

AN ABSTRACT OF THE THESIS OF

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Title: A Comparison Between Anthropometric Regression Equations and Hydrostatic Weighing for Predicting Percent Body Fat of Adult Males with Down Syndrome

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The purpose of this study was to compare the accuracy of eight anthropometric regression equations with hydrostatic weighing for predicting the percent body fat of adult males with Down Syndrome (DS). Body fat percentages were predicted for 18 adult males with DS. Skinfold, circumference, and bioelectric impedance analysis data were collected to determine how accurately the regression equations could predict the percent fat of these individuals when compared to hydrostatic weighing. Since hydrostatic weighing involves a number of complex procedures two pilot studies were conducted.

Four subjects participated in the pilot studies. The first pilot was conducted to determine if a constant value of residual volume could be utilized during hydrostatic weighing, or if a measured value, determined by oxygen dilution, needed to be used. The second pilot was performed to determine if hydrostatic weighing at total lung capacity without head submersion could be substituted for the conventional method of hydrostatic weighing.

Paired t -tests revealed no significant differences in either pilot study, $t(3) = .274$, $p < .05$ and $t(3) = .314$, $p < .05$, respectively. Pearson product-moment correlations revealed r values of .99 for both pilot studies. Based on these results a constant residual volume value

of 1.50 L and hydrostatic weighing at total lung capacity without head submersion were the procedures utilized in the main research study.

A one-way repeated measures analysis of variance revealed a significant difference between the body fat data obtained from hydrostatic weighing and the regression equations, $F(8, 136) = 16.05$, $p < .05$. Dunnett's post-hoc procedure revealed significant differences in five of the eight equations. Of the three equations that did not yield significantly different results, only the Kelly and Rimmer (1987), $r = .89$, $SEE = 2.51$, $p < .05$, can be recommended for use.

Based on these results, it appears that a constant value of 1.50 L for residual volume and hydrostatic weighing at total lung capacity without head submersion can be utilized when predicting the percent body fat of adult males with DS. This will allow increased numbers of individuals with DS to be hydrostatically weighed. Also, the use of the Kelly and Rimmer (1987) equation will allow researchers and practitioners to utilize an easy, fast, accurate, and inexpensive method of predicting the percent body fat of adult males with DS.

A Comparison Between Anthropometric Regression
Equations And Hydrostatic Weighing For Predicting
Percent Body Fat Of Adult Males With Down Syndrome

by

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Crystal, Regina, Michael, Tina, Eva, Mike, Lucas, Daniel, thank you all.
I love you!

To my brother Daniel, whom I love with all my heart, "I give you this charge: Preach the Word; be prepared in season and out of season; correct, rebuke and encourage—with great patience and careful instruction. For the time will come when men will not put up with sound doctrine. Instead, to suit their own desires, they will gather around them a great number of teachers to say what their itching ears want to hear. They will turn their ears away from the truth and turn aside to myths. But you, keep your head in all situations, endure hardship, do the work of an evangelist, discharge all the duties of your ministry" (2 Timothy 4: 2-5).

DEDICATION

This study is dedicated to my parents, Arthur and Frances Ovalle. What they have taught me no school could ever give a degree in, no professor could lecture on. They have exhibited to me all the qualities that compose the very fiber of true human love.

If I could describe the joy that you give, you'd know why this life is worth while to live.

If you knew the comfort you bring to my pain, like the sun bursting through when the tears fall like rain.

Encouraging words during difficult trials, your tender touch that turns frowns into smiles.

It was easy to grow up with a sense of pride, every venture I took you stood close by my side.

If I could explain what involves sacrifice, there are only two words that could ever suffice.

The two words that encompass all the descriptions above, are mother and father my examples of love.

All My Love,

Steven

SALUTATION

To my Lord and Savior Jesus Christ, through whom all wisdom and knowledge are attained, I give you thanks. I could not have accomplished this with out your guidance in my life.

"For the message of the cross is foolishness to those who are perishing, but to us who are being saved it is the power of God. For it is written:

"I will destroy the wisdom of the wise;

the intelligence of the intelligent I will frustrate."

Where is the wise man? Where is the scholar? Where is the philosopher of this age? Has not God made foolish the wisdom of the world? For since in the wisdom of God the world through it's wisdom did not know him, God was pleased through the foolishness of what was preached to save those who believe. Jews demand miraculous signs and Greeks look for wisdom, but we preach Christ crucified: a stumbling block to Jews and foolishness to Gentiles, but to those whom God has called, both Jews and Greeks, Christ the power of God and the wisdom of God. For the foolishness of God is wiser than man's wisdom, and the weakness of God is stronger than man's strength"(1 Corinthians 1: 18-25).

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A Comparison Between Anthropometric Regression Equations and Hydrostatic Weighing for Predicting Percent Body Fat of Adult Males with Down Syndrome

CHAPTER 1

INTRODUCTION

One of the greatest health problems in the United States is obesity (Buskirk, 1986; Diety, 1983; Fox, Burkart, & Rotatori, 1983). The prevalence of obesity in America is well documented (Abraham, 1983, cited in Burkart, Fox, & Rotatori, 1985; Irwin, 1980). Abraham (1983) estimates that over 29 million adults in the United States between the ages of 20 and 74 years are obese. Research has shown a relationship between obesity and many health concerns such as cardiovascular disease, diabetes mellitus, pulmonary and renal problems, and surgical risk (DiGirolamo, 1986; Van Itallie, 1979).

Obesity is also prevalent in the mentally retarded (MR) population (Fox & Rotatori, 1982; Kelly, Rimmer, & Ness, 1986; Polednak & Auliffe, 1976). Obesity is much more than a health problem for the mentally retarded. Obese MR individuals become victims of increased social prejudice and nonacceptance due to the social stigma associated with being both retarded and obese. This dual handicap reduces opportunities for social interaction with nonhandicapped peers (Chumlea & Cronk, 1981; Rotatori, Switzky, & Fox, 1983).

Although the literature supports the existence of obesity as a problem among the MR population, few studies have investigated the body composition of adults with Down Syndrome (DS) (Bronks & Parker, 1985). This is surprising since DS is one of the most prevalent congenital conditions associated with mental retardation (Cronk, 1978; McIntire & Dutch, 1964). Many studies have shown that individuals with DS are shorter in stature, in both standing and sitting height, than the nonretarded population (Bronks & Parker, 1985; Rarick & Seefeldt, 1974; Roche, 1965). Although it appears that obesity is a common problem in the DS population, there is a lack of research to support this statement. Polednak and Auliffe (1976) found that 20.4% of the males in an institutionalized MR population were obese. Included in this population was a group of 11 men with DS. The DS group was separated from the MR group and the incidence of obesity in both groups was determined. It was found that 18% of the MR group was obese, while 27.3% of the DS group exhibited obesity. Although there was a large difference in sample size, 97 in the MR group and 11 in the DS group, it is easy to see why Burkart et al. (1985) stressed the importance of further studies to assess the relationship between overweight and clinical conditions (e.g. Down syndrome) associated with mental retardation.

The DS population has been shown to differ in standing and sitting height, growth rate, and body weight, when compared to the nonhandicapped population, therefore, the most important factor when classifying DS individuals as obese or overweight is the use of valid measurement tools (Burkart et al., 1985). Measurement tools used with the DS population to determine body composition, such as

height and weight tables and triceps skinfold, have exhibited poor validity and have been reported to be in error by as much as 150% (Jackson & Pollock, 1985; Katch & Micheal, 1969). Methods for determining body composition, which have been designed for the nonhandicapped population, need to be validated for the DS population. Of particular interest to this study was the use of regression equations as a measurement technique in predicting body fat percentages for adult males with DS. One cannot assume that regression equations validated with the nonhandicapped population, will be valid with the DS population. This is especially true knowing that the DS population differs in physical structure compared to the nonhandicapped population. Lohman (1981) stated, "Once an equation has been derived... it is necessary to cross validate the equations on other samples from the same and other populations to determine its general applicability" (p. 207).

Significance of the Study

Adults with DS are frequently classified as obese or nonobese using measurement procedures that have not been validated for the DS population. The validity of existing measurement techniques, specifically regression equations, need to be determined with the DS population. This is particularly important for weight reduction programs that have been designed and implemented to reduce body fat in DS individuals. This study will allow practitioners to use validated measurement tools for predicting percent body fat when

developing and implementing weight reduction programs for adult males with DS.

Statement of the Problem

The purpose of this study was to analyze eight regression equations to ascertain their ability to predict the percent body fat of adult males with DS.

Research Hypothesis

It was hypothesized that there will be statistically significant differences between hydrostatic weighing and eight regression equations in the measurement of percent body fat of adult males with DS.

Statistical Hypotheses

The following statistical hypotheses relate to the research hypothesis:

$$H_{01} : \mu_1 = \mu_2$$

$$H_{02} : \mu_1 = \mu_3$$

$$H_{03} : \mu_1 = \mu_4$$

$$H_{04} : \mu_1 = \mu_5$$

$$H_{05} : \mu_1 = \mu_6$$

$$H_{06} : \mu_1 = \mu_7$$

$$H_{07} : \mu_1 = \mu_8$$

$$H_{08} : \mu_1 = \mu_9$$

Alternative Hypotheses

$$H_{11} : \mu_1 \neq \mu_2$$

$$H_{12} : \mu_1 \neq \mu_3$$

$$H_{13} : \mu_1 \neq \mu_4$$

$$H_{14} : \mu_1 \neq \mu_5$$

$$H_{15} : \mu_1 \neq \mu_6$$

$$H_{16} : \mu_1 \neq \mu_7$$

$$H_{17} : \mu_1 \neq \mu_8$$

$$H_{18} : \mu_1 \neq \mu_9$$

Key: μ_1 = Hypothesized population mean of percent fat using the hydrostatic weighing technique.

μ_2 = Hypothesized population mean of percent fat using the Kelly and Rimmer (1987) regression equation.

μ_3 = Hypothesized population mean of percent fat using the McArdle, Katch, and Katch (1986) regression equation.

μ_4 = Hypothesized population mean of percent fat using the Lohman (1981) regression equation.

μ_5 = Hypothesized population mean of percent fat using the Jackson and Pollock (1978) regression equation.

μ_6 = Hypothesized population mean of percent fat using the Weltman and Katch (1978) regression equation.

μ_7 = Hypothesized population mean of percent fat using the Durnin and Womersley (1974) regression equation.

μ_8 = Hypothesized population mean of percent fat using
the Sloan (1967) regression equation.

μ_9 = Hypothesized population mean of percent fat using
the Lukaski, Bolonchuk, Hall, and Sinderson, (1986)
regression equation.

Operational Definitions

Mentally Retarded: "Refers to a significantly sub-average general intellectual functioning existing concurrently with deficits in adaptive behavior and manifested during the developmental period" (Grossman, 1973, p. 11). There are four different classifications and each subject was classified according to the results of intelligent quotient tests

Mild Mentally Retarded: "A term used to describe the degree of MR present when intelligence testing scores range between two and three standard deviations below the norm (52 to 68 on the Stanford-Binet and 55 to 69 on the Wechsler scales)" (Grossman, 1973, p. 11).

Moderately Mentally Retarded: "A term used to describe the degree of MR when intelligence testing scores range between three and four standard deviations below the norm (36 to 51 on the Stanford-Binet and 40 to 54 on the Wechsler scales)" (Grossman, 1973, p. 11).

Severely Mentally Retarded: "A term used to describe the degree of MR when intelligence testing scores range between four and five standard deviations below the norm (20 to 30 on the Stanford-Binet and 25 to 39 on the Wechsler scales)" (Grossman, 1973, p. 11).

Profoundly Mentally Retarded: "A term used to describe the degree of MR when intelligence testing scores are more than five standard

deviations below the norm (19 and below on the Stanford- Binet scale)" (Grossman, 1973, p. 11).

Total Lung Capacity: "The volume of air in the lungs after a maximal inspiratory effort" (Total lung capacity = vital capacity + residual volume) (Levitzky, 1986, p. 54).

Obesity: An excess of subcutaneous, nonessential fat greater than twenty percent of body weight (Craig, 1969).

Overweight: An excess of body weight relative to standards of height (Bray, 1979, cited in Burkart et al., 1985).

Hydrostatic Weighing Head Not Submerged: The submersion of a subject in a hydrostatic weighing tank up to a reference point marked on the subject. "The reference point was drawn with the aid of a level, as a horizontal line from the angle of the mandible to an area on the neck below the inferior ear and the subjects were raised and lowered accordingly"(Donnelly, Brown, Israel, Smith-Stinek, O'Brien, & Caslavka, 1988).

Bioelectrical Impedance Analysis: An electrical current, fifty HKz, introduced at a surface electrode placed on the right wrist and a surface electrode placed on the right ankle, measures resistance to the current in ohms. Important variables involved in this measurement include; amount of fat distributed throughout the body; the conductors cross-sectional area, which for a given subject is held constant; the length of the conductor, which again is held constant by the constant placement of the electrodes; frequency of the electrical current, which is held constant at fifty HKz; and strength of the signal held constant in milliamps (Maksud, 1987).

Skinfolds: All skinfold measurements were taken on the right side using the procedures described by Behnke and Wilmore (1974). Eight sites were measured (chest, forearm, calf, thigh, subscapular, biceps, triceps & suprailiac) using a Harpenden skinfold caliper measured in millimeters.

Circumference: All circumference measurements were taken on the right side using the procedures described by Behnke and Wilmore (1974) and Weltman and Katch (1978). Seven sites were measured (abdomen, chest, upper arm, forearm, buttocks, calf & thigh) using a Lufkin tape measure measuring in centimeters.

Height: A Health-O-Meter height measuring stick was used to record height measuring in inches.

Weight: Weight was recorded on a Homs full capacity beam scale measuring to the nearest 1/10th of a pound.

Definitions

Down Syndrome: "An abnormality of the 21st chromosome which results in specific physical features observed in the majority of individuals with DS" (Oseland, 1980, p. 9).

There are three types of DS.

Trisomy 21: "The presence of an extra 21st group, thus resulting in 47 chromosomes instead of 46. This type represents approximately 95 percent of the DS population" (Oseland, 1980, p. 9).

Translocation: "The presence of an extra 21st chromosome which is attached to another chromosome. The total number of chromosomes is 46 but one chromosome is actually two joined together. This type

represents approximately four percent of the DS population" (Oseland, 1980, p. 9).

Mosaic: "Some of the cells have 47 chromosomes (with the 21st group having three instead of two) while others have the normal 46. This type represents approximately one percent of the DS population" (Oseland, 1980, p. 9).

Residual Volume: "The volume of gas left in the lungs after a forced maximal expiration" (Levitzky, 1986, p. 52).

Vital Capacity: "The volume of air expelled from the lungs during a maximal forced expiration starting after a maximal forced inspiration" (Levitzky, 1986, p 54).

Mass Centroid: Center of mass (center of gravity) (DePauw, 1984).

Body Density: The density of a person is computed as body weight in (g) divided by volume of water displaced in (cc) and expressed as $\text{g} \cdot \text{cc}^{-1}$ (McArdle, Katch & Katch, 1986).

Percent Body Fat: The total amount of body fat exists in two deposit sites, essential and storage fat. The amount of storage fat in the body in relation to bone and muscle is percent body fat. Storage fat is fat found in adipose tissue, which includes fat that protects internal organs from trauma and the larger subcutaneous fat deposited beneath the skin surface (McArdle et al., 1986).

Assumptions

It was assumed that total submersion following forced maximal expiration will be too difficult for the majority of subjects to comprehend and perform.

The use of skinfolds as a method of measurement assumes that a major portion of adipose tissue is located subcutaneously throughout the body.

The use of circumference measurements as a method of measurement assumes that a major portion of adipose tissue is located subcutaneously throughout the body.

Furthermore it was assumed that the tissue densities determined from twenty five cadavers, reported in Clarys, Martin, & Drinkwater, (1984), are representative of the tissue densities found in the DS population and that the water content of lean body mass determined from six cadavers, reported in Garrow (1987), was representative of the water content of lean body mass found in the DS population.

Delimitations

This study was delimited to 18 healthy adult male individuals with DS residing in the state of Oregon. Subjects included noninstitutionalized populations, ranging in age from 18 to 50 years. The measurement of body composition included an analysis of eight regression equations normally employed with nondisabled populations. The study was delimited to those DS subjects who could perform the procedures required in this study.

Limitations

The results of this study can only be generalized to that part of the DS population that meet the same characteristics as the sample of DS subjects in this study.

CHAPTER 2

REVIEW OF LITERATURE

Introduction

The review of literature will examine the use of hydrostatic weighing as the criterion measure when indirectly determining an individual's body fat percentage. The use of anthropometric measurements, bioelectrical impedance analysis, and regression equations as valid methods of predicting percent body fat among the nonhandicapped, mentally retarded (MR) and Down syndrome (DS) populations, will also be discussed, as well as the validity of hydrostatic weighing without head submersion among the nonhandicapped population. Lastly, structural differences between the DS population and the nonhandicapped population will be explored.

Hydrostatic Weighing as the Criterion Measure

The application of Archimedes' principle, introduced by Behnke, Feen, and Welham (1942, cited in Sloan, 1967), for the determination of body density by hydrostatic weighing has gained wide acceptance. Although changes to Behnke's original design have been made, this technique is considered a standard procedure in most laboratories dealing with fitness, nutrition and weight control (Weltman & Katch, 1981). Many studies have used hydrostatic weighing as the criterion measure when comparing the validity of various anthropometric techniques used to predict body composition (Durnin & Rahaman,

1967; Katch & Katch, 1980; Katch & McArdle, 1973; Katch & McArdle, 1975; Pollock, Hickman, Kendrick, Jackson, Linnerud, & Dawson, 1976; Rimmer, Kelly, & Rosentswieg, 1987). The replicability and accuracy of hydrostatic weighing has also been discussed in detail (Durnin & Taylor, 1960; Keys & Brozek, 1953). Although hydrostatic weighing has been shown to be a valid method of measuring body composition, it does have a number of limitations. High cost, time consumption and difficulty in transporting the measuring device are some examples of the limitations associated with hydrostatic weighing. Because of these limitations hydrostatic weighing is not always practical for mass testing. Therefore, field methods feasible for mass testing using anthropometric variables and regression equations have been developed to predict body composition.

Validity of Anthropometric Measurements (Nonhandicapped)

Anthropometric variables such as height, weight, skinfold fat, body circumference, and bone diameter have been used as independent variables to determine body composition. Different aspects of body composition such as body density, lean body weight or total body volume can be estimated from anthropometric variables. According to Katch and McArdle (1975), the reasoning behind the use of such measurements is based on the high multiple correlations and low standard errors of prediction ($S_{y.x}$) found between the anthropometric measurements and the criterion measure (hydrostatic

weighing). The higher the multiple correlation and the lower the standard error of prediction, the more valid the prediction equation. Research has revealed that reported multiple correlations tend to be a function of the dependent variable used (Jackson & Pollock, 1977). Using body density as the dependent variable, multiple correlations for samples of men ranged from 0.74 to 0.89 (Brozek & Keys, 1951; Jackson & Pollock, 1977; Katch & McArdle, 1973; Pascale, Grossman, Sloan, & Frankel, 1956; Pollock et al., 1976). Using lean body weight as the dependent variable, multiple correlations were higher, ranging from 0.93 to 0.96 (Jackson & Pollock, 1976; Jackson & Pollock, 1977; Wilmore & Behnke, 1969). When total body volume was used as the dependent variable, the multiple correlations ranged from 0.88 to 0.99 (Behnke & Wilmore, 1974; Jackson & Pollock, 1977; Weltman & Katch, 1975).

Since body density, lean body weight and total body volume use different measurement units, one can not compare the standard errors. The standard error, not the multiple correlation, is the most valid index of an equations accuracy (Jackson & Pollock, 1977; Katch & Katch, 1980). Because percent body fat has a common measurement unit it can be used to evaluate equation accuracy. Jackson and Pollock (1977) examined the accuracy of percent body fat estimates derived from regression equations that used body density, lean body weight and total body volume as dependent variables. They found that the equations used to predict body density were more accurate than those used to predict lean body weight and total body volume when transformed into percent body fat. Various equations have been derived to estimate the percent body fat of an individual

from body density results. Many authors have used the Siri (1961, cited in Jackson & Pollock, 1977) or Brozek, Grande, Anderson, and Keys (1963) equation to estimate percent body fat.

Numerous studies have been done to determine which anthropometric body measurements: height, weight, skinfold, circumference or bone diameter best predict body density and percent body fat when compared to body density and percent body fat measured by hydrostatic weighing. The reported multiple correlations for published regression equations using combined anthropometric variables as independent variables are high, ranging from 0.80 to 0.99 with low standard error of estimates, ranging from .0066 to .0077 (Behnke & Wilmore, 1974; Jackson, Pollock, & Gettman, 1978; Jackson & Pollock, 1985). Other regression equations, which do not combine different anthropometric variables, have lower multiple correlations of 0.03 to 0.89 (Behnke & Wilmore, 1974; Jackson & Pollock, 1978; Jackson & Pollock, 1985; Katch & McArdle, 1973; Pollock et al., 1976). Only skinfold and circumference measurements, when not combined with other anthropometric variables, yield high multiple correlations of 0.83 to 0.89 and low standard error of estimates, ranging from .0072 to .0091 (Behnke & Wilmore, 1974, Jackson & Pollock, 1978; Jackson & Pollock, 1985; Katch & McArdle, 1973). Regression equations that use height, weight, weight/height², or bone diameters, by themselves have low multiple correlations, ranging from 0.03 to 0.69 (Behnke & Wilmore, 1974; Jackson & Pollock, 1978; Jackson & Pollock, 1985; Katch & McArdle, 1973; Wilmore & Behnke, 1969). Because of their high validity coefficients, most studies measuring percent body fat from anthropometric

measurements, use either regression equations which incorporate combined anthropometric variables or the non combined equations which use skinfold or circumference variables alone. In the past 30 years more than 100 regression equations using anthropometric variables to predict body composition in various populations have been designed (Lohman, 1981). The above multiple correlations and standard error of estimates come from equations that were designed for young and middle aged men. It is suggested that these anthropometric variables, because of their high validity coefficients, can be reliably measured because validity is a function of reliability (Safrit, 1973, p. 26).

According to Katch and Katch (1980) high reliability coefficients, test-retest greater than $r = .90$, would indicate that individual differences were present with measurement errors having an insignificantly small influence. The major concern with anthropometric measurements is reliability of test scores. Reliability can be achieved with a high degree of precision by having the same person take all the measurements, marking the sites to be measured and practice. Following these steps will reduce error and provide the most reliable anthropometric measurements (Jackson, Pollock, & Gettman, 1978; Lohman, Wilmore, Roby, & Massey, 1979; Katch & Katch, 1980). The reported test-retest reliability estimates for selected anthropometric variables are: skinfold from 0.96 to 0.99; circumference from 0.95 to 0.99; bone diameter from 0.94 to 0.99; height 0.99, and weight 0.99 (Behnke & Wilmore, 1974; Pollock et al., 1976). Thus it appears that anthropometric variables are reliable and

valid methods of measurement that can be used to estimate body composition.

Validity of Regression Equations (Nonhandicapped)

The most common procedure to determine the validity of a regression equation is to calculate the predicted score for every person in a second sample by substituting the particular anthropometric variables in the regression equation. The size of the correlation coefficient between predicted and observed scores, as well as the standard error of estimate, will give the relative validity of the regression equation (Katch & Katch, 1980). Since the concern of this study is with young and middle aged men, the focus will be on equations designed for this population. As previously stated, many regression equations have been designed in the past 30 years. Most studies using regression equations to predict body density have yielded population specific results rather than results which are predictive of body composition across various populations (Lohman, 1981). In a study of his own equation, and that of other researchers, Lohman (1981) suggested that cross validation studies be performed using equations which have high validity such as Sloan's (1967); Jackson & Pollock's (1978); Durnin & Womersley's (1974); and Lohman's (1981). Sloan's equation has been developed for young men, while the rest of the equations, though designed for men, have been developed using a generalized approach across various age groups and types of populations.

Validity of Bioelectrical Impedance Analysis (Nonhandicapped)

The bioelectrical impedance technique involves an electrical current introduced at a surface electrode placed on the right wrist and a surface electrode placed on the ankle, measuring the resistance to the current in ohms. The concept is that lean tissue and fat offer different dielectrical properties and thus resistance to the current is a function of the amount of these tissues distributed throughout the body (Maksud, 1987; Segal, Gutin, Presta, Wang, & Van Itallie, 1985). Fat, because of its low salt ion and water levels, offers high resistance to the electrical current and is a poor conductor (Maksud, 1987). Lean tissue has a higher salt ion and water level than fat, thus offers lower resistance to the current and is a better conductor (Maksud, 1987). Therefore, an electrical current passing through a person with a high percent body fat would require higher ohms to go from the wrist to the ankle electrode, than it would in a person with a lower percent body fat. According to Maksud (1987), other important variables involved in bioelectrical impedance analysis are the conductors cross-sectional area, which for a given subject is held constant; the length of the conductor, which again is held constant by the constant placement of the electrodes; and the frequency of the electrical current, which is also held constant at 50KHz. Also held constant is the strength of the signal, in milliamps.

The bioelectrical technique appears to be a reliable method for predicting percent body fat. Studies have found a test-retest correlation ranging from $r = 0.991$ to 0.996 (Colvin, Pollock, Graves, &

Braith, 1988; Jackson, Pollock, Graves, & Mahar, 1988; Katch, 1985; Lawlor, Crisman, & Hodgdon, 1985).

The validity of the bioelectrical impedance analysis technique, when compared to hydrostatic weighing, has been questioned. Validity coefficients have ranged from $r = 0.71$ to 0.93 (Colvin et al., 1988; Jackson et al., 1988; Katch, 1985; Lukaski, Bolonchuk, Hall, & Siders, 1986; Van Itallie, Segal, Yung, & Funk, 1985). Lukaski et al. (1986) reported a high correlation coefficient $r = 0.93$, and a low standard error of estimate 2.7 . Jackson et al. (1988) compared the accuracy of bioelectrical impedance, skinfold measurements and body mass index with hydrostatic weighing for predicting percent body fat of men and women. They used two different regression equations (Lukaski et al., 1986; Segal et al., 1985) to predict body fat using the bioelectric impedance method, the Jackson and Pollock (1978) skinfold regression equation and the body mass index, wt/ht^2 . The results showed that the skinfold method had the highest correlation coefficient and lowest standard error, $r = 0.92$, $SEE = 2.6$, followed by body mass index, $r = 0.75$, $SEE = 4.3$ and bioelectrical impedance analysis, $r = 0.71$, $SEE = 4.6$ for both equations. These results failed to support the results reported by Lukaski et al. (1986) and question the validity of bioelectrical impedance analysis for predicting percent body fat.

In all studies using bioelectric impedance (Colvin et al., 1988; Jackson, et al., 1988; Katch, 1985; Lawlor et al., 1985; Van Itallie et al., 1985) the standard error of estimates have been high, ranging from 2.4 to 5.08 . These studies emphasize why it is important to look past the correlation coefficients when comparing methods of

predicting percent body fat. It is the standard error, not the correlation coefficient that is the most reliable index of the methods ability to predict a body composition value (Jackson & Pollock, 1977; Katch & Katch, 1980; Maksud, 1987).

Validity of Hydrostatic Weighing Without Head Submersion (Nonhandicapped)

Research has been performed to determine a method of hydrostatic weighing that is easier for a person to perform and is as accurate in its prediction of body density as the conventional method of hydrostatic weighing at residual volume. Hydrostatic weighing at residual volume and at total lung capacity was compared, and no significant difference was found between the two methods (Weltman and Katch, 1981). Timson and Coffman (1984) found that body density and percent fat measurements by hydrostatic weighing at total lung capacity and total lung capacity measured in water, to be an acceptable alternative to hydrostatic weighing at residual volume. In this study the subjects, using a Borg scale, rated hydrostatic weighing at total lung capacity easier and more comfortable to perform than hydrostatic weighing at residual volume.

Hydrostatic weighing at total lung capacity without head submersion has recently been studied (Donnelly, Brown, Israel, Smith-Sintek, O'Brien, & Caslavka, 1988). Donnelly et al. (1988) compared hydrostatic weighing at residual volume to hydrostatic weighing at total lung capacity without head submersion. The results of their study showed that estimates of body density from hydrostatic weighing at

total lung capacity without head submersion compared very well with body density from hydrostatic weighing at residual volume. There was a correlation coefficient of $r = 0.88$ which is slightly better than those usually found when comparing body density from hydrostatic weighing at residual volume to body density determined by anthropometric equations (Pollock et al., 1976). The standard error of estimate of 0.0067 was considered to be within the normal measurement error found with hydrostatic weighing techniques, and below the normal error found using anthropometric techniques (Lohman, 1981).

The results from a cross-validation group displayed no significant differences between body density from hydrostatic weighing at residual volume and predicted body density from hydrostatic weighing at total lung capacity without head submersion. In addition to statistical non-significance, the mean differences in body fat between hydrostatic weighing at residual volume and total lung capacity without submersion (0%) was found in a practical sense to be not important. A test-retest correlation of ($r = 0.98$) compared favorably with test-retest coefficients from comparisons of hydrostatic weighing at total lung capacity (Weltman and Katch, 1981) and hydrostatic weighing at residual volume (Lohman, 1981). A Borg scale was used to determine which method the subjects found more comfortable and easier to perform. The subjects expressed a preference for the total lung capacity without head submersion method.

These results can impact heavily on future studies dealing with body composition in the MR population. It will allow the MR population to be hydrostatically weighed at total lung capacity without

head submersion thus avoiding the obvious problems associated with measuring this population at residual volume while submerged.

Validity of Anthropometric Measurements (MR)

The use of anthropometric variables to estimate overweight and obesity among the MR population is well documented (Fox & Rotatori, 1982; Kelly, Rimmer, & Ness, 1986; Polednak & Auliffe, 1976). Measurement of obesity is crucial for appropriate classification and treatment of obesity (Burkart, Fox, & Rotatori, 1985; Fox, Burkhardt, & Rotatori, 1983). However, much confusion lies in how to measure and define obesity. An example of this is the interchangeable use of the terms overweight and obesity in most of the studies involving the MR population. These terms are not synonymous. Overweight is defined as an excess of body weight relative to standards of height (Bray, 1979, cited in Burkart et al., 1985), whereas obesity refers to an excess of subcutaneous, nonessential fat (Craig, 1969). Because of this, many studies (Fox & Rotatori, 1982; Kreze, Zelina, & Gabora, 1974; Wallen & Roszkowski, 1980) using height-weight charts have labeled MR adults as obese, when the measurement tool actually measures overweight. In a study concerning the appropriate classification of obese MR adults, Fox et al. (1983) found when using the height-weight table as a measurement tool 29.5% of the males would have been misclassified as nonobese. This information, along with the low correlation between height-weight tables and hydrostatic weighing, indicates the need for a more valid method of measuring obesity in the adult MR population.

Other studies have used the measurement of triceps skinfold alone as an indicator of obesity for MR adults. The study by Fox et al. (1983) found the use of triceps skinfold alone would have misclassified 7.5% of the males as nonobese. The use of this measurement technique greatly reduced the misclassification when compared to the misclassification results from use of the height-weight tables alone. In another study Polednak and Auliffe (1976) took anthropometric measurements of triceps skinfold, upper arm circumference and height-weight and chose triceps skinfold as their best indicator of obesity. Their decision appears to be based on a review of other research which suggested the best criterion for assessing obesity included skinfold measurements at selected sites and that obesity standards based on triceps skinfold have been recommended for large field surveys and clinical work. However, Katch and Michael (1969) discovered that using the triceps skinfold measurement by itself, as an indicator of obesity, could be in error of 150% or more, causing a disservice to the measurement and classification of obese MR adults. Other studies have concluded that using triceps skinfold or height-weight tables alone as indicators of obesity may result in large errors (Fox et al., 1983; Katch & Katch, 1980; Kelly et al., 1986).

Validity of Regression Equations (MR)

In a recent study Kelly et al. (1986) used a generalized regression equation, developed by Jackson and Pollock (1978), to determine body density. Percent body fat was determined using Siri's equation (Siri, 1956, cited in Kelly et al., 1986) for predicting percent body fat. The

results of the study indicated a high incidence of obesity among the adult MR population. Although they used a regression equation that had been validated and widely used, it was validated on a different population, nonhandicapped adult males. They assumed, because it is a generalized equation which has been validated, it must also provide valid results when applied to the MR population.

Kelly and Rimmer (1987) carried this thought one step further when they developed their own regression equation and used the Jackson and Pollock (1978) equation as the criterion measure. The purpose of their study was to develop a simple equation which would give practitioners an accurate, simple and inexpensive method of estimating percent body fat for adult MR males (Kelly & Rimmer, 1987). There was an r value of 0.81, $p < .001$ and standard error of estimate of 4.41 between the Kelly and Rimmer equation and the criterion equation. Kelly and Rimmer considered this to be a low relationship for research purposes but strong for pragmatic application, due to the ease in collecting measurements and low cost of equipment. They did caution about the use of another prediction equation as the criterion measure when validating their equation and stated "a more technically sound procedure would have been to compare the Kelly and Rimmer equation to an estimate of percent body fat based on hydrostatic weighing" (Kelly & Rimmer, 1987. p. 123).

Rimmer, Kelly, and Rosentswieg (1987) followed this advice and used hydrostatic weighing as the criterion measure and compared the accuracy of six regression equations to hydrostatic weighing in predicting percent body fat in the adult MR population.

Anthropometric measurements were taken at selected skinfold and circumference sites, height and weight, and the appropriate variables were applied to the six regression equations to predict body density and percent body fat. Three of the equations, Durnin and Womersley's, (1974); Kelly and Rimmer's, (1987); and McArdle's, Katch and Katch's, (1986), predicted percent body fat, while the other three, Jackson and Pollock's, (1978); Lohman's, (1981); and Sloan's, (1967), estimated body density. The results from the body density equations were used in the Brozek, Grande, Anderson, & Keys (1963) equation to predict percent body fat. Body density as determined by hydrostatic weighing used the Brozek et al. (1963) equation to predict percent body fat.

The regression equations were ranked from best to worst predictors of percent body fat. Ranking was based on correlation, constant error and standard error of estimate, with a ranking of 1.00 as a perfect score (Rimmer et al., 1987). The results ranked as follows:

<u>COMPOSITE SCORE</u>	<u>EQUATION(males)</u>
2.00	Durnin & Womersley, 1974
2.67	Kelly & Rimmer, 1987
3.00	Jackson & Pollock, 1978
3.33	McArdle et al., 1986
4.67	Lohman, 1981
5.33	Sloan, 1967

The Rimmer et al. (1987) study is the one of the more statistically sound assessment of the accuracy of regression equations for predicting percent body fat for the adult MR population.

Validity of Bioelectrical Impedance Analysis (MR)

A review of the literature produced only one study that used the bioelectrical impedance analysis technique to predict percent body fat for the MR population (Pitetti, Fernandez, Pizarro, & Stubbs, 1988), while no studies could be found for the DS population. Pitetti et al. (1988) measured the percent body fat of 26 males and 7 females using the RJL systems bioelectrical impedance analysis and two regression equations from Jackson and Pollock (1978). Pitetti et al. (1988) compared the skinfold results to the impedance results and found only slight differences between the two. They cautioned against the use of the bioelectrical impedance analysis method because of its questionable validity for predicting percent body fat. The results from the skinfold measurements were used to predict percent body fat in this study. Caution should be taken when interpreting the results of the Pitetti et al. (1988) study because the Jackson and Pollock (1978) regression equations used in their study have been shown to consistently underestimate the percent body fat of MR adult males when compared to hydrostatic weighing (Rimmer, Kelly, & Rosentsweig, 1987).

Validity of Anthropometric Measurements (DS)

As previously stated, DS is one of the most common forms of MR, yet few studies have assessed the body composition of this population. Wallen and Roszkowski (1980), while studying the patterns of weight disorders in 149 MR adults, found only 1 of 8 subjects with DS was

overweight suggesting that this condition had little to do with the variance of overweight found in their study. Fox et al. (1983) also found that the condition of DS did not account for obesity differences found in their study. A major concern in both of these studies is that overweight and obesity were determined by height-weight tables. It has already been shown that height-weight tables correlate poorly with hydrostatic weighing as a predictor of percent body fat, $r=.69$. Also, since people with DS have been found to differ in stature compared to the nonhandicapped population (Benda, 1949; Brousseau, 1928) and in weight (Bronks & Parker, 1985), it would appear that height-weight tables are of limited value as a classification tool for overweight and obesity in this population (Burkart et al., 1985). Wallen and Roszkowski (1980) caution that the measurement tool used in their study had numerous flaws and their study should only be seen as an exploratory effort.

Polednak and Auliffe (1976) studying the body fat percentages of adult males with MR separated their subjects into two groups. The first group included all MR individuals—excluding those with DS—while the second group included only those subjects who had DS. They reported that 27.3% of the adult males with DS were obese, whereas 18% of the MR adult males—excluding the DS group—were obese. This finding appears to contradict the studies of Wallen and Roszkowski (1980) and Fox and Rotatori (1982) which suggested that the condition of DS does not have an effect on the variation of obesity in the MR population. Caution needs to be taken when interpreting the results from the Polednak and Auliffe (1976) study. The method of measurement used to predict percent body fat was the triceps skinfold

alone and this method can be in error as much as 150% or more (Katch & Micheal, 1969).

Knowing that obesity is a major health hazard and prevalent among the DS population, Rotatori, Fox, and Switzky (1979) administered a weight reduction program to 6 obese adolescence with DS. The method of measurement used to determine obesity was 20% overweight according to height-weight and age tables. As has already been shown, height-weight tables are poor predictors of obesity, particularly with the DS population, because these individuals differ in height and weight (Bronks & Parker, 1985; Burkart et al., 1985) from the nonhandicapped population on whom the height-weight tables (Robinson, 1977) were derived. Although all the subjects in the Rotatori et al. (1979) study achieved significant weight loss it is not certain that this loss was due to a fat reduction, because the measurement instrument they used is a poor indicator of body fat. The development of a sound weight reduction and maintenance program is dependent upon accurate measurements of body composition (Jackson & Pollock, 1985).

Validity of Regression Equations (DS)

In a more recent study, Bronks and Parker (1985) took anthropometric measurements of height and weight as well as selected skinfold, circumference and bone diameter of adults with DS. They used a generalized regression equation, developed by Weltman and Katch (1978), to predict the percent body fat in adults with DS. Their results were compared to percent body fat results reported for a

nonhandicapped population, which also used the Weltman and Katch (1978) equation. The results revealed an abnormally high percentage of body fat for the adult DS group when compared by gender and age to the nonhandicapped group (Bronks & Parker, 1985). Again caution must be used when interpreting these results, because the method used to predict percent body fat in the DS group has not been validated for use with this population. Also, the results of this study were compared to the results of another study, which used the same regression equation on a different population, as the criterion measure. A more statistically sound procedure would have been to correlate the results of the Bronks and Parker (1985) study to a group of adult DS subjects who had their percent body fat estimated by hydrostatic weighing.

Structural Differences with DS

Many studies have been done to determine if the DS population differ in stature compared to the nonhandicapped population. Rarick and Seefeldt (1974) studied the growth in stature and sitting height of children with DS. There were 5 to 9 children in each group with ages ranging from 7 to 12 for the boys and 6 to 11 for the girls. The age of the youngest and oldest subjects was 18 and 20 when the last measurements were taken. The study showed at all ages the means for the stature of children with DS fell more than 2 standard deviations (SD) below the means for nonhandicapped children reported from the Denver Child Research Council. These findings are in agreement with the results of other published studies (Benda, 1949; Brousseau, 1928;

Cronk, 1978; Roche, 1965). The Rarick and Seefeldt (1974) study also revealed smaller measurements in sitting height of the DS boys, though not as great as that found in the standing height. This would suggest the difference in stature can be attributed to the greater leg growth in the Denver boys, since the Denver boys grew significantly more in stature (4.8cm) than the DS boys with only a (1.5cm) difference in sitting height favoring the Denver boys. This shows an abnormal leg to trunk growth in the DS boys.

Body weight has also been studied in children with DS. Two books written for parents of children with DS have mentioned obesity as a problem associated with DS (Pueschel, 1980; Smith & Wilson, 1973). Cronk (1978) studied the weights and lengths of 90 children with DS at birth and found the means for both length and weight were .5 SD below the control group of nonhandicapped children. The finding of retarded growth in the DS population, before birth, is supported by Benda, (1949) and Brousseau (1928). Cronk (1978) also found by the age of 3 the mean lengths were more than 2 SD below the control group, while the mean weights were 1.5 SD below. Even though the DS children displayed lower weights, almost 30% of the children revealed excess weight for length at three years of age. Cronk, Chumlea and Roche (1985) using data from three previous studies, (Cronk, 1978; Rarick, & Seefeldt, 1974; Roche, 1965) reported an age-independent analysis of weight for stature in DS children. They found statistically significant larger mean weights began at statures of 105 to 110cm for boys and continued through the larger statures observed. These statures are typical for children with DS at ages 4 to 6 years old (Cronk et al., 1985).

It would appear from the available research that length and weight, at birth, for children with DS is less when compared to nonhandicapped children (Benda, 1949; Brousseau, 1928; Chumlea & Cronk, 1981; Cronk, 1978; Roche, 1965). The literature also supports the finding that abnormal growth rate in stature occurs around the age of two, so that by the age of three the mean stature of children with DS is almost 2 SD below that of nonhandicapped children (Chumlea & Cronk, 1981; Cronk, 1978). It is also apparent by approximately age three that children with DS are overweight and this condition continues up to adolescence (Chumlea & Cronk, 1981). It has been suggested that overweight and shortness of stature are characteristics of DS (Bronks & Parker, 1985; Chumlea & Cronk, 1981).

Bronks and Parker (1985) undertook a study to see if reported trends of overweight in childhood and adolescence were still evident or changed in adults with DS. The subjects were 11 males and 8 females, ranging in age between 19 and 42. The results showed the average height of males was more than 2 SD below those reported for a nonhandicapped population (Weltman & Katch, 1978), while the body weights were about 1 SD below. A somatotype assessment was performed in the Bronks and Parker (1985) study. They found that ectomorphy, which denotes linearity was largely reduced. The reason given for this result was the short stature of people with DS. Also mesomorphy, which measures lean body mass per unit height, might have been exaggerated. This occurred because the adults had exhibited an abnormal trunk to leg length relationship. Peripheral clustering of somatypes was found and attributed to the very high endomorphic assessments, which reflects a persons relative fatness.

All subjects displayed high endomorphic components with 62 percent being classified as mesomorphic-endomorph. The percent body fat values for the DS group, when compared with the nonhandicapped group by gender and age, were abnormally high. When individual body fat percentages were plotted against age for the DS group, an increase in body fat did not occur with an increase in age. However, across the whole age range, high levels of body fat were present. This led Bronks and Parker (1985) to suggest that in adults with DS the development of high percentages of body fat may begin prior to adulthood.

DePauw (1984) studied the total body and segmental centers of mass of people with DS. A photogramatic technique was used to collect data on mass centroid locations. The results showed adult males had a lower total body center of mass when compared to data on nonhandicapped adults (Hall & DePauw, 1982). In addition, for the head and trunk segment, DS adults exhibited a consistently lower segmental mass centroid than did the nonhandicapped adults. These results suggest that DS adults display an overall lowering of the center of mass (DePauw, 1984). The differences described here, along with those already reviewed, clearly show a difference in the physical structure between the adult DS population and the nonhandicapped population.

Summary

The review of the literature reveals that the use of anthropometric measurements, especially those used in combinations, and regression equations are valid measurement tools for predicting

body fat percentages in both nonhandicapped and MR populations (Behnke & Wilmore, 1974; Jackson et al. 1978; Jackson & Pollock, 1985; Lohman, 1981; Kelly & Rimmer, 1987; Kelly et al., 1986; Rimmer et al., 1987). A major concern is the lack of research on the body composition of the DS population. Considering the overwhelming research which has shown the DS population to differ in standing and sitting height, body weight, and total body center of mass (Benda, 1949; Bronks & Parker, 1985; Brousseau, 1928; Chumlea & Roche, 1985; Cronk, 1978; DePauw, 1984; Rarick & Seefeldt, 1974, Roche, 1965), it is surprising that few studies have been done on the body composition of people with DS. Methods of predicting body composition, which have been designed on the nonhandicapped population, need to be validated for the DS population. Research has yet to validate the methods of predicting percent body fat, specifically regression equations, compared to the use of hydrostatic weighing for the DS population.

Based on the review of the literature, it is apparent that there are eight regression equations which are commonly used to assess percent body fat on nondisabled populations. Table 1 provides a list of these equations.

Table 1
List of Equations Utilized

Reference	Equation
Jackson & Pollock, 1978*	$D = 1.1093800 - 0.0008267(J1) + 0.0000016(J1)^2 - 0.00025(J2)$
Lohman, 1981*	$D = 1.0982 - .00815(L1) + 0.000002574(L1)$
Sloan, 1967*	$D = 1.1043 - 0.00133(S1) - 0.00131(S2)$
Kelly & Rimmer, 1987*	$\%Fat = 13.545 + .48691649(K1) - .52662154(K2) - .15504013(K3) + .077079958(K4)$
McArdle et al., 1986 *	$\%Fat = \text{Constant A} + \text{Constant B} + \text{Constant C} - 15.0$
Durnin & Womersley, 1974*	Tables given to predict % BF from the sum of triceps, biceps, suprailliac, subscapular + age.
Lukaski et al., 1986	$BIA \text{ (ffw)} = 0.827(B1/R) + 5.214$
Weltman & Katch, 1978†	$TBV = .8719(W1) + .2629(W2) - 7.795$ $D = W1/W3$

Note: Percent fat will be predicted using the Brozek et al. (1963) equation:
 $\%fat = (4.570/Bd - 4.142) \times 100$ or $\%fat = [(wt - BIAffw)/wt] \times 100$. **D** = body density; **BIAffw** = bioelectrical impedance analysis fat free weight; **TBV** = total body volume; **J1** = sum of chest, abdomen, and thigh skinfolds; **J2** = age; **L1** = sum of triceps, abdomen, and subscapular skinfolds; **S1** = thigh skinfold; **S2** = subscapular skinfold; **K1** = abdomen circumference; **K2** = forearm circumference; **K3** = Ht(cm); **K4** = Wt(kg); **Constant A** = buttocks circumference(cm); **Constant B** = abdomen circumference(cm); **Constant C** = forearm circumference(cm); **B1** = ht(cm); **R** = resistance; **W1** = wt(kg); **W2** = thigh girth; **W3** = total body volume.

The use of these eight equations with disabled populations, including the MR(*) and DS(†), is limited. However, given their widespread use, statistical validity and gender specific predictability, validity of these equations and their ability to predict body fat for individuals with DS needs to be investigated.

CHAPTER 3

METHODS AND PROCEDURES

Introduction

The purpose of this study was to compare eight anthropometric regression equations to hydrostatic weighing for determining the percent body fat of adult males with Down Syndrome (DS). This chapter will describe how the study was conducted. Information will be presented in five sections: Subjects; Instruments and Apparatus; Procedures; Pilot Study; and Statistical Analysis.

Subjects

The subjects in this study were 18 adult males with DS who reside in a group home, alone, or with a parent or guardian in Oregon. All subjects were free from other handicapping condition not generally associated with DS (i.e., amputee) and ranged in age from 18 to 50 years old. See Table 3 (p. 57) for a list of their physical characteristics. All subjects were volunteers and signed a consent form or had it signed by a legal guardian (see appendix B). Approval to conduct this study was given by the Human Subjects Committee at Oregon State University and the Oregon State Mental Health Division (see appendix A).

A training period was conducted before collecting underwater weighing data. The hydrostatic weighing technique (Donnelly, Brown, Israel & Smith-Sintek, O'Brien, & Caslavka, 1988) was practiced by all

the subjects. The purpose of the training session was to screen the subjects and familiarize them with the technical parts of the test. Subjects who exhibited discomfort with the water or testing procedures were excluded from the study.

Pilot Studies

Two pilot studies were performed. Four subjects were selected to participate in both studies in the Human Performance Lab., at Oregon State University. See Table 2 (p. 47) for a list of the subjects' physical characteristics. The first pilot study was conducted to determine an accurate and simple method for measuring residual volume and the second, to determine an accurate and simple method of hydrostatic weighing for the subjects in this study. Because of the complexity associated with the standard methods of measurement of these two procedures, alternative methods were explored. There were no statistically significant differences between the standard methods and the alternate methods, therefore the alternate methods were used in this study.

Residual Volume

The two methods compared in the first study were an estimated measure of residual volume and a constant measure of residual volume. The residual volume procedure was performed on land using the oxygen-dilution technique, following the procedures described by Wilmore, Vodka, Parr, Girandola, and Billing (1980).

The results of the estimated measure of residual volume were then compared to a constant measure of residual volume. Residual

volume is assumed constant at 1500ml for males (Astrand, 1952, cited in Astrand & Rodohl, 1977; Donnelly et al., 1988; Lamb, 1984). A t -test was used to determine any significant difference between an estimated residual volume and the constant residual volume.

Hydrostatic Weighing

In the second pilot study, two methods of hydrostatic weighing were compared. In the first method, ten trials of hydrostatic weighing at residual volume were administered according to the procedures of Katch (1968), with the criterion score selected as the average of the last three trials.

The alternative method, hydrostatic weighing without head submersion at total lung capacity, followed the procedures of Donnelly et al. (1988). Vital capacity was determined following the procedures of Donnelly et al. (1988). Three trials of vital capacity were administered, with the highest measurement used for subsequent calculations. The estimated residual volume values determined during the pilot study were used. Total lung capacity is expressed as vital capacity + residual volume corrected to barometric temperature and pressure saturated (BTPS).

The next phase followed the procedures of Donnelly et al. (1988). The subjects were seated in the chair with the water line up to the shoulders. To assure proper placement of the head in the water during this procedure, a reference mark was drawn, with the aid of a Stanley level, model 42-824, as a horizontal line from the angle of the mandible to an area on the neck below the inferior ear. The head was rotated up or down so that the water touched the inferior surface of the chin and the reference line. The subjects were instructed to inhale maximally

and hold their breath until a reading was secured. Five trials were administered, with the criterion being the average of the three middle values. The middle three values were used in this method in an attempt to correct for experimental error which can occur if during the placement of the subject in the tank, the head is either too high or too low in relation to the reference line. Body densities from both methods were calculated using the equation of Goldman and Buskirk (1961). Body fat percentages were determined using the Brozek, Grande, Anderson, and Keys (1963) equation.

Donnelly et al. (1988) developed a regression equation to predict body density (pBd) by hydrostatic weighing (HW) at residual volume (RV) from body density (Bd) by HW at total lung capacity not submerged (TLCNS): $pBd \text{ (HW at RV)} = 0.5829 \text{ (Bd HW at TLCNS)} + 0.4059$. Paired t -tests and correlation coefficients were used to determine the difference between the means and the degree of association between the hydrostatic weighing methods. Standard deviations, standard error of estimates, and total error were also calculated.

Instruments and Apparatus

The measurements used in this study were recorded on four data sheets (see appendix C). The first sheet was used to record the skinfold measurements for each subject at nine different sites. The sites measured included the biceps, triceps, forearm, pectoralis, subscapular, suprailiac, abdomen, thigh, and calf. Included on the first sheet was age, living situation, and level of retardation. The second sheet was used to record the circumference measurements for each

subject at seven different sites. The sites measured included the upper arm, forearm, chest, waist, buttocks, thigh, and calf. Also on the second sheet, bioelectrical impedance measurements, height, weight, and residual volume measurements were recorded. The third sheet was used to record residual volume measurements. On the fourth sheet forced vital capacity, hydrostatic weight, and comments were recorded.

A description of the apparatus (equipment) used in this study including the type of equipment and its validity and reliability is given as follows:

Hydrostatic Weighing Head-Not-Submerged

A stainless steel tank with water temperature maintained between 34 and 38 degrees C was used. A chair was suspended from a Masstron Scale Inc. load cell, model ML2210, attached to a 1/4 Ton Jet mechanical crank, model 3L9250222-1. The load cell was interfaced with a Toledo scale digital screen, model 8140. A Stanely level, model 42-824 was used to draw a reference line on each subject to assure proper placement in the tank. All subjects wore a nose clip. Donnelly et al., (1988) reported high validity ($r=0.99$) and same day test-retest reliability ($r=0.99$) when comparing the use of hydrostatic weighing at residual volume with hydrostatic weighing the head not submerged for predicting percent body fat.

Residual Volume

A five-liter Collins anaesthesia bag was used to collect expired gas. The bag was filled with three to five liters of 100 percent oxygen, Industrial Welding Supply USP Medical cylinder #5989, approximating 80 to 90 percent vital capacity. The bag was closed off at one end with a standard stopcock. The other end was fitted with a Collins "T"

shaped three-way valve. A standard mouthpiece was attached to the base of the "T" valve which was open either to room air or to the breathing bag. A Beckman CO₂ Medical Gas Analyzer, model LB-2, was used to analyze the CO₂ concentration from the breathing bag. An Ametek Oxygen analyzer, model S-3A, was used to analyze O₂ concentrations from the breathing bag. Nose clips were worn by all subjects.

Vital Capacity

An Ohio Airco spirometer, model 827 was interfaced with an Apple IIe computer, model A9M108 which was interfaced with an Apple IIe Imagewriter printer, model A9MC303. A W.E. Collins Inc. breathing hose, 37 inches long and 1 inch in diameter, is connected to the spirometer at one end and to a cardboard mouthpiece, 2 10/16 inches long and 1 5/16 inches in diameter. A nose clip was worn by all subjects.

Bioelectrical Impedance Analysis

A Valhalla Scientific bioelectrical impedance analyzer, model 1990B, bio-resistance body composition analyzer was used with a Hewlett Packard Think Jet printer, model 2225D. Valhalla Scientific disposable body composition electrodes, part # EC-2, were used. The reported validity and same day test-retest reliability are, $r=0.71$ and $r=0.99$, respectively (Colvin, Pollock, Graves, & Braith, 1988) when comparing the prediction of percent body fat between hydrostatic weighing and bioelectrical impedance analysis. Valhalla Scientific Incorporated would not disclose the regression equation used in their analyzer, therefore, Colvin, Pollock, Graves & Braith (1988) used a regression equation by Lukaski, Bolonchuk, Hall, & Siders (1986).

Lukaski et al's. (1986) equation was used in this study, because Valhalla Scientific Incorporated would not disclose their equation for this research.

Skinfold Caliper

A Harpenden skinfold caliper, model 3496, was used, measurements were recorded in millimeters. The reported validity and same day test-retest reliability are, $r=0.90$ and $r=0.99$, respectively (Behnke & Wilmore, 1974; Durnin & Womersley, 1974; Pollock, Hickman, Hendrick, Jackson, Linnerud, & Dawson, 1976) when comparing the predicted percent body fat between hydrostatic weighing and skinfold measurements.

Tape Measure

A Lufkin 6ft woven tape measure, model 3176ME, was used, measurements were recorded to the nearest 1.0 centimeter. The reported validity and same day test-retest reliability are, $r=0.89$ and $r=0.99$, respectively (Behnke & Wilmore, 1974; Jackson & Pollock, 1978; Pollock et al., 1976) when comparing the predicted percent body fat between hydrostatic weighing and circumference measurements.

Weight Scale

A Homs full capacity beam scale, model 300AD, was used (measuring to the nearest 1/10 lb). The reported validity and same day test-retest reliability are, $r=0.99$ and $r=0.99$, respectively (Behnke & Wilmore, 1974; Pollock et al., 1976) when comparing the body weights obtained from an autopsy scale with those obtained using the Homs scale.

Height Stick

A Health-O-Meter height measuring stick, model 4 083 418, was used, measurements were recorded in inches. The reported validity and same day test-retest reliability for assessing height using the height stick are, $r=0.99$ and $r=0.99$, respectively (Behnke & Wilmore, 1974; Pollock et al., 1976).

Procedures

The subjects were received at the Human Performance Laboratory in the Women's Building at Oregon State University. The subjects were taken to the men's locker room where they changed into their swimming trunks. Two people, one who had 7 years experience and is certified in body composition measurement from the American College of Sports Medicine and the other, who was the coordinator of the Human Performance Laboratory at Oregon State University, performed all the skinfold measurements. The calculated reliabilities for the mean of two recorded trials for all the anthropometric measurements taken in this study, for both testers, ranged from .97 to .99. All the measurements were taken on the right side of the body according to the procedures of Behnke and Wilmore (1974). Two separate measurements were taken at each site. If a discrepancy greater than 1mm was noted among the two values, additional measurements were recorded until two measurements fell within 1mm of each other. The mean score was recorded as the actual measurement. A full series of measurements were recorded prior to the start of the second series of

measurements on each subject. This reduced the possibility of experimenter bias (Rimmer, Kelly & Rosentswieg, 1987).

After completion of the skinfold testing, the same two people conducted the circumference measurements. All measurements were taken on the right side of the body using the procedures of Behnke and Wilmore (1974). The circumferences were measured in two different series. If a discrepancy greater than 1cm was noted among the two values, additional measurements were recorded until two measurements fell within 1cm of each other. The mean measurement was recorded as the actual measurement. Height and weight measurements were recorded following completion of the circumference measurements.

The next procedure was bioelectrical impedance analysis. The same assistants took all of the measurements. The subjects were placed in a supine position on a padded table with legs apart so that the thighs did not touch. Electrode placement followed standard procedures. Current injector electrodes were placed just below the phalangeral-metacarpal joint in the middle of the dorsal side of the right hand and just below the transverse (metatarsal) arch on the superior side of the right foot. Detector electrodes were placed on the posterior side of the right wrist, mid line, with the prominent pisiform bone on the medial (fifth phalangeal) side and ventrally across the medial ankle bone of the right ankle with the foot semiflexed. Resistance (R) to the flow of a 50kHz injected current was measured on a 0-1000 ohm scale.

When the impedance testing was completed all subjects showered and dressed with assistance, as appropriate. The subjects were then

taken to the Human Performance Laboratory, where vital capacity measurements were taken. Vital capacity was determined according to the procedures of Donnelly et al. (1988). The subjects were seated and submerged in water to the shoulders. Three trials were administered, with the highest measurement used for the calculations of vital capacity.

Statistical Analysis

A comparison was made between percent body fat as predicted by the eight regression equations and that determined by hydrostatic weighing. The eight regression equations were ranked as they apply independently to the correlation coefficient, constant error, and standard error of estimate. A mean composite ranking was calculated for each equation.

A one-way analysis of variance with repeated measures was used to determine the significance of differences between the percent body fat estimated by the regression equations and the criterion measure. Significant differences in the omnibus F -test were followed by a Dunnett's post-hoc test with an alpha of .05 to determine which equation(s) were different.

According to Barcikowski and Roby (1985) the power for detecting a large effect size between any two means at an alpha level of .05 with the estimated correlation of all equations set at .50, using 18 subjects, is estimated to be between .70 and .80. This sample size estimate assumes that the dependent variables are perfectly reliable.

CHAPTER 4

RESULTS AND DISCUSSION

Introduction

The purpose of this study was to compare the accuracy of eight anthropometric regression equations to that of hydrostatic weighing for predicting the percent body fat of adult males with Down Syndrome (DS). The eight regression equations incorporated skinfold, circumference, and bioelectric impedance techniques; they were chosen for their widespread use, statistical validity, and gender specific predictability among the nonhandicapped population. The results of the study offer a more convenient tool with which practitioners and clinicians can accurately predict the percent body fat of adult males with DS, using a method of measurement other than hydrostatic weighing.

Chapter 4 consists of four sections. The first section presents the results of the two pilot studies, while discussion of each pilot study follows, in section two. Section three examines the results of the main research question, and is followed by a discussion of the main study, in section four.

Pilot Study

Results

Hydrostatic weighing requires each subject to perform a number of difficult procedures. Two procedures—the measurement of residual

volume and hydrostatic weighing with head submersion at residual volume— were assumed to be too difficult for the majority of subjects in this study to comprehend and perform. Therefore, two pilot studies were conducted before the collection of data for the main study was initiated.

The first pilot study was designed to determine whether a constant value of residual volume could be used in predicting body density and percent body fat from hydrostatic weighing or whether an actual measurement of residual volume was needed. Residual volume was assumed constant at 1.50L (Astrand, 1952 cited in Astrand & Rodohl, 1977; Donnelly, Brown, Israel, Smith-Sintek, O'Brien & Caslavka, 1988; Lamb, 1984). The estimated mean residual volume for the group was 1.55L, SD \pm .15. Residual volume was estimated using the oxygen dilution technique, following the procedures of Wilmore, Vodka, Parr, Girandola & Billing (1980). Four subjects participated in the pilot study (see Table 2 for their physical characteristics). Table 2 also presents body density and percent body fat. The statistical package SPSS-X was used to run paired *t*-tests, at an alpha level of .05, to identify any statistically significant differences between the means. Pearson product-moment correlation coefficients were employed, at an alpha level of .05, to determine the degree of association between a constant residual volume and an actual measure estimate of residual volume when used to determine percent body fat. Standard deviations and standard errors were also calculated and the results are presented in Table 2.

Table 2
Description of Subjects in Pilot Study (N = 4)

Variable	Mean	S D	S E E
Age (years)	34.3	15.6	
Weight (kg)	82.1	21.1	
Height (cm)	159.2	5.2	
Residual Volume (liters)	1.55	0.15	
Vital Capacity (liters)	2.98	0.79	
Total Lung Capacity (liters)	4.54	0.93	
Body Density Residual Volume	1.031	0.05	0.007
Body Density TLCNS*	1.032	0.013	0.008
% Body Fat Residual Volume	29.15	5.59	2.79
% Body Fat TLCNS*	28.48	6.56	3.28

*TLCNS = total lung capacity, head not submerged

The paired t -tests revealed no statistically significant differences between the use of a constant value of residual volume and the actual measurement of residual volume for determining body density and percent body fat from hydrostatic weighing $t(3) = .274$, $p < .05$ and $t(3) = .314$, $p < .05$ respectively, with an average difference of .22L. The Pearson product-moment correlation revealed a correlation of $r = .99$, $p < .05$ for both body density and percent body fat. These findings are consistent with results from Rimmer, Kelly & Rosentswieg (1987); Sinning (1974); and Wilmore (1969). These results indicate that the use of a constant value for residual volume is an acceptable alternative

to actually measuring residual volume, when determining percent body fat of adult males with DS.

The second pilot study compared two methods of hydrostatic weighing. The first method—hydrostatic weighing at total lung capacity, head not submerged—was hypothesized to provide values of body density and percent body fat similar to the values derived from the second method—hydrostatic weighing at residual volume with the head submerged (conventional method). Total lung capacity was calculated as vital capacity plus residual volume. Because the first pilot study, comparing the use of a constant residual volume to an estimated measure of residual volume, revealed no statistically significant difference when calculating body density and percent fat, a constant residual volume value of 1.50L was used for both methods of hydrostatic weighing. The statistical package SPSS-X was again used to run paired t -tests, at an alpha level of .05, to detect any statistically significant differences between the means derived from the two methods of hydrostatic weighing. Pearson product-moment correlation coefficients were employed, at an alpha level of .05, to determine the degree of association between predictions of percent body fat as determined by the two methods of hydrostatic weighing. Standard deviation and standard error were also calculated, and the results are presented in Table 2.

Paired t -tests revealed no statistically significant differences in predictions of body density and percent body fat derived from the two methods of hydrostatic weighing $t(3) = .254$, $p < .05$ and $t(3) = .282$, $p < .05$, respectively. The Pearson product-moment correlation revealed a correlation of $r = .99$, $p < .05$ for body density, and $r = .99$,

$p < .05$ for percent body fat. These findings confirm previous studies (Donnelly et al., 1988), and indicate that—when determining body density and percent fat of adult males with DS—hydrostatic weighing at total lung capacity without head submersion is an acceptable substitute for the conventional method

Discussion

There is a need for determining accurate methods of predicting percent body fat of adult males with DS. Although many studies have investigated body composition among the mentally retarded (MR) population, very little work has focused on adults with DS. Many studies have stressed that further research should assess the relationship between clinical conditions (e.g. Down Syndrome) and overweight (Burkart, Fox & Rotatori, 1985; Polednak & Auliffe, 1976). In order to determine if a particular method of predicting percent body fat is accurate, the method must be compared to hydrostatic weighing, the standard in body composition measurement. Because hydrostatic weighing involves complex procedures (i.e., measuring residual volume and head submersion at residual volume) which were assumed too difficult for the majority of adult males with DS, alternatives to these procedures were explored. The alternatives investigated in these pilot studies involved: a) a comparison of a constant value of residual volume to an actual measurement of residual volume; and b) hydrostatic weighing at total lung capacity with the head not submerged to the conventional method of hydrostatic weighing.

The results of the first pilot study indicate that a constant value of residual volume is a viable alternative to individually measuring each

subject's residual volume. This is encouraging, because it will save time and eliminate a difficult procedure for testing adult males with DS. With the nonhandicapped population, repeated measurements of residual volume, using the oxygen dilution technique, can be done in about 5 to 10 minutes. For the DS subjects in this study, by contrast, this procedure took about 20 to 25 five minutes each.

The measurement of residual volume requires that the subject perform a forced-vital-capacity maneuver—forced vital capacity is the volume of air a subject can expire following a maximal inspiration. The volume of air remaining in the lungs after a forced maximal expiration is residual volume. In other words, the amount of air that is forced out, subtracted from the subject's total lung capacity, yields the subject's residual volume. Therefore, to obtain reliable measures of residual volume, forced vital capacity must be measured consistently. This need for consistency led to questions, during the pilot studies, as to whether a true physiological measure of residual volume was obtained from the subjects. (To avoid confusion, remember that, though both forced vital capacity and residual volume were determined, residual volume—not forced vital capacity—was the measurement sought for this study, and is the measurement under discussion here.)

When estimating the residual volume of nonhandicapped individuals, certain physical features accompany a maximal expiration. Features such as redness of the face and neck, shaking, and a large inhalation following the maximal expiration can be observed. Only one of the four subjects in the pilot study demonstrated these features. By inference the others appeared to be performing a peak expiration,

instead of a maximal expiration. There are several reasons why the subjects may not have performed a maximal expiration.

First, since most of the subjects were not very physically active, they may not have possessed the ability to contract the diaphragm and abdominal muscles past the point they exhibited. Interestingly, the only subject who appeared to perform a maximal expiration was the only one who was physically active. Second, the subjects may have needed more practice performing the procedure before they were tested. The subjects had approximately 15 practice trials on four different occasions, but this may not have been enough. Because the subjects are MR, they may have needed more practice than was afforded them. Finally, the subjects may not have fully comprehended what was required of them. Even though the procedure had been demonstrated to them many times and a number of methods to help them understand the procedure were explored (i.e., "Make believe you are blowing out birthday candles," "Pretend you are blowing up a balloon," and "Pretend you are blowing bubbles under water"), this procedure may have been too difficult for the subjects to comprehend and perform. But, it is the belief of this investigator that it was a combination of these factors that may have prevented the subjects from performing a maximal expiration. It is possible that the subjects were performing a maximal expiration, and what was measured was a true indication of their residual volumes. In any case, the important thing was whether what was being measured as residual volume on land was the same as the residual volume that was still in the subjects' lungs when they were hydrostatically weighed during submersion.

This is important because the residual volume as measured on land, is a variable in an equation to determine body density, and what is measured on land should equal what is left in the lungs during hydrostatic weighing at residual volume. The equation used in this study was: $Db = BW / (BW - UWW / DW) - RV$, where Db is body density; BW is body weight; UWW is underwater weight; DW is density of water; and RV is residual volume. The measurement of residual volume is subtracted from the denominator to account for the amount of air still in the lungs during the underwater weighing procedure. This is done so that the air is not interpreted as body fat. For example, if a person who weighed 100 kg was hydrostatically weighed at residual volume, and expired the same amount of air underwater as on land (1.0 L), his underwater weight would be some value, say 2.0 kg. If, however, his on-land measurement of residual volume was 1.0 L and, when he was hydrostatically weighed he expired a value lower than the 1.0 L value, his underwater weight would be less than 2.0 kg, say 1.0 kg. Underwater weight will be less when less air is expired, because the air that remains in the lungs makes one buoyant, as does body fat, and this extra air will be interpreted as body fat. Using the examples above, if the same person was hydrostatically weighed twice and had one underwater body weight of 2.0 kg and another of 1.0 kg, yet the same measurement of residual volume (1.0 L) was subtracted for each trial, there would be a difference in body density and body fat. Body density, with an underwater weight of 1.0 kg would be about 1.0101, which corresponds to approximately 38 percent body fat. A body density with an underwater weight of 2.0 kg would be about 1.0204, which corresponds to approximately 34 percent body fat. Even

though there is a relatively small difference in body densities—1.0101 and 1.0204—this leads to a big difference in the final body fat percentages—34 percent to 38 percent—respectively. This is why it is important that the value estimated as residual volume on land match, as closely as possible, the residual volume achieved during hydrostatic weighing with head submersion.

One way to address the concern about the subjects' achievement of maximal expiration during residual volume measurements, is to determine whether a maximal effort was needed in order to obtain an accurate measurement of body density and percent body fat during hydrostatic weighing; if not, the efforts the subjects gave would be acceptable. The issue is really whether the amount of air that remains in the lungs during hydrostatic weighing at residual volume is the same as that left in the lungs during the measurement of residual volume on land. This can only be determined by measuring residual volume during hydrostatic weighing. It was not possible to obtain this measure with the subjects in this study.

One way of estimating whether the subjects achieved the same residual volume value is to check for individual consistency in underwater weight during hydrostatic weighings at residual volume. If there were differences in an individual's underwater weight, that would indicate that the subject was leaving varying amounts of air in the lungs during underwater weighings, and, therefore, was not providing a consistent measurement of residual volume. This was not the case. All subjects demonstrated minimal fluctuations in underwater weight. Although this does not indicate that the same residual volume values were achieved on land as during hydrostatic

weighing, it does indicate that the subjects were expiring the same amount of air during each trial. Another way of estimating if the subjects were achieving the same residual volume measurements is to conduct a test-retest reliability comparison of each subjects' vital capacity. If the reliability is high, the vital capacity efforts are consistent, and this suggests the subjects would have consistent residual volume values. The reliabilities were high, yielding an R value of .99. This helps support the belief that the subjects were achieving similar residual volume values on land as during hydrostatic weighing. In both situations, the subjects demonstrated very little ability to expire forcefully for any extended time before they began to inhale. The important factor is to obtain residual volume measurements on land which are as close as possible to those during underwater weighing; the subjects in this study appeared to have achieved that criteria.

The results of the second pilot study indicated that the use of hydrostatic weighing at total lung capacity with the head not submerged, is an acceptable alternative to the conventional method of hydrostatic weighing. This is an important finding, because it will save time when hydrostatically weighing adult males with DS. The conventional method requires 10 trials, while the alternative method requires only five. The conventional method takes about 40 minutes to complete, whereas the alternative method takes only approximately 15 minutes. Another important factor is the ease in performing the alternative method, compared with the conventional method. The conventional method requires the subject to submerge the head and then to expire maximally and stay underwater until a stable

measurement of underwater weight can be secured. This is a difficult maneuver for nonhandicapped individuals to comprehend and perform, and is even more so for MR individuals. The alternative method requires only that the subject keep the head above water, take a maximal inhalation, and hold that until a stable, underwater weight can be secured. Each subject who participated in the pilot study stated that the alternate hydrostatic weighing procedure was easier to perform.

The results of both pilot studies will allow alternate methods of measuring residual volume and hydrostatic weighing to be used when testing adult males with DS. These alternate methods will save testing time and enable more individuals—who may not have been able to perform the more difficult, conventional methods—to participate in research involving the body composition of adult males with DS, without sacrificing the accuracy of the measurements. It should be noted that—even with these easier, alternate methods—there are still many individuals with mental retardation who can not comprehend and perform the required maneuvers.

The results of these pilot studies indicate that no statistically significant differences exist between: A) the use of a constant value of residual volume and an actual measurement of residual volume; and B) hydrostatic weighing at total lung capacity with the head not submerged and the conventional method of hydrostatic weighing, when determining body density and percent body fat. Yet, some caution needs to be taken when interpreting these results. A small number of subjects (four) participated in the pilot study and these subjects were not randomly selected. This raises a question of

statistical power. With four subjects in the pilot study, the power of the study was low. This increases the chance of committing a Type II error. Due to the complexity of the procedures in both pilot studies, screening of the four subjects was performed to assure success in obtaining the necessary measurements. The complex procedures also limited the numbers of available subjects for the pilot study. It is possible, therefore, that these subjects may not truly represent the adult male DS population, and that a selection of another group might yield different results.

The screening of the pilot study subjects assured the selection of individuals who were capable of performing the necessary procedures. During the selection of subjects for the pilot study, a good representation of the different levels of mental retardation and body fat percentages was desired. If this were accomplished it would be an indication that the subjects who were chosen for the pilot study were representative of the sample of adult males with DS used in the main study. This, along with the results of the two pilot studies which revealed high correlations and low standard errors, should reduce some of the concerns about the small numbers of subjects in the pilot study.

The selection of the four subjects included one individual with mild MR, two with moderate MR, and one with severe MR. The subjects also displayed a wide variety of body fat percentages as determined by hydrostatic weighing at residual volume. The subjects were measured at 21.7, 28.0, 33.4 and 33.5 percent body fat. Upon examining the percent body fat of all 18 subjