bone mineral at the two beam energies are known constants whereas the ratio of the mass attenuation coefficient of soft-tissue (R_{st}) is related to the fatty fraction and must be calculated from all the pixels that contain soft-tissue only. Non-bone fat-free mass is the remainder (Svendsen et al., 1993).

Early investigations conducted by Mazess et al. (1990) were the first to demonstrate DEXA's high precision in the measurement of percent fat (1.4%) and fat mass (1.0kg) in 12 young adult men and women. In another study using younger adults, the precision of two different manufacturers of DEXA (Hologic QDR 1000W and Lunar DPX) and the UWW method were compared (Pritchard et al., 1993). The Hologic model of DEXA measured percentage fat with far greater precision than the Lunar model as reflected by the coefficient of variation (CV) for Hologic (CV=1.3%) versus Lunar (CV=3-4%), and both were superior to UWW (CV=4.8%). A look at between-method differences showed better agreement between Hologic and UWW than with Lunar and UWW (Pritchard et al., 1993). These results have been confirmed elsewhere (Jebb, 1997).

DEXA's ability to assess various body constituents with high accuracy still awaits validation studies against cadavers; however, this is also true for densitometry and it has been considered the gold standard criterion method for several years now. Until then, the validity of

DEXA depends on its accurate measurement of known quantities of meat and lard, inanimate materials whose physical and chemical properties simulate that of humans, animal carcasses and 4C determined body composition (Gotfredsen et al., 1997; Kohrt, 1998; Prior et al., 1997; Svendsen et al., 1993; Visser et al., 1998). *In vitro* studies and comparisons with other methods have indicated good accuracy for DEXA measurements of FM and FFM (Kohrt, 1998; Snead et al., 1993; Van Loan & Mayclin, 1992; Wellens et al., 1994); however, results based on these studies are limited because of the unknown accuracy of other reference methods. Until 1993, the validity and accuracy of DEXA had not been examined *in vivo* (Svendsen et al., 1993). Svendsen and colleagues (1991) measured whole body composition in seven adult sized pigs using the Lunar DPX version. Pigs were then killed and homogenized, then subjected to chemical analysis and compared to results obtained from DEXA. Correlation and regression analyses yielded r-values > 0.97 for all compartments assessed. Measurement error was low with values of 2.9%, 1.9kg, and 2.7kg for the SEE of %fat, FM, and non-bone FFM, respectively.

Svendsen et al. (1993) also showed that DEXA accurately detected changes in body fat by measuring body composition before and after 8.8kg of lard were placed on the ventral side of the bodies of six women, ages 24-49. The ability for DEXA to monitor change in body fat was confirmed in 10 young adults, age 28 years, with 1.51kg packets of lard using Hologic 1000W instrumentation (Kohrt, 1998).

Several researchers have validated DEXA against 4C models. Prior and colleagues (1983) found DEXA fat and fat measured using a 4C model to be highly correlated (r = 0.94) and not significantly different in 172 college-aged men and women. Furthermore, DEXA demonstrated superior accuracy and precision than methods of densitometry (Prior et al., 1997).

Others have shown reasonable agreement between these two methods at the group level, but substantial error in individuals (Jebb, 1997). In a different study, however, densitometry was found to be more accurate and precise than DEXA in both young and elderly women (Bergsma-Kadijk, Baumeister, & Deurenberg, 1996).

DEXA also has the ability to measure regional body composition (Baumgartner et al., 1995). This may have an advantage in health related studies as abdominal fat appears to be a stronger risk factor for disease than total body fat.

2.8 Hologic QDR-4500W

Three manufacturers of DEXA exist (Lunar, Hologic and Norland), yet to date only a paucity of information is available on the cross-calibration of different manufacturers for soft tissue measurement (Jebb, 1997). Although general conclusions from the literature can be applied to most DEXA instrumentation, the exact level of accuracy and precision for one model cannot be assumed for another. Consequently, data generated by different manufacturer's machines cannot be compared (Roubenoff et al., 1993). Moreover, discussions of DEXA thus far have been based on pencil-beam technology and cannot be assumed for the most recent model of DEXA, the Hologic 4500W, which uses a fan-array scanning technique.

The Hologic 4500W is considered equally precise, yet more accurate than earlier Hologic pencil-beam instrumentation (1000, 1500 and 2000 series) in whole body composition analysis (Kelly, 1998a; Kelly et al., 1997; Visser et al., 1998). The fan-beam scanner completely and uniquely samples the subject, whereas the pencil-beam typically under samples and then relies on linear extrapolation to estimate missing data (Kelly et al., 1997). Although the fan and pencil-beam assessments are highly correlated (r =0.98) (Fuerst & Genant, 1996), fan beam models compared more closely with CT scans in the assessment of limb fat mass (Kelly, 1998a). The precision for the fan beam in the measure of FM was 300 grams and 600 grams for the pencil beam. Due to superior spatial assessment, QDR-4500 has overcome some of previous problems associated with fan-array which made this method less precise (Clasey et al., 1997).

Because of the superior sampling technology, minimal scan time, and high accuracy and precision of QDR- 4500, this model has been selected for two national studies supported by the National Institute of Health (NIH). The Health ABC Study and the NHANES IV (National Health and Nutrition Examination) will provide large volumes of data related to health, aging and body composition.

2.9 Limitations of DEXA

DEXA, however, is not without limitations. Some suggest that its inability to detect differences in hydration may be problematic in the measurement of the elderly (Roubenoff et al., 1993). Small but systematic and predictable errors in soft tissue composition were noted with fluid balance changes in a recent study (Pietrobelli, Wang, Formica, & Heymsfield, 1998). Similarly, another group of researchers showed that an increase in lean tissue mass was correlated to fluid intake (Thomsen, Jensen, & Henriksen, 1998), while others found the density of FFM to be unaffected by declines in total body water due to proportional losses in both water and muscle tissue seen with aging, (Deurenberg et al., 1989). Kohrt (1998) also found that fat mass measured by DEXA appeared to be relatively unaffected by fluctuations in hydration status. Although DEXA assumes a constant value for the water content of the FFM (73.2%), Baumgartner et al., (1995) suggested that there is no theoretical or empirical evidence that suggests DEXA under or over estimates body fat in elderly. Therefore, the effect of hydration on the measurement of body composition remains unclear.

A previous problem of DEXA underestimating central regions of body fat was not found in this study and was attributed to improvements in software and instrumentation. Beam hardening may occur in large subjects in the trunk regions (Baumgartner et al., 1995; Gotfredsen et al., 1997) and thus may be a concern when assessing obese individuals. Further, the scanning arm, and thus the scanning area is limited in size to approximately 190 X 60cm; again, problematic for measuring large or obese persons (Jebb & Elia, 1993). Finally, little is known about the algorithms used for analysis, which seem to be in state of constant review (Gotfredsen et al., 1997; Jebb & Elia, 1993).

Despite these possible limitations, DEXA has greater validity than UWW in the assessment of elderly body composition. Like UWW, however, DEXA instrumentation is not highly accessible outside of research. Practical indirect methods based on DEXA would therefore be useful. The relationship between anthropometry and DEXA has not been thoroughly explored in the elderly and warrants further attention.

2.10 Prediction equations

Several prediction equations have now been developed for specific use in the elderly population. A summary of the more common and more recent equations is presented in Appendix I. Of these, 8 equations were based on methods of anthropometry and are discussed further.

One of the most widely used equations to assess body composition is that of Durnin and Womersley (1974)(DW); however, several have criticized its use in the elderly population. A large age-range of subjects was used to develop the equation and of these, only 37 females ages 50-68 years were included at the elderly end of the spectrum. Furthermore, the SF equation was derived from reference body fat measured by densitometry. Visser and colleagues (1994) improved upon this by using more than 200 subjects with an average age of 70 years. However, UWW and densitometry were again used to measure criterion body fat, and was therefore, still subject to problems associated with the 2C model. Dupler (1997) considered some of the previous limitations and used modified UWW procedures to develop new SF equations for the elderly. Again, a large sample was used and the average age was 70 years. Furthermore, age-related changes in fat patterning were considered and therefore only trunk SF sites were measured. However, this study still retains the problems with 2C model and Siri's equation.

Chapman and co-researchers (1998), predicted DEXA FFM ($R^2 = 0.96$) from WT, HT and the thickness of the triceps (TRI) SF. However, the subcutaneous fat of the TRI is only weakly correlated to FFM, and was probably not the most appropriate choice of predictor variables (Guo et al., 1996). Furthermore, only 17 women were used to develop this equation and no cross-validation was attempted. The FM equation developed by Svendsen and colleagues (1991) included BMI, WT, HT, TRI, and the ratio of subscapular:triceps SF's (SSTRI) and was based on DEXA ($R^2 =0.94$). The sample size of women was small with an n=23, and again, this equation was not cross-validated. As well, the ratio of the number of subjects to number of independent variables was just over 4:1, when the minimum recommended is 10:1 (Heyward & Stolarczyk, 1996b).

In many of these studies, only TRI or the sum four skinfolds (SUM4SF = biceps+triceps+suprailiac+subscapular) were the only SF's measured, therefore it was unclear whether other SF sites might have improved the prediction equation. Waist (WC) and hip (HC) circumferences did not significantly improve the prediction equation for Durnin and Womersley (1974), Svendsen et al. (1991) or Visser et al. (1994), but HC was included in the final equations for Dupler (1997). Waist circumference correlated strongly with both the absolute amount of fat in the trunk measured by DEXA (r =.90 in women) and with the manually determined abdominal fat (r =.87); however, equations were not developed in this study (Baumgartner et al., 1995).

Only two studies to date have examined more practical techniques of body composition assessment against a 4C model. Williams et al. (1995) found a lower SEE associated with bioelectric impedance analysis (BIA) regressed against FFM than for the sum of 10 SF's and FM and therefore developed new equations FFM based on BIA only. Individual SF's and body circumferences were not examined in this study. As well, only 23 women ranging from 49-80 years (m=65yrs) were measured. A similarly aged but slightly larger sample was used to validate existing equations against 4C criterion body fat and to consider new equations for the elderly (Goran et al., 1997). Hip circumference, WT, BMI and the sum of 9 SF's were highly correlated with FM, while WT, HC, and the calf skinfold (CF) were included in the final regression equation. Neither of these 4C equations were cross-validated for their accuracy in other samples.

Because of many changes in body composition that continue with aging, Baumgartner (1995) recommends not grouping all elderly persons together as one homogeneous group, but rather, treating each decade after 60 as a separate age cohort. Future development of prediction equations should therefore focus on narrower age ranges. As well, prediction equations for the elderly should be based on criterion methods that involve minimal assumptions. Prediction equations based on Hologic QDR4500 will therefore be an improvement to existing 2C equations.

2.11 Development of new prediction equations

The prediction equation allows the estimation of criterion body fat from indirect measurements by way of regression analysis. One or several predictor (independent) variables are typically entered into the regression analysis, along with the criterion (dependent) variable. Outwardly simple, however a range of procedures and criteria should be used to optimize the development of new prediction equations (Guo et al., 1996; Heyward & Stolarczyk, 1996a).

First, the validity of the criterion method must be demonstrated. Second, the measurement precision of both criterion and predictor variables should be high. Assumptions of linearity, homogeneity and normality must be met. When a non-linear relationship between independent and dependent variables is apparent, linear transformation of the data may be necessary. This is often the case for the relationship between SF's and body density, and therefore, log transformations of the data or quadratic equations are common (Durnin & Womersley, 1974; Lohman, 1981). Strong correlations between predictor variables and the criterion measure are also requisite for the development of a useful equation. Pearson product correlation coefficients (r) are used to describe the strength of the statistical relationship between two variables; $r \geq 0.75$ indicates a good to excellent correlation (Portney & Watkins, 1993). However, often this is the only selection criterion used, and sometimes a weak scientific or biological association between the variables is overlooked. Examples of this are when skinfold thicknesses are used to predict FFM, or BIA is used to estimate FM, and should be avoided (Guo et al., 1996). Finally, a variety of statistical applications are necessary to determine which predictor variables should be entered into the equation, how many, in what order, and to test the stability and accuracy of the equation (Cohen & Cohen, 1975; Guo et al., 1996).

When the nature of the research is exploratory, the most common approaches are stepwise, forward, maximum R^2, and all possible subsets regression procedures (Brodie, 1988a; Cohen & Cohen, 1975; Durnin & Womersley, 1974; Hansen et al., 1993; Teran et al., 1991; Visser et al., 1994). However, when sample sizes are small and an independent sample for external cross-validation is not available, the stepwise procedure is not recommended (Guo et al., 1996). Alternatively, Draper and Smith (1966) recommend using a combination of both stepwise and all possible subsets procedures. The magnitude of the multiple regression coefficient of determination (R^2) determines how much of the prediction of body fat can be explained by the predictor variables, and the standard error of the estimate (SEE) indicates how precise this prediction is. The use of Mallow's statistic (C_p) has also been recommended when the sample size and number of predictor variables are small (Ott, 1984). The C_p statistic is the ratio $SEEp/s^2 - (N - 2p)$ where $SEEp$ is the residual sum of squares for a model with p parameters, and s^2 is the residual mean square based on the regression equation with all the independent variables. The lowest C_p value corresponds to the subset of predictors with the highest R^2 and lowest SEE; however, a C_p value that is close to equal the number of regression coefficients is said to be the most stable equation when sample size is small. The equation selected should be parsimonious. Additional variables should be included if they improve the precision of the equation, but not too many so that multicollinearity among independent variables becomes a problem and affects the stability of the equation (Guo et al., 1996). To avoid this problem, the variance inflation factor (VIF) can be calculated to detect significant interrelations among the predictors.

The size of the sample required can be determined by power analysis. (Cohen & Cohen, 1975). To detect a difference in $R^2 = 0.05$, with an alpha level of 0.05 and a power of 0.8, a sample size of n = 222 is required, whereas an n = 46 will detect a difference in $R^2 = 0.15$ with a power of 0.6 when three predictor variables are used. An alternative recommendation is to ensure a minimum of 10 to 20 subjects for each predictor variable (Heyward & Stolarczyk, 1996a). Nonetheless, a survey of the literature demonstrates a range of sample sizes when deriving new regression equations from as small as n = 34 to n > 200 (Chapman et al., 1998; Durnin & Womersley, 1974; Svendsen et al., 1991; Teran et al., 1991; Visser et al., 1994). Many of these studies have included men and women of several different ages in their sample; further inspection showed that very few investigations contained large numbers of elderly women.

Finally, cross validation on an independent sample is then recommended to test the accuracy of the newly derived regression equation, but is often not feasible (Howell, 1997). Alternatively, when the sample sizes are large, it is acceptable to use internal cross-validation by dividing the sample into a prediction and validation group but should not be considered an equal substitute for the more stringent external validation (Baumgartner et al., 1991; Cohen & Cohen, 1975; Teran et al., 1991). When sample sizes are small, and internal cross-validation is not appropriate, the jackknife or press technique can be employed to check robustness of the newly derived equation (Baumgartner et al., 1991; Guo et al., 1996). Using this technique, the study sample is split into 10 equal groups and regression analysis is performed 10 times with a different group eliminated each round. Residual errors are compared to the corresponding SEE of the equation to determine the validity (Guo et al., 1996).

2.12 Summary and study objectives

The number of elderly women in the population is growing rapidly in North America. In order to contribute to the successful aging of this older adult population, further research is needed to improve our understanding of specific changes in body composition and their subsequent impact on health and functioning, as well as to learn more about factors influencing these changes. Accurate and reliable body composition assessment methods, that are also practical and easy to administer, are essential for the collection of large volumes of data requisite for epidemiological research. As well, private health care and fitness facilities would benefit from the availability of simple assessment tools to evaluate body composition status and monitor the effectiveness of exercise, diet or medical interventions. The following objectives are proposed for this research:

1) to assess the relationship between anthropometry and DEXA body fat in women 75-80 years;
2) to test the performance of previously published equations in these women;
3) to determine the best anthropometric predictors of body fat in elderly women;
4) to develop new and improved body composition prediction equations for total body fat and regional trunk fat
    (i) using an appropriate selection of predictor variables,
    (ii) using DEXA as the criterion method,
    (iii) and using appropriate regression methods;
5) to test the performance of new prediction equations in independent samples
    (i) in similarly aged women
    (ii) and in younger women to evaluate the impact of age on equation development and performance.

3. Methods

3.1 Subjects

The study sample consisted of 40 Caucasian women and 3 Asian women between the ages of 75-80 years. All participants were considered healthy and were free-living in the community. Participants were recruited through advertisements in community centres, senior centres, and local media as part of a larger study that examined the effects of progressive resistance exercises on muscle strength, functional ability, bone mineral density and body composition in women 75-80 years old. More than 140 women volunteered for the study, but over half were considered ineligible because they were too young (< 75 years), too active (exercising 3 or more times per week) or required transportation assistance. Additional respondents were excluded for medical conditions outlined in the physician's clearance form (Appendix III). A final requirement for entry into the study was the participant's consent (Appendix IV). Ethics approval was granted by the Research Ethics Board of the University of British Columbia (Appendix V).

Forty-six women participated in the study; however, two individuals were outliers (more than 2 standard deviations from the mean) for both body fat and BMI and were eliminated from further analyses as skinfold anthropometry is considerably less reliable at extremely high body fat (Heyward & Stolarczyk, 1996b). A third participant was eliminated because her DEXA data was not available for analysis. Thus, 43 women comprised the final study sample on which the results and discussion are based.

3.2 Equipment and measurement procedures

Body composition was assessed by dual energy X-ray absorptiometry (DEXA) and anthropometry at the baseline of the "parent" strength training study, and by anthropometry only during the study and at the end. The purpose of collecting body composition data in this "parent" study was to monitor the effects of strength training on body composition for a year-long period. Only the baseline data were used for this current research.

DEXA (QDR-4500W; V8.20a:5; Hologic Inc., Waltham, MA) was used to measure criterion body fat. The QDR-4500W model used fan-beam technology to perform whole body scans with the subject lying supine. Subjects wore light clothing with all jewelry and metal items removed. Each scan took approximately 5 minutes at the slow array speed. Default values for total body fat mass (FM), total percent fat (%fat), regional trunk fat mass (TFM) and percent fat of the trunk (%fatT) were used as criterion measures.

Standard anthropometry methods were used to collect indirect measures of body fatness. Height (HT) was measured to the nearest 0.1cm using a standard stadiometer and weight (WT) was measured with a digital scale to the nearest 0.1kg. Waist (WC) and hip (HC) circumferences were measured to the nearest 0.1cm using a non-expandable tape measure. The site of the WC was defined as the narrowest girth between the ribs and the iliac crest, while the HC was measured at the maximum girth around the buttocks. Harpenden calipers were used to measure the following eight skinfold (SF) sites described by Ross & Marfell-Jones (1982) and Heyward and Stolarczyk (1996b): triceps (TRI), biceps (BIC), subscapular (SS), midaxillary (MA), suprailiac (SI), abdomen (ABD), mid-thigh (TH) and medial calf (CF). Descriptions of the anatomical sites are shown below. Each SF site was marked and measured in duplicate on the right side of the body in rotational order, with the exception of the abdominal SF, which was measured on the left side. A third measurement was taken if the first two differed by more than 2 mm (or 10%). The final SF measurement was the average of the closest two SF values. Harpenden calipers were set at a constant pressure of 9.4g/mm^2 and calibrated regularly.

Skinfold	Direction of fold	Anatomical site
TRI	vertical	Midpoint between the acromial process and olecranon process on the posterior aspect of the arm.
BIC	vertical	Same level as marked for the triceps but on the anterior aspect of the arm.
SS	diagonal	The inferior angle of the scapula along the natural cleavage line.
MA	vertical	Along the midaxillary line at the level of the xiphoid process.
SI	oblique	Superior to the iliac crest and anterior to the midaxillary line.
ABD	vertical	2 cm lateral to the umbilicus and at the level of the umbilicus.
TH	vertical	Midpoint between the inguinal crease and the patella with the knee and hip flexed at right angles and the foot supported.
CF	vertical	At the level of maximum calf circumference on the medial aspect of the calf, again with the knee and hip at right angles.

Anthropometric data were collected within one day of the DEXA assessments. Where possible, subjects were measured at the same time of day for the two methods. Again, the same qualified fitness appraiser conducted all anthropometric measurements to eliminate inter-rater variability.

3.3 External databases

To determine whether or not existing body composition equations recommended for elderly women could accurately predict body composition in 75-80 year old women, 8 published equations (Appendix II) were selected from the literature and tested in this study sample. The literature was surveyed specifically for studies that derived prediction equations in elderly women using anthropometry and SF's for the independent variables. Furthermore, studies were chosen for a range in dependent variables in order to examine equations based on two (2C), three

(3C) and four (4C) compartment models of body composition. Additionally, descriptive data provided in these studies were used as reference data with which to compare our current data.

Finally, in order to test the application of new prediction equations for body composition, a search through Medline, Dissertation Abstracts and the Oregon Microfiche databases was conducted to find independent studies that measured similar variables to this study. More specifically, studies that measured reference body fat by DEXA, anthropometry and a minimum of 4 SF's in young, middle-age and elderly women were sought out. As a result of this search, letters were sent to 6 external investigators requesting raw data for DEXA, anthropometry and SF's (Appendix VI). Gary Brodowicz (Brodowicz, 1999) and Richard Baumgartner (Baumgartner, 1999) shared their data sets with us. Brodowicz provided data for both elderly women and young adult women, while Baumgartner supplied data for elderly women only. An email request was also sent to Michael Goran on Baumgartner's (1999) suggestion, but data were not available.

3.4 Data analysis

SPSS (version 8.0) and BMDP software were used for the following data analyses. Before proceeding with the development of new equations, assumptions of the linear regression model were considered. Scatter plots and Pearson correlation analyses were used to determine the nature and strength of the relationships between independent and dependent variables, and to evaluate the need for linear transformations. Distributions for the independent and dependent variables were observed, and skewness and kurtosis statistics were examined to determine the need for data transformations. Skewness and kurtosis values of less than 1 were considered acceptable. The Pearson's correlation coefficient and the paired t-tests difference score for repeated SF measures were used to determine the reliability of the SF measurement. Finally, the accuracy of DEXA in the measurement of total mass was examined by regressing DEXA mass against standard body weight (WT).

To confirm the need for new body composition prediction equations for elderly women, 8 published equations, described previously (Appendix II), were applied to the current data. Paired t-tests were used to calculate the mean differences between predicted and reference body fat for these equations, while the Pearson's correlation coefficient and the Bland-Altman (1986) comparison technique were used to assess the agreement between prediction equations and the reference method of DEXA. The Bland-Altman technique compares the difference between predicted and reference body fat against the average value of these two measurements.

A combination of stepwise and all possible subsets regression procedures was used to develop four new prediction equations for total fat mass (FM), total percent body fat (%Fat), trunk fat mass (TFM) and percent trunk fat (%TF) as recommended by Draper and Smith (1966). They suggested using stepwise procedures first to determine the number of predictor variables included in the "best" regression model, and then, all possible subsets procedures to select the most stable and practical equation. According to stepwise methods, the best model is determined by the subset of predictor variables that maximizes the multiple regression coefficient (R^2) and minimizes the standard error of the estimate (SEE) for the prediction of the dependent variable. However, in this study, the adjusted R^2 (adj. R^2) was used because of the relatively small sample size (<100). Furthermore, predictor variables are only included if their contribution to the regression model is significant. The all possible subsets method generates an additional equation statistic, Mallow's C_p; the subset with the lowest C_p value is generally considered the best overall model. However, when both sample size and the number of regression coefficients are small, the most stable equation has a C_p value approximately equal to the number of predictor variables (Ott, 1984).

Height, WT, BMI, SF's (ABD, BIC, MA, SI, SS, TRI, CF and TH), the sum of BIC, TRI, SI and SS (SUM4SF), the ratio of SS and TRI SF's (SSTRI,), and trunk girths (HC and WC) were initially regressed against FM and %Fat. HT, WT, BMI, ABD, MA, SI, SS, SSTRI and WC were entered as predictor variables for TFM and %TF. The selection of the final regression equations was primarily based on the adj.R^2, SEE, and C_p criteria. However, strong biological associations for the individual predictors and body fatness, and each variable's significance in previously published equations were also considered (Guo et al., 1996). New equations were considered useful and acceptable tools to predict total body fat in women 75-80 years if the corresponding SEE was less than 2.5 kg for FM and less than 3.5% for %Fat (Heyward and Stolarczyk, 1996b). No guidelines were available for the prediction of trunk fat.

Residual analyses were conducted for the final regression equations to ensure homogeneity in the variance of predicted body fat for all values of the dependent variable (Dupler, 1997). An independent group of women was not measured for the purpose of external validation; therefore, the equations were validated internally. The jackknife procedure described by Guo et al. (1996) and Baumgartner et al. (1991) was used to test the internal validity of the new equations as conventional data splitting was not recommended for sample sizes of less than 100. The data was split into 10 almost equal groups (7 groups of n = 4, and 3 groups of n = 5). For each round of the jackknife validation, one group was omitted and the regression equation was developed for the remaining nine groups. This process was repeated 10 times. The smaller the error of the residuals (body fat predicted – body fat measured by DEXA) for each jackknifed equation, the more stable and accurate the equation was within the sample (Guo et al, 1996).

As %Fat is the body composition measure of interest, the new equation for %Fat was applied to the independent databases of Brodowicz (1999) and Baumgartner (1999) which included DEXA %Fat, anthropometry and SF measurements for both similarly aged women and younger women. Unfortunately, the best model for the prediction of %Fat included the MA SF, which was not measured in either of the other studies. Modified equations were therefore developed, using only the variables measured in the other studies as possible predictor variables. Paired t-tests and correlations were used to determine the difference between predicted and measured %Fat. Agreement between the prediction equation and DEXA was again assessed according to Bland and Altman (1986).

3.5 Expectations

1. Existing 2C equations selected from the literature are expected to overestimate DEXA fat in our sample of women ages 75-80 years; while 3C and 4C equations are expected to estimate DEXA fat more closely but will not be reliable due to methodological limitations.

2. As the relationship between anthropometry and DEXA composition in elderly women is presumed more valid than that anthropometry and body density, new prediction equations based on DEXA will have higher R^2 values than those reported for 2C equations.

3. Due to changes in fat patterning and the relationship between anthropometry and total body fat with aging, new equations will predict body fat more accurately (smaller difference between measured and predicted fat) and more precisely (smaller SEE, and narrower limits of agreement) in the independent sample of elderly women compared to the younger women.

4. Results

4.1 Characteristics of the study sample

Results were based on data from 43 women 75-80 years old. Sample population descriptives for age, anthropometry, skinfold measures and DEXA measures are summarized in Table 4.1.1.

Table 4.1.1: Descriptive Characteristics of the Study Sample

	Age	HT (cm)	WT (kg)	BMI	WC (cm)	HC (cm)	WHR
Mean	77.4	158.1	66.4	26.6	87.4	101.4	0.86
s.d.	1.8	6.4	11.0	4.0	11.6	8.7	0.08
Skewness	N/a	0.3	0.6	0.5	0.2	0.5	N/a
Kurtosis	N/a	-0.7	0.2	-0.2	-1.1	-0.3	N/a

	ABD	BIC	CF	MA	SI	SS	TH	TRI	SUM4SF	SSTRI
Mean	32.1	20.0	26.1	23.2	19.5	21.4	36.5	27.6	143.7	0.76
s.d.	8.6	7.1	8.2	7.2	6.7	8.2	9.2	7.4	39.6	0.20
Skewness	-0.8	0.3	0.2	-0.8	-0.1	-0.0	-0.5	0.1	-0.2	-0.1
Kurtosis	1.1	-0.3	-0.9	-0.3	-0.3	-0.7	-0.5	-0.4	-0.1	-0.4

SUM4SF= triceps + biceps + subscapular + suprailiac
SSTRI = subscapular : triceps skinfold thickness ratio

	FM (kg)	% Fat	Trunk FM (kg)	% Trunk Fat	FFM(kg)	Total Mass(kg)
Mean	23.79	35.83	11.87	34.78	39.78	65.21
s.d.	7.03	5.27	4.08	6.7	4.5	10.88
Skewness	0.7	-0.0	0.3	-0.4	N/a	N/a
Kurtosis	0.3	-0.4	-0.2	-0.5	N/a	N/a

*n/a = not applicable

The data were further analyzed to test for assumptions of the linear regression model. Scatter plots for independent and dependent variables demonstrated the existence of moderate to strong linear relationships between the predictor variables and dependent variables with the exception of HT, which showed no correlation (Figure 4.1.1). Table 4.1.2 summarizes the corresponding correlation coefficients. All correlations were significant at $p \leq 0.01$, except for height.

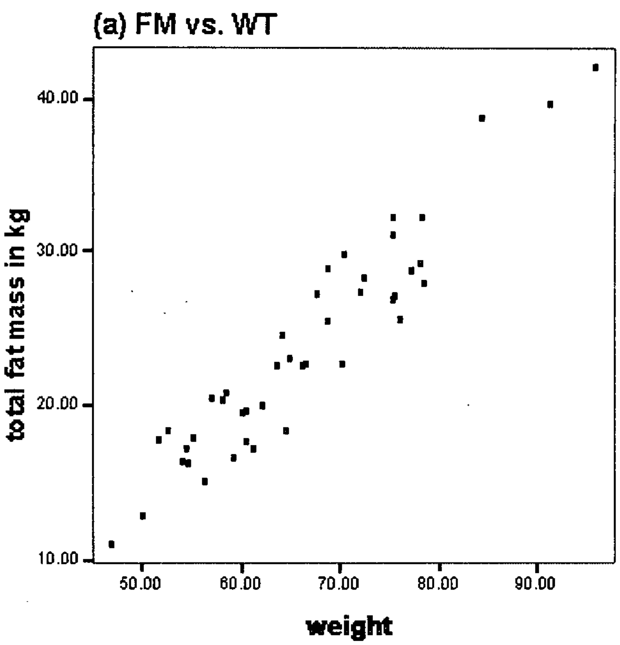
Table 4.1.2: Correlation Between Predictor Variables and Criterion Body Fat

	ABD	BIC	CALF	SI	MA	SS	TRI	THIGH	SUM4SF	SUBTRI
DEXA FM	0.65	0.92	0.63	0.65	0.62	0.78	0.83	0.54	0.88	0.34
DEXA %FAT	0.69	0.85	0.62	0.72	0.71	0.75	0.84	0.54	0.87	0.30
DEXA TRUNK FM	0.66	N/A	N/A	0.71	0.68	0.81	N/A	N/A	0.87	0.47
DEXA %TRUNK FAT	0.69	N/A	N/A	0.75	0.76	0.79	N/A	N/A	0.85	0.48

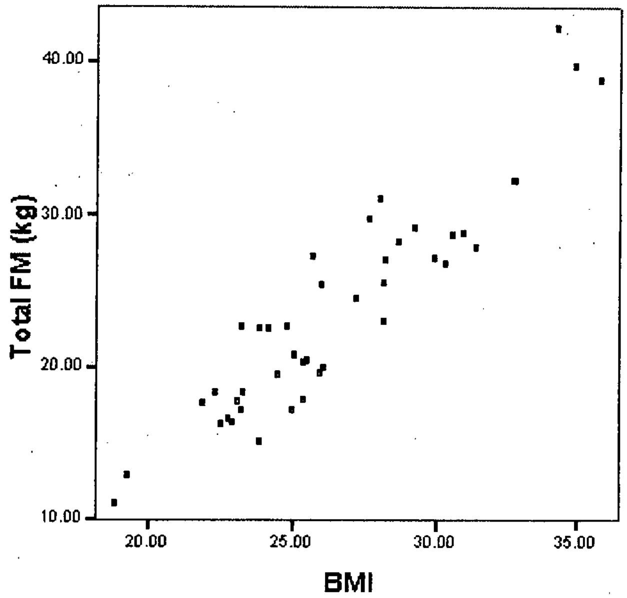
	HT	WT	BMI	WC	HC
DEXA FM	0.18	0.95	0.93	0.87	0.89
DEXA %FAT	-0.08	0.75	0.86	0.77	0.76
DEXA TRUNK FM	0.15	0.89	0.89	0.92	0.79
DEXA %TRUNK FAT	-0.08	0.70	0.81	0.83	0.64

*N/A – not applicable

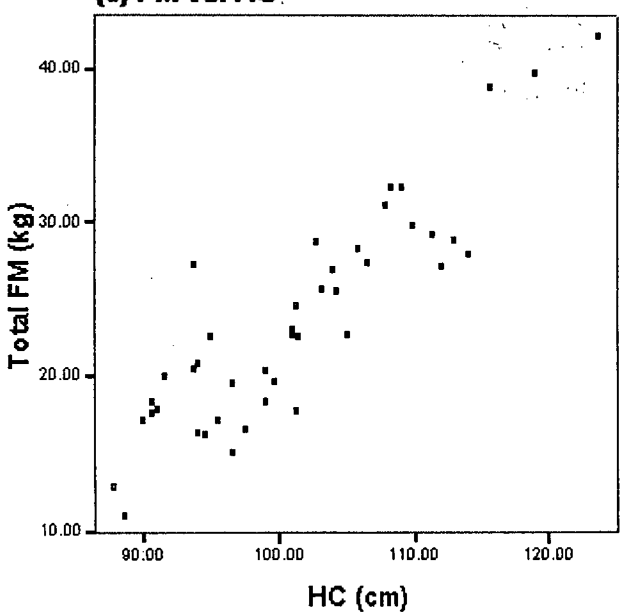
Figure 4.1.1: Fat mass vs. independent variables



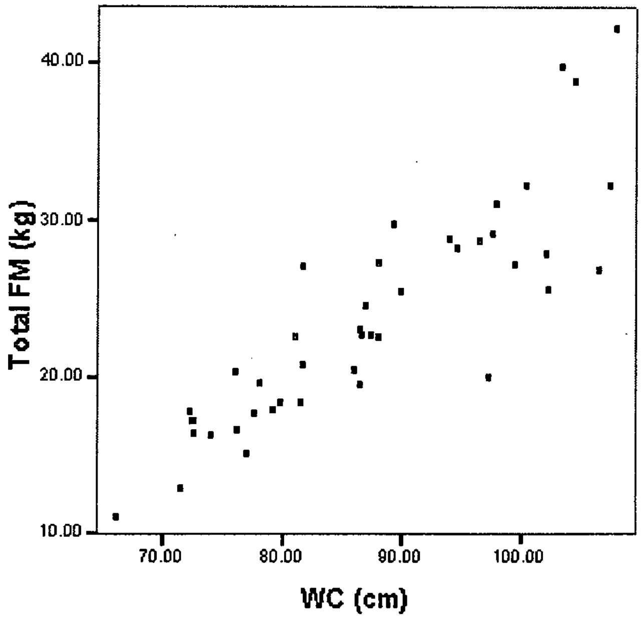
(b) FM vs. BMI



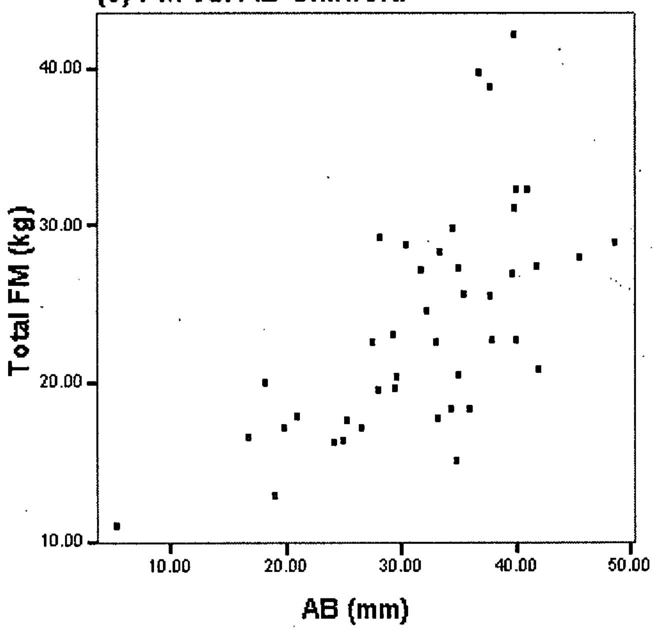
(c) FM vs. HC



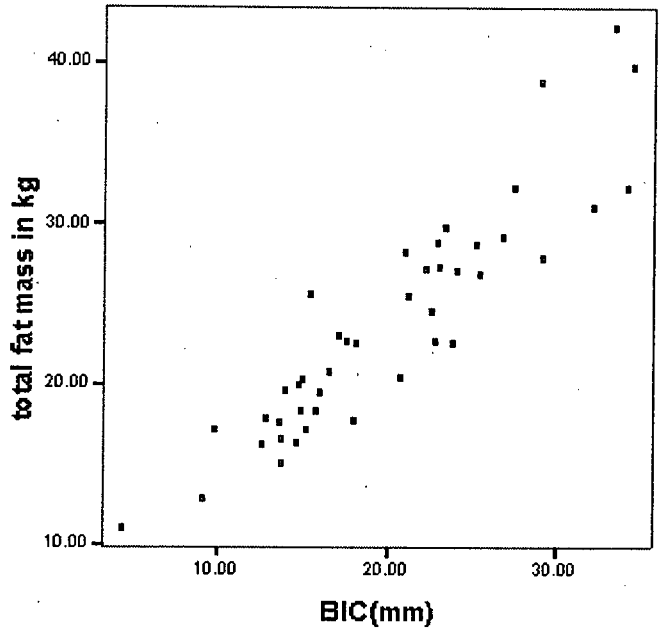
(d) FM vs. WC



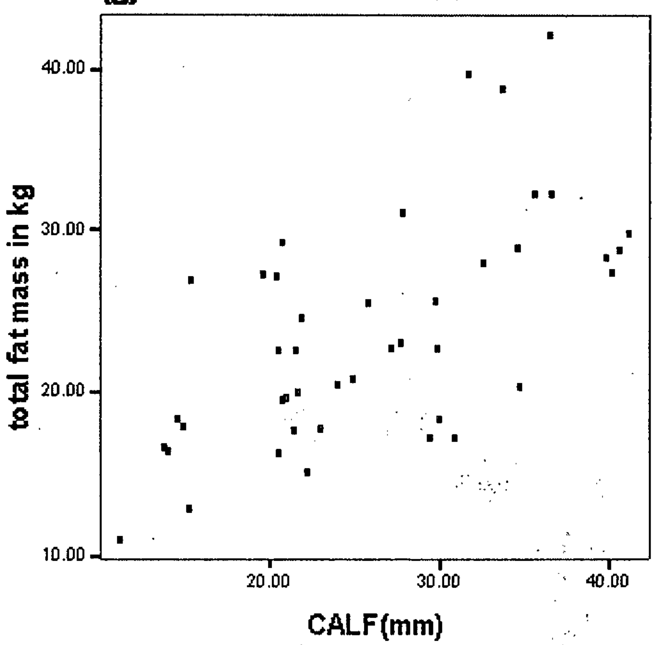
(e) FM vs. AB Skinfold



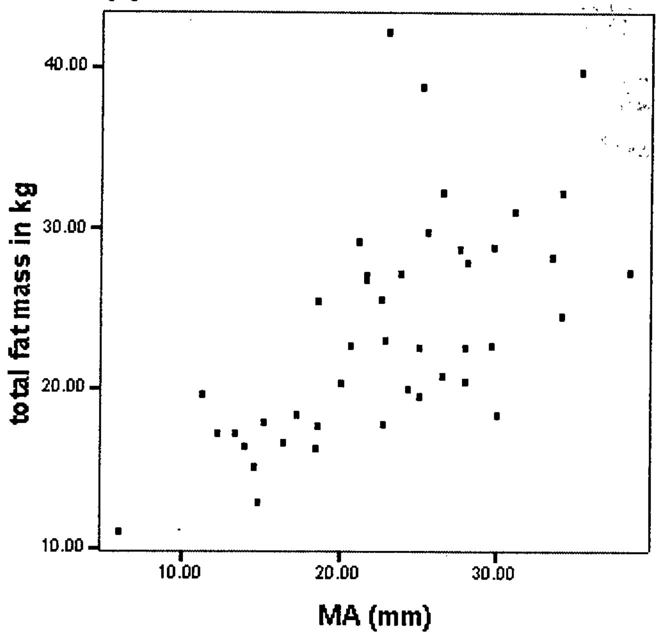
(f) FM vs. BIC Skinfold



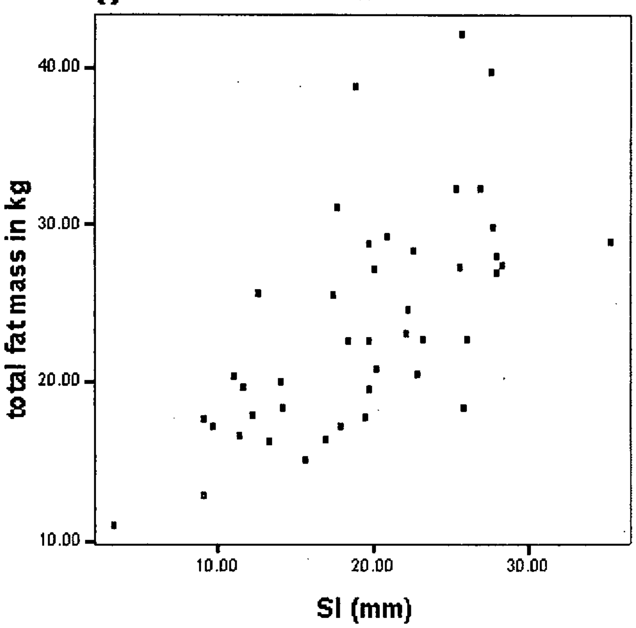
(g) FM vs. CALF Skinfold

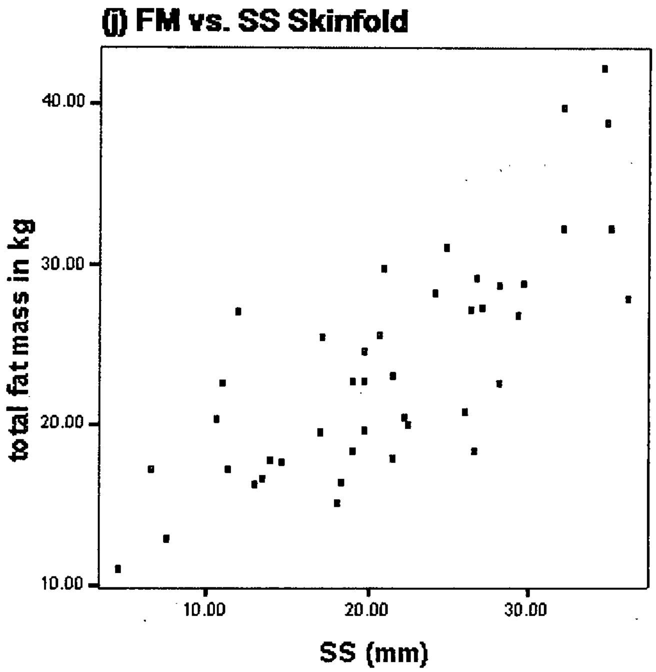


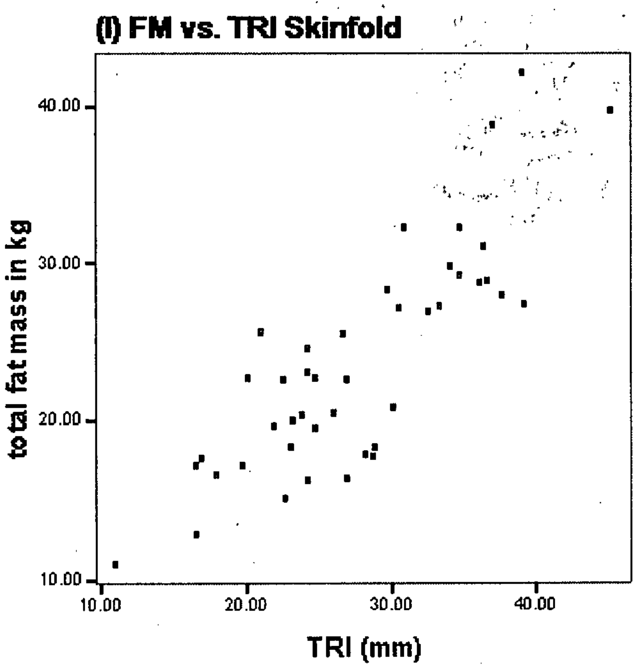
(h) FM vs. MA Skinfold

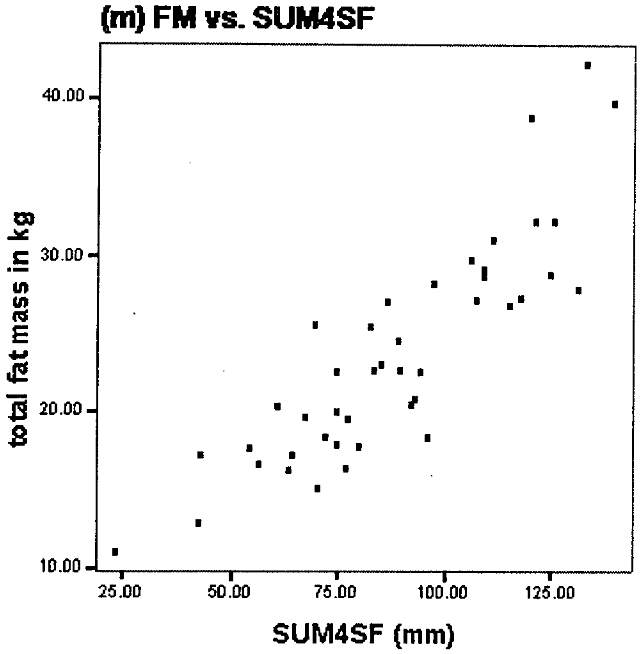


(i) FM vs. SI Skinfold

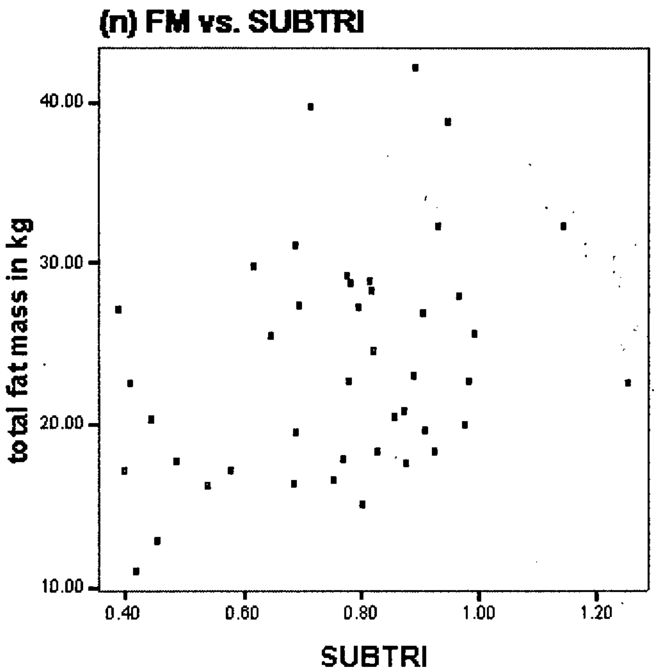



(j) FM vs. SS Skinfold
total fat mass in kg
40.00
30.00
20.00
10.00
10.00
20.00
30.00
SS (mm)


(l) FM vs. TRI Skinfold
total fat mass in kg
40.00
30.00
20.00
10.00
10.00
20.00
30.00
40.00
TRI (mm)



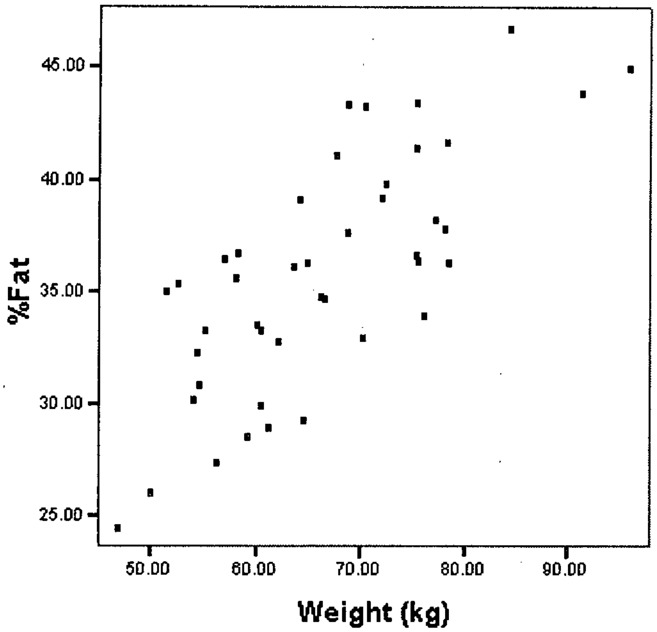
(m) FM vs. SUMSF
total fat mass in kg
SUM4SF (mm)
40.00
30.00
20.00
10.00
25.00
50.00
75.00
100.00
125.00



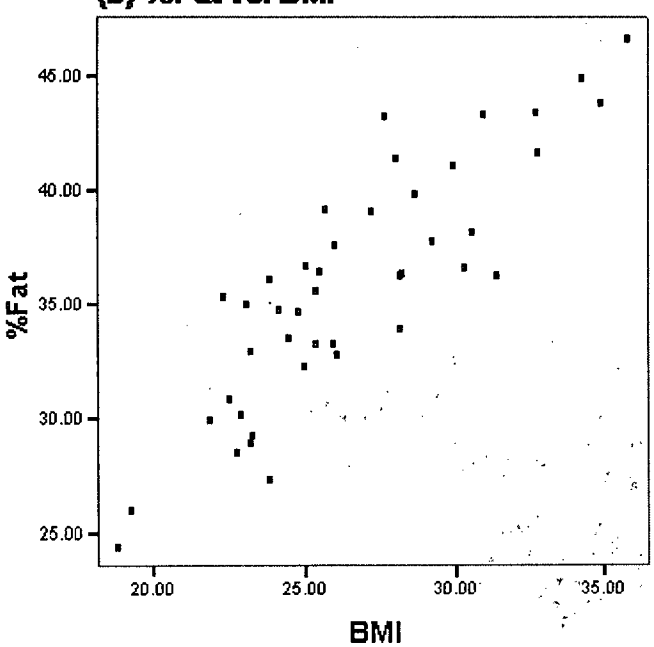
(n) FM vs. SUBTRI
total fat mass in kg
SUBTRI
40.00
30.00
20.00
10.00
0.40
0.60
0.80
1.00
1.20

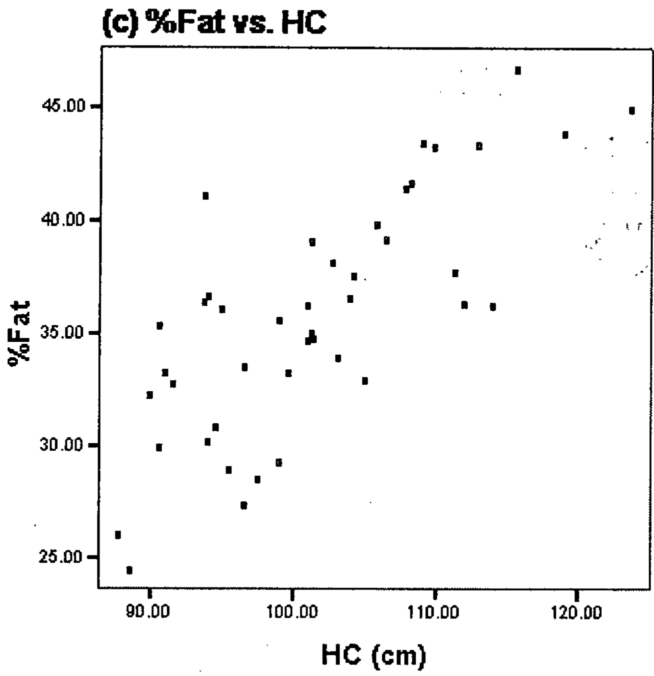
Figure 4.1.2: %Fat vs. Independent Variables

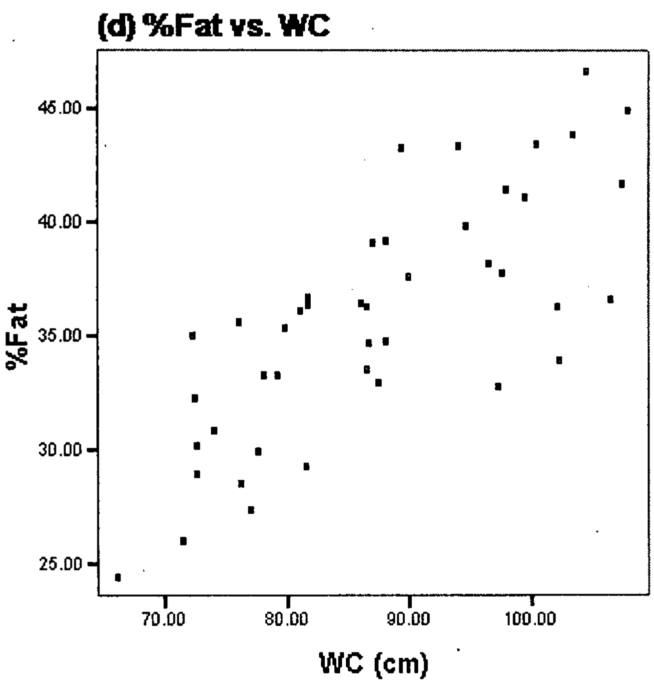
(a) %Fat vs. WT

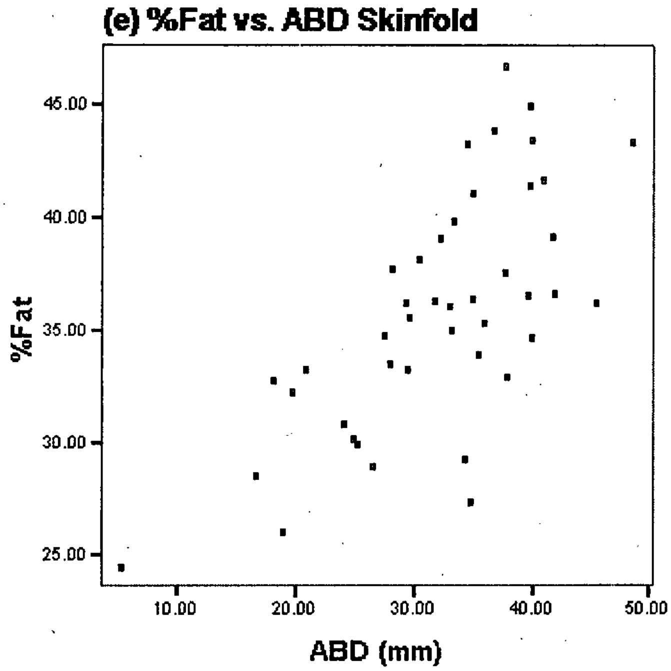


(b) %Fat vs. BMI

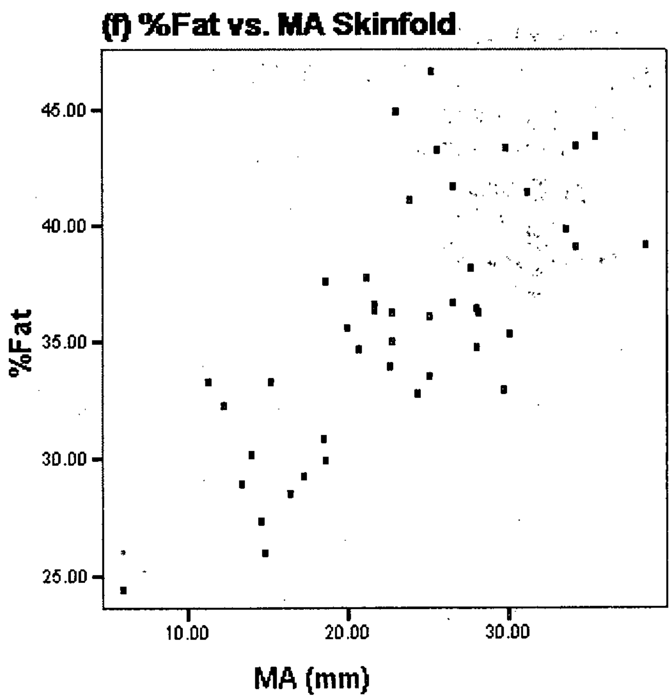



(c) %Fat vs. HC
%Fat
45.00
40.00
35.00
30.00
25.00
90.00
100.00
110.00
120.00
HC (cm)


(d) %Fat vs. WC
%Fat
45.00
40.00
35.00
30.00
25.00
70.00
80.00
90.00
100.00
WC (cm)

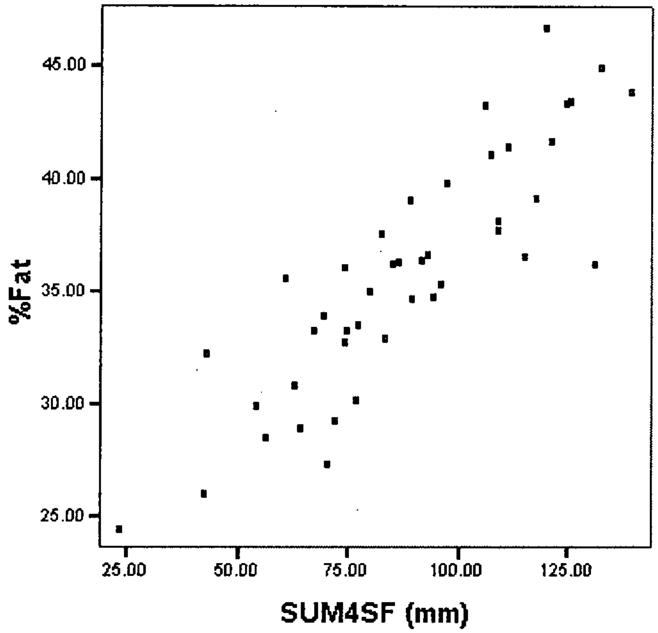


(e) %Fat vs. ABD Skinfold
45.00
40.00
35.00
30.00
25.00
%Fat
10.00
20.00
30.00
40.00
50.00
ABD (mm)

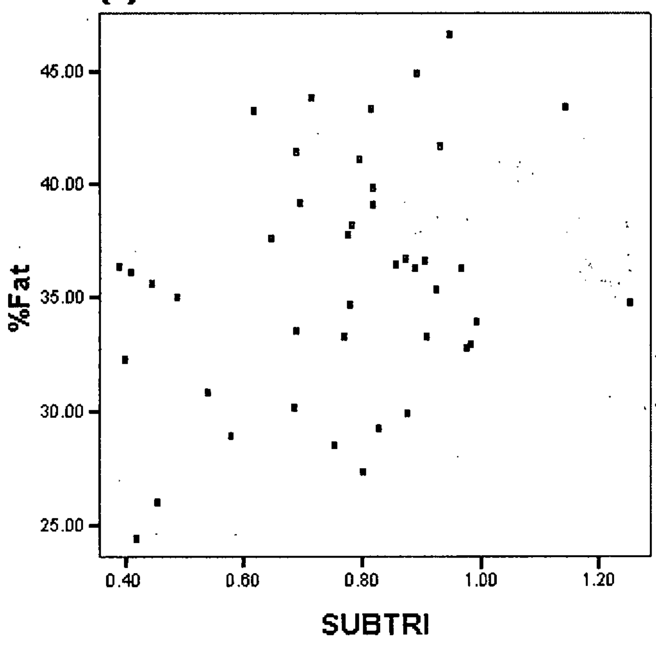


(f) %Fat vs. MA Skinfold
45.00
40.00
35.00
30.00
25.00
%Fat
10.00
20.00
30.00
MA (mm)

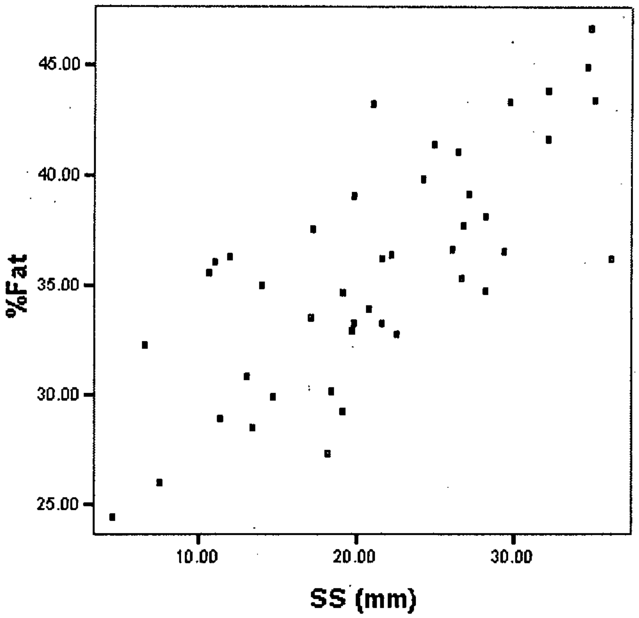
(g) %Fat vs. SUM4SF



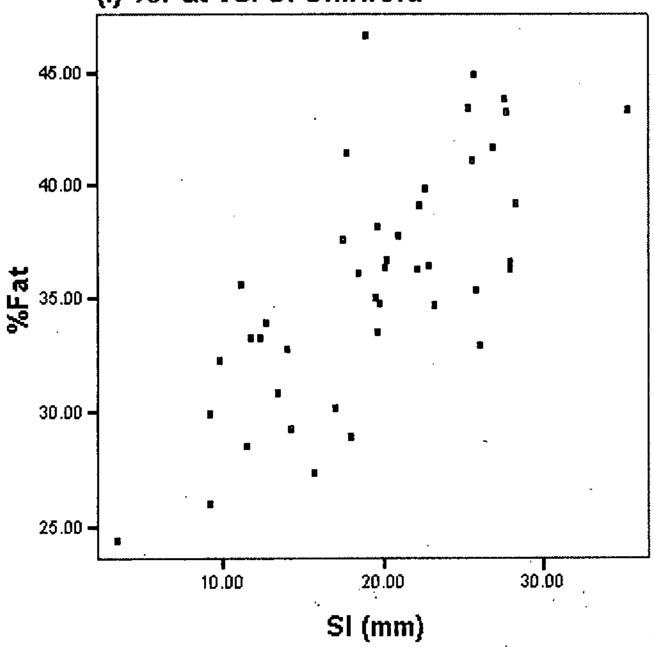
(h) %Fat vs. SUBTRI



(j) %Fat vs. SS Skinfold



(i) %Fat vs. SI Skinfold



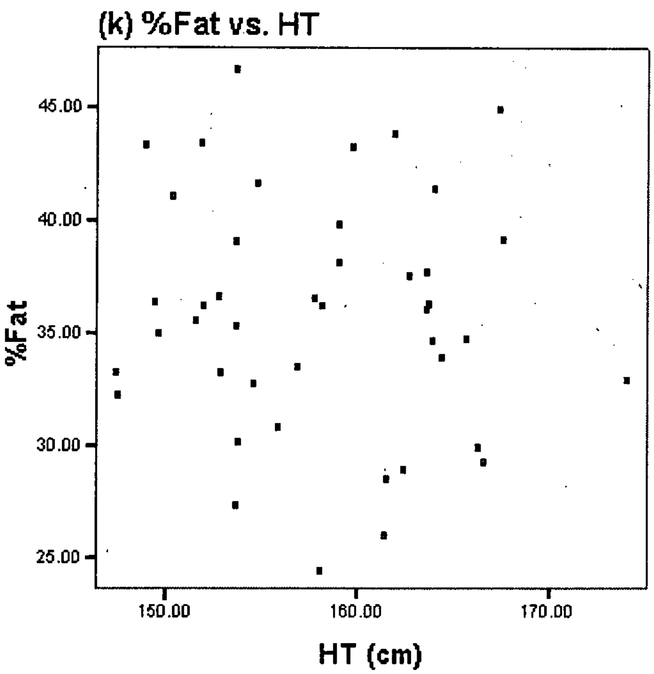
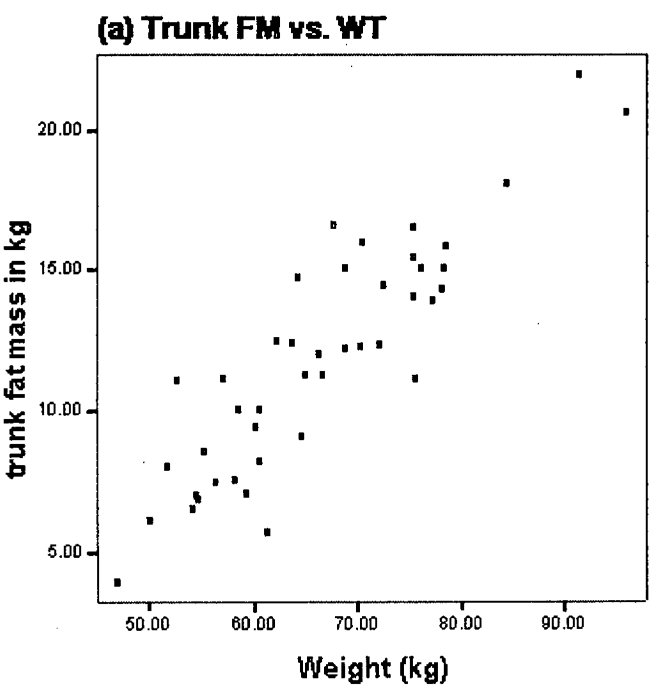
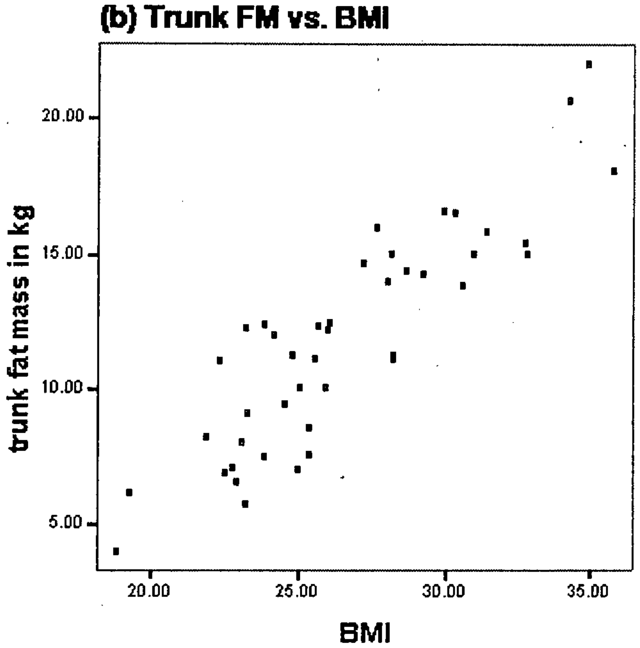
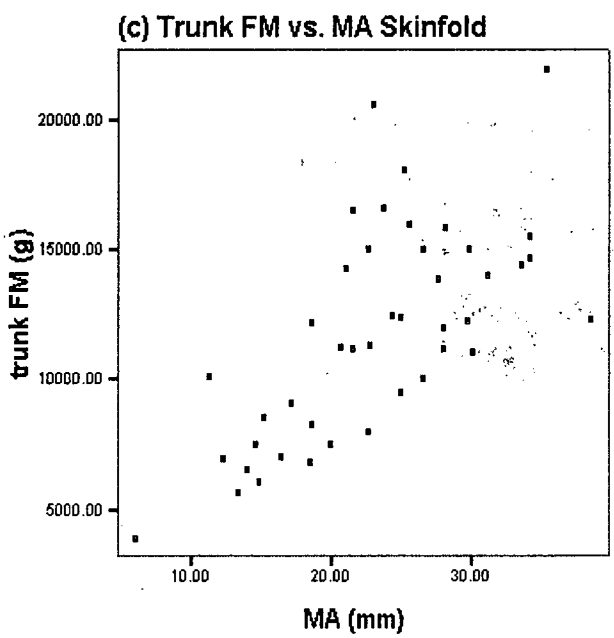


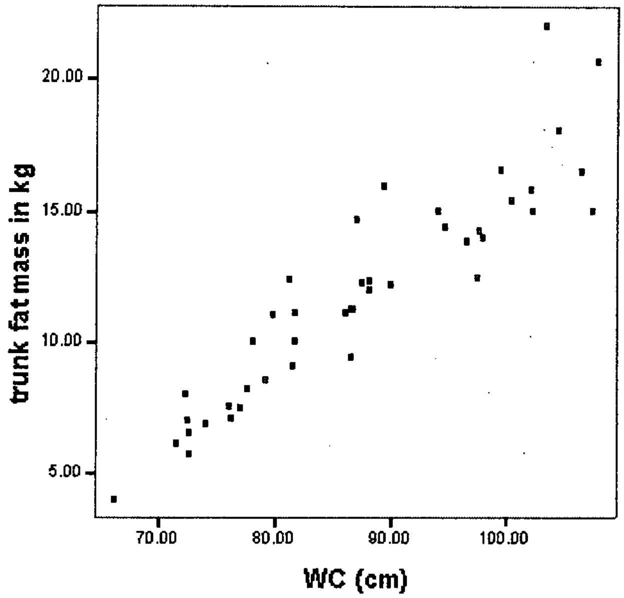
Figure 4.1.3: Trunk Fat Mass vs. Independent Variables



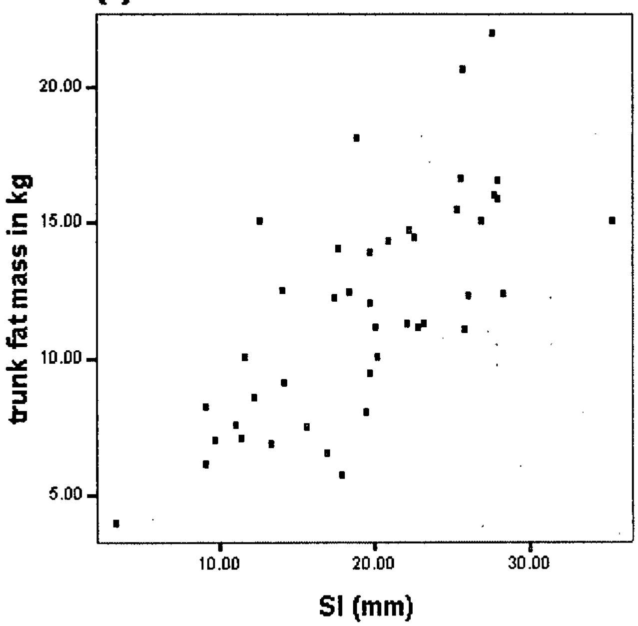

(b) Trunk FM vs. BMI
20.00
15.00
10.00
5.00
trunk fat mass in kg
20.00
25.00
30.00
35.00
BMI


(c) Trunk FM vs. MA Skinfold
20000.00
15000.00
10000.00
5000.00
trunk FM (g)
10.00
20.00
30.00
MA (mm)

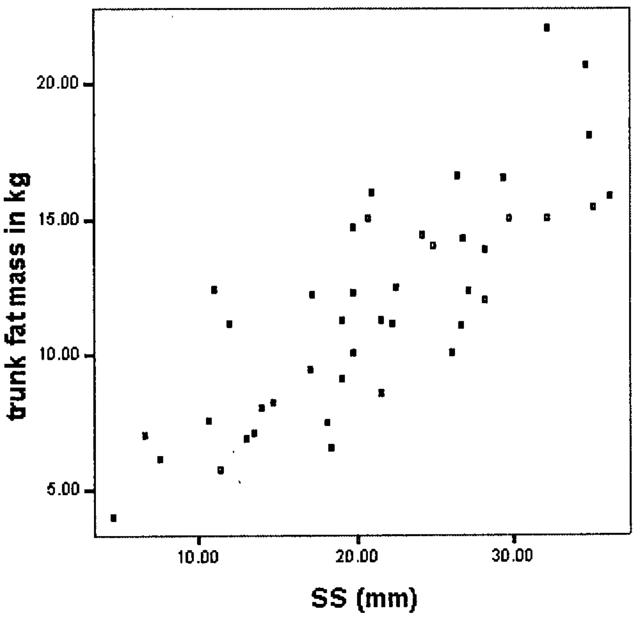
(d) Trunk FM vs. WC



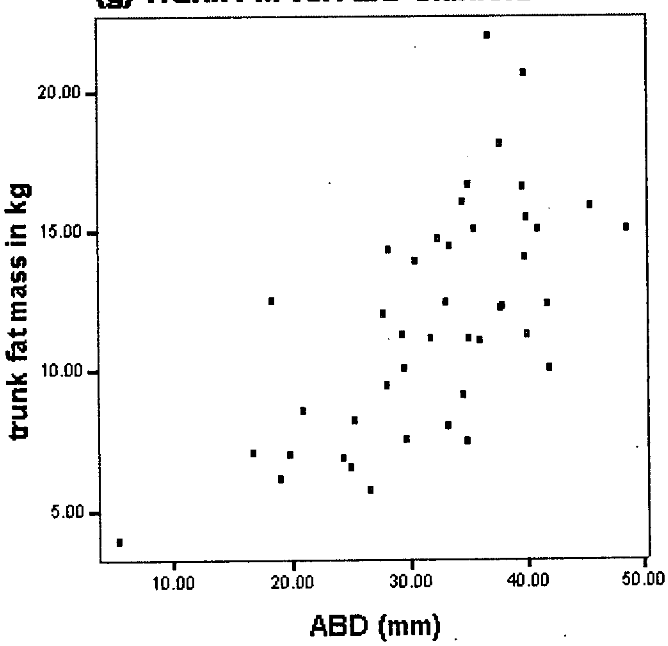
(e) Trunk FM vs. SI Skinfold



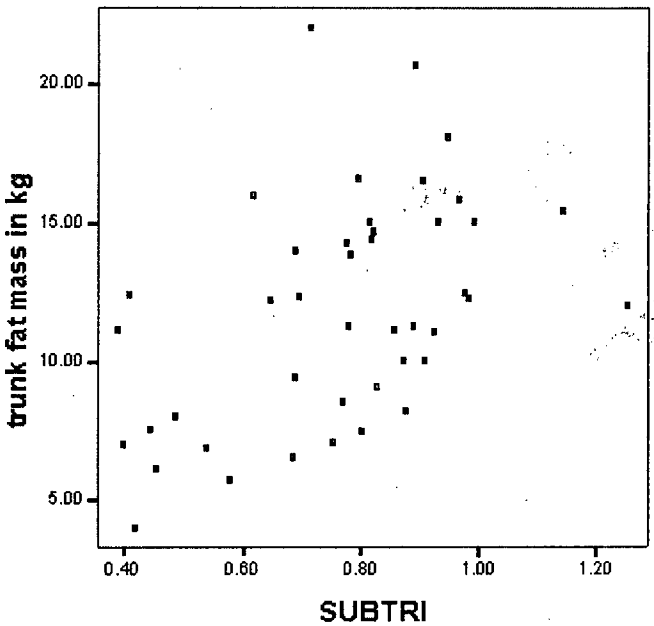
(f) Trunk FM vs. SS Skinfold



(g) Trunk FM vs. ABD Skinfold



(h) Trunk FM vs. SUBTRI



(i) Trunk FM vs. HT

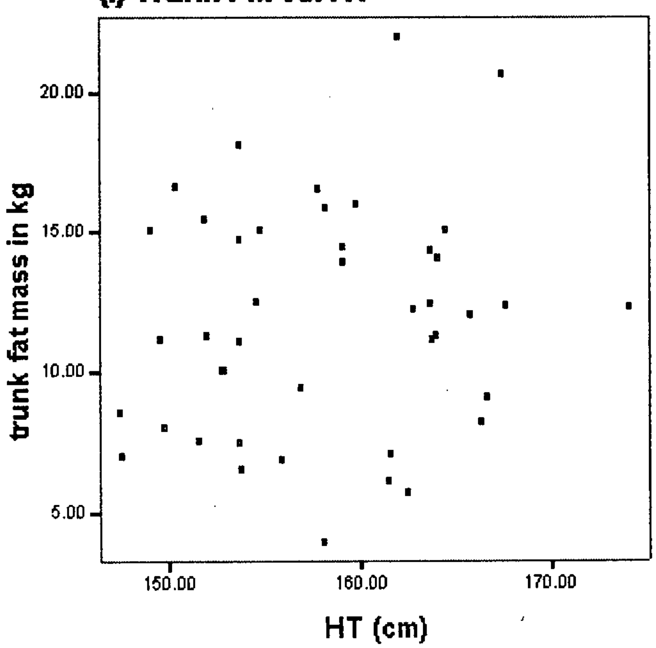
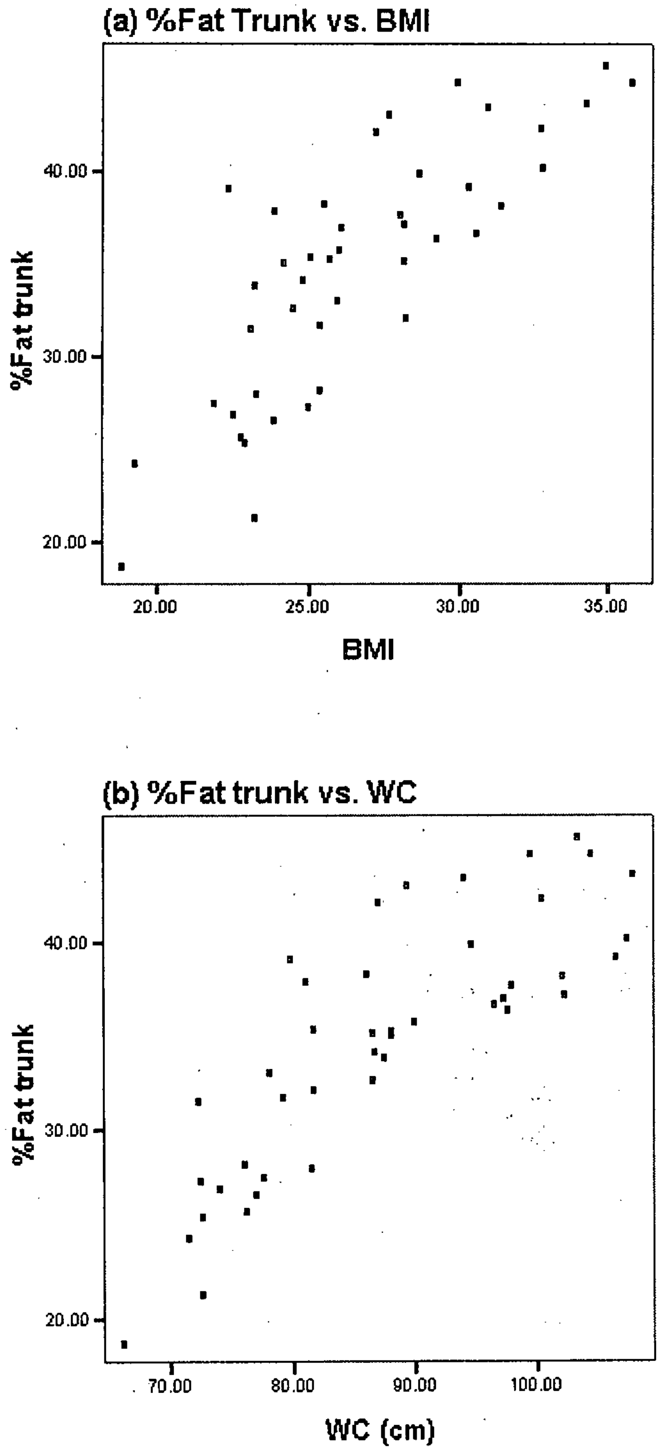
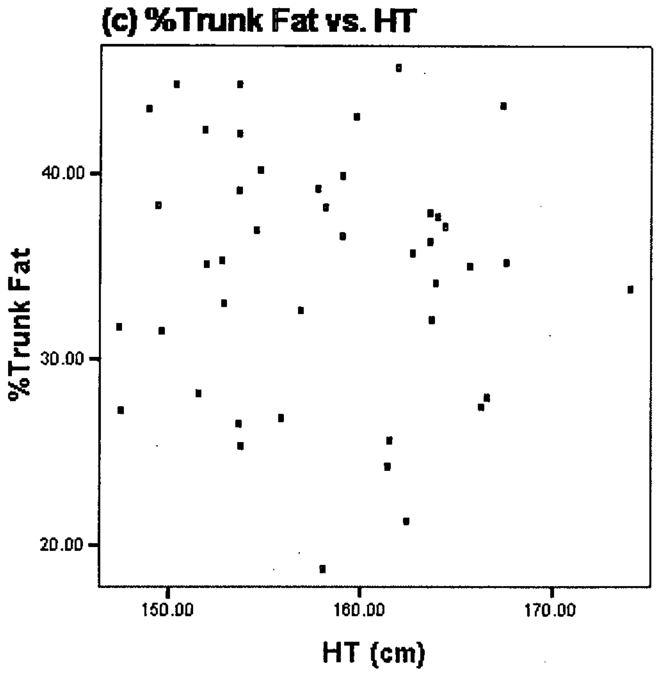
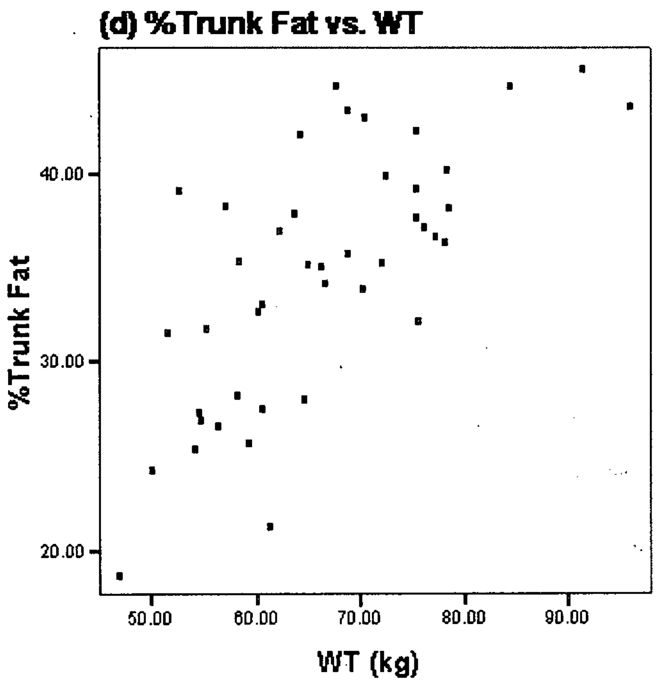


Figure 4.1.4: %Trunk Fat vs. Independent Variables




(c) %Trunk Fat vs. HT
%Trunk Fat
40.00
30.00
20.00
150.00
160.00
170.00
HT (cm)


(d) %Trunk Fat vs. WT
%Trunk Fat
40.00
30.00
20.00
50.00
60.00
70.00
80.00
90.00
WT (kg)

Second, it is important that independent variables and particularly dependent variables are normally distributed in the sample population. Frequency distributions for the four dependent variables (Appendix VIII) and selected independent variables (Appendix IX) showed no major departures from normality and values of the skewness and kurtosis statistics were within the acceptable range (between +1 and –1). Therefore no data transformations were carried out.

Final considerations were for the accuracy and reliability of both the criterion methods and anthropometry methods used. Paired t-tests and correlations were used to test the reliability of the SF measurement (Table 4.1.3). The differences between repeated SF measures were all less than or equal to 0.4mm and the two measures were highly correlated ($r \geq 0.94$), thus showing similar or better values than those reported in the literature (Goran et al., 1997; Lohman et al., 1988).

Table 4.1.3: Reliability of Skinfold Measurements

	ABD	BIC	CF	MA	SI	SS	TRI	TH
Trial 1	31.82	20.07	26.20	23.28	19.47	21.47	27.84	36.76
Trial 2	31.90	19.87	25.94	22.88	19.44	21.31	27.53	36.37
Difference	-0.09	0.20	0.25	0.40	0.04	0.16	0.32	0.38
r	0.95	0.94	0.94	0.97	0.96	0.99	0.94	0.98

All significant at $p < 0.05$

Although testing the accuracy and reliability of DEXA were not specific objectives of this study (these have been documented previously in the literature review), it was of interest to see how closely DEXA total mass (TM) compared with body weight (WT) measured by traditional weigh scales. A near perfect correlation was demonstrated between the two measurement methods (Figure 4.1.5); however, paired t-test results indicated that DEXA underestimated total body mass by 1.2kg, on average (Table 4.1.4).

Figure 4.1.5: DEXA Total Body Mass Regressed Against Standard Body Weight

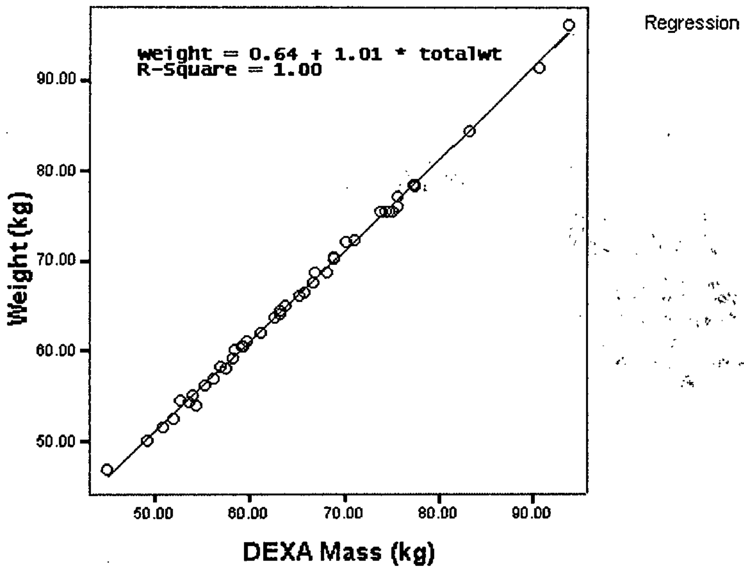


Table 4.1.4: Prediction of Total Body Mass from DEXA

Comparison	r	Mean Diff.	s.d.(mean)	P(mean)
Standard body mass – DEXA body mass	.999	1.2kg	0.49	<0.001

4.2 Comparisons with existing databases

Before continuing with the planned analyses, current data were compared with published body composition data for elderly women to examine similarities and differences between data sets and to identify any extreme outliers or unusual characteristics (Table 4.2.1). The body composition literature was surveyed specifically for studies that measured body fat in elderly women using both DEXA and anthropometry. As well, studies that provided body composition information on women over the age of 75 years were considered suitable. Data shared with us by Brodowicz (1999) and Baumgartner (1999) were also included. No remarkable differences were observed; however, there were some inconsistencies.

Table 4.2.1: Summary of Current and Previously Published Population Descriptives

	n	Age	HT(cm)	WT(kg)	BMI	WC(cm)	HC(cm)	WHR
U.B.C.	43	77.4 (1.8)	158.1 (6.4)	66.4 (11.0)	26.6 (4.0)	87.4 (11.6)	101.4 (8.7)	0.86 (.08)
BAUM(1999)	101	74.5 (5.6)	155.9 (6.8)	64.8 (12.6)	26.7 (5.0)	91.9 (11.7)	104.1 (11.4)	0.88 (.07)
BAUM(1995)	82	71-80	158.3 (6.2)	63.1 (10.9)	25.1 (3.6)	87.8 (9.8)	101.5 (8.6)	0.87 (.06)
BROD(1999)	31	71.1 (4.6)	161.3 (6.2)	65.1 (10.1)	25.0 (3.5)	N/A	N/A	N/A
VISSER(1994)	128	70.2 (5.3)	161.6 (6.1)	68.1 (9.5)	26.1 (3.6)	N/A	N/A	N/A
SVEND(1991)	23	75 (0)	158.9 (6.9)	65.5 (11.6)	25.9 (4.3)	N/A	N/A	0.84 (.08)

	n	SS(mm)	SI(mm)	BIC(mm)	TRI(mm)	FM(kg)	%FAT	Trunk FM(kg)
U.B.C.	43	21.4 (8.2)	19.5 (6.7)	20.0 (7.1)	27.6 (7.4)	23.8 (7.0)	35.8 (5.3)	11.9 (4.8)
BAUM(1999)	101	20.7 (9.6)	N/A	N/A	22.6 (8.3)	26.4 (9.3)	39.6 (7.5)	N/A
BAUM(1995)	82	21.9 (9.9)	N/A	N/A	N/A	24.5 (8.2)	38.0 (6.8)	11.8 (4.2)
BROD(1999)	31	19.5 (7.0)	19.8 (7.3)	10.7 (3.9)	20.8 (5.3)	25.8 (7.0)	39.1 (5.6)	N/A
VISSER(1994)	128	19.8 (7.5)	19.8 (8.0)	11.8 (4.5)	19.8 (5.1)	N/A	43.3 (6.1)	N/A
SVEND(1991)	23	N/A	N/A	N/A	N/A	21.7 (8.8)	33.7 (9.9)	N/A

*N/A-not applicable

As the regression equation is strongly influenced by the relationship between the independent and dependent variables, it was important to compare the current findings for the correlation between anthropometry and criterion body fat with those described in the literature. Correlation coefficients were examined across several study populations and are presented in Table 4.2.2. Not all authors performed the same analyses, and thus, data sets for Table 4.2.1 and Table 4.2.2 are somewhat different. Data for elderly women were not provided by Dupler (1997) or Chapman et al. (1998).

Table 4.2.2: Summary of Current and Previously Published Correlations for Anthropometry and Criterion Body Fat

	Dependent Variable	SS	TRI	BIC	ABD	MA	SUM4SF
U.B.C.	DEXA FM (Hologic)	0.78	0.83	0.92	0.65	0.62	0.88
BAUM(1999)	DEXA FM (Lunar)	0.77	0.75	N/A	N/A	N/A	N/A
BROD(1999)	DEXA FM (Lunar)	0.65	0.60	0.61	N/A	N/A	N/A
GORAN(1997)	FM (4C model)	0.61	0.68	N/A	0.67	0.72	N/A
BAUM(1995)	DEXA FM (Lunar)	N/A	0.68	N/A	N/A	N/A	N/A
VISSER(1994)	Body Density	-0.39	-0.28	-0.27	N/A	N/A	-0.4

Table 4.2.2 (cont'd)

	Dependent Variable	WT	BMI	WC	HC
U.B.C.	DEXA FM (Hologic)	0.95	0.93	0.87	0.89
BAUM(1999)	DEXA FM (Lunar)	0.96	0.91	0.85	0.93
BROD(1999)	DEXA FM (Lunar)	0.90	0.86	N/A	N/A
GORAN(1997)	FM (4C model)	0.88	0.85	0.72	0.83
BAUM(1995)	DEXA FM (Lunar)	N/A	0.93	N/A	0.93
VISSER(1994)	Body Density	N/A	-0.61	N/A	N/A

4.3 Performance of previously published equations

Eight anthropometry equations from the literature have been selected to test their ability to predict DEXA body fat in our sample of elderly women. These equations have been referred to previously (Appendix II) and are summarized here in Table 4.3.1.

Table 4.3.1: Previously Published Equations Selected for Analyses

Author	Equation
Chapman et al. (1998)	FFM(kg) = 0.582(WT) - 0.397(TRI) + 0.392(HT) - 48.956
Dupler (1997)	(a)%Fat = 0.1688(BMI) + 0.542(HC) – 0.1639(WT) – 7.9498
Dupler (1997)	(b)FM = 0.2449(WT) + 0.5218(HC) – 0.076(TC) – 37.8619
Durnin & Womersley (1974)	D_b = 1.1339 - 0.0645 [log (BIC + TRI + SI + SS)] *for elderly women
Goran et al. (1997)	FM = 0.31(HC) + 0.22(CALF) + 0.31(WT) – 31.33
Svendsen et al. (1991)	FM = 0 .63(TRI)+4.47(BMI)+9.32(SUBTRI)+1.35(WT)+1.04(HT) -192.48
Visser et al. (1994)	(a) D_b = - 0.0356[log(BIC + TRI + SI + SS)] +1.0688
Visser et al. (1994)	(b) D_b = -0.0022(BMI) + 1.0605

Paired t-test comparisons were conducted to determine the difference between predicted and measured FM and %Fat from these equations and are shown in Tables 4.3.2 and 4.3.3, respectively. All previously published equations significantly overestimated FM and %Fat when applied to our data ($p<0.001$), with the exception of the Svendsen equation, which significantly underestimated body fat.

Table 4.3.2: Prediction of FM from Published Equations

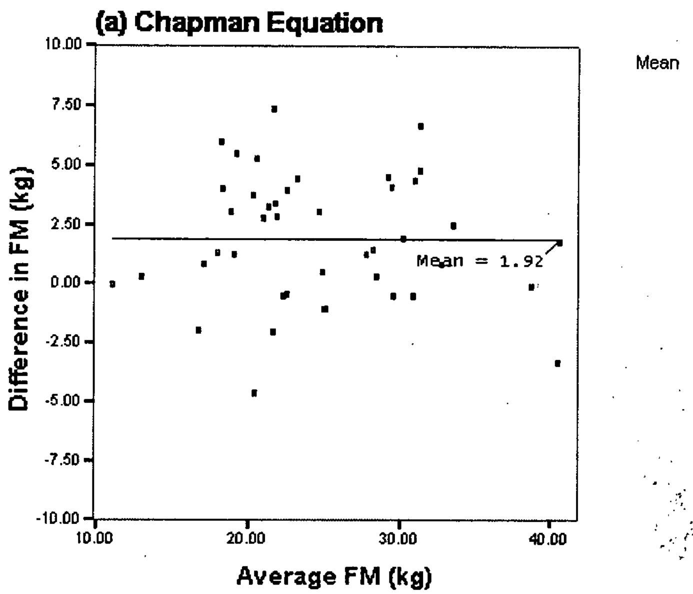
Comparison	r	Mean Diff.	S.D.	t	p
CHAPMAN EQN - DEXA FM	0.92	1.92	2.72	4.64	<0.001
DUPLER EQNa - DEXA FM	0.92	4.05	2.53	10.27	<0.001
GORAN EQN - DEXA FM	0.94	2.63	2.48	6.96	<0.001
SVENDSEN EQN – DEXA FM	0.97	-3.30	3.51	-6.17	<0.001

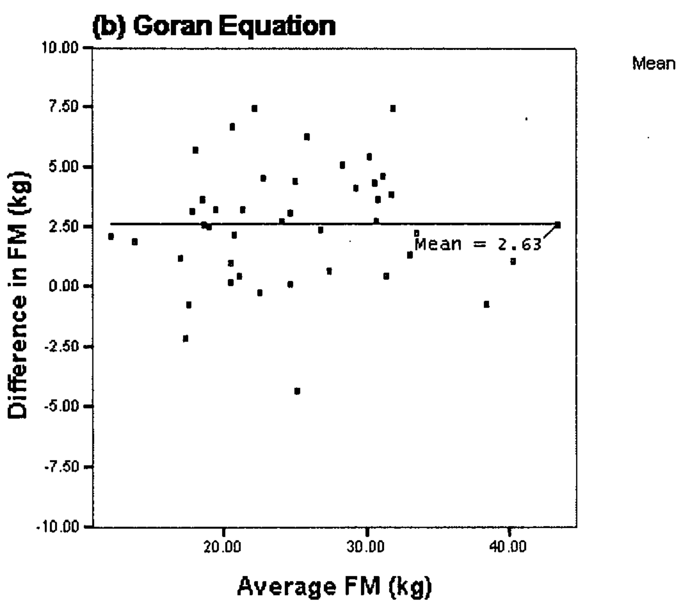
Table 4.3.3: Prediction of %Fat from Published Equations

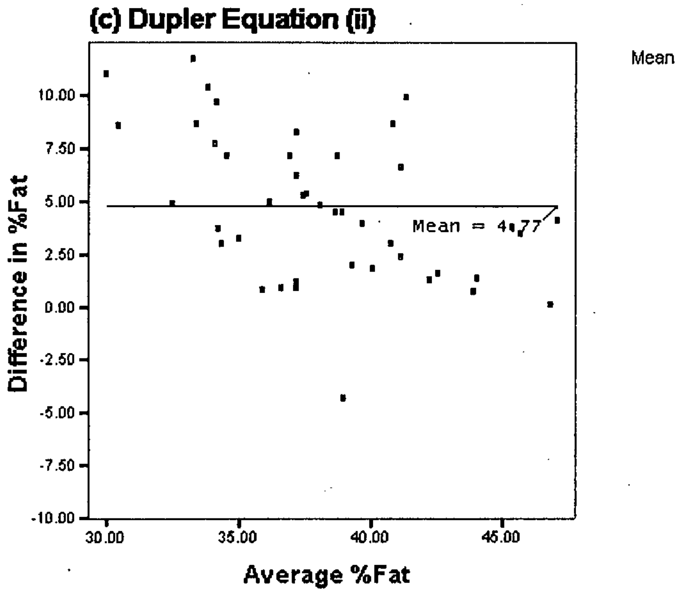
Comparison	r	Mean Diff.	S.D.	t	p
DUPLER EQNb - DEXA %FAT	0.76	4.77	3.47	9.03	<0.001
D&W EQN - DEXA %FAT	0.84	4.38	2.87	10.03	<0.001
VISSER EQNa - DEXA %FAT	0.84	9.02	3.35	17.64	<0.001
VISSER EQNb - DEXA %FAT	0.86	8.20	2.68	20.07	<0.001

The correlation coefficients for predicted and measured body fat were all >0.75, despite the significant differences between these measures. Moreover, correlations were higher for the prediction of FM (.92-.97) than for %Fat (.76-.86). However, further analysis of four of the better performing equations showed poor agreement between predicted and measured body fat in all cases (Figure 4.3.1). Both the Dupler equation (Fig.4.3.1c) and the Durnin & Womersely equation (Fig.4.3.1d) appeared to overestimate %Fat at low levels of body fat but were reasonable accurate at high body fat levels. The corresponding limits of agreement between predicted and measured body fat are summarized in Table 4.3.4. Together, these results demonstrate the inability of existing equations to accurately estimate body composition in the current sample of women 75-80 years of age.

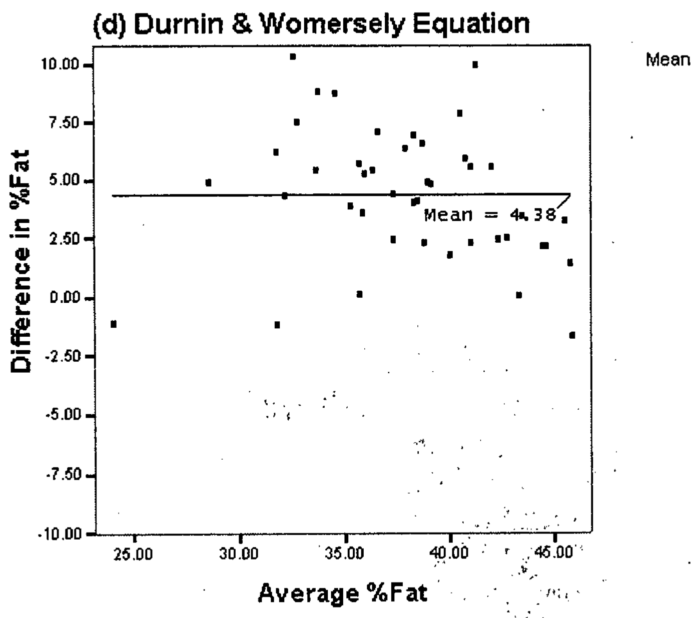
Figure 4.3.1: Agreement Between Predicted and Measured Fat from Published Equations







(c) Dupler Equation (ii)
Mean
10.00
7.50
5.00
2.50
0.00
-2.50
-5.00
-7.50
-10.00
Difference in %Fat
Mean = 4.77
30.00
35.00
40.00
45.00
Average %Fat



(d) Durnin & Womersely Equation
Mean
10.00
7.50
5.00
2.50
0.00
-2.50
-5.00
-7.50
-10.00
Difference in %Fat
Mean = 4.38
25.00
30.00
35.00
40.00
45.00
Average %Fat

Table 4.3.4: Limits of Agreement for Previously Published Equations and DEXA

Comparison	Difference	s.d. (diff)	d +/- 2 X SD
CHAPMAN EQN vs. DEXA FM	1.92kg	2.72kg	-3.52 to 7.36
GORAN EQN vs. DEXA FM	2.63kg	2.48kg	-2.33 to 7.59
DUPLER EQNb vs. DEXA %FAT	4.77%	3.47%	-2.17 to 11.71
D&W EQN vs. DEXA %FAT	4.38%	2.87%	-1.38 to 10.12

4.4 Development of new prediction equations

Four new prediction equations to estimate fat mass (FM), percent fat (%Fat), trunk fat mass (TFM), and percent trunk fat (%TF) in women aged 75-80 years were derived using a combination of all possible subsets and stepwise regression procedures. Prior to equation development, a preliminary stepwise regression was performed for FM and all predictor variables to examine the overall data (Appendix X). As expected, SF sites of the limbs (BIC, TRI, CF and TH) did not significantly contribute to the explanation of body fatness in elderly women and were not entered in subsequent regression analyses. Stepwise regression analyses for each of the dependent variables were performed first to determine the number and selection of significant predictors according to maximum adj.R^2 and minimum SEE criteria (Appendix XI). Following this, all possible subsets regression analyses were used to evaluate other possible prediction models that might be more stable (appropriate $C_{p)}$, practical and biologically meaningful (Appendix XII). Equations for FM and %Fat using only SF measurements as predictor variables were similarly developed (Table 4.4.3). Regression outputs were included in Appendices XI and XII.

The group of predictor variables entered into the equation development for FM and %Fat were HT, WT, BMI, ABD, MA, SI, SS, SUM4SF, SSTRI, HC and WC; while HT, WT, BMI, ABD, MA, SI, SS, SSTRI and WC were entered into the TFM and %TF regression analyses. A set of possible regression models were selected using the above criteria and are presented in

Table 4.4.1. A single equation was then proposed for each of the dependent variables: FM (EQN1), %Fat (EQN2), TFM (EQN3) and %TF (EQN4) (Table 4.4.2).

Table 4.4.1: New Regression Models for the Prediction of Body Fat

DEXA	Predictor Variables	Adj. R^2	Cp	SEE	CV
FM	WT, HT, MA	0.95	4.46	1.53kg	6.4%
	WT, HT, MA, SSTRI	0.96	1.77	1.46kg	6.1%
	WT, HT, MA, HC	0.96	3.78	1.50kg	6.3%
	WT, HT, MA, WC	0.95	4.20	1.51kg	6.3%
%FAT	BMI, MA	0.84	4.25	2.14%	6.0%
	HT, WT, MA	0.84	4.61	2.12%	5.9%
	BMI, MA, SSTRI	0.85	1.63	2.04%	5.7%
	BMI, MA, WC	0.84	3.74	2.10%	5.9%
TFM	WT, HT, MA, WC	0.90	3.77	1.27kg	10.7%
	WT, BMI, MA, WC	0.90	4.54	1.28kg	10.8%
% TF	HT, MA, WC	0.83	3.9	2.76%	7.9%
	HT, MA, WC, ABD	0.84	3.99	2.72%	7.8%

Table 4.4.2: Best New Prediction Equations for Body Fat

Eqn	New Prediction Equations	Adj. R^2	Cp	SEE	CV
1	FM = 0.611(WT) - .231(HT) + .143(MA) + 16.462	0.95	4.46	1.53kg	6.4%
2	%Fat = 0.341(WT) – .339(HT) + .285(MA) + 60.122	0.84	4.61	2.12%	5.9%
3	TFM = 0.185(WT) - .008(HT) + .112(MA) + .136(WC) – 2.072	0.90	3.77	1.27kg	10.7%
4	%TF = 0.387(MA) - .227(HT) + .356(WC) + 30.659	0.83	3.9	2.76%	7.9%

Table 4.4.3: New Skinfold Equations for Total Body Fat

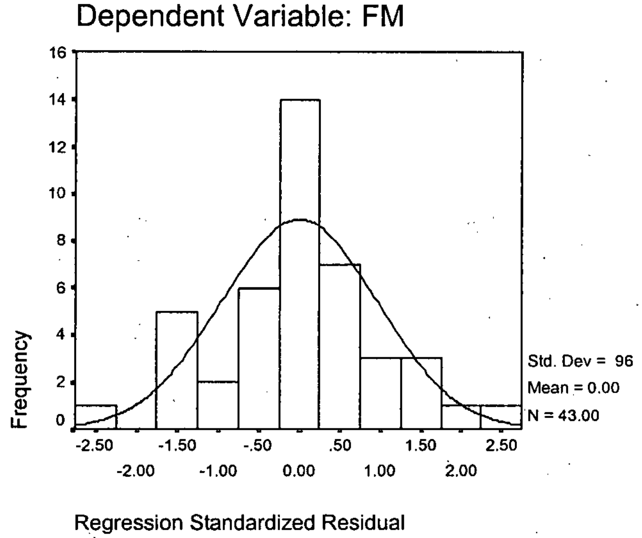
DEXA	Predictor Variables	Regression method	Adj. R^2	Cp	SEE	CV
FM	TRI, BIC, CALF, ABD	All poss. subsets	0.87	5.04	2.56kg	10.8%
FM	BIC, CALF	Stepwise	0.86		2.66kg	11.2%
%FAT	MA, CALF, SUM4SF	All poss. subsets	0.77	2.93	2.52%	7.0%
%FAT	SUM4SF, CALF	Stepwise	0.77		2.51%	7.0%

All regression models included the MA skinfold and some combination of HT, WT or BMI, which together, explained 70% or more of the variation in body fat. Additionally, measures of central fat (HC, WC and SSTRI) were important in the prediction of FM; however, HC and WC were not statistically significant. The model which included HT, WT, MA and SSTRI involved the measurement of essentially 5 variables which exceeded the recommended ratio of 10-20 subjects for every predictor variable (Heyward & Stolarczyk, 1996b), and was somewhat less stable than the others (C_p =1.77). Thus, the model with HT, WT and MA was chosen for FM. Similarly, for %Fat, the contribution from SSTRI was significant but not for WC. The equation with BMI, MA and SSTRI, again, involved the measurement of 5 predictor variables and was ruled out. The combination of HT, WT and MA was marginally better (smaller SEE) than that of BMI and MA, and was therefore chosen for the best %Fat model. For TFM, the model which included HT, WT, MA and WC was superior to the 3-variables equations and all predictors were significant. Once again, the model with WT, BMI, MA and WC involved essentially 5 variables. Finally, the best equation to predict %TF included HT, MA and WC. Although the addition of the ABD SF improved the equation, it was not significant.

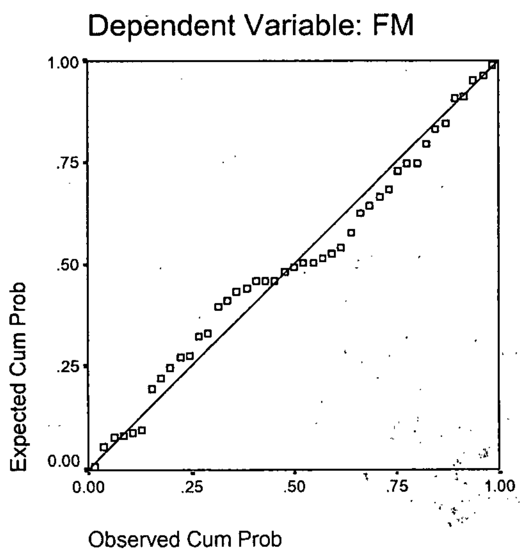
Residual analyses were conducted for the four new equations (Figures 4.4.1- 4.4.4). The agreements between predicted and measured fat for the new FM and %Fat equations were stronger than that for previously published equations (Figure 4.3.1) indicated by a tighter clustering of residual data (Svendsen et al., 1991). No excessive trends in the residuals were apparent (ie.homogeneity of variance was not violated). However, the magnetude of residual variability was much larger for the trunk fat equations, which reflected the higher errors associated TFM and %TF.

Figure 4.4.1: Residual Analyses for the New FM Equation

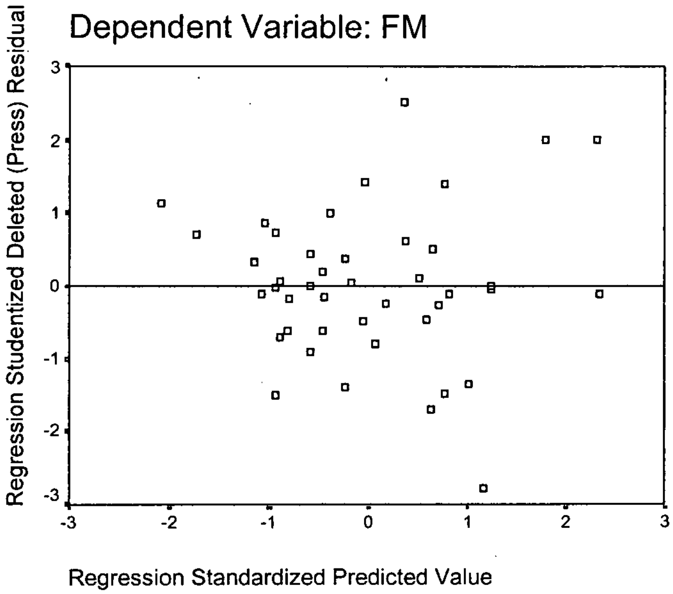
(a) Histogram of Residuals



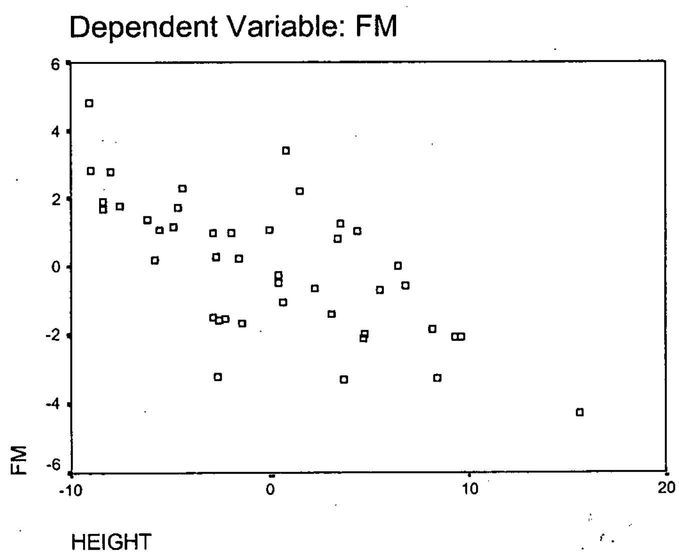
(b) Normal P-P plot of regression standardized residual



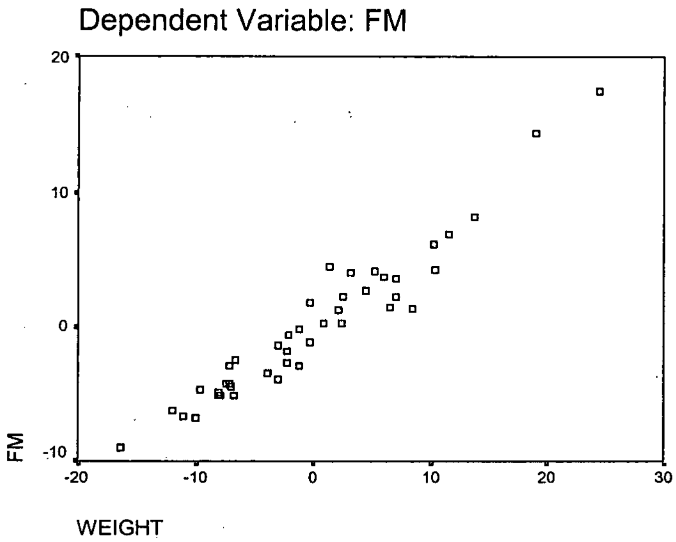
(c) Scatter plot of residuals vs. predicted FM



(d) Partial regression plot for FM and Height



(e) Partial regression plots for FM and Weight



(f) Partial regression plots for FM and the MA skinfold

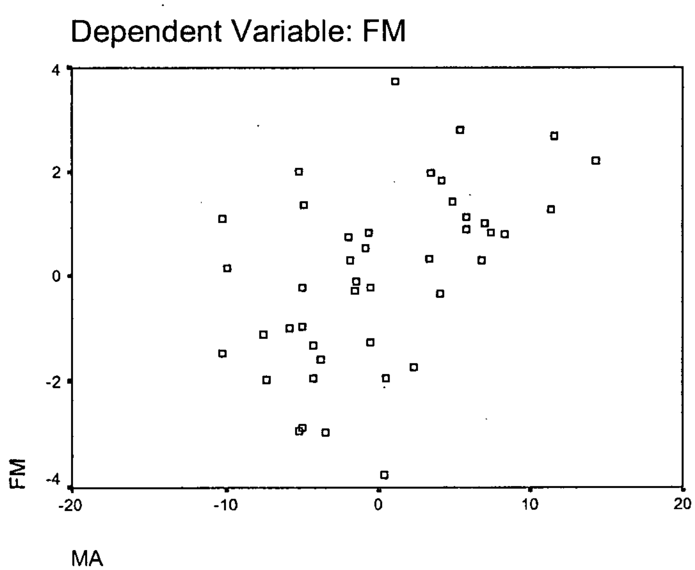
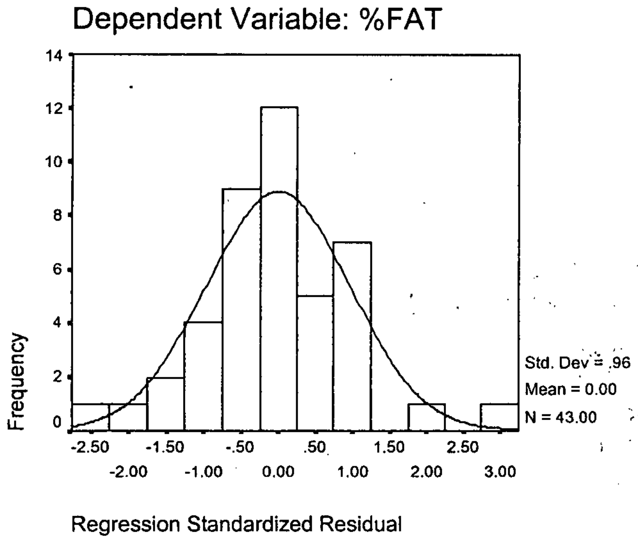
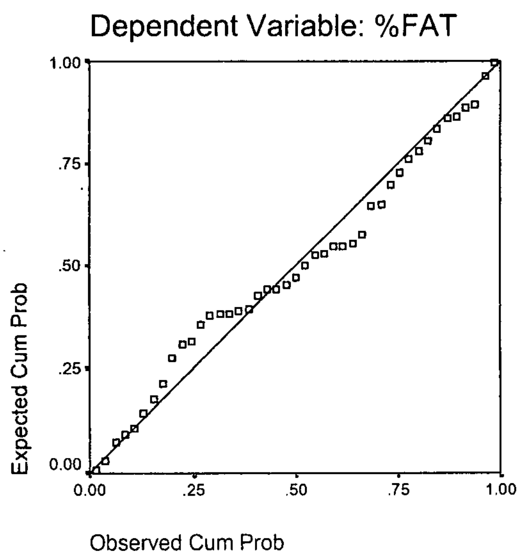


Figure 4.4.2: Residual Analyses for the New %Fat Equation

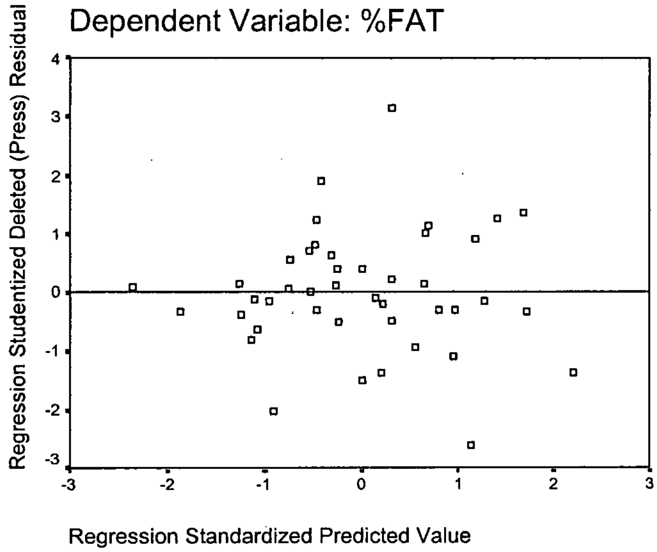
(a) Histogram of residuals



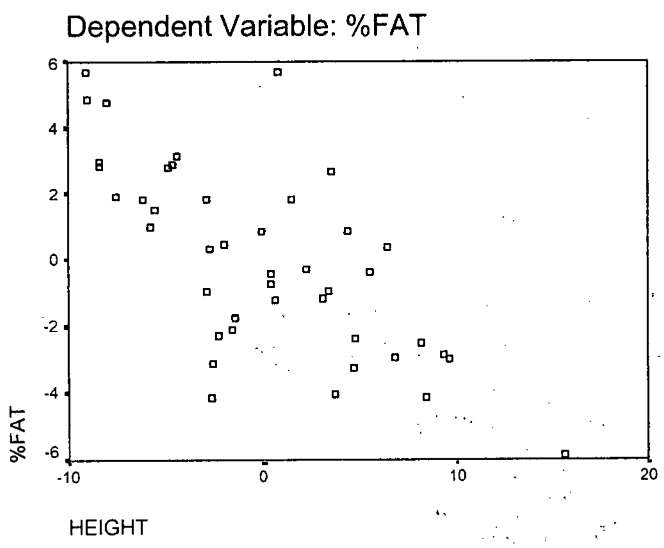
(b) Normal P-P plot of regression standardized residual



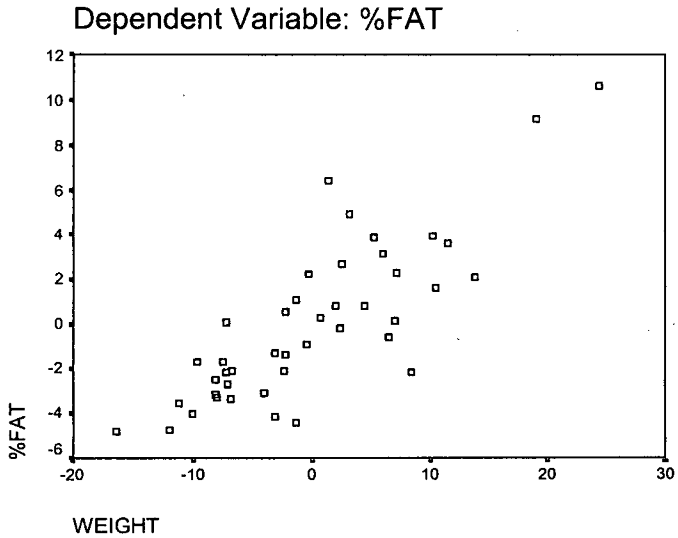
(c) Scatter plot of residuals vs. predicted %Fat



(d) Partial regression plot for %Fat and Height



(e) **Partial regression plot for %Fat and Weight**



(f) **Partial regression plot for %Fat and MA Skinfold**

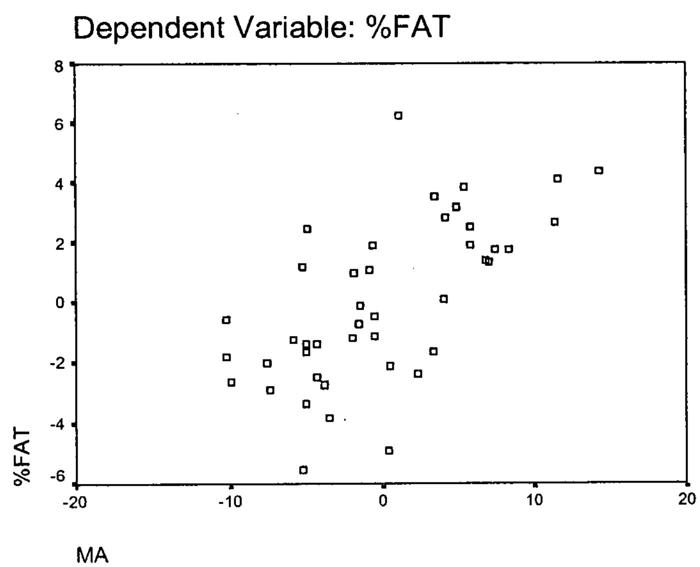
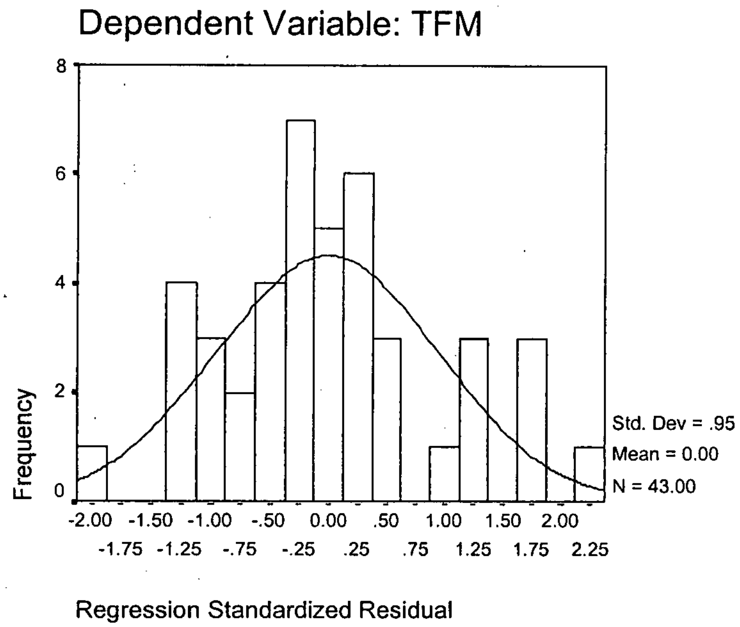
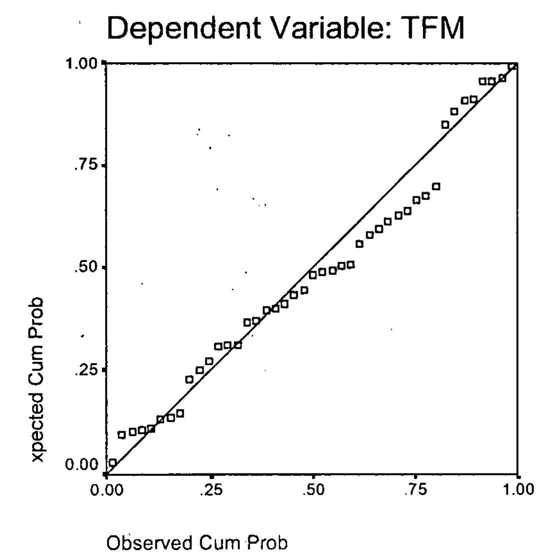


Figure 4.4.3: Residual Analyses for the New TFM Equation

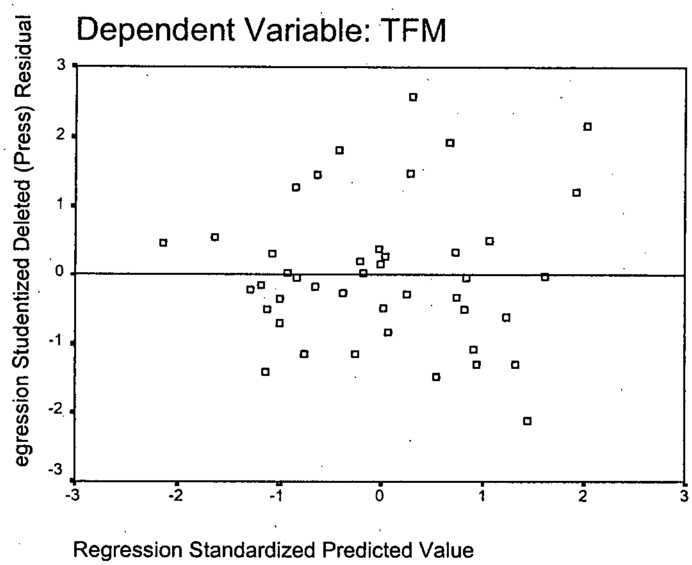
(a) Histogram of residuals



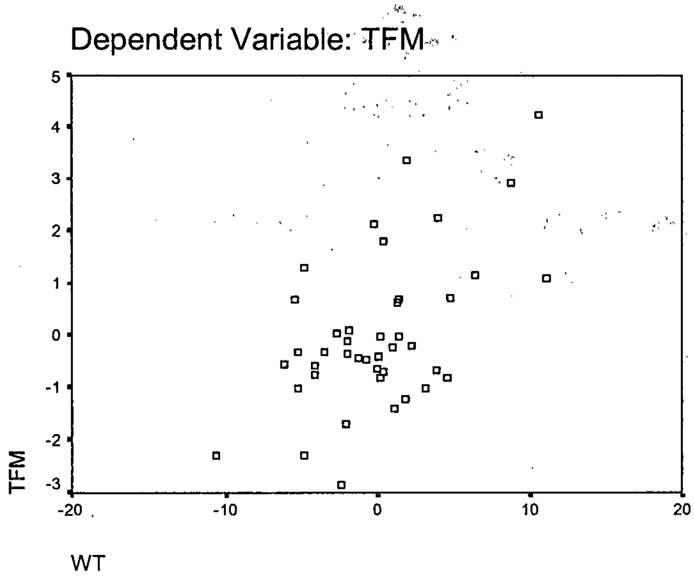
(b) Normal P-P plot of regression standardized residual



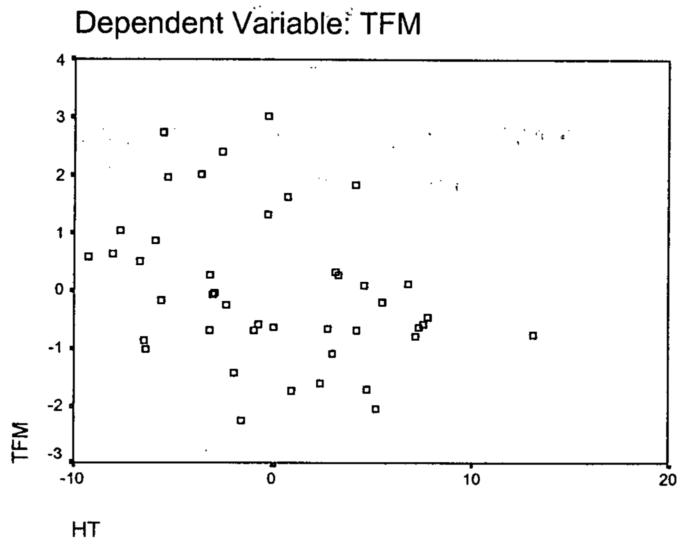
(c) Scatter plot of residuals vs. predicted TFM



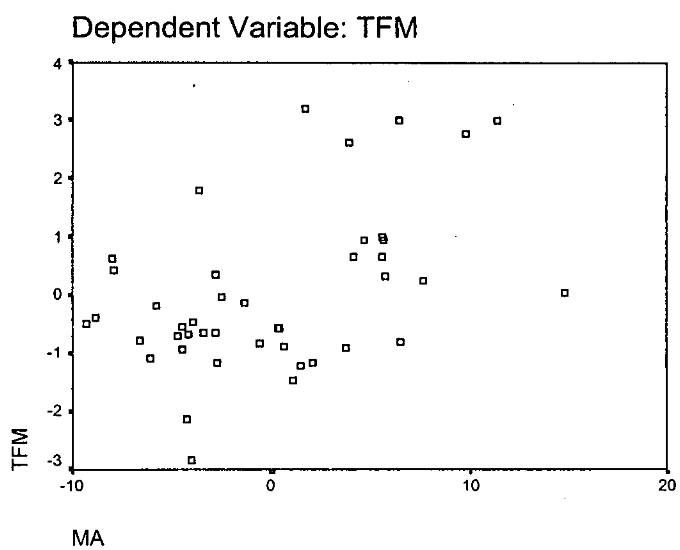
(d) Partial regression plot for TFM and WT



(e) Partial regression plot for TFM and HT



(f) Partial regression plot for TFM and MA



(g) **Partial regression plot for TFM and WC**

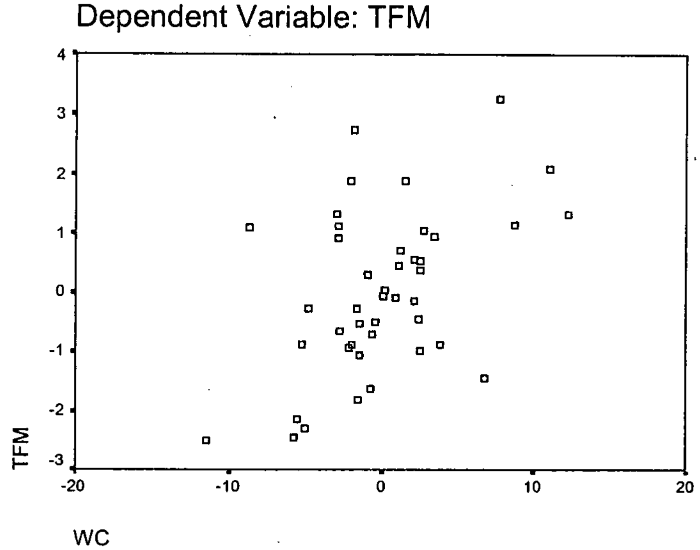
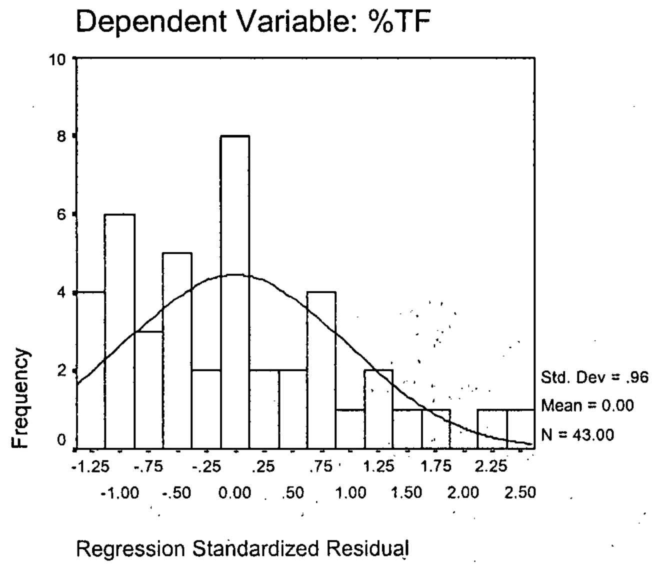
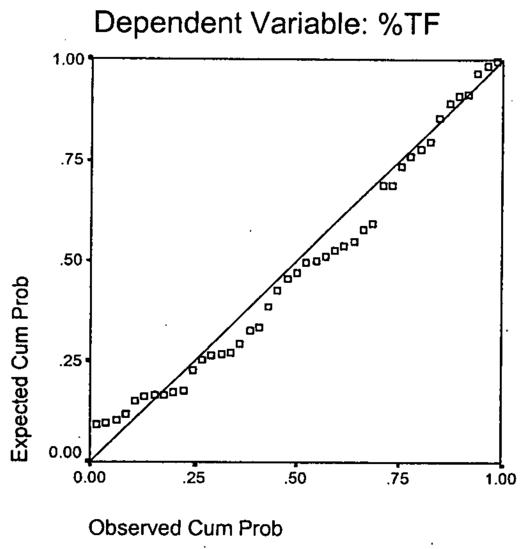


Figure 4.4.4: Residual Analyses for the New %TF Equation

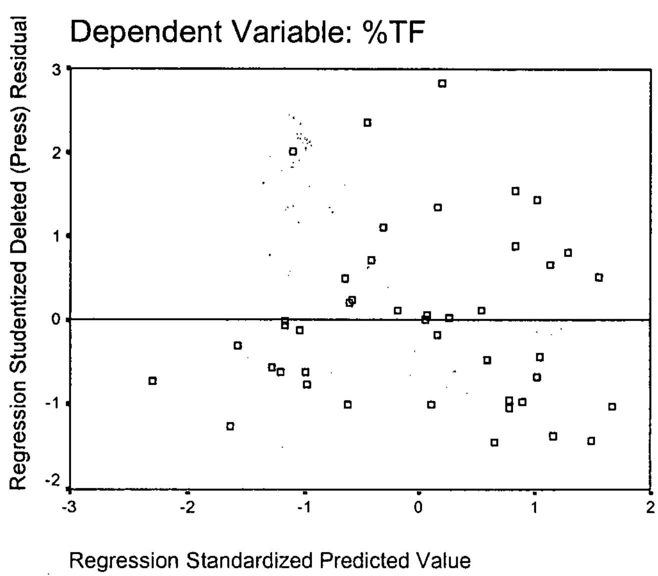
(a) **Histogram of residuals**



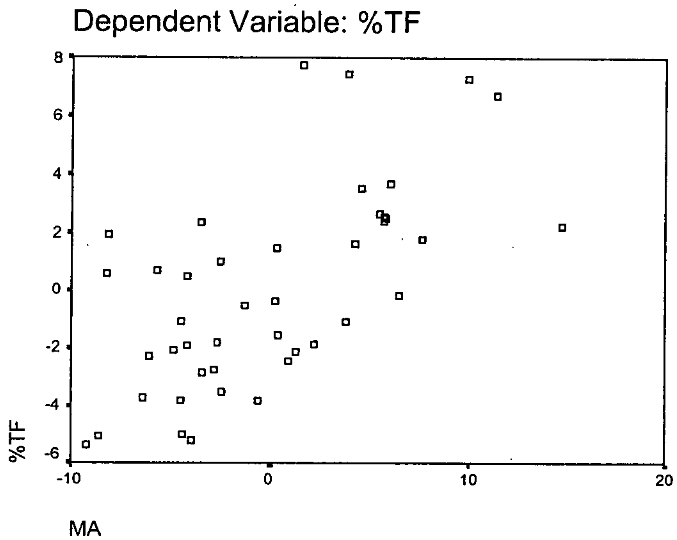
(b) Normal P-P plot of regression standardized residual



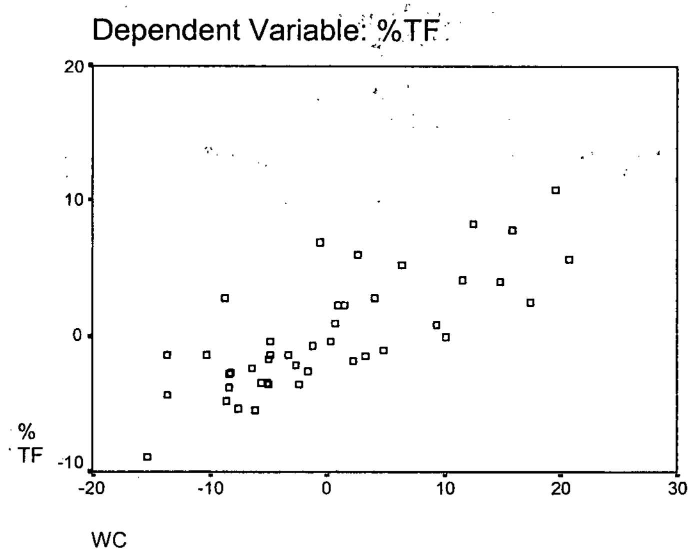
(c) Scatter plot of residuals vs. predicted %TF



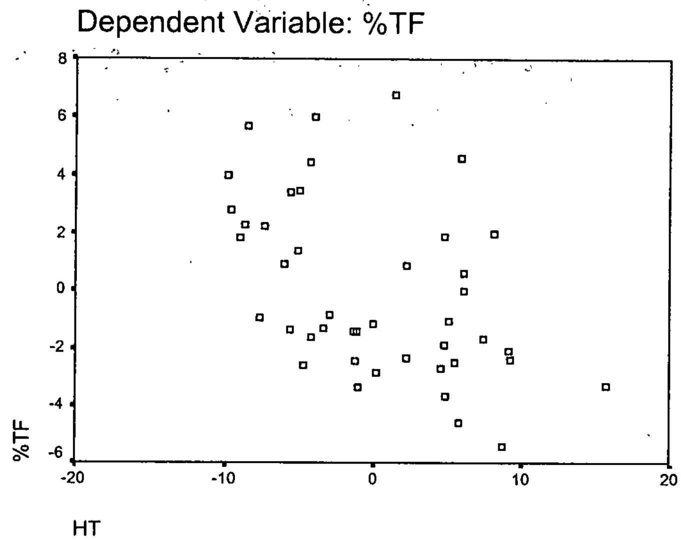
(d) Partial regression plot for %TF and MA



(e) Partial regression plot for %TF and WC



(g) Partial regression plot for %TF and HT



Overall, the total body fat equations (FM and %Fat) were superior to the regional trunk fat equations (TFM and %TF), for both the adj.R^2 value and the coefficient of variance (C.V.), and met the guidelines for acceptable prediction equations (SEE < 2.5kg and < 3.5%, respectively) according to Heyward and Stolarczyk (1996a). Moreover, equations using only skinfolds as predictor variables proved inferior (smaller adj.R^2 and larger SEE) to those that included a combination of skinfolds and anthropometry. Equations for FM and TFM explained more of the variance in body fat (adj.R^2 = .95 and .90, respectively) than the corresponding %Fat and %TF equations (adj.R^2 = .84, .83). However, the precision of the percent fat equations (C.V.%Fat = 5.9%, C.V.%TF = 7.9%) was greater than the fat mass equations (C.V.FM = 6.4%, C.V.TFM = 10.7%). Lohman (1981) suggested that the values of SEE and C.V. were more important in the selection and comparison of prediction equations than that of maximum or adj.R^2. In light of this, the %Fat equation would be recommended over the FM equation. Moreover, %Fat is the measure of interest associated with important health and functional implications, not total fat. Thus, the new %Fat equation was subsequently validated and tested for its performance in independent samples.

4.5 Validation of new prediction equations

The study sample was not considered large enough for internal cross-validation using the conventional data-splitting method, and an independent sample for external validation was not available. Instead, the jackknife procedure was used to test the stability and accuracy of the new %Fat equation within the sample. Summaries of the residuals for each round of the jackknife procedure for both equations are shown in table 4.5.1. Except for round 6, each jackknifed equation significantly predicted body fat in the corresponding omitted group of subjects. Averages for the 10 rounds of regression analysis are summarized in Table 4.5.2. The smaller and closer the error of the residuals is to the SEE of the jackknifed equation, the more accurate the equation. Low average jackknife statistics (s.d. =1.54kg; s.d. =1.95%) are considered favourable (Heyward & Stolarczyk, 1996). These results therefore indicated that the %Fat equation was valid within the sample.

Table 4.5.1: Summary of Residuals for Jackknife Validation

	%Fat Equation				
Round	**Mean Diff. b/w Jackknifed Estimate of %Fat and DEXA%Fat**	**s.d. (diff)**	**n**	**t**	**p**
1	0.096	2.406	4	0.080	0.941
2	1.326	3.395	4	0.781	0.492
3	0.320	0.641	4	0.999	0.392
4	-1.211	2.675	4	-0.905	0.432
5	-0.146	1.993	4	-0.146	0.893
6	1.531	0.848	5	4.038	0.016
7	-0.888	2.149	4	-0.826	0.469
8	-1.698	2.767	5	-1.372	0.242
9	-0.173	0.312	5	-1.106	0.349
10	0.659	2.352	4	0.627	0.565

Table 4.5.2: Jackknifed Estimates (average of 10 prediction equations and residual analyses)

Prediction Eqn.	Adj. R^2	SEE	Residual Analysis	Diff.	s.d.
%Fat	0.835	2.14	%Fat	0.184%	1.95%

4.6 Performance of new prediction equations

External databases for both similarly aged women and younger women were obtained to test the performance of the new equations and to examine the impact of age. Descriptive summaries of the independent databases shared by Gary Brodowicz (Department of Public Education, Portland State University) and Richard Baumgartner (Clinical Nutrition Laboratories, School of Medicine, University of New Mexico) are listed in Appendix XIII. Unfortunately, the predictor variables included in the new equations were not all measured in these independent samples and thus did not allow for their direct application. Additionally, a Lunar manufactured DEXA instrument was used by both Baumgartner and Brodowicz to assess criterion body fat, and at present, no conversion equations between manufacturers are available.

In order to test the performance of an equation derived from this study sample in the independent samples of women, 2 modified equations for %Fat were developed using only the variables measured in the Brodowicz (EQN5) and Baumgartner (EQN6) databases. Table 4.6.1 lists the new equations derived using the maximum adj.R^2, minimum SEE and appropriate C_p criteria. Regression outcomes are appended (Appendix XIV).

Table 4.6.1: Modified Prediction Equations

Eqn#	Prediction Equation	Adj. R^2	Cp	SEE	CV
5	%Fat = 9.819 + .162(SUM4SF) + .652(BMI) - .261(SS)	0.82	n/a	2.21	6.2%
6	%Fat = 9.198 + .696(BMI) + .295(TRI)	0.80	n/a	2.37	6.6%

Paired t-test comparisons were conducted to determine the difference between measured and predicted body fat in similarly aged women (Table 4.6.2) and in younger women (Table 4.6.3). The modified equations significantly underestimated %Fat in both groups of elderly women, yet accurately predicted %Fat in the younger women. Residual graphs (Figure 4.6.1) indicated that the error in the prediction of %Fat increased with body fat in the elderly women. Graphs for the younger women showed that the new equation underestimated %Fat at low body fat levels and overestimated %Fat at high body fat. Therefore, despite its accuracy, the equation was not reliable for this population. Futhermore, the limits of agreement for predicted and measured fat were wider for the younger population than for the older population (Table 4.6.4). Thus, the equations performed with less variability in the elderly women.

Table 4.6.2: Paired t-Test Comparisons for Elderly Women

Comparison	n	r	Mean Diff.	S.D.	CV	t	p
%Fat($BROD_1$) – EQN5	31	.727	6.63	3.91	9.99	9.44	<0.001
%Fat(BAUM) – EQN6	100	.805	5.12	4.45	11.25	11.52	<0.001

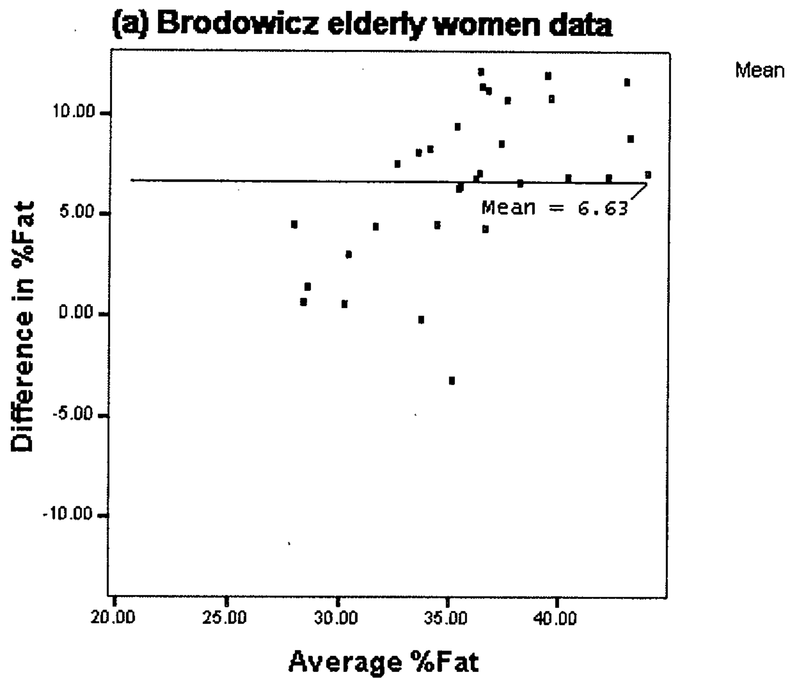
Table 4.6.3: Paired T-Test Comparisons for Younger Women

Comparison	n	r	Mean Diff.	S.D.	CV	t	p
%Fat($BROD_2$) – EQN5	33	.887	-0.717	5.43	18.37	-0.76	0.454

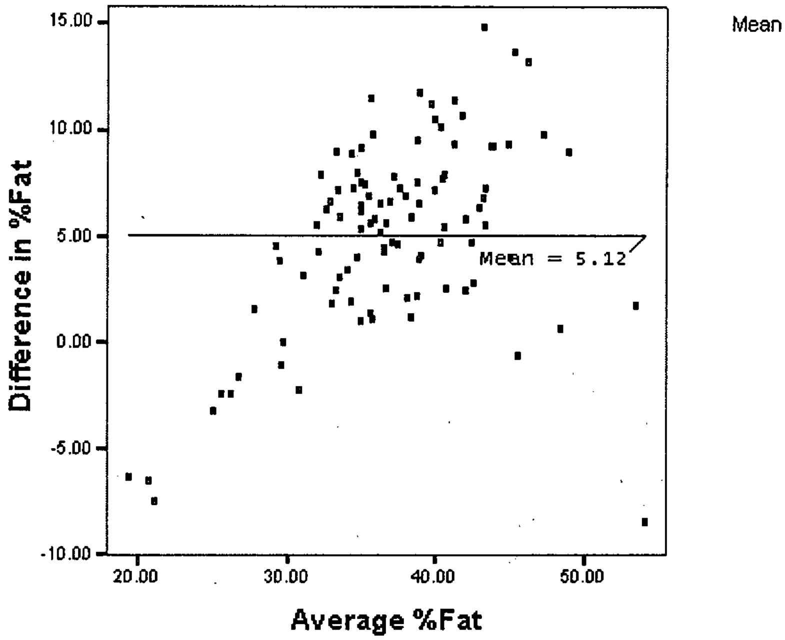
Table 4.6.4: Limits of Agreement for Modified Equations and DEXA

Comparison	Difference	SD	d +/- 2 X SD
%Fat($BROD_1$) - %Fat(Eqn5)	6.63	3.91	-1.19 to 14.45
%Fat(BAUM) - %Fat(Eqn6)	5.12	4.45	-4.20 to 14.02
%Fat($BROD_2$) - %Fat(Eqn5)	-0.717	5.43	-11.58 to 10.14

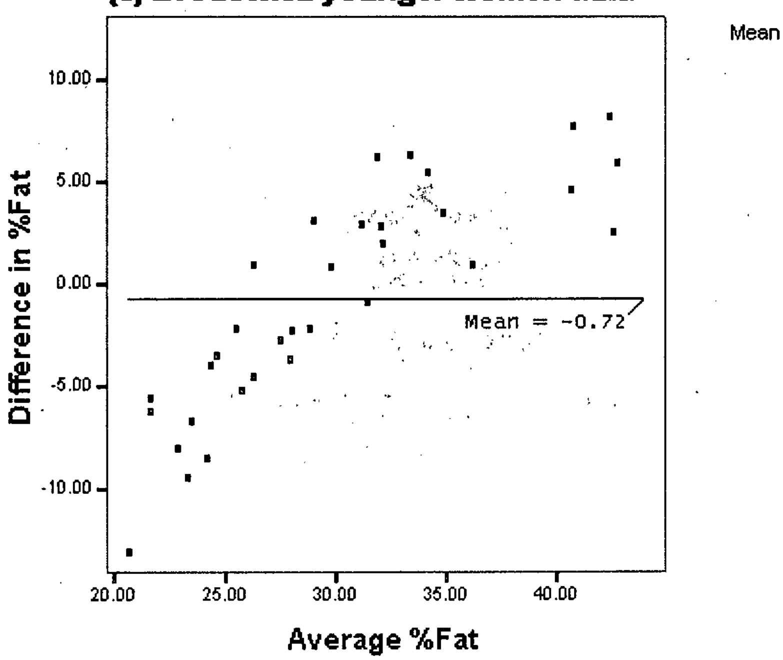
Figure 4.6.1: Agreement Between Predicted and Measured %Fat



(b) Baumgartner data



(c) Brodowicz younger women data



5. Discussion

A review of the literature indicated that existing anthropometry prediction equations may not be valid for estimating body composition in women 75 years and older. The intent of this research, therefore, was to further explore and confirm the need for improved prediction equations for this elderly population and to derive new equations based on DEXA criterion fat in a sample of healthy women 75-80 years of age.

5.1 New prediction equations for women 75-80 years

All but one of the previously published body composition prediction equations significantly overestimated body fatness in our sample and showed poor agreement with current DEXA measured fat. Further analysis of our data, however, revealed strong correlations between anthropometry and DEXA fat and thus supported the development of new equations for this population. Four new prediction equations were developed for FM, %Fat, TF and %TF in women 75-80 years old (Table 4.4.2). A common group of anthropometric variables surfaced as the best predictors of body fat: HT, WT, BMI, MA, SSBTRI, WC, and HC (Table 4.4.1). Of these, the MA SF was common to all.

An important finding of this research was that there was no single "best" equation; rather, several alternatives were acceptable. Due to the strong inter-correlations among anthropometric predictor variables, small differences in SF values that are not biologically significant can alter the regression equation. This perhaps explains why so many different equations are presented in the literature, even when methodologies in the equation development are the same.

In terms of equation diagnostics, adj.R^2 and SEE values for the new equations were comparable to and in some cases better than those for reported for published equations. Within the current sample of edlerly women, the goodness of fit was better for FM (adj.R^2 = 0.95) than for %Fat (adj.R^2 = 0.84) due to slightly lower correlations for anthropometry and %Fat than for anthropometry and FM. However, the %Fat equation (CV = 5.9%) was more precise than the equation for FM (CV = 6.4%). In each case, total body fat equations were more precise than regional body fat equations (CV= 7.8%, 10.7%). Residual analyses revealed no excessive trends for the FM and %Fat equations, but indicated a greater error in the prediction of trunk fat with increasing trunk fat (Figures 4.4.1-4.4.4). It is likely that DEXA is not sensitive enough in the measurement of trunk fat and this has been raised before (Baumgartner et al., 1995). As the %Fat equation demonstrated a smaller error, and as %Fat is ultimately the measure of interest, only the %Fat equation was further analyzed.

An independent sample was not measured for external validation of the new equation, therefore, only the internal validity was tested. Due to the small sample size, the jackknife technique was used over the conventional data splitting method. The low residual error for each round of the jackknife procedure compared to the SEE of the corresponding jackknifed equation indicated good internal validity for the %Fat equation (Table 4.5.2).

Several factors affect the development and performance of a regression equation including the nature of the sample from which the equations were derived, choice of anthropometric predictors and criterion body fat, and the regression procedures used. Each of these is discussed further to help explain differences between our new equations and published equations, and why one equation may be better or more appropriate than another.

5.2 Nature of the sample population

The study participants were primarily Caucasian, middle class women between the ages of 75 and 80 years. All subjects were considered healthy and were living independently in the community. Although the demographics of this sample may not be representative of all women 75-80 years, they are consistent with those described in the literature. Conclusions based on results from this study may not be widely generalized to all elderly women as it is well known that individuals who volunteer for studies tend to be more active and healthy than those less inclined. Furthermore, our results may not apply to women of different ethnic and cultural background.

The average age of our participants exceeded most other studies in which equations were derived by approximately 7 years (Table 4.2.1). This was an important distinction as one of the objectives of this research was to determine whether or not the relationship between anthropometry and body fatness continues to change with advancing age. If significant changes in body composition and fat distribution are apparent with each decade beyond 60 years, as suggested by Baumgartner (1995), then it would be reasonable to expect that equations carefully derived in 60 year old women would not perform as well when applied to women in the their 70's and 80's. This could explain why the Goran equation (4C), derived in women of average age 68, did not predict body fat adequately in our sample. Similarly, women in the Visser (70yrs), Dupler (70yrs) and Durnin & Womersley (50-68 yrs) studies were all younger. However, these studies all used UWW, and thus, the independent effects of age on equation performance are confounded by the problems associated with UWW.

Although Chapman et al. (Chapman et al., 1998) developed equations in women with mean age of 75 using DEXA as the reference method, their equation was unable to significantly predict body fat in our sample. This study had a relatively small n of 17, thus limiting the precision and accuracy of the prediction equation.

All four equations showed a similar lack of agreement with DEXA body fat measurements (Figure 4.3.1). Therefore, it was difficult to isolate and comment on the effects of age. To our knowledge, the only other database involving a large group of women over the age of 75 where DEXA (or 4C model) was used to measure body composition is that of Baumgartner et al. (Baumgartner et al., 1995); however, no equations were derived for this group.

5.3 Predictor variables

Predictor variables measured in this study exhibited strong statistical and biological associations with criterion body fat. This is an important factor in linear regression analyses to ensure the development of robust prediction equations. A range of SF's were measured, along with circumferences, height and weight to evaluate the overall relationships between anthropometry and criterion body fat. This was a key distinction of our study as often only one SF is measured and very seldom are circumferences considered.

A survey of existing equations indicated that HT, WT, BMI, SUM4SF, TRI, CALF, SSTRI and HC are the most common predictors of body fat in elderly women. The best individual predictors of body fat in our study participants were WT, BMI, BIC, SUM4SF, and HC; however, the best regression models all included the MA skinfold. This skinfold site does not appear in any other equation perhaps because it is not often measured in body composition studies. The MA SF was not as strongly correlated to body fat as some of the other skinfolds, yet significantly contributed to the explanation in body fat after WT or BMI was entered. As body fat is expected to accumulate more centrally with age, there is strong biological support for the inclusion of MA. Moreover, the MA SF may be related to the internalization of body fat which was not explained by BIC or TRI. Clearly, the MA skinfold should be considered a useful predictor of body fat in elderly women in the future.

Other studies have shown that SF's alone did not predict body fat as well as when they were in combination with HT, WT or BMI. This too was the case with our data. Although the use of BMI in younger populations has been criticized, it is reasonable to conclude that for a given height, over-weightness is more likely due to excess fat than to extreme musculature or high bone mineral density among the elderly population. In fact, BMI explains 73% and 86% of the variance in %Fat and FM, respectively in this study sample. However WT and HT together seemed to explain the variation in body fat more so than BMI. Perhaps the ratio of weight to height-squared is not appropriate in elderly women.

Finally, some concern has been raised over the use of the SF in the elderly because of changes in compressibility and elasticity of the SF, reduced muscle tone, and the internalization of body fat (Baumgartner et al., 1995). Repeated measures tests for the various SF's (Table 4.1.4), and scatter plots with body fat indicated that SF's are reliable and useful measures for body composition prediction in elderly women. Moreover, there is no evidence that this relationship diminishes with age in our sample. Perhaps the problems associated with UWW have contributed to earlier observations of poor agreement between anthropometry and body fat in the elderly.

5.4 Criterion body fat

The measurement of body composition in the elderly has been a topic of great debate in the literature. Clearly, 3C and 4C methods that involve minimal assumptions about the physical and chemical properties of the major body components should be used in the aging population (Baumgartner et al., 1995; Going et al., 1995; Kohrt, 1998; Williams et al., 1995). Reference body fat was measured by DEXA (QDR-4500W; Hologic, Inc.) in this study and, therefore, not subject to the measurement errors associated with UWW and the 2C model.

The fan-beam technology of the QDR-4500 is considered more accurate than pencil-beam scanners in the assessment of body composition due to superior sampling techniques, and has demonstrated high accuracy when compared to 4C measures of FM and FFM in elderly persons (Kelly et al., 1997; Visser et al., 1998). Additionally, the QDR-4500 has demonstrated low measurement error (300g) for FM (Kelly, 1998a). Existing equations standardized to DEXA used earlier models of DEXA as well as different manufacturers (Chapman et al., 1998; Svendsen et al., 1991), and therefore it is likely that the new equations are an improvement over these.

Equations based on 4C criterion body composition are considered to be the most valid in the aging population as they require the fewest assumptions (Goran et al., 1997; Heymsfield et al., 1989; Williams et al., 1995). However, where accuracy is gained in the 4C model, precision may be lost due to an accumulation of error associated with the use of multiple assessment techniques (Guo et al., 1996).

A final advantage in using the QDR-4500 instrumentation in our study is the connection to epidemiological research. The National Institute of Health has selected the QDR-4500 model to obtain body composition data in the next national health and nutrition survey (NHANES IV) and in their study on health, aging and body composition (Health ABC) (Kelly, 1999). Body composition predicted by our new equations can be directly compared to the mounting collection of normative data on health and body composition in the elderly.

Based on this information, body fat measured in our study was presumed more accurate and precise than much of the existing data for the elderly. Average FM and %FAT values were lower than those reported in the literature (Table 4.2.1) which would explain the over-prediction of body fat when published equations were applied to our data. Published FM values obtained from 3C and 4C models compared more closely to current DEXA FM than did published 2C %Fat values to DEXA %Fat. In studies where UWW was used as the criterion method, reported mean %FAT values were more than 7% higher than current DEXA %Fat. This is consistent with assumptions in the literature that UWW, together with Siri's formula, erroneously overestimates fatness in the elderly.

Two studies seemed to be outside the range of average body fat values. Mean body fat from the Svendsen (1991) study was lower than in this study and all others reported, which may reflect ethnic differences among Northern European populations and those typical of North America. Earlier versions of DEXA, like that used by Svendsen, have been shown to underestimate total body fat due to difficulties in measuring trunk fat (Kohrt, 1998; Snead et al., 1993). This could also explain the poor performance of the Svendsen equation in our sample despite other similarities in the methodology of these two studies. Williams and colleagues (1995) used 4C methods to measure body composition in older adults (49-80 yrs) and reported average fat values of 40%. They found that equations based on anthropometry were unsatisfactory; however, at high body fat levels anthropometry methods are known to be less reliable. Moreover, both studies had small n's of 17 and 23 women, respectively.

DEXA, however, is not without limitations. DEXA does account for the hydration status of the body, which may change with aging (Roubenoff et al., 1993). However, this has been somewhat debated in the literature. The possibility that DEXA may systematically underestimate total FM (Table 4.1.4) would introduce further error when predicted FM is divided by standard body weight to calculate %Fat. However, DEXA's underestimation of total body mass may be related to an error in the measurement of the FFM component and may not affect the measure of FM. DEXA's accuracy in the measurement of body components still warrants further research.

5.5 Regression procedures

A final factor affecting the development and performance of new regression equations is the regression procedure. A combination of stepwise and all possible subsets regression procedures was used to develop new regression models in this investigation. Most studies simply use stepwise regression and select the final equation based on statistics alone. All possible subsets allows one to examine all possible combinations to determine if one equation may have more practical value or be more biologically meaningful. Moreover, one can better understand the true nature of the relationship between anthropometry and body fat when several models are considered. Furthermore, due to the multi-collinearity present among anthropometry predictor variables, all possible subsets regression was recommended over the more commonly used methods of stepwise regression (Dupler, 1997; Guo et al., 1996). Alternatively, Draper and Smith (1966) suggested using stepwise methods first, followed by all possible subsets procedures in order to make the most informed decisions with respect to max. adj.R^2, min. SEE and appropriate C_p criteria when selecting the final equations. To my knowledge, the only other studies that used all possible subsets regression procedures were those of Dupler (1997) and Durnin and Womersley (1974).

Based on these statistical criteria, there were little differences between the best subsets described in Table 4.4.1. The recommended number of prediction variables for a sample of 40 was 2-4 (Heyward & Stolarczyk, 1996a). It was useful to look for patterns that emerged in all possible subsets. HT, WT, BMI and MA explained most of the variance in body fatness. The addition of the central fat measure did not markedly improve the precision or predictability of the FM or %Fat equations. However, HC was important in the prediction of body fat in both the Goran and Dupler equations. As expected, central fat measurements contributed significantly to the prediction and precision of the trunk fat equations.

5.6 Performance of the modified equations

Neither of the modified FM and %Fat equations was able to accurately predict DEXA fat in the independent databases of elderly women shared by Brodowicz (1999) and Baumgartner (1999). However, in the younger sample, %Fat was significantly predicted but not FM. This was unexpected. Further analysis showed that the limits of agreement for predicted and measured fat were much wider in the younger sample than for the samples of elderly women. These results emphasize the importance of examining the agreement between two methods recommended by Bland and Altman (1986) and of not relying solely on the correlation between two methods or the average measurement difference.

There are several explanations for why these modified equations may have performed poorly in external samples. One, the best predictors of body fat in elderly women were not measured in these independent samples and therefore a lesser equation was tested. Two, MA and HC may become increasingly important in the prediction of body fat in elderly women. Three, inter-rater differences in the measurement of anthropometry may have affected the relationship between some of the predictor variables and criterion fat. Finally, different manufacturers of DEXA machines have not been cross-calibrated (Shepherd, 1999), and therefore, inter-method differences may contribute to the poor agreement between our equations and Lunar versions of DEXA.

5.7 Summary and recommendations

An important finding of this study was that neither existing equations nor the newly derived equations were able to accurately and reliably predict body fat in independent samples of elderly women. Some of the prediction error can be attributed to inter-method differences and differences in DEXA manufacturer, but the lack of agreement between methods also emphasizes the problem of sample specificity with regression equations. Equations will always perform better in the sample from which they were derived and must be interpreted with caution when applied externally. A second major finding of this research was that a single "best" equation did not exist for these data, but rather, several alternative models provided similar equation statistics and regression coefficients. However, total body fat equations were more precise than regional trunk fat equations, and percent fat equations were more precise than fat mass equations. Furthermore, the combination of WT, HT (or BMI) and SF's was better than SF's alone.

Nonetheless, this study demonstrated that a strong relationship between anthropometry and DEXA exists among elderly women and that internally valid equations for %Fat can be proposed for this population. The equation involves simple and practical measurements and would be useful tools in epidemiological research and health screening practice. Moreover, it is reasonable to conclude that prediction equations based on DEXA have greater face validity in elderly women than those based on densitometry, as the DEXA model is associated with fewer assumptions. Furthermore, this is the only study to use all possible subsets regression and a 3C model for criterion fat in elderly women and the first study to use the QDR-4500 version of DEXA. The use of QDR-4500 in two future national surveys conducted by the NIH will enable the comparison of body fat predicted by the new equation to a large normative database related to health, body composition and aging. Due to the relatively small sample size, the new %Fat equation cannot be recommended at this time. However, this study shows promise for future use of DEXA and anthropometry in elderly women.

6. References

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7. Appendices

Appendix I: Summary of Published Equations for Body Composition Assessment in Elderly Women

Source	Criterion Method	Dependent Variable	Predictor Variables	Mean Age	Age Range	N	R^2	SEE	CV
Baumgartner et al., 1991	UWW	%Fat	BIA, CIRC	74.7	65-94yrs	63	0.546	4.99%	
Dupler, 1997	UWW	Db	HT, SF's	70	65-81 yrs	75	0.625	0.002	2.5%
Dupler, 1997	UWW	%Fat	WT, BMI, CIRC.	70	65-81 yrs	75	0.626	0.928	4.0%
Dupler, 1997	UWW	FM	WT, CIRC	70	65-81 yrs	75	0.841	1.09	
Hansen et al., 1993	UWW	%Fat	BMI, SF's, BIA		28-39 yrs	100	0.75	2.92%	9.8%
Durnin & Womersley, 1974	UWW	Db	SF's		50-68 yrs	37		0.0082	
Visser et al., 1994	UWW	Db	SF's	70.2	60-87 yrs	128	0.58	0.0113	
Visser et al., 1994	UWW	Db	BMI	70.2	60-87 yrs	128	0.67	0.0100	
Chapman, 1998	DEXA	FFM	HT, WT, SF	82	76-95 yrs	17	0.96	1.95 kg	
Svendsen et al., 1991	DEXA	FM	HT, WT, BMI, SF's	75	75	23	.94	2.43	
Baumgartner et al., 1991	4C	%FAT	BIA, CIRC	74.7	65-94 yrs	63	0.725	3.76%	
Goran, 1997	4C	FM	WT, SF, CIRC	68.2		41	0.80	N/A	
Goran, 1997	4C	FM	WT, SF, CIRC, BIA	68.2		41	0.84	N/A	
Williams et al., 1995	4C	FFM	BIA, WT	65	49-80 yrs	23	0.76	1.5kg	

Appendix II: Selected Published Body Composition Equations for Comparison Analyses

Author	Equation	Age range	N	R^2	SEE	CV
Chapman, 1998	FFM(kg) = 0.582(WT) - 0.397(TRI) + 0.392(HT) - 48.956 FM = WT - FFM	76-95 (m=82)	17	0.96	1.95 kg	N/A
Dupler, 1997	(a)%Fat = 0.1688(BMI) + 0.542(HC) – 0.1639(WT) – 7.9498	65-81 (m=70)	75	0.626	0.928	2.5%
Dupler, 1997	(b)FM = 0.2449(WT) + 0.5218(HC) – 0.076(TC) – 37.8619	65-81 (m=70)	75	0.841	1.09	4.0%
Durnin & Womersley, 1974	D_b = 1.1339 - 0.0645 [log (BIC + TRI + SI + SS)] %Fat = 495/D_b - 450	50-68	37	N/A	0.0082	0.8%
Goran, 1997	FM = 0.31(HC) + 0.22(CALF) + 0.31(WT) – 31.33	68.2	41	0.8	N/A	N/A
Svendsen et al., 1991	FM = 0 .63(TRI)+4.47(BMI)+9.32(SUBTRI)+1.35(WT)+1.04(HT) -192.48	75	23	.94	2.43	11%
Visser et al., 1994	(a) D_b = - 0.0356[log(BIC + TRI + SI + SS)] +1.0688 %Fat = 495/D_b - 450	60-87 (m=70.2)	128	0.58	0.0113	1.1%
Visser et al., 1994	(b) D_b = -0.0022(BMI) + 1.0605 %Fat = 495/D_b - 450	60-87 (m=70.2)	128	0.67	0.0100	1.0%

Appendix III: Medical Clearance

UBC Department of Family Practice and the Seniors interAction Society

March 25th, 1998

Dear Doctor:

Your patient has expressed interest in entering a study of exercise effectiveness on measures of bone density, muscular strength, body composition, functional mobility and psychosocial well-being in healthy women aged 75-80 years. The study population will be assigned to either an exercise or control group. Your patient would like to participate in the exercise group which will require her attendance three times per week for the next full year. The first twelve weeks of the exercise program will be supervised by specialized trainers and be held at Executive Fitness facility at UBC. At the end of the twelve weeks, participants will continue their exercises independently either at UBC or a fitness centre of their choice and will be monitored monthly. Exercise sessions will run for approximately one hour, and will include a light warm-up on cardio-equipment, strength training with free-weights and resistance equipment, and a stretch/cool-down component. Participants will receive free memberships for the UBC's Executive Fitness facility for the duration of the study.

Subjects will be excluded from this study with:

1. restricted limb or trunk movement
2. medical contraindications to maximum muscle strength testing
3. uncontrolled hypertension or diabetes
4. symptomatic cardiorespiratory disease
5. severe renal or hepatic disease
6. uncontrolled epilepsy
7. progressive neurological disease
8. dementia
9. marked anemia (with a hemoglobin less than 100G/L)
10. marked obesity with inability to exercise
11. medication with betablockers, Warfarin, CNS stimulants, hormone replacement therapy, or bone enhancing drugs
12. subjects will also be excluded if they are already performing intense cardiovascular/strength enhancing exercise for more than 30 minutes, three times per week

We would be grateful if you decide your patient is suitable.

Appendix IV: Informed Consent

Strength Training Study in Older Adult Women, Ages 75-83 years

J.E. Taunton, M.D., E.C. Rhodes, PhD., M.Donnelly, M.D., A.D.Martin, PhD., J.Elliott, P.T.

The purpose of this investigation is to examine the effects of a progressive strength training program on measures of bone density, muscle strength, balance, functional ability and psychosocial well-being among older adult women, aged 75-83 years. Adherence to exercise programs will also be analyzed. Specific research objectives are as follows:

1. To determine the effect of a short (12 week) and long term (1 year) progressive resistance exercise program on muscular strength and endurance of the large muscles of the body;

2. To assess the effect of a one-year resistance exercise program on the maintenance of bone mineral density;

3. To determine changes in body composition (body fatness) following a short and long term resistance exercise program;

4. To assess the impact of short (12 week) and long term resistance training on balance and functional abilities;

5. To evaluate the relationship between strength gains and improvements in functional status

6. To explore the influence of a regular exercise program on the quality of life and psychological health in older adult women;

7. To assess exercise compliance in this population.

You will perform tests of strength, balance and functional ability, and complete questionnaires on psychological health, personal demographics and exercise compliance. Body composition and bone mineral density will be assessed by Dual-energy X-ray Absorptiometry (DEXA). Additional anthropometric measures (height, weight and selected girths) will also be taken. You may experience some muscle soreness and fatigue.

The exercise program will be performed three times per week for one full year. The initial 12 weeks of exercise will be supervised by a specialized trainer. Exercisers will continue the program for an additional 9 months on their own and will keep track of their workouts using a training log.

In signing this consent form you state that you have read and understand the description of the tests, the exercise intervention and their complications. You enter the battery of tests and experiment willingly and may withdraw at any time. Additionally, your identity and test results will be kept in confidence and will become the property of the above investigators. For safety, exercise trainers will have access to your personal and medical information.

CONSENT

I have read the above comments and understand the explanation, and I wish to proceed with the tests and experiment. In agreeing to such an examination, I waive any legal recourse against members of the staff of: The John M. Buchanan Fitness & Research Centre, the U.B.C. Aquatic Centre, and the Lonsdale location of North Shore Recreation Centres.

Date:________________________

Subject: ________________________ (print)

Witness: ________________________ (print)

________________________ (signature)

________________________ (signature)

Appendix VI: List of Contact Authors

Authors
Wattanapenpaiboon N., Lukito W., Strauss B.J., Hsu-Hage B.H., Wahlqvist M.L. and Stroud D.B.
Institution
Monash University Department of Medicine, Monash medical Centre, Melbourne, Australia
Title
Agreement of skinfold measurement and bioelectrical impedance analysis (BIA) methods with dual energy X-ray absorptiometry (DEXA) in estimating total body fat in Anglo-Celtic Australians
Source
International Journal of Obesity & Related Metabolic Disorders. 22(9): 854-60, 1998 Sept.
Subjects
130 females ages 26-86 years
Related methods
Percent body fat was estimated by the four skinfold thickness measurement and DEXA.

Authors
Brodowicz G.R., Mansfield R.A., McClung M.R. and Althoff S.A.
Institution
Dep. Public Health Education, Portland State University, Portland, Oregon
Title
Measurement of body composition in the elderly: Dual energy X-ray absorptiometry, underwater weighing, bioelectircal impedance analysis and anthropometry.
Source
Gerontology 40(6). 1994. 332-339.
Subjects
48 men and women (ages 26-40 years)
44 older men and women (ages 65-85 years)
Related methods
Percent body fat was estimated using skinfold measurements and DEXA

Authors
Nelson M.E., Fiatarone M.A., Layne J.E., Trice I., Economos C.D., Fielding R.A., ma R., Pierson R.N. and Evans W.J.
Institution
Human Physiology Lab, JM-USDA-HNRC, Boston, MA
Title
Analysis of body-composition techniques and models for detecting change in soft tissue with strength training.
Source
American Journal of Clinical Nutrition 63(5). 1996. 678-686.
Subjects
39 women ages 50-70 years

Related Methods
Body composition was assessed using anthropometry and DEXA

Authors
Pritchard J.E., Nowson C.A., Strauss B.J., Carlson J.S., Kaymakci B. and Wark J.D.
Institution
Department of Medicine, University of Melbourne, The Royal Melbourne Hospital, Melbourne, Australia
Source
European Journal of Clinical Nutrition. 1993. 47, 216-228.
Title
Evaluation of dual energy X-ray absorptiometry as a method of measurement of body fat.
Subjects
8 adult women ages 19-58 years
Related methods
Measurement of body fat from DEXA and skinfold anthropometry (4-sites)

Authors
Baumgartner R.N., Stauber P.M., McHugh D., Koehler K.M. and Garry P.J.
Institution
Clinical Nutrition Laboratories, School of Medicine, University of New Mexico.
Source
Journal of Gerontology: Medical Sciences. 1995. 50A(6), M307-M316.
Title
Cross-sectional age differences in body composition in persons 60+ years of age.
Subjects
181 women ages 60-95 years
Related methods
Body composition was quantified using DEXA and anthropometry (4 skinfold sites)

Authors
Hansen N.J., Lohman T.G., Going S.B., Hall M.C., Pamenter R.W., Bare L.A., Boyden T.W. and Houtkooper L.B.
Institution
Departments of Exercise and Sport Sciences and of Nutrition and Food Science, University of Arizona and Department of Veterans Affairs Medical Center, Tucson, Arizona
Source
Journal of Applied Physiology. 1993. 75(4), 1637-41.
Subjects
100 women ages 28-39 years
Related methods
Body composition was assessed using DEXA and anthropometry (9 skinfold sites)

Appendix VII: Letter of Request for Data

To Whom It May Concern:

I am a graduate student in the School of Human Kinetics at the University of British Columbia and currently working on my thesis for a Masters of Science degree under the supervision of Dr. Alan D. Martin. The primary objective of my research is to examine the relationship between anthropometry and body composition measured by dual-energy x-ray absorptiometry in elderly women ages 75 to 80 years, and to determine whether or not new skinfold equations are needed to more accurately predict body fat in this population. To date, we have conducted body composition assessments on forty-six elderly women. Anthropometric measurements included eight skinfold thicknesses, four body girths, height, and weight. Estimates for whole body fat, bone mineral content, and non-fat-non-bone lean body tissue were obtained using QDR-4500 Hologic instrumentation.

Although not a substitute for true cross-validation, testing our equation in similar data bases of elderly women will help us to evaluate its stability and accuracy. Additionally, applying our equation to data bases of younger women (peri- and early post-menopausal) will enable us to demonstrate the need for new body composition prediction equations specific to women over the age of 75 years. In order to pursue the secondary purpose of my research, requests for additional data bases are necessary. Recent work conducted by you and your colleagues (reference) is of interest to me and I would greatly appreciate your permission to access this data for secondary analysis.

The intended use of your data is for my thesis publication for which you will receive acknowledgment. If journal publication opportunities arise, we can further discuss your contribution and co-authorship possibilities. We are open to your suggestions if there are any other terms you would like to include.

Sincerely,

Andrea Dalton

Appendix VIII: Distribution of Dependent Variables

Figure 1: DEXA Fat Mass

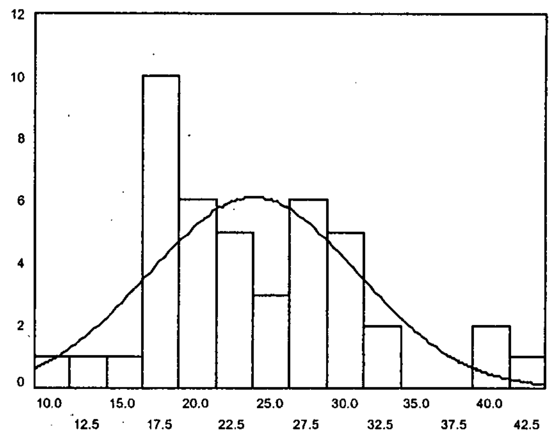


Figure 2: DEXA % Body Fat

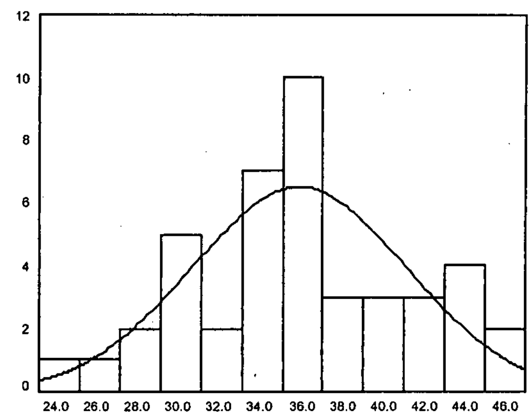


Figure 3: DEXA Trunk Fat Mass

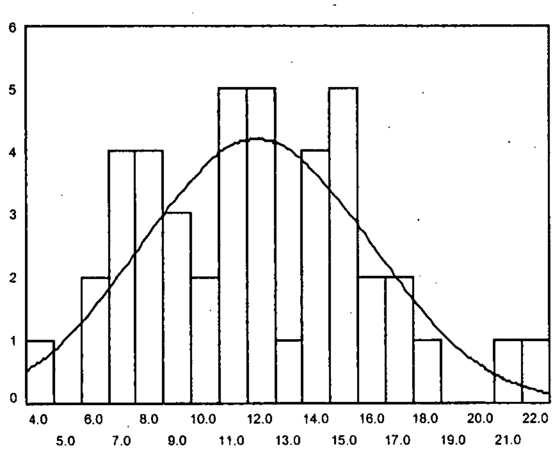
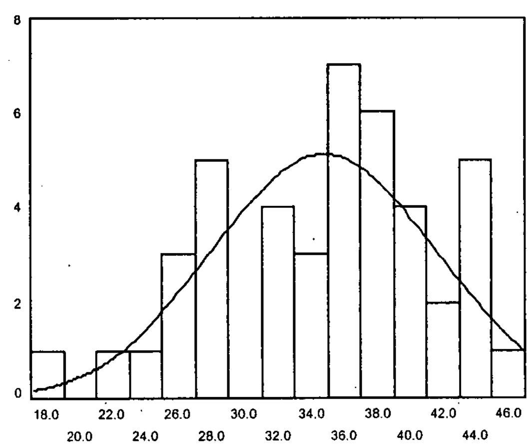


Figure 4: DEXA % Trunk Fat



Appendix IX: Distributions of Independent Predictor Variables

Figure 1: Abdominal SF Thickness

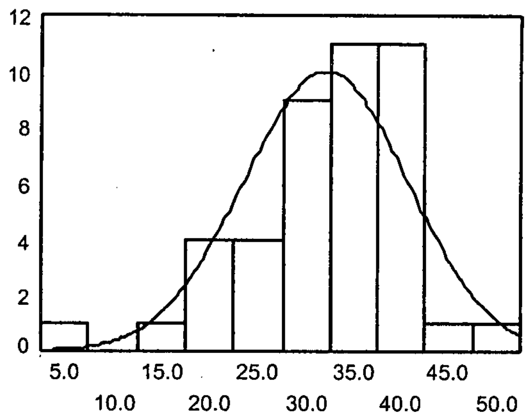


Figure 2: Biceps SF Thickness

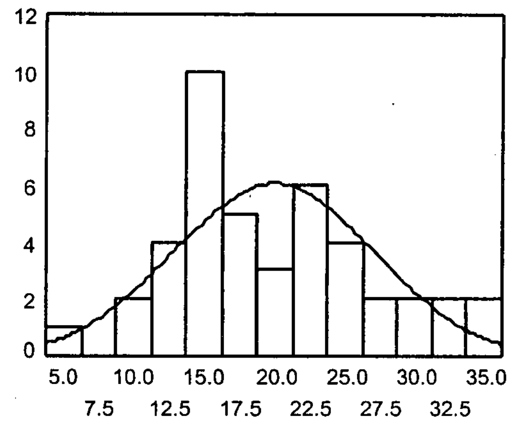


Figure 3: Calf SF Thickness

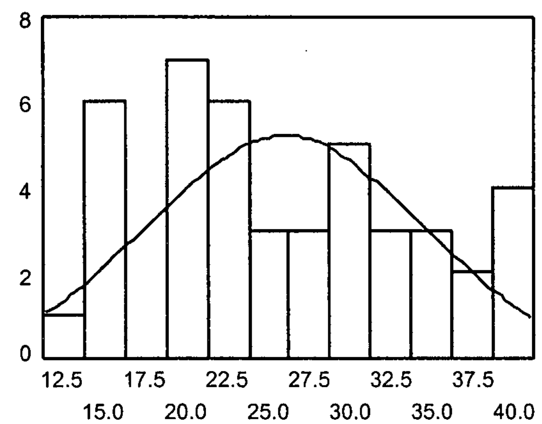


Figure 4: Midaxilary SF Thickness

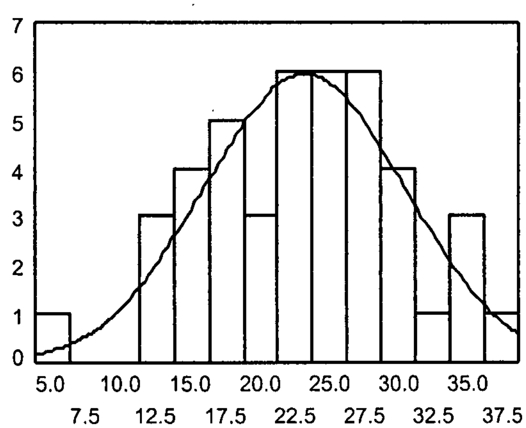


Figure 5: Suprailiac SF Thickness

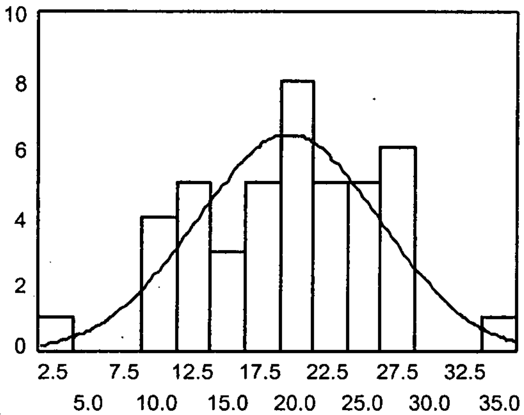


Figure 6: Subscapular SF Thickness

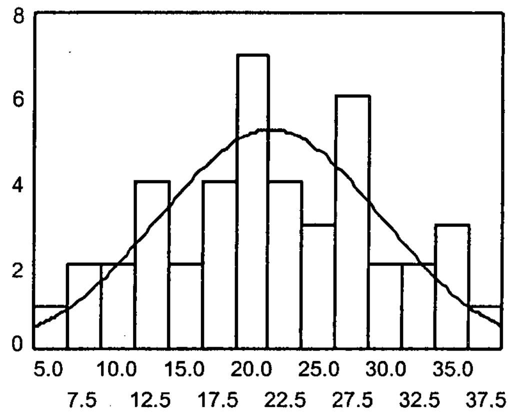


Figure 7: Thigh SF Thickness

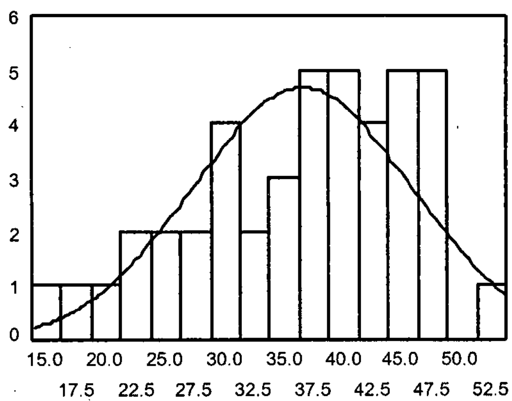


Figure 8: Triceps SF Thickness

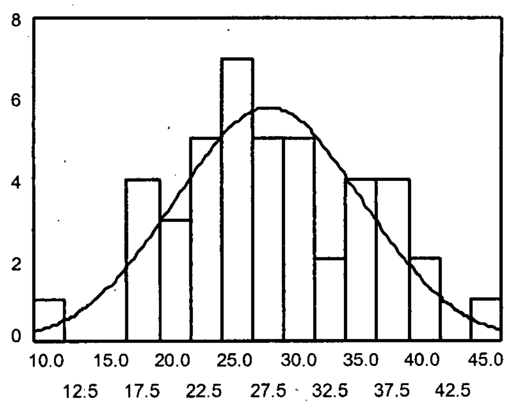


Figure 9: SUM4SF

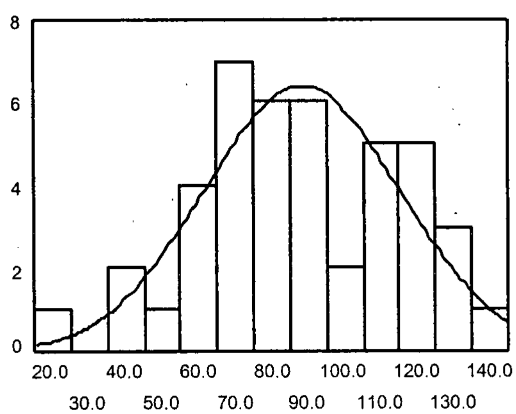


Figure 10: SSTRI Ratio

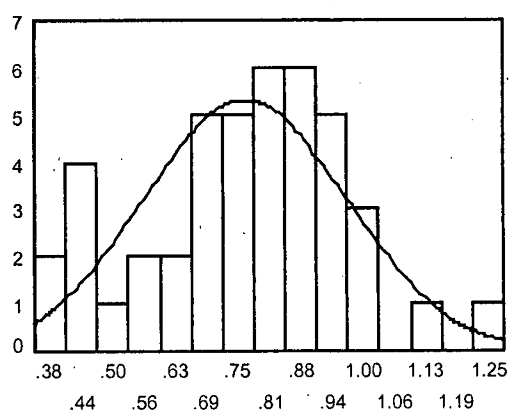


Figure 11: Height

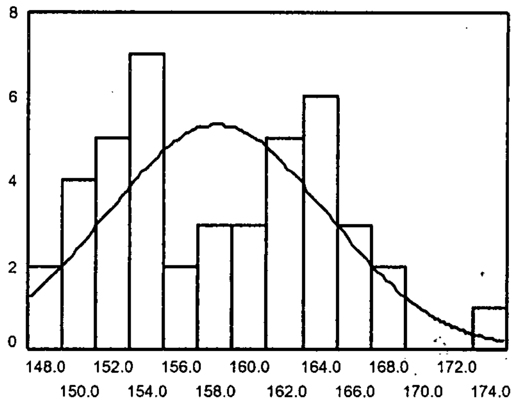


Figure 12: Weight

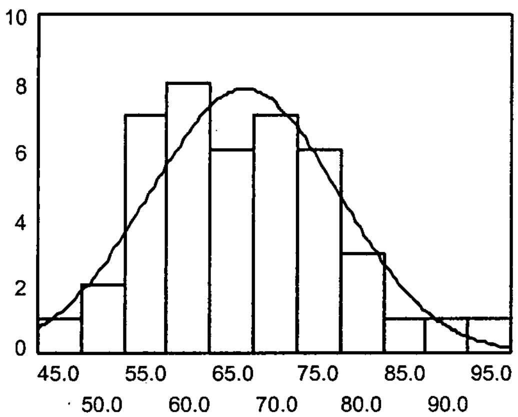


Figure 13: BMI

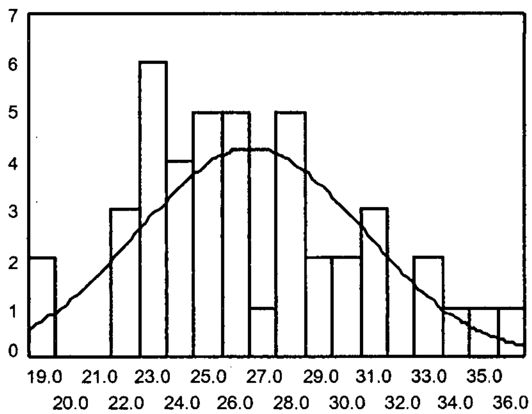


Figure 14: Hip Circumference

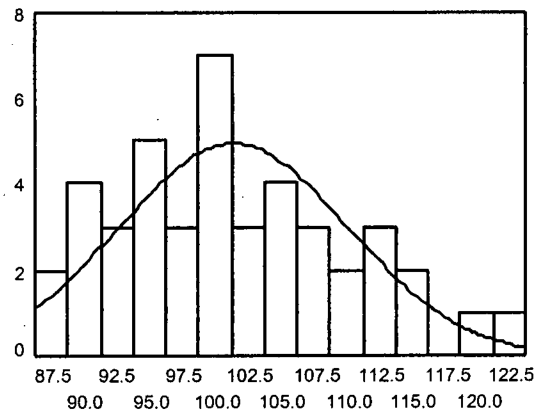
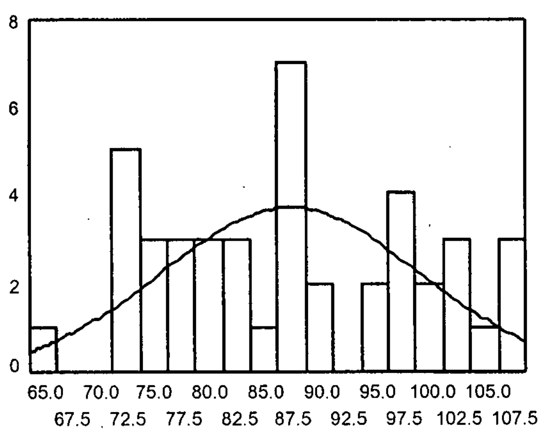


Figure 15: Waist Circumference



Appendix X: Preliminary Stepwise Multiple Regression for FM

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	WEIGHT	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).
2	HEIGHT	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).
3	MIDAX1	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).
4	subscap/triceps sf ratio	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).

a. Dependent Variable: total fat mass in kg

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.948[a]	.898	.895	2.2763
2	.970[b]	.941	.938	1.7558
3	.978[c]	.956	.953	1.5326
4	.980[d]	.961	.957	1.4565

a. Predictors: (Constant), WEIGHT

b. Predictors: (Constant), WEIGHT, HEIGHT

c. Predictors: (Constant), WEIGHT, HEIGHT, MIDAX1

d. Predictors: (Constant), WEIGHT, HEIGHT, MIDAX1, subscap/triceps sf ratio

ANOVA[e]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1865.484	1	1865.484	360.013	.000[a]
	Residual	212.450	41	5.182		
	Total	2077.934	42			
2	Regression	1954.617	2	977.309	317.008	.000[b]
	Residual	123.317	40	3.083		
	Total	2077.934	42			
3	Regression	1986.324	3	662.108	281.870	.000[c]
	Residual	91.610	39	2.349		
	Total	2077.934	42			
4	Regression	1997.325	4	499.331	235.389	.000[d]
	Residual	80.609	38	2.121		
	Total	2077.934	42			

a. Predictors: (Constant), WEIGHT

b. Predictors: (Constant), WEIGHT, HEIGHT

c. Predictors: (Constant), WEIGHT, HEIGHT, MIDAX1

d. Predictors: (Constant), WEIGHT, HEIGHT, MIDAX1, subscap/triceps sf ratio

e. Dependent Variable: total fat mass in kg

Coefficients[a]

Model		Unstandardized Coefficients B	Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	-16.509	2.152		-7.672	.000
	WEIGHT	.607	.032	.948	18.974	.000
2	(Constant)	18.731	6.761		2.771	.008
	WEIGHT	.664	.027	1.037	24.721	.000
	HEIGHT	-.247	.046	-.225	-5.377	.000
3	(Constant)	16.462	5.934		2.774	.008
	WEIGHT	.611	.028	.953	22.156	.000
	HEIGHT	-.231	.040	-.211	-5.735	.000
	MIDAX1	.143	.039	.146	3.674	.001
4	(Constant)	18.295	5.696		3.212	.003
	WEIGHT	.624	.027	.974	23.247	.000
	HEIGHT	-.238	.038	-.217	-6.193	.000
	MIDAX1	.166	.038	.170	4.328	.000
	subscap/triceps sf ratio	-2.854	1.253	-.082	-2.277	.028

a. Dependent Variable: total fat mass in kg

Excluded Variables[e]

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics Tolerance
1	HEIGHT	-.225[a]	-5.377	.000	-.648	.844
	BMI	.423[a]	5.320	.000	.644	.237
	TRISF1	.293[a]	4.949	.000	.616	.451
	SUBSCAP1	.185[a]	2.736	.009	.397	.472
	MIDAX1	.171[a]	3.213	.003	.453	.720
	BICEP1	.373[a]	4.396	.000	.571	.239
	ILIAC1	.163[a]	2.925	.006	.420	.676
	ABD1	.131[a]	2.218	.032	.331	.651
	THIGHSF1	.130[a]	2.461	.018	.363	.790
	CALFSF1	.099[a]	1.623	.112	.249	.642
	SUM4SF	.321[a]	4.751	.000	.601	.357
	WAISTG1	.180[a]	1.791	.081	.272	.234
	HIPG1	.215[a]	1.951	.058	.295	.193
	WHR	.029[a]	.528	.600	.083	.827
	subscap/triceps sf ratio	-.018[a]	-.324	.748	-.051	.858

Excluded Variables[e]

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics
						Tolerance
2	BMI	.084[b]	.149	.883	.024	4.806E-03
	TRISF1	.187[b]	3.141	.003	.449	.342
	SUBSCAP1	.050[b]	.781	.440	.124	.361
	MIDAX1	.146[b]	3.674	.001	.507	.712
	BICEP1	.257[b]	3.444	.001	.483	.210
	ILIAC1	.105[b]	2.285	.028	.344	.631
	ABD1	.085[b]	1.807	.078	.278	.628
	THIGHSF1	.045[b]	.963	.341	.152	.667
	CALFSF1	.066[b]	1.369	.179	.214	.630
	SUM4SF	.200[b]	2.951	.005	.427	.272
	WAISTG1	-.017[b]	-.185	.854	-.030	.186
	HIPG1	.149[b]	1.722	.093	.266	.189
	WHR	-.037[b]	-.844	.404	-.134	.762
	subscap/triceps sf ratio	-.041[b]	-.982	.332	-.155	.849
3	BMI	-.232[c]	-.467	.643	-.076	4.661E-03
	TRISF1	.113[c]	1.795	.081	.280	.268
	SUBSCAP1	-.059[c]	-.935	.356	-.150	.281
	BICEP1	.158[c]	1.885	.067	.292	.151
	ILIAC1	.013[c]	.243	.809	.039	.384
	ABD1	.012[c]	.246	.807	.040	.478
	THIGHSF1	.039[c]	.939	.354	.151	.666
	CALFSF1	.025[c]	.568	.573	.092	.583
	SUM4SF	.073[c]	.838	.407	.135	.149
	WAISTG1	-.123[c]	-1.519	.137	-.239	.166
	HIPG1	.127[c]	1.665	.104	.261	.187
	WHR	-.071[c]	-1.862	.070	-.289	.726
	subscap/triceps sf ratio	-.082[c]	-2.277	.028	-.347	.791
4	BMI	.074[d]	.149	.882	.025	4.291E-03
	TRISF1	.070[d]	1.048	.301	.170	.229
	SUBSCAP1	.118[d]	1.249	.220	.201	.112
	BICEP1	.152[d]	1.902	.065	.298	.151
	ILIAC1	.018[d]	.342	.734	.056	.384
	ABD1	.022[d]	.474	.638	.078	.473
	THIGHSF1	.014[d]	.328	.745	.054	.608
	CALFSF1	.008[d]	.190	.851	.031	.564
	SUM4SF	.114[d]	1.359	.182	.218	.143
	WAISTG1	-.041[d]	-.436	.666	-.071	.120
	HIPG1	.092[d]	1.219	.231	.196	.177
	WHR	-.040[d]	-.955	.346	-.155	.571

a. Predictors in the Model: (Constant), WEIGHT

b. Predictors in the Model: (Constant), WEIGHT, HEIGHT

c. Predictors in the Model: (Constant), WEIGHT, HEIGHT, MIDAX1

d. Predictors in the Model: (Constant), WEIGHT, HEIGHT, MIDAX1, subscap/triceps sf ratio

e. Dependent Variable: total fat mass in kg

Appendix XI: Stepwise Multiple Regression Analyses

(a) Equation development for FM

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	WT	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).
2	HT	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).
3	MA	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).
4	subscap/triceps sf ratio	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).

a. Dependent Variable: total fat mass in kg

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.948[a]	.898	.895	2.2763
2	.970[b]	.941	.938	1.7558
3	.978[c]	.956	.953	1.5326
4	.980[d]	.961	.957	1.4565

a. Predictors: (Constant), WT

b. Predictors: (Constant), WT, HT

c. Predictors: (Constant), WT, HT, MA

d. Predictors: (Constant), WT, HT, MA, subscap/triceps sf ratio

ANOVA[e]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1865.484	1	1865.484	360.013	.000[a]
	Residual	212.450	41	5.182		
	Total	2077.934	42			
2	Regression	1954.617	2	977.309	317.008	.000[b]
	Residual	123.317	40	3.083		
	Total	2077.934	42			
3	Regression	1986.324	3	662.108	281.870	.000[c]
	Residual	91.610	39	2.349		
	Total	2077.934	42			
4	Regression	1997.325	4	499.331	235.389	.000[d]
	Residual	80.609	38	2.121		
	Total	2077.934	42			

a. Predictors: (Constant), WT

b. Predictors: (Constant), WT, HT

c. Predictors: (Constant), WT, HT, MA

d. Predictors: (Constant), WT, HT, MA, subscap/triceps sf ratio

e. Dependent Variable: total fat mass in kg

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	-16.509	2.152		-7.672	.000
	WT	.607	.032	.948	18.974	.000
2	(Constant)	18.731	6.761		2.771	.008
	WT	.664	.027	1.037	24.721	.000
	HT	-.247	.046	-.225	-5.377	.000
3	(Constant)	16.462	5.934		2.774	.008
	WT	.611	.028	.953	22.156	.000
	HT	-.231	.040	-.211	-5.735	.000
	MA	.143	.039	.146	3.674	.001
4	(Constant)	18.295	5.696		3.212	.003
	WT	.624	.027	.974	23.247	.000
	HT	-.238	.038	-.217	-6.193	.000
	MA	.166	.038	.170	4.328	.000
	subscap/triceps sf ratio	-2.854	1.253	-.082	-2.277	.028

a. Dependent Variable: total fat mass in kg

Excluded Variables[e]

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics Tolerance
1	HT	-.225[a]	-5.377	.000	-.648	.844
	BMI	.423[a]	5.320	.000	.644	.237
	ABD	.131[a]	2.218	.032	.331	.651
	MA	.171[a]	3.213	.003	.453	.720
	SI	.163[a]	2.925	.006	.420	.676
	SS	.185[a]	2.736	.009	.397	.472
	SUM4SF	.321[a]	4.751	.000	.601	.357
	subscap/triceps sf ratio	-.018[a]	-.324	.748	-.051	.858
	WC	.180[a]	1.791	.081	.272	.234
	HC	.215[a]	1.951	.058	.295	.193
2	BMI	.084[b]	.149	.883	.024	4.806E-03
	ABD	.085[b]	1.807	.078	.278	.628
	MA	.146[b]	3.674	.001	.507	.712
	SI	.105[b]	2.285	.028	.344	.631
	SS	.050[b]	.781	.440	.124	.361
	SUM4SF	.200[b]	2.951	.005	.427	.272
	subscap/triceps sf ratio	-.041[b]	-.982	.332	-.155	.849
	WC	-.017[b]	-.185	.854	-.030	.186
	HC	.149[b]	1.722	.093	.266	.189
3	BMI	-.232[c]	-.467	.643	-.076	4.661E-03
	ABD	.012[c]	.246	.807	.040	.478
	SI	.013[c]	.243	.809	.039	.384
	SS	-.059[c]	-.935	.356	-.150	.281
	SUM4SF	.073[c]	.838	.407	.135	.149
	subscap/triceps sf ratio	-.082[c]	-2.277	.028	-.347	.791
	WC	-.123[c]	-1.519	.137	-.239	.166
	HC	.127[c]	1.665	.104	.261	.187
4	BMI	.074[d]	.149	.882	.025	4.291E-03
	ABD	.022[d]	.474	.638	.078	.473
	SI	.018[d]	.342	.734	.056	.384
	SS	.118[d]	1.249	.220	.201	.112
	SUM4SF	.114[d]	1.359	.182	.218	.143
	WC	-.041[d]	-.436	.666	-.071	.120
	HC	.092[d]	1.219	.231	.196	.177

a. Predictors in the Model: (Constant), WT

b. Predictors in the Model: (Constant), WT, HT

c. Predictors in the Model: (Constant), WT, HT, MA

d. Predictors in the Model: (Constant), WT, HT, MA, subscap/triceps sf ratio

e. Dependent Variable: total fat mass in kg

(b) Equation development for %Fat

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	SUM4SF	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).
2	BMI	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).
3	MA	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).
4	.	SUM4SF	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).
5	subscap/triceps sf ratio	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).

a. Dependent Variable: PCFAT

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.867[a]	.751	.745	2.6606
2	.901[b]	.811	.802	2.3474
3	.920[c]	.847	.835	2.1396
4	.918[d]	.843	.835	2.1385
5	.928[e]	.861	.851	2.0382

a. Predictors: (Constant), SUM4SF

b. Predictors: (Constant), SUM4SF, BMI

c. Predictors: (Constant), SUM4SF, BMI, MA

d. Predictors: (Constant), BMI, MA

e. Predictors: (Constant), BMI, MA, subscap/triceps sf ratio

ANOVA[f]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	876.879	1	876.879	123.873	.000[a]
	Residual	290.232	41	7.079		
	Total	1167.111	42			
2	Regression	946.696	2	473.348	85.901	.000[b]
	Residual	220.415	40	5.510		
	Total	1167.111	42			
3	Regression	988.565	3	329.522	71.978	.000[c]
	Residual	178.546	39	4.578		
	Total	1167.111	42			
4	Regression	984.181	2	492.091	107.602	.000[d]
	Residual	182.929	40	4.573		
	Total	1167.111	42			
5	Regression	1005.099	3	335.033	80.650	.000[e]
	Residual	162.011	39	4.154		
	Total	1167.111	42			

a. Predictors: (Constant), SUM4SF

b. Predictors: (Constant), SUM4SF, BMI

c. Predictors: (Constant), SUM4SF, BMI, MA

d. Predictors: (Constant), BMI, MA

e. Predictors: (Constant), BMI, MA, subscap/triceps sf ratio

f. Dependent Variable: PCFAT

Coefficients[a]

Model		Unstandardized Coefficients B	Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	20.711	1.418		14.608	.000
	SUM4SF	.171	.015	.867	11.130	.000
2	(Constant)	11.548	2.862		4.035	.000
	SUM4SF	9.503E-02	.025	.481	3.755	.001
	BMI	.598	.168	.456	3.560	.001
3	(Constant)	7.950	2.867		2.773	.008
	SUM4SF	3.070E-02	.031	.156	.979	.334
	BMI	.755	.162	.576	4.670	.000
	MA	.220	.073	.301	3.024	.004
4	(Constant)	6.157	2.204		2.794	.008
	BMI	.882	.096	.674	9.220	.000
	MA	.268	.053	.367	5.019	.000
5	(Constant)	7.139	2.146		3.327	.002
	BMI	.932	.094	.711	9.931	.000
	MA	.300	.053	.410	5.672	.000
	subscap/triceps sf ratio	-3.949	1.760	-.151	-2.244	.031

a. Dependent Variable: PCFAT

Excluded Variables[f]

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics Tolerance
1	HT	-.125[a]	-1.637	.109	-.251	.998
	WT	.166[a]	1.286	.206	.199	.357
	BMI	.456[a]	3.560	.001	.490	.287
	ABD	.015[a]	.113	.911	.018	.376
	MA	.151[a]	1.304	.200	.202	.442
	SI	-.122[a]	-.780	.440	-.122	.249
	SS	-.314[a]	-1.641	.109	-.251	.159
	subscap/triceps sf ratio	-.153[a]	-1.764	.085	-.269	.769
	WC	.157[a]	1.125	.267	.175	.309
	HC	.185[a]	1.459	.152	.225	.366
2	HT	-.066[b]	-.929	.359	-.147	.931
	WT	-.136[b]	-.934	.356	-.148	.222
	ABD	.101[b]	.880	.384	.140	.360
	MA	.301[b]	3.024	.004	.436	.397
	SI	.133[b]	.851	.400	.135	.196
	SS	-.405[b]	-2.473	.018	-.368	.156
	subscap/triceps sf ratio	-.147[b]	-1.937	.060	-.296	.769
	WC	-.160[b]	-1.045	.302	-.165	.201
	HC	.013[b]	.105	.917	.017	.298

Excluded Variables[f]

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics Tolerance
3	HT	-.078[c]	-1.202	.237	-.191	.928
	WT	-.148[c]	-1.120	.270	-.179	.222
	ABD	.071[c]	.675	.504	.109	.357
	SI	.068[c]	.471	.640	.076	.191
	SS	-.368[c]	-2.456	.019	-.370	.155
	subscap/triceps sf ratio	-.167[c]	-2.484	.018	-.374	.763
	WC	-.246[c]	-1.774	.084	-.277	.194
	HC	.041[c]	.352	.727	.057	.296
4	HT	-.067[d]	-1.042	.304	-.165	.948
	WT	-.123[d]	-.939	.354	-.149	.228
	ABD	.098[d]	1.085	.285	.171	.480
	SI	.104[d]	1.030	.309	.163	.383
	SS	-.128[d]	-1.080	.287	-.170	.277
	subscap/triceps sf ratio	-.151[d]	-2.244	.031	-.338	.785
	WC	-.219[d]	-1.590	.120	-.247	.198
	HC	.071[d]	.642	.525	.102	.329
	SUM4SF	.156[d]	.979	.334	.155	.155
5	HT	-.059[e]	-.963	.342	-.154	.945
	WT	-.117[e]	-.935	.356	-.150	.228
	ABD	.116[e]	1.355	.183	.215	.476
	SI	.110[e]	1.146	.259	.183	.383
	SS	.155[e]	.884	.382	.142	.117
	WC	-.100[e]	-.651	.519	-.105	.154
	HC	.033[e]	.306	.761	.050	.320
	SUM4SF	.218[e]	1.442	.158	.228	.151

a. Predictors in the Model: (Constant), SUM4SF

b. Predictors in the Model: (Constant), SUM4SF, BMI

c. Predictors in the Model: (Constant), SUM4SF, BMI, MA

d. Predictors in the Model: (Constant), BMI, MA

e. Predictors in the Model: (Constant), BMI, MA, subscap/triceps sf ratio

f. Dependent Variable: PCFAT

(c) Equation development for TFM

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	WC	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).
2	WT	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).
3	SI	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).

a. Dependent Variable: trunk fat mass in kg

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.922[a]	.850	.846	1.6034
2	.937[b]	.879	.873	1.4581
3	.951[c]	.904	.896	1.3163

a. Predictors: (Constant), WC

b. Predictors: (Constant), WC, WT

c. Predictors: (Constant), WC, WT, SI

ANOVA[d]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	595.217	1	595.217	231.519	.000[a]
	Residual	105.408	41	2.571		
	Total	700.624	42			
2	Regression	615.581	2	307.790	144.768	.000[b]
	Residual	85.044	40	2.126		
	Total	700.624	42			
3	Regression	633.054	3	211.018	121.794	.000[c]
	Residual	67.571	39	1.733		
	Total	700.624	42			

a. Predictors: (Constant), WC

b. Predictors: (Constant), WC, WT

c. Predictors: (Constant), WC, WT, SI

d. Dependent Variable: trunk fat mass in kg

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-16.594	1.886		-8.797	.000
	WC	.326	.021	.922	15.216	.000
2	(Constant)	-15.772	1.736		-9.086	.000
	WC	.217	.040	.613	5.383	.000
	WT	.131	.042	.353	3.095	.004
3	(Constant)	-14.317	1.633		-8.769	.000
	WC	.178	.038	.504	4.648	.000
	WT	.124	.038	.333	3.230	.003
	SI	.124	.039	.203	3.176	.003

a. Dependent Variable: trunk fat mass in kg

Excluded Variables[d]

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics
						Tolerance
1	HT	.016[a]	.258	.798	.041	.979
	WT	.353[a]	3.095	.004	.440	.234
	BMI	.329[a]	2.800	.008	.405	.228
	ABD	.142[a]	1.899	.065	.288	.620
	MA	.192[a]	2.721	.010	.395	.638
	SI	.215[a]	3.038	.004	.433	.610
	SS	.123[a]	1.092	.281	.170	.287
	subscap/triceps sf ratio	-.094[a]	-1.283	.207	-.199	.669
2	HT	-.117[b]	-1.795	.080	-.276	.672
	BMI	.210[b]	1.660	.105	.257	.181
	ABD	.115[b]	1.660	.105	.257	.609
	MA	.190[b]	3.030	.004	.437	.638
	SI	.203[b]	3.176	.003	.453	.608
	SS	.139[b]	1.367	.179	.214	.286
	subscap/triceps sf ratio	-.031[b]	-.427	.672	-.068	.600
3	HT	-.093[c]	-1.547	.130	-.243	.659
	BMI	.159[c]	1.357	.183	.215	.177
	ABD	-.041[c]	-.469	.641	-.076	.330
	MA	.114[c]	1.508	.140	.238	.421
	SS	.004[c]	.040	.968	.007	.225
	subscap/triceps sf ratio	-.040[c]	-.625	.536	-.101	.599

a. Predictors in the Model: (Constant), WC

b. Predictors in the Model: (Constant), WC, WT

c. Predictors in the Model: (Constant), WC, WT, SI

d. Dependent Variable: trunk fat mass in kg

(d) Equation development for %TF

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	WC	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).
2	MA	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).
3	HT	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).

a. Dependent Variable: PCTRUNK

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.832[a]	.693	.686	3.7574
2	.892[b]	.796	.786	3.0987
3	.918[c]	.843	.831	2.7574

a. Predictors: (Constant), WC

b. Predictors: (Constant), WC, MA

c. Predictors: (Constant), WC, MA, HT

ANOVA[d]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1306.671	1	1306.671	92.554	.000[a]
	Residual	578.834	41	14.118		
	Total	1885.505	42			
2	Regression	1501.422	2	750.711	78.182	.000[b]
	Residual	384.083	40	9.602		
	Total	1885.505	42			
3	Regression	1588.977	3	529.659	69.662	.000[c]
	Residual	296.528	39	7.603		
	Total	1885.505	42			

a. Predictors: (Constant), WC

b. Predictors: (Constant), WC, MA

c. Predictors: (Constant), WC, MA, HT

d. Dependent Variable: PCTRUNK

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-7.388	4.421		-1.671	.102
	WC	.482	.050	.832	9.621	.000
2	(Constant)	-3.812	3.731		-1.022	.313
	WC	.342	.052	.591	6.611	.000
	MA	.374	.083	.402	4.504	.000
3	(Constant)	30.659	10.687		2.869	.007
	WC	.356	.046	.614	7.697	.000
	MA	.387	.074	.416	5.222	.000
	HT	-.227	.067	-.218	-3.393	.002

a. Dependent Variable: PCTRUNK

Excluded Variables[d]

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics Tolerance
1	HT	-.202[a]	-2.440	.019	-.360	.979
	WT	-.112[a]	-.619	.539	-.097	.234
	BMI	.328[a]	1.862	.070	.282	.228
	ABD	.288[a]	2.837	.007	.409	.620
	MA	.402[a]	4.504	.000	.580	.638
	SI	.384[a]	4.078	.000	.542	.610
	SS	.314[a]	2.012	.051	.303	.287
	subscap/triceps sf ratio	.004[a]	.034	.973	.005	.669
2	HT	-.218[b]	-3.393	.002	-.477	.977
	WT	-.116[b]	-.784	.438	-.125	.234
	BMI	.350[b]	2.490	.017	.370	.228
	ABD	.131[b]	1.303	.200	.204	.495
	SI	.219[b]	2.020	.050	.308	.403
	SS	.125[b]	.882	.383	.140	.254
	subscap/triceps sf ratio	-.036[b]	-.409	.685	-.065	.662
3	WT	.195[c]	1.237	.224	.197	.160
	BMI	.175[c]	1.165	.251	.186	.177
	ABD	.125[c]	1.400	.170	.221	.495
	SI	.177[c]	1.807	.079	.281	.396
	SS	-.005[c]	-.035	.973	-.006	.231
	subscap/triceps sf ratio	-.045[c]	-.570	.572	-.092	.662

a. Predictors in the Model: (Constant), WC

b. Predictors in the Model: (Constant), WC, MA

c. Predictors in the Model: (Constant), WC, MA, HT

d. Dependent Variable: PCTRUNK

(e) Equation development for FM using SF's only

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	BICEP1	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).
2	CALFSF1	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).

a. Dependent Variable: total fat mass in kg

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.916[a]	.839	.835	2.8602
2	.930[b]	.864	.857	2.6572

a. Predictors: (Constant), BICEP1

b. Predictors: (Constant), BICEP1, CALFSF1

ANOVA[c]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1742.512	1	1742.512	212.995	.000[a]
	Residual	335.422	41	8.181		
	Total	2077.934	42			
2	Regression	1795.508	2	897.754	127.149	.000[b]
	Residual	282.426	40	7.061		
	Total	2077.934	42			

a. Predictors: (Constant), BICEP1

b. Predictors: (Constant), BICEP1, CALFSF1

c. Dependent Variable: total fat mass in kg

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	5.578	1.322		4.221	.000
	BICEP1	.912	.063	.916	14.594	.000
2	(Constant)	3.379	1.467		2.304	.027
	BICEP1	.810	.069	.813	11.712	.000
	CALFSF1	.163	.060	.190	2.740	.009

a. Dependent Variable: total fat mass in kg

Excluded Variables[c]

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics Tolerance
1	ABD	.007[a]	.083	.934	.013	.510
	MA	-.001[a]	-.013	.990	-.002	.534
	SI	-.003[a]	-.039	.969	-.006	.494
	SS	.119[a]	1.138	.262	.177	.359
	TRISF1	.221[a]	1.980	.055	.299	.294
	CALFSF1	.190[a]	2.740	.009	.397	.706
	THIGHSF1	.056[a]	.751	.457	.118	.705
	SUM4SF	.204[a]	1.270	.211	.197	.151
2	ABD	-.068[b]	-.784	.438	-.125	.462
	MA	-.053[b]	-.644	.523	-.103	.507
	SI	-.035[b]	-.411	.684	-.066	.485
	SS	.111[b]	1.141	.261	.180	.359
	TRISF1	.188[b]	1.779	.083	.274	.290
	THIGHSF1	-.028[b]	-.357	.723	-.057	.583
	SUM4SF	.155[b]	1.026	.311	.162	.149

a. Predictors in the Model: (Constant), BICEP1

b. Predictors in the Model: (Constant), BICEP1, CALFSF1

c. Dependent Variable: total fat mass in kg

(f) Equation development for %Fat using SF's only

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	SUM4SF	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).
2	CALFSF1	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).

a. Dependent Variable: PCFAT

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.867[a]	.751	.745	2.6606
2	.885[b]	.783	.772	2.5189

a. Predictors: (Constant), SUM4SF

b. Predictors: (Constant), SUM4SF, CALFSF1

ANOVA[c]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	876.879	1	876.879	123.873	.000[a]
	Residual	290.232	41	7.079		
	Total	1167.111	42			
2	Regression	913.324	2	456.662	71.976	.000[b]
	Residual	253.786	40	6.345		
	Total	1167.111	42			

a. Predictors: (Constant), SUM4SF

b. Predictors: (Constant), SUM4SF, CALFSF1

c. Dependent Variable: PCFAT

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	20.711	1.418		14.608	.000
	SUM4SF	.171	.015	.867	11.130	.000
2	(Constant)	19.172	1.488		12.885	.000
	SUM4SF	.149	.017	.753	8.599	.000
	CALFSF1	.135	.056	.210	2.397	.021

a. Dependent Variable: PCFAT

Excluded Variables[c]

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics Tolerance
1	ABD	.015[a]	.113	.911	.018	.376
	MA	.151[a]	1.304	.200	.202	.442
	SI	-.122[a]	-.780	.440	-.122	.249
	SS	-.314[a]	-1.641	.109	-.251	.159
	TRISF1	.250[a]	1.194	.240	.185	.137
	BICEP1	.336[a]	1.718	.093	.262	.151
	CALFSF1	.210[a]	2.397	.021	.354	.708
	THIGHSF1	.058[a]	.604	.550	.095	.671
2	ABD	-.067[b]	-.530	.599	-.085	.350
	MA	.105[b]	.930	.358	.147	.427
	SI	-.120[b]	-.809	.424	-.128	.249
	SS	-.259[b]	-1.402	.169	-.219	.156
	TRISF1	.234[b]	1.182	.245	.186	.137
	BICEP1	.280[b]	1.481	.147	.231	.148
	THIGHSF1	-.035[b]	-.352	.727	-.056	.561

a. Predictors in the Model: (Constant), SUM4SF

b. Predictors in the Model: (Constant), SUM4SF, CALFSF1

c. Dependent Variable: PCFAT

Appendix XII: All Possible Subsets Regression Analyses

(a) Equation development for FM

```
BMDP9R - ALL POSSIBLE SUBSETS REGRESSION


/INPUT TITLE IS 'REGRESSION FOR BODY COMPOSITION'.
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       CASES=44.
       FORMAT='31F8.2'.

/VARIABLE NAMES ARE
GROUP, AGE, HEIGHT, WEIGHT, BMI, TRISF, SUBSCPSF, MIDAXSF, BICEPSF, ILIACSF,
ABDSF, THIGHSF, CALFSF, SUMSFU, SUMSFL, SUBTRI, SUM4SF, LOGSUM4, WAISTG, HIPG,
WHR, THIGHG, TRUNKFAT, PCTRUNK, STFAT, TOTFAT, STLEAN, TOTLEAN, STPCFAT,
TOTPCFAT, TOTWT.

       USE= TOTFAT, WAISTG, HIPG, SUBTRI, HEIGHT, WEIGHT, BMI, SUM4SF,
MIDAXSF, SUBSCPSF, ILIACSF, ABDSF.

 /REGRESS

       DEPENDENT= TOTFAT.
       INDEPENDENT = WAISTG, HIPG, SUBTRI, HEIGHT, WEIGHT, BMI, SUM4SF,
MIDAXSF, SUBSCPSF, ILIACSF, ABDSF.

/END.



DATA AFTER TRANSFORMATIONS
--------------------------
 CASE   19       20       16        3        4        5        17        8
 NO. WAISTG   HIPG     SUBTRI   HEIGHT   WEIGHT   BMI      SUM4SF   MIDAXSF
----- -------- -------- -------- -------- -------- -------- -------- --------
          7       10       11       26
     SUBSCPSF ILIACSF  ABDSF    TOTFAT
     -------- -------- -------- --------
    1    81.50    99.00     0.83   166.60    64.50    23.24    72.00    17.20
         19.00    14.20    34.40 18461.00
    2    88.00   101.40     1.25   165.70    66.20    24.11    94.20    28.00
         28.20    19.70    27.60 22630.00
    3    98.00   107.80     0.69   164.00    75.40    28.03   111.00    31.20
         24.90    17.60    39.80 31082.10
    4   107.50   108.20     0.93   154.70    78.40    32.76   121.00    26.50
         32.20    26.80    41.00 32286.80
    5    86.70   101.00     0.78   163.90    66.60    24.79    89.60    20.70
         19.10    23.10    40.00 22763.00
    6   102.20   114.00     0.97   158.10    78.50    31.41   131.00    28.10
         36.30    27.90    45.50 28038.20
    7    86.50    96.50     0.69   156.80    60.20    24.49    77.30    25.00
         17.00    19.60    28.00 19610.10
 CASE   19       20       16        3        4        5        17        8
 NO. WAISTG   HIPG     SUBTRI   HEIGHT   WEIGHT   BMI      SUM4SF   MIDAXSF
----- -------- -------- -------- -------- -------- -------- -------- --------
          7       10       11       26
     SUBSCPSF ILIACSF  ABDSF    TOTFAT
     -------- -------- -------- --------
    8    72.50    95.50     0.58   162.40    61.20    23.20    64.05    13.40
         11.30    17.90    26.60 17296.30
    9    87.40   105.00     0.98   174.10    70.30    23.19    83.40    29.70
         19.70    26.00    37.90 22712.90
   10   103.50   119.00     0.71   161.90    91.40    34.87   139.50    35.40
         32.20    27.50    36.80 39753.60

NUMBER OF CASES READ. . . . . . . . . . . . . .         44
```

CASES WITH DATA MISSING OR BEYOND LIMITS . . 1
REMAINING NUMBER OF CASES 43

SUMMARY STATISTICS FOR EACH VARIABLE

VARIABLE	MEAN	STANDARD DEVIATION	COEFFICIENT OF VARIATION	SMALLEST VALUE	LARGEST VALUE
19 WAISTG	87.42558	11.56382	0.132270	66.20000	108.00000
20 HIPG	101.38605	8.66178	0.085434	87.90000	123.70000
16 SUBTRI	0.76442	0.20099	0.262931	0.39000	1.25000
3 HEIGHT	158.05814	6.42240	0.040633	147.50000	174.10001
4 WEIGHT	66.40581	10.98312	0.165394	47.00000	96.00000
5 BMI	26.57000	4.02438	0.151463	18.83000	35.77000
17 SUM4SF	88.37791	26.70828	0.302205	23.50000	139.50000
8 MIDAXSF	23.20000	7.20305	0.310476	6.10000	38.60000
7 SUBSCPSF	21.38023	8.19030	0.383078	4.60000	36.30000
10 ILIACSF	19.45349	6.69173	0.343986	3.50000	35.30000
11 ABDSF	32.10233	8.54925	0.266313	5.40000	48.60000
26 TOTFAT	23785.85813	7033.81977	0.295714	11076.50000	42201.50000

CORRELATIONS

		WAISTG 19	HIPG 20	SUBTRI 16	HEIGHT 3	WEIGHT 4	BMI 5	SUM4SF 17
WAISTG	19	1.000						
HIPG	20	0.720	1.000					
SUBTRI	16	0.576	0.265	1.000				
HEIGHT	3	0.145	0.296	0.060	1.000			
WEIGHT	4	0.875	0.899	0.378	0.395	1.000		
BMI	5	0.879	0.812	0.397	-0.097	0.874	1.000	
SUM4SF	17	0.831	0.796	0.481	0.049	0.802	0.844	1.000
MIDAXSF	8	0.601	0.511	0.411	0.126	0.529	0.516	0.747
SUBSCPSF	7	0.845	0.663	0.740	-0.019	0.727	0.803	0.917
ILIACSF	10	0.624	0.630	0.375	0.031	0.569	0.608	0.867
ABDSF	11	0.616	0.641	0.392	0.093	0.590	0.599	0.790
TOTFAT	26	0.871	0.893	0.344	0.184	0.948	0.928	0.875

		MIDAXSF 8	SUBSCPSF 7	ILIACSF 10	ABDSF 11	TOTFAT 26
MIDAXSF	8	1.000				
SUBSCPSF	7	0.653	1.000			
ILIACSF	10	0.739	0.718	1.000		
ABDSF	11	0.653	0.685	0.802	1.000	
TOTFAT	26	0.624	0.776	0.650	0.645	1.000

FIRST DIGITS OF CORRELATIONS

```
19 WAISTG   *
20 HIPG     7*
 4 WEIGHT   88*
26 TOTFAT   889*
 5 BMI      8889*
17 SUM4SF   87888*
 7 SUBSCPSF 867789*
10 ILIACSF  6656687*
11 ABDSF    66565768*
 8 MIDAXSF  655657676*
16 SUBTRI   5233347334*
 3 HEIGHT   1231     1 *
```

SUBSETS WITH 1 VARIABLES

R-SQUARED	ADJUSTED R-SQUARED	CP	
0.897759	0.895265	52.51	WEIGHT
0.860936	0.857544	85.47	BMI
0.796944	0.791991	142.74	HIPG
0.764781	0.759044	171.53	SUM4SF
0.759458	0.753591	176.30	WAISTG
0.601565	0.591847	317.62	SUBSCPSF
0.422324	0.408234	478.05	ILIACSF
0.415886	0.401639	483.81	ABDSF
0.389721	0.374836	507.23	MIDAXSF
0.118139	0.096630	750.30	SUBTRI

SUBSETS WITH 2 VARIABLES

R-SQUARED	ADJUSTED R-SQUARED	CP		
0.940654	0.937687	16.12	HEIGHT	WEIGHT
0.940080	0.937084	16.63	WEIGHT	BMI
0.936936	0.933783	19.45	HEIGHT	BMI
0.934637	0.931368	21.50	WEIGHT	SUM4SF
0.918738	0.914675	35.73	WEIGHT	MIDAXSF
0.917868	0.913762	36.51	HIPG	BMI
0.915778	0.911567	38.38	WEIGHT	ILIACSF
0.913875	0.909568	40.09	WEIGHT	SUBSCPSF
0.908957	0.904405	44.49	WEIGHT	ABDSF
0.906644	0.901976	46.56	HIPG	WEIGHT

SUBSETS WITH 3 VARIABLES

R-SQUARED	ADJUSTED R-SQUARED	CP			
0.955913	0.952522	4.46	HEIGHT	WEIGHT	MIDAXSF
0.954274	0.950757	5.93	WEIGHT	BMI	MIDAXSF
0.951488	0.947757	8.42	HEIGHT	WEIGHT	SUM4SF
0.950879	0.947100	8.97	WEIGHT	BMI	SUM4SF
0.950258	0.946431	9.52	HEIGHT	BMI	MIDAXSF
0.948117	0.944126	11.44	HEIGHT	BMI	SUM4SF
0.947659	0.943633	11.85	HEIGHT	WEIGHT	ILIACSF
0.946559	0.942448	12.83	WEIGHT	BMI	ILIACSF

0.945239	0.941027	14.01	HEIGHT	WEIGHT	ABDSF	
0.944845	0.940603	14.37	HIPG	HEIGHT	WEIGHT	

SUBSETS WITH 4 VARIABLES

R-SQUARED	ADJUSTED R-SQUARED	CP	VARIABLE		COEFFICIENT	T-STATISTIC
0.961151	0.957061	1.77	VARIABLE		COEFFICIENT	T-STATISTIC
			16 SUBTRI		-2849.16	-2.26
			3 HEIGHT		-238.172	-6.19
			4 WEIGHT		624.126	23.22
			8 MIDAXSF		165.516	4.32
			INTERCEPT		18323.2	
0.960639	0.956495	2.23	VARIABLE		COEFFICIENT	T-STATISTIC
			16 SUBTRI		-3153.26	-2.48
			4 WEIGHT		342.465	7.94
			5 BMI		717.670	6.11
			8 MIDAXSF		162.583	4.21
			INTERCEPT		-19385.8	
0.958910	0.954585	3.78	HIPG	HEIGHT	WEIGHT	MIDAXSF
0.958435	0.954060	4.20	WAISTG	HEIGHT	WEIGHT	MIDAXSF
0.958098	0.953687	4.50	SUBTRI	HEIGHT	BMI	MIDAXSF
0.957782	0.953338	4.79	HIPG	WEIGHT	BMI	MIDAXSF
0.957309	0.952815	5.21	SUBTRI	WEIGHT	BMI	SUM4SF
0.957262	0.952763	5.25	WAISTG	WEIGHT	BMI	MIDAXSF
0.957025	0.952502	5.46	HEIGHT	WEIGHT	SUM4SF	SUBSCPSF
0.957007	0.952482	5.48	WEIGHT	BMI	SUM4SF	SUBSCPSF

SUBSETS WITH 5 VARIABLES

R-SQUARED	ADJUSTED R-SQUARED	CP			
0.962983	0.957980	2.13	VARIABLE	COEFFICIENT	T-STATISTIC
			16 SUBTRI	-3174.70	-2.50
			3 HEIGHT	-204.646	-4.51
			4 WEIGHT	575.594	12.89
			17 SUM4SF	29.7873	1.35
			8 MIDAXSF	122.154	2.46
			INTERCEPT	14869.3	
0.962850	0.957830	2.25	VARIABLE	COEFFICIENT	T-STATISTIC
			16 SUBTRI	-3463.42	-2.73
			4 WEIGHT	332.015	7.71
			5 BMI	610.808	4.48
			17 SUM4SF	32.3078	1.48
			8 MIDAXSF	115.914	2.35
			INTERCEPT	-17388.1	
0.962669	0.957624	2.41	VARIABLE	COEFFICIENT	T-STATISTIC
			16 SUBTRI	-4730.78	-2.39
			3 HEIGHT	-200.727	-4.10
			4 WEIGHT	582.406	13.47
			8 MIDAXSF	142.450	3.35
			7 SUBSCPSF	99.8403	1.23
			INTERCEPT	15014.0	

0.962666	0.957621	2.42	HIPG	SUBTRI	HEIGHT	WEIGHT	MIDAXSF
0.962623	0.957572	2.45	SUBTRI	WEIGHT	BMI	MIDAXSF	SUBSCPSF
0.962364	0.957278	2.69	HIPG	SUBTRI	WEIGHT	BMI	MIDAXSF
0.961424	0.956211	3.53	HEIGHT	WEIGHT	SUM4SF	MIDAXSF	SUBSCPSF
0.961394	0.956177	3.55	SUBTRI	HEIGHT	WEIGHT	MIDAXSF	ABDSF
0.961356	0.956134	3.59	WAISTG	SUBTRI	HEIGHT	WEIGHT	MIDAXSF
0.961271	0.956037	3.66	SUBTRI	HEIGHT	WEIGHT	MIDAXSF	ILIACSF

```
STATISTICS FOR 'BEST' SUBSET
----------------------------
MALLOWS' CP                          1.77
SQUARED MULTIPLE CORRELATION      0.96115
MULTIPLE CORRELATION              0.98038
ADJUSTED SQUARED MULT. CORR.      0.95706
RESIDUAL MEAN SQUARE       2124377.831358
STANDARD ERROR OF EST.        1457.524556
F-STATISTIC                        235.03
NUMERATOR DEGREES OF FREEDOM            4
DENOMINATOR DEGREES OF FREEDOM         38
SIGNIFICANCE (TAIL PROB.)          0.0000

*** N O T E *** THE ABOVE F-STATISTIC AND ASSOCIATED SIGNIFICANCE TEND TO BE
                LIBERAL WHENEVER A SUBSET OF VARIABLES IS SELECTED BY THE CP OR
                ADJUSTED R-SQUARED CRITERIA.
```

VARIABLE NO.	NAME	REGRESSION COEFFICIENT	STANDARD ERROR	STAND. COEF.	T-STAT.	2TAIL SIG.	TOL-ERANCE	CONTRI-BUTION TO R-SQ
	INTERCEPT	18323.2	5702.46	2.605	3.21	0.003		
16	SUBTRI	-2849.16	1258.76	-0.081	-2.26	0.029	0.790229	0.00524
3	HEIGHT	-238.172	38.4637	-0.217	-6.19	0.000	0.828870	0.03920
4	WEIGHT	624.126	26.8804	0.975	23.22	0.000	0.580311	0.55116
8	MIDAXSF	165.516	38.3240	0.169	4.32	0.000	0.663755	0.01907

(b) Equation development for %Fat

```
BMDP9R - ALL POSSIBLE SUBSETS REGRESSION


/INPUT TITLE IS 'REGRESSION FOR BODY COMPOSITION'.
       FILE='A:\BDYCMP2.DAT'.
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       CASES = 44.
       FORMAT= '31F8.2'.

/VARIABLE NAMES ARE
SUBJECT, AGE, HEIGHT, WEIGHT, BMI, TRISF, SUBSCPSF, MIDAXSF, BICEPSF, ILIACSF,
ABDSF, THIGHSF, CALFSF, SUMSFU, SUMSFL, SUBTRI, SUM4SF, LOGSUM4, WAISTG, HIPG,
WHR, THIGHG, TRUNKFAT, PCTRUNK, STFAT, TOTFAT, STLEAN, TOTLEAN, STPCFAT,
TOTPCFAT, TOTWT.

       USE= TOTPCFAT, HEIGHT, WEIGHT, BMI, ILIACSF,
```

```
ABDSF, MIDAXSF, SUBSCPSF, WAISTG, HIPG, SUBTRI, SUM4SF.

 /REGRESS

       DEPENDENT= TOTPCFAT.
       INDEPENDENT =  HEIGHT, WEIGHT, BMI, ILIACSF, ABDSF, MIDAXSF,
SUBSCPSF, WAISTG, HIPG, SUBTRI, SUM4SF.


/END.


NUMBER OF CASES READ. . . . . . . . . . . . . . .        44
   CASES WITH DATA MISSING OR BEYOND LIMITS . .           1
      REMAINING NUMBER OF CASES . . . . . . . . .        43
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SUMMARY STATISTICS FOR EACH VARIABLE

VARIABLE	MEAN	STANDARD DEVIATION	COEFFICIENT OF VARIATION	SMALLEST VALUE	LARGEST VALUE
30 TOTPCFAT	35.83023	5.27147	0.147123	24.50000	46.70000

CORRELATIONS

	HEIGHT 3	WEIGHT 4	BMI 5	ILIACSF 10	ABDSF 11	MIDAXSF 8	SUBSCPSF 7
TOTPCFAT 30	-0.083	0.754	0.863	0.721	0.690	0.714	0.745

	WAISTG 19	HIPG 20	SUBTRI 16	SUM4SF 17	TOTPCFAT 30
TOTPCFAT 30	0.769	0.758	0.301	0.867	1.000

SUBSETS WITH 1 VARIABLES

R-SQUARED	ADJUSTED R-SQUARED	CP	
0.751324	0.745259	26.38	SUM4SF
0.744395	0.738161	28.20	BMI
0.591202	0.581232	68.47	WAISTG
0.574301	0.563918	72.92	HIPG
0.569190	0.558682	74.26	WEIGHT
0.555044	0.544191	77.98	SUBSCPSF
0.519526	0.507807	87.32	ILIACSF
0.510147	0.498199	89.78	MIDAXSF
0.476218	0.463443	98.70	ABDSF
0.090573	0.068392	200.09	SUBTRI

SUBSETS WITH 2 VARIABLES

R-SQUARED	ADJUSTED R-SQUARED	CP		
0.843104	0.835259	4.25	BMI	MIDAXSF
0.811053	0.801606	12.67	BMI	SUM4SF
0.805450	0.795723	14.15	BMI	ILIACSF
0.791234	0.780796	17.88	BMI	ABDSF
0.768728	0.757165	23.80	SUBTRI	SUM4SF
0.767009	0.755359	24.25	SUBSCPSF	SUM4SF
0.766944	0.755291	24.27	HEIGHT	SUM4SF
0.763897	0.752092	25.07	HIPG	SUM4SF
0.761465	0.749538	25.71	MIDAXSF	SUM4SF
0.761204	0.749265	25.78	WEIGHT	SUM4SF

SUBSETS WITH 3 VARIABLES

R-SQUARED	ADJUSTED R-SQUARED	CP			
0.860686	0.849969	1.63	VARIABLE	COEFFICIENT	T-STATISTIC
			5 BMI	0.931890	9.91
			8 MIDAXSF	0.299125	5.65
			16 SUBTRI	-3.92679	-2.22
			INTERCEPT	7.13194	
0.852639	0.841304	3.74	BMI	MIDAXSF	WAISTG
0.849348	0.837759	4.61	HEIGHT	WEIGHT	MIDAXSF
0.847717	0.836002	5.04	BMI	ABDSF	MIDAXSF
0.847646	0.835926	5.05	BMI	MIDAXSF	SUBSCPSF
0.847360	0.835618	5.13	HEIGHT	BMI	MIDAXSF
0.847280	0.835533	5.15	BMI	ILIACSF	MIDAXSF
0.846887	0.835109	5.25	BMI	MIDAXSF	SUM4SF
0.846557	0.834753	5.34	WEIGHT	BMI	MIDAXSF
0.844753	0.832811	5.81	BMI	MIDAXSF	HIPG

SUBSETS WITH 4 VARIABLES

R-SQUARED	ADJUSTED R-SQUARED	CP			
0.867866	0.853957	1.74	VARIABLE	COEFFICIENT	T-STATISTIC
			5 BMI	0.793308	5.18
			8 MIDAXSF	0.205923	2.99
			7 SUBSCPSF	-0.236875	-2.46
			17 SUM4SF	0.0953064	2.41
			INTERCEPT	6.61611	
0.867853	0.853943	1.74	VARIABLE	COEFFICIENT	T-STATISTIC

			5 BMI		0.758689	4.98
			8 MIDAXSF		0.234806	3.41
			16 SUBTRI		-4.34828	-2.46
			17 SUM4SF		0.0430038	1.44
			INTERCEPT		9.74766	

0.867183	0.853202	1.92	BMI	ABDSF	MIDAXSF	SUBTRI
0.865320	0.851143	2.41	BMI	ILIACSF	MIDAXSF	SUBTRI
0.864025	0.849712	2.75	HEIGHT	BMI	MIDAXSF	SUBTRI
0.863819	0.849484	2.80	WEIGHT	BMI	MIDAXSF	SUBTRI
0.863306	0.848917	2.94	BMI	MIDAXSF	SUBSCPSF	SUBTRI
0.862904	0.848472	3.04	HEIGHT	WEIGHT	MIDAXSF	SUBTRI
0.862277	0.847780	3.21	BMI	MIDAXSF	WAISTG	SUBTRI
0.861045	0.846418	3.53	BMI	MIDAXSF	HIPG	SUBTRI

(c) Equation development for TFM

```
BMDP9R - ALL POSSIBLE SUBSETS REGRESSION

/INPUT TITLE IS 'REGRESSION FOR BODY COMPOSITION'.
       FILE='A:\BDYCMP2.DAT'.
       VARIABLES = 31.
       CASES=44.
       FORMAT='31F8.2'.

/VARIABLE NAMES ARE
GROUP, AGE, HEIGHT, WEIGHT, BMI, TRISF, SUBSCPSF, MIDAXSF, BICEPSF, ILIACSF,
ABDSF, THIGHSF, CALFSF, SUMSFU, SUMSFL, SUBTRI, SUM4SF, LOGSUM4, WAISTG, HIPG,
WHR, THIGHG, TRUNKFAT, PCTRUNK, STFAT, TOTFAT, STLEAN, TOTLEAN, STPCFAT,
TOTPCFAT, TOTWT.

       USE= TRUNKFAT, MIDAXSF, SUBSCPSF, ABDSF, ILIACSF, HEIGHT, WEIGHT,
BMI, SUBTRI, WAISTG.
 /REGRESS

       DEPENDENT= TRUNKFAT.
       INDEPENDENT = MIDAXSF, SUBSCPSF, ABDSF, ILIACSF, HEIGHT, WEIGHT, BMI,
SUBTRI, WAISTG.

/END.

NUMBER OF CASES READ. . . . . . . . . . . . . . .          44
   CASES WITH DATA MISSING OR BEYOND LIMITS . .             1
      REMAINING NUMBER OF CASES . . . . . . . .            43

SUMMARY STATISTICS FOR EACH VARIABLE
-----------------------------------
```

VARIABLE	MEAN	STANDARD DEVIATION	COEFFICIENT OF VARIATION	SMALLEST VALUE	LARGEST VALUE
23 TRUNKFAT	11866.58840	4084.30318	0.344185	4009.00000	22012.00000

CORRELATIONS

		MIDAXSF 8	SUBSCPSF 7	ABDSF 11	ILIACSF 10	HEIGHT 3	WEIGHT 4	BMI 5
TRUNKFAT	23	0.677	0.814	0.656	0.707	0.150	0.889	0.885

		SUBTRI 16	WAISTG 19	TRUNKFAT 23
TRUNKFAT	23	0.468	0.922	1.000

SUBSETS WITH 1 VARIABLES

R-SQUARED	ADJUSTED R-SQUARED	CP	
0.849552	0.845882	24.39	WAISTG
0.790695	0.785590	49.19	WEIGHT
0.782746	0.777447	52.54	BMI
0.662285	0.654048	103.29	SUBSCPSF
0.499487	0.487279	171.88	ILIACSF
0.458117	0.444901	189.31	MIDAXSF
0.430259	0.416363	201.05	ABDSF
0.219307	0.200266	289.93	SUBTRI
0.022363	-0.001482	372.91	HEIGHT

SUBSETS WITH 2 VARIABLES

R-SQUARED	ADJUSTED R-SQUARED	CP		
0.878617	0.872548	14.14	WEIGHT	WAISTG
0.877753	0.871641	14.51	ILIACSF	WAISTG
0.874179	0.867888	16.01	BMI	WAISTG
0.873047	0.866699	16.49	MIDAXSF	WAISTG
0.861994	0.855094	21.15	ABDSF	WAISTG
0.855503	0.848279	23.88	SUBTRI	WAISTG
0.853911	0.846606	24.55	SUBSCPSF	WAISTG
0.850315	0.842831	26.07	SUBSCPSF	WEIGHT
0.850134	0.842641	26.14	ILIACSF	WEIGHT
0.849813	0.842304	26.28	MIDAXSF	WEIGHT

SUBSETS WITH 3 VARIABLES

R-SQUARED	ADJUSTED R-SQUARED	CP			
0.903556	0.896138	5.63	ILIACSF	WEIGHT	WAISTG
0.901751	0.894194	6.40	MIDAXSF	WEIGHT	WAISTG
0.899309	0.891563	7.42	MIDAXSF	BMI	WAISTG
0.895142	0.887076	9.18	ILIACSF	BMI	WAISTG
0.887882	0.879258	12.24	HEIGHT	WEIGHT	WAISTG
0.887876	0.879251	12.24	MIDAXSF	HEIGHT	WEIGHT
0.886631	0.877910	12.77	ABDSF	WEIGHT	WAISTG
0.886609	0.877887	12.78	WEIGHT	BMI	WAISTG
0.886593	0.877870	12.78	MIDAXSF	WEIGHT	BMI
0.884749	0.875883	13.56	HEIGHT	BMI	WAISTG

SUBSETS WITH 4 VARIABLES

R-SQUARED	ADJUSTED R-SQUARED	CP	VARIABLE	COEFFICIENT	T-STATISTIC
0.912721	0.903534	3.77	8 MIDAXSF	112.034	3.29
			3 HEIGHT	-81.4047	-2.19
			4 WEIGHT	184.823	4.15
			19 WAISTG	136.490	3.29
			INTERCEPT	-2071.93	
0.910894	0.901515	4.54	8 MIDAXSF	110.701	3.22
			4 WEIGHT	92.8691	2.22
			5 BMI	228.082	1.97
			19 WAISTG	137.129	3.22
			INTERCEPT	-14917.5	

R-SQUARED	ADJUSTED R-SQUARED	CP				
0.909271	0.899721	5.23	ILIACSF	HEIGHT	WEIGHT	WAISTG
0.909000	0.899421	5.34	MIDAXSF	ILIACSF	WEIGHT	WAISTG
0.908682	0.899070	5.47	MIDAXSF	HEIGHT	BMI	WAISTG
0.908009	0.898325	5.76	ILIACSF	WEIGHT	BMI	WAISTG
0.905787	0.895869	6.70	ILIACSF	HEIGHT	BMI	WAISTG
0.904524	0.894474	7.23	ILIACSF	WEIGHT	SUBTRI	WAISTG
0.904112	0.894019	7.40	ABDSF	ILIACSF	WEIGHT	WAISTG
0.903561	0.893409	7.63	SUBSCPSF	ILIACSF	WEIGHT	WAISTG

STATISTICS FOR 'BEST' SUBSET

MALLOWS' CP	3.77
SQUARED MULTIPLE CORRELATION	0.91272
MULTIPLE CORRELATION	0.95536
ADJUSTED SQUARED MULT. CORR.	0.90353

```
RESIDUAL MEAN SQUARE      1609196.603463
STANDARD ERROR OF EST.       1268.541132
F-STATISTIC                        99.35
NUMERATOR DEGREES OF FREEDOM           4
DENOMINATOR DEGREES OF FREEDOM        38
SIGNIFICANCE (TAIL PROB.)         0.0000
```

VARIABLE NO. NAME	REGRESSION COEFFICIENT	STANDARD ERROR	STAND. COEF.	T-STAT.	2TAIL SIG.	TOL-ERANCE	CONTRI-BUTION TO R-SQ
INTERCEPT	-2071.93	6001.15	-0.507	-0.35	0.732		
8 MIDAXSF	112.034	34.0674	0.198	3.29	0.002	0.636279	0.02484
3 HEIGHT	-81.4047	37.2480	-0.128	-2.19	0.035	0.669514	0.01097
4 WEIGHT	184.823	44.5079	0.497	4.15	0.000	0.160337	0.03961
19 WAISTG	136.490	41.4993	0.386	3.29	0.002	0.166370	0.02485

(d) Equation development for %TF

```
BMDP9R - ALL POSSIBLE SUBSETS REGRESSION


/INPUT TITLE IS 'REGRESSION FOR BODY COMPOSITION'.
       FILE='A:\BDYCMP2.DAT'.
       VARIABLES = 31.
       CASES = 44.
       FORMAT= '31F8.2'.

/VARIABLE NAMES ARE
SUBJECT, AGE, HEIGHT, WEIGHT, BMI, TRISF, SUBSCPSF, MIDAXSF, BICEPSF, ILIACSF,
ABDSF, THIGHSF, CALFSF, SUMSFU, SUMSFL, SUBTRI, SUM4SF, LOGSUM4, WAISTG, HIPG,
WHR, THIGHG, TRUNKFAT, PCTRUNK, STFAT, TOTFAT, STLEAN, TOTLEAN, STPCFAT,
TOTPCFAT, TOTWT.

       USE= PCTRUNK, HEIGHT, WEIGHT, BMI, ILIACSF,
ABDSF, MIDAXSF, SUBSCPSF, WAISTG.

 /REGRESS

       DEPENDENT= PCTRUNK.
       INDEPENDENT =  HEIGHT, WEIGHT, BMI, ILIACSF, ABDSF, MIDAXSF,
SUBSCPSF, WAISTG.

       METHOD=RSQ.
       NUMBER=1.
       MAXVAR=4.

/END.


NUMBER OF CASES READ. . . . . . . . . . . . . . .        44
   CASES WITH DATA MISSING OR BEYOND LIMITS . .          1
      REMAINING NUMBER OF CASES . . . . . . . . .        43


SUMMARY STATISTICS FOR EACH VARIABLE
-----------------------------------
                                 STANDARD    COEFFICIENT   SMALLEST      LARGEST
```

VARIABLE	MEAN	DEVIATION	OF VARIATION	VALUE	VALUE
24 PCTRUNK	34.78140	6.70022	0.192638	18.80000	45.70000

CORRELATIONS

		HEIGHT 3	WEIGHT 4	BMI 5	ILIACSF 10	ABDSF 11	MIDAXSF 8	SUBSCPSF 7
PCTRUNK	24	-0.076	0.703	0.806	0.754	0.692	0.757	0.793

		WAISTG 19	PCTRUNK 24
PCTRUNK	24	0.832	1.000

SUBSETS WITH 1 VARIABLES

R-SQUARED	ADJUSTED R-SQUARED	CP	VARIABLE	COEFFICIENT	T-STATISTIC
0.693008	0.685521	36.93			
			19 WAISTG	0.482344	9.62
			INTERCEPT	-7.38783	
0.649656	0.641111	47.66	BMI		
0.628911	0.619860	52.79	SUBSCPSF		
0.573753	0.563356	66.43	MIDAXSF		
0.569096	0.558586	67.58	ILIACSF		
0.493573	0.481221	86.26	WEIGHT		
0.478375	0.465653	90.02	ABDSF		
0.005829	-0.018419	206.90	HEIGHT		

SUBSETS WITH 2 VARIABLES

R-SQUARED	ADJUSTED R-SQUARED	CP	VARIABLE	COEFFICIENT	T-STATISTIC
0.808713	0.799148	10.31			
			5 BMI	0.942066	7.01
			8 MIDAXSF	0.433055	5.77
			INTERCEPT	-0.296173	
0.796297	0.786112	13.39	MIDAXSF WAISTG		
0.783175	0.772334	16.63	ILIACSF WAISTG		
0.760479	0.748503	22.24	BMI ILIACSF		
0.744417	0.731638	26.22	ABDSF WAISTG		
0.732768	0.719407	29.10	HEIGHT WAISTG		
0.729205	0.715665	29.98	MIDAXSF SUBSCPSF		
0.721231	0.707293	31.95	SUBSCPSF WAISTG		

0.717691	0.703576	32.83	BMI	ABDSF	
0.717429	0.703300	32.89	BMI	WAISTG	

SUBSETS WITH 3 VARIABLES

R-SQUARED	ADJUSTED R-SQUARED	CP	VARIABLE	COEFFICIENT	T-STATISTIC
0.842733	0.830635	3.90	3 HEIGHT	-0.227498	-3.39
			8 MIDAXSF	0.386580	5.22
			19 WAISTG	0.355864	7.70
			INTERCEPT	30.6591	

R-SQUARED	ADJUSTED R-SQUARED	CP			
0.824160	0.810634	8.49	BMI	MIDAXSF	WAISTG
0.820099	0.806261	9.50	BMI	ILIACSF	MIDAXSF
0.815597	0.801412	10.61	ILIACSF	MIDAXSF	WAISTG
0.815497	0.801304	10.64	HEIGHT	BMI	MIDAXSF
0.815144	0.800924	10.72	HEIGHT	WEIGHT	MIDAXSF
0.815080	0.800855	10.74	WEIGHT	BMI	MIDAXSF
0.814341	0.800060	10.92	HEIGHT	ILIACSF	WAISTG
0.813634	0.799298	11.10	BMI	ABDSF	MIDAXSF
0.813038	0.798657	11.24	BMI	MIDAXSF	SUBSCPSF

SUBSETS WITH 4 VARIABLES

R-SQUARED	ADJUSTED R-SQUARED	CP	VARIABLE	COEFFICIENT	T-STATISTIC
0.855181	0.839937	2.82	3 HEIGHT	-0.211881	-3.22
			10 ILIACSF	0.177608	1.81
			8 MIDAXSF	0.291657	3.27
			19 WAISTG	0.325986	6.81
			INTERCEPT	29.5499	

R-SQUARED	ADJUSTED R-SQUARED	CP				
0.850447	0.834704	3.99	HEIGHT	ABDSF	MIDAXSF	WAISTG
0.848821	0.832908	4.39	HEIGHT	WEIGHT	MIDAXSF	WAISTG
0.848122	0.832135	4.57	HEIGHT	BMI	MIDAXSF	WAISTG
0.846067	0.829864	5.07	WEIGHT	BMI	MIDAXSF	WAISTG

STATISTICS FOR 'BEST' SUBSET

MALLOWS' CP	2.82
SQUARED MULTIPLE CORRELATION	0.85518
MULTIPLE CORRELATION	0.92476
ADJUSTED SQUARED MULT. CORR.	0.83994
RESIDUAL MEAN SQUARE	7.185717
STANDARD ERROR OF EST.	2.680619
F-STATISTIC	56.10
NUMERATOR DEGREES OF FREEDOM	4
DENOMINATOR DEGREES OF FREEDOM	38
SIGNIFICANCE (TAIL PROB.)	0.0000

VARIABLE NO. NAME	REGRESSION COEFFICIENT	STANDARD ERROR	STAND. COEF.	T-STAT.	2TAIL SIG.	TOL-ERANCE	CONTRI-BUTION TO R-SQ
INTERCEPT	29.5499	10.4076	4.410	2.84	0.007		
3 HEIGHT	-0.211881	0.0657440	-0.203	-3.22	0.003	0.959651	0.03958
10 ILIACSF	0.177608	0.0982729	0.177	1.81	0.079	0.395619	0.01245
8 MIDAXSF	0.291657	0.0890948	0.314	3.27	0.002	0.415416	0.04084
19 WAISTG	0.325986	0.0478898	0.563	6.81	0.000	0.557870	0.17659

(e) Equation development for FM using SF's only

```
BMDP9R - ALL POSSIBLE SUBSETS REGRESSION


/INPUT TITLE IS 'REGRESSION FOR BODY COMPOSITION'.
       FILE='A:\BDYCMP2.DAT'.
       VARIABLES = 31.
       CASES=44.
       FORMAT='31F8.2'.

/VARIABLE NAMES ARE
GROUP, AGE, HEIGHT, WEIGHT, BMI, TRISF, SUBSCPSF, MIDAXSF, BICEPSF, ILIACSF,
ABDSF, THIGHSF, CALFSF, SUMSFU, SUMSFL, SUBTRI, SUM4SF, LOGSUM4, WAISTG, HIPG,
WHR, THIGHG, TRUNKFAT, PCTRUNK, STFAT, TOTFAT, STLEAN, TOTLEAN, STPCFAT,
TOTPCFAT, TOTWT.

       USE= TOTFAT, MIDAXSF, SUBSCPSF, ILIACSF, ABDSF, SUM4SF, TRISF,
BICEPSF, THIGHSF, CALFSF.
 /REGRESS

       DEPENDENT= TOTFAT.
       INDEPENDENT = MIDAXSF, SUBSCPSF, ILIACSF, ABDSF, SUM4SF, TRISF,
BICEPSF, THIGHSF, CALFSF.
/END.


NUMBER OF CASES READ. . . . . . . . . . . . . .        44
   CASES WITH DATA MISSING OR BEYOND LIMITS . .         1
      REMAINING NUMBER OF CASES . . . . . . . .        43
```

SUMMARY STATISTICS FOR EACH VARIABLE

VARIABLE	MEAN	STANDARD DEVIATION	COEFFICIENT OF VARIATION	SMALLEST VALUE	LARGEST VALUE
8 MIDAXSF	23.20000	7.20305	0.310476	6.10000	38.60000
7 SUBSCPSF	21.38023	8.19030	0.383078	4.60000	36.30000
10 ILIACSF	19.45349	6.69173	0.343986	3.50000	35.30000
11 ABDSF	32.10233	8.54925	0.266313	5.40000	48.60000
17 SUM4SF	88.37791	26.70828	0.302205	23.50000	139.50000
6 TRISF	27.58605	7.41837	0.268917	11.00000	45.20000
9 BICEPSF	19.95814	7.06035	0.353758	4.40000	34.60000
12 THIGHSF	36.52791	9.16677	0.250953	14.80000	53.00000
13 CALFSF	26.05000	8.19786	0.314697	11.30000	41.20000
26 TOTFAT	23785.85813	7033.81977	0.295714	11076.50000	42201.50000

CORRELATIONS

		MIDAXSF 8	SUBSCPSF 7	ILIACSF 10	ABDSF 11	SUM4SF 17	TRISF 6	BICEPSF 9
MIDAXSF	8	1.000						
SUBSCPSF	7	0.653	1.000					
ILIACSF	10	0.739	0.718	1.000				
ABDSF	11	0.653	0.685	0.802	1.000			
SUM4SF	17	0.747	0.917	0.867	0.790	1.000		
TRISF	6	0.652	0.788	0.748	0.698	0.929	1.000	
BICEPSF	9	0.682	0.800	0.712	0.700	0.921	0.840	1.000
THIGHSF	12	0.305	0.460	0.451	0.448	0.574	0.635	0.543
CALFSF	13	0.509	0.450	0.466	0.564	0.540	0.512	0.542
TOTFAT	26	0.624	0.776	0.650	0.645	0.875	0.834	0.916

		THIGHSF 12	CALFSF 13	TOTFAT 26
THIGHSF	12	1.000		
CALFSF	13	0.588	1.000	
TOTFAT	26	0.537	0.631	1.000

```
***  ERROR  *** COVARIANCE MATRIX OF INDEPENDENT VARIABLES IS SINGULAR.
                COMPUTATIONS CANNOT PROCEED BECAUSE THE FOLLOWING VARIABLES ARE
                (UP TO TOLERANCE) LINEAR COMBINATIONS OF THE OTHER VARIABLES.
                THESE, OR OTHER VARIABLES, NEED TO BE ELIMINATED BEFORE
                RERUNNING THIS PROGRAM UNLESS YOU SPECIFY METHOD=NONE IN THE
                REGRESSION PARAGRAPH.
   VARIABLE
  NO.     NAME

   10 ILIACSF
```

BMDP9R - ALL POSSIBLE SUBSETS REGRESSION

```
/INPUT TITLE IS 'REGRESSION FOR BODY COMPOSITION'.
       FILE='A:\BDYCMP2.DAT'.
       VARIABLES = 31.
       CASES=44.
       FORMAT='31F8.2'.

/VARIABLE NAMES ARE
GROUP, AGE, HEIGHT, WEIGHT, BMI, TRISF, SUBSCPSF, MIDAXSF, BICEPSF, ILIACSF,
ABDSF, THIGHSF, CALFSF, SUMSFU, SUMSFL, SUBTRI, SUM4SF, LOGSUM4, WAISTG, HIPG,
WHR, THIGHG, TRUNKFAT, PCTRUNK, STFAT, TOTFAT, STLEAN, TOTLEAN, STPCFAT,
TOTPCFAT, TOTWT.

       USE= TOTFAT, MIDAXSF, SUBSCPSF, ABDSF, SUM4SF, TRISF,
BICEPSF, THIGHSF, CALFSF.
 /REGRESS

       DEPENDENT= TOTFAT.
       INDEPENDENT = MIDAXSF, SUBSCPSF, ABDSF, SUM4SF, TRISF,
BICEPSF, THIGHSF, CALFSF.
/END.
```

NUMBER OF CASES READ.   44

CASES WITH DATA MISSING OR BEYOND LIMITS . . 1
REMAINING NUMBER OF CASES 43

SUMMARY STATISTICS FOR EACH VARIABLE

VARIABLE	MEAN	STANDARD DEVIATION	COEFFICIENT OF VARIATION	SMALLEST VALUE	LARGEST VALUE
8 MIDAXSF	23.20000	7.20305	0.310476	6.10000	38.60000
7 SUBSCPSF	21.38023	8.19030	0.383078	4.60000	36.30000
11 ABDSF	32.10233	8.54925	0.266313	5.40000	48.60000
17 SUM4SF	88.37791	26.70828	0.302205	23.50000	139.50000
6 TRISF	27.58605	7.41837	0.268917	11.00000	45.20000
9 BICEPSF	19.95814	7.06035	0.353758	4.40000	34.60000
12 THIGHSF	36.52791	9.16677	0.250953	14.80000	53.00000
13 CALFSF	26.05000	8.19786	0.314697	11.30000	41.20000
26 TOTFAT	23785.85813	7033.81977	0.295714	11076.50000	42201.50000

CORRELATIONS

		MIDAXSF 8	SUBSCPSF 7	ABDSF 11	SUM4SF 17	TRISF 6	BICEPSF 9	THIGHSF 12
MIDAXSF	8	1.000						
SUBSCPSF	7	0.653	1.000					
ABDSF	11	0.653	0.685	1.000				
SUM4SF	17	0.747	0.917	0.790	1.000			
TRISF	6	0.652	0.788	0.698	0.929	1.000		
BICEPSF	9	0.682	0.800	0.700	0.921	0.840	1.000	
THIGHSF	12	0.305	0.460	0.448	0.574	0.635	0.543	1.000
CALFSF	13	0.509	0.450	0.564	0.540	0.512	0.542	0.588
TOTFAT	26	0.624	0.776	0.645	0.875	0.834	0.916	0.537

		CALFSF 13	TOTFAT 26
CALFSF	13	1.000	
TOTFAT	26	0.631	1.000

SUBSETS WITH 1 VARIABLES

R-SQUARED	ADJUSTED R-SQUARED	CP	
0.838579	0.834642	12.11	BICEPSF
0.764781	0.759044	35.48	SUM4SF
0.696306	0.688899	57.16	TRISF
0.601565	0.591847	87.16	SUBSCPSF
0.415886	0.401639	145.95	ABDSF
0.397992	0.383309	151.62	CALFSF
0.389721	0.374836	154.23	MIDAXSF
0.288299	0.270940	186.35	THIGHSF

SUBSETS WITH 2 VARIABLES

R-SQUARED	ADJUSTED R-SQUARED	CP		
0.864083	0.857287	6.04	BICEPSF	CALFSF
0.852984	0.845633	9.55	TRISF	BICEPSF
0.844835	0.837077	12.13	SUM4SF	BICEPSF
0.843644	0.835826	12.51	SUBSCPSF	BICEPSF
0.840826	0.832868	13.40	BICEPSF	THIGHSF
0.838607	0.830538	14.10	ABDSF	BICEPSF
0.838580	0.830509	14.11	MIDAXSF	BICEPSF
0.800234	0.790246	26.25	SUM4SF	CALFSF
0.770366	0.758884	35.71	ABDSF	SUM4SF
0.769173	0.757632	36.09	SUBSCPSF	SUM4SF

SUBSETS WITH 3 VARIABLES

R-SQUARED	ADJUSTED R-SQUARED	CP	VARIABLE	COEFFICIENT	T-STATISTIC
0.874285	0.864615	4.81	6 TRISF	177.953	1.78
			9 BICEPSF	660.606	6.15
			13 CALFSF	150.217	2.57
			INTERCEPT	1779.24	

R-SQUARED	ADJUSTED R-SQUARED	CP			
0.868471	0.858354	6.65	SUBSCPSF	BICEPSF	CALFSF
0.867657	0.857477	6.90	SUM4SF	BICEPSF	CALFSF
0.866193	0.855900	7.37	ABDSF	BICEPSF	CALFSF
0.865513	0.855167	7.58	MIDAXSF	BICEPSF	CALFSF
0.864527	0.854106	7.90	BICEPSF	THIGHSF	CALFSF
0.853908	0.842670	11.26	SUBSCPSF	TRISF	BICEPSF
0.853881	0.842641	11.27	ABDSF	TRISF	BICEPSF
0.853608	0.842347	11.35	MIDAXSF	TRISF	BICEPSF
0.853165	0.841870	11.49	SUM4SF	TRISF	BICEPSF

SUBSETS WITH 4 VARIABLES

R-SQUARED	ADJUSTED R-SQUARED	CP	VARIABLE	COEFFICIENT	T-STATISTIC
0.879872	0.867226	5.04	11 ABDSF	-93.7022	-1.33
			6 TRISF	213.383	2.08
			9 BICEPSF	694.333	6.35
			13 CALFSF	173.133	2.87
			INTERCEPT	2539.80	
0.878405	0.865605	5.50	6 TRISF	224.316	2.08
			9 BICEPSF	650.480	6.06
			12 THIGHSF	-69.7242	-1.13
			13 CALFSF	179.341	2.82

			INTERCEPT	2490.55		
0.877466	0.864567	5.80	MIDAXSF	TRISF	BICEPSF	CALFSF
0.875600	0.862505	6.39	ABDSF	SUM4SF	BICEPSF	CALFSF
0.875340	0.862218	6.47	SUBSCPSF	TRISF	BICEPSF	CALFSF
0.874709	0.861520	6.67	SUM4SF	TRISF	BICEPSF	CALFSF
0.873179	0.859830	7.16	SUBSCPSF	ABDSF	BICEPSF	CALFSF
0.872203	0.858751	7.46	MIDAXSF	SUM4SF	BICEPSF	CALFSF
0.871551	0.858030	7.67	MIDAXSF	SUBSCPSF	BICEPSF	CALFSF
0.869039	0.855254	8.47	SUBSCPSF	BICEPSF	THIGHSF	CALFSF

SUBSETS WITH 5 VARIABLES

R-SQUARED	ADJUSTED R-SQUARED	CP	VARIABLE	COEFFICIENT	T-STATISTIC
0.885418	0.869934	5.28	VARIABLE	COEFFICIENT	T-STATISTIC
			11 ABDSF	-105.875	-1.50
			6 TRISF	272.235	2.46
			9 BICEPSF	686.867	6.34
			12 THIGHSF	-81.5849	-1.34
			13 CALFSF	210.189	3.19
			INTERCEPT	3470.91	
0.885025	0.869488	5.40	VARIABLE	COEFFICIENT	T-STATISTIC
			8 MIDAXSF	-119.684	-1.46
			6 TRISF	271.249	2.45
			9 BICEPSF	693.861	6.31
			12 THIGHSF	-99.7542	-1.56
			13 CALFSF	210.579	3.18
			INTERCEPT	3389.92	

STATISTICS FOR 'BEST' SUBSET

MALLOWS' CP	4.81
SQUARED MULTIPLE CORRELATION	0.87429
MULTIPLE CORRELATION	0.93503
ADJUSTED SQUARED MULT. CORR.	0.86461
RESIDUAL MEAN SQUARE	6698123.276117
STANDARD ERROR OF EST.	2588.073275
F-STATISTIC	90.41
NUMERATOR DEGREES OF FREEDOM	3
DENOMINATOR DEGREES OF FREEDOM	39
SIGNIFICANCE (TAIL PROB.)	0.0000

VARIABLE NO. NAME	REGRESSION COEFFICIENT	STANDARD ERROR	STAND. COEF.	T-STAT.	2TAIL SIG.	TOL-ERANCE	CONTRI-BUTION TO R-SQ
INTERCEPT	1779.24	1688.23	0.253	1.05	0.298		
6 TRISF	177.953	100.027	0.188	1.78	0.083	0.289635	0.01020
9 BICEPSF	660.606	107.447	0.663	6.15	0.000	0.277114	0.12185
13 CALFSF	150.217	58.4348	0.175	2.57	0.014	0.694960	0.02130

Appendix XIII: Regression Outputs for Final Prediction Equations

(a) EQN1-FM

Variables Entered/Removed[b]

Model	Variables Entered	Variables Removed	Method
1	MA, HT, WT[a]	.	Enter

a. All requested variables entered.

b. Dependent Variable: total fat mass in kg

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.978[a]	.956	.953	1.5326

a. Predictors: (Constant), MA, HT, WT

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1986.324	3	662.108	281.870	.000[a]
	Residual	91.610	39	2.349		
	Total	2077.934	42			

a. Predictors: (Constant), MA, HT, WT

b. Dependent Variable: total fat mass in kg

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	16.462	5.934		2.774	.008
	HT	-.231	.040	-.211	-5.735	.000
	WT	.611	.028	.953	22.156	.000
	MA	.143	.039	.146	3.674	.001

a. Dependent Variable: total fat mass in kg

(b) EQN2-%Fat

Variables Entered/Removed[b]

Model	Variables Entered	Variables Removed	Method
1	MA, HT, WT[a]	.	Enter

a. All requested variables entered.

b. Dependent Variable: PCFAT

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.922[a]	.849	.838	2.1233

a. Predictors: (Constant), MA, HT, WT

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	991.283	3	330.428	73.292	.000[a]
	Residual	175.827	39	4.508		
	Total	1167.111	42			

a. Predictors: (Constant), MA, HT, WT

b. Dependent Variable: PCFAT

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	60.122	8.220		7.314	.000
	HT	-.339	.056	-.413	-6.070	.000
	WT	.341	.038	.711	8.942	.000
	MA	.285	.054	.390	5.294	.000

a. Dependent Variable: PCFAT

(c) EQN3-TFM

Variables Entered/Removed[b]

Model	Variables Entered	Variables Removed	Method
1	WC, HT, MA, WT[a]	.	Enter

a. All requested variables entered.

b. Dependent Variable: trunk fat mass in kg

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.955[a]	.913	.904	1.2685

a. Predictors: (Constant), WC, HT, MA, WT

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	639.475	4	159.869	99.347	.000[a]
	Residual	61.149	38	1.609		
	Total	700.624	42			

a. Predictors: (Constant), WC, HT, MA, WT

b. Dependent Variable: trunk fat mass in kg

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-2.072	6.001		-.345	.732
	HT	-8.140E-02	.037	-.128	-2.185	.035
	WT	.185	.045	.497	4.153	.000
	MA	.112	.034	.198	3.289	.002
	WC	.136	.041	.386	3.289	.002

a. Dependent Variable: trunk fat mass in kg

(d) EQN4-%TF

Variables Entered/Removed[b]

Model	Variables Entered	Variables Removed	Method
1	WC, HT, MA[a]	.	Enter

a. All requested variables entered.

b. Dependent Variable: PCTRUNK

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.918[a]	.843	.831	2.7574

a. Predictors: (Constant), WC, HT, MA

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1588.977	3	529.659	69.662	.000[a]
	Residual	296.528	39	7.603		
	Total	1885.505	42			

a. Predictors: (Constant), WC, HT, MA

b. Dependent Variable: PCTRUNK

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	30.659	10.687		2.869	.007
	HT	-.227	.067	-.218	-3.393	.002
	MA	.387	.074	.416	5.222	.000
	WC	.356	.046	.614	7.697	.000

a. Dependent Variable: PCTRUNK

Appendix XIV: Descriptive Summaries for Independent Databases

Baumgartner Data for Elderly Women (n=100) (BAUM)

	AGE	WT	HT	BMI	TRI	SS	WAIST	HIP	THIGH	TOTFAT(g)	%FAT
Mean	74.47	64.84	155.92	26.66	22.62	20.68	91.87	104.05	47.83	26429.19	39.57
SD	5.59	12.63	6.81	5.03	8.35	9.60	11.66	11.41	5.61	9294.52	7.47

Brodowicz Data for Elderly Women (n=31) ($BROD_1$)

	AGE	HT	WT	TRI	BIC	SI	SS	%FAt	TOTFAT(g)
Mean	71.13	1.61	65.08	20.76	10.73	19.82	19.50	39.13	25813.87
SD	4.62	0.06	10.13	5.25	3.89	7.29	7.00	5.64	7005.63

Brodowicz Data for Younger Women (n=33) ($BROD_2$)

	Age	HT	WT	TRI	BIC	SI	SS	%Fat	TOTFAT(g)
Mean	33.39	1.66	63.48	19.61	7.80	15.73	15.18	29.56	19276.67
SD	4.72	0.07	9.35	8.84	4.83	7.80	8.65	8.95	8145.80

Appendix XV: Stepwise Multiple Regression for Modified %Fat Eqn

(a) using variables from Brodowicz study

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	SUM4SF	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).
2	BMI	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).
3	SS	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).

a. Dependent Variable: PCFAT

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.867[a]	.751	.745	2.6606
2	.901[b]	.811	.802	2.3474
3	.915[c]	.837	.824	2.2103

a. Predictors: (Constant), SUM4SF

b. Predictors: (Constant), SUM4SF, BMI

c. Predictors: (Constant), SUM4SF, BMI, SS

ANOVA[d]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	876.879	1	876.879	123.873	.000[a]
	Residual	290.232	41	7.079		
	Total	1167.111	42			
2	Regression	946.696	2	473.348	85.901	.000[b]
	Residual	220.415	40	5.510		
	Total	1167.111	42			
3	Regression	976.575	3	325.525	66.631	.000[c]
	Residual	190.535	39	4.886		
	Total	1167.111	42			

a. Predictors: (Constant), SUM4SF

b. Predictors: (Constant), SUM4SF, BMI

c. Predictors: (Constant), SUM4SF, BMI, SS

d. Dependent Variable: PCFAT

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	20.711	1.418		14.608	.000
	SUM4SF	.171	.015	.867	11.130	.000
2	(Constant)	11.548	2.862		4.035	.000
	SUM4SF	9.503E-02	.025	.481	3.755	.001
	BMI	.598	.168	.456	3.560	.001
3	(Constant)	9.819	2.784		3.527	.001
	SUM4SF	.162	.036	.818	4.496	.000
	BMI	.652	.160	.497	4.082	.000
	SS	-.261	.105	-.405	-2.473	.018

a. Dependent Variable: PCFAT

Excluded Variables[d]

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics Tolerance
1	HT	-.125[a]	-1.637	.109	-.251	.998
	WT	.166[a]	1.286	.206	.199	.357
	BMI	.456[a]	3.560	.001	.490	.287
	TRI	.250[a]	1.194	.240	.185	.137
	SS	-.314[a]	-1.641	.109	-.251	.159
	BIC	.336[a]	1.718	.093	.262	.151
	SI	-.122[a]	-.780	.440	-.122	.249
	subscap/triceps sf ratio	-.153[a]	-1.764	.085	-.269	.769
2	HT	-.066[b]	-.929	.359	-.147	.931
	WT	-.136[b]	-.934	.356	-.148	.222
	TRI	.204[b]	1.101	.278	.174	.136
	SS	-.405[b]	-2.473	.018	-.368	.156
	BIC	.145[b]	.767	.447	.122	.135
	SI	.133[b]	.851	.400	.135	.196
	subscap/triceps sf ratio	-.147[b]	-1.937	.060	-.296	.769
3	HT	-.089[c]	-1.336	.189	-.212	.915
	WT	-.193[c]	-1.410	.167	-.223	.217
	TRI	.013[c]	.067	.947	.011	.109
	BIC	-.013[c]	-.065	.948	-.011	.117
	SI	.000[c]	-.002	.999	.000	.169
	subscap/triceps sf ratio	.046[c]	.309	.759	.050	.191

a. Predictors in the Model: (Constant), SUM4SF

b. Predictors in the Model: (Constant), SUM4SF, BMI

c. Predictors in the Model: (Constant), SUM4SF, BMI, SS

d. Dependent Variable: PCFAT

(b) using variables from Baumgartner study

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	BMI	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).
2	TRI	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).

a. Dependent Variable: PCFAT

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.863[a]	.745	.738	2.6965
2	.898[b]	.807	.797	2.3722

a. Predictors: (Constant), BMI

b. Predictors: (Constant), BMI, TRI

ANOVA[c]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	868.996	1	868.996	119.514	.000[a]
	Residual	298.115	41	7.271		
	Total	1167.111	42			
2	Regression	942.009	2	471.005	83.696	.000[b]
	Residual	225.102	40	5.628		
	Total	1167.111	42			

a. Predictors: (Constant), BMI

b. Predictors: (Constant), BMI, TRI

c. Dependent Variable: PCFAT

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	5.800	2.778		2.088	.043
	BMI	1.130	.103	.863	10.932	.000
2	(Constant)	9.198	2.619		3.511	.001
	BMI	.696	.151	.531	4.608	.000
	TRI	.295	.082	.415	3.602	.001

a. Dependent Variable: PCFAT

Excluded Variables[c]

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics Tolerance
1	HT	.001[a]	.016	.987	.003	.991
	WT	.003[a]	.017	.986	.003	.237
	TRI	.415[a]	3.602	.001	.495	.363
	SS	.146[a]	1.105	.276	.172	.355
	subscap/triceps sf ratio	-.050[a]	-.579	.566	-.091	.844
	WC	.048[a]	.286	.777	.045	.228
	HC	.168[a]	1.249	.219	.194	.341
2	HT	-.027[b]	-.386	.701	-.062	.978
	WT	-.075[b]	-.518	.608	-.083	.232
	SS	-.031[b]	-.241	.811	-.039	.295
	subscap/triceps sf ratio	.007[b]	.085	.933	.014	.807
	WC	.022[b]	.150	.881	.024	.228
	HC	.043[b]	.341	.735	.055	.310

a. Predictors in the Model: (Constant), BMI

b. Predictors in the Model: (Constant), BMI, TRI

c. Dependent Variable: PCFAT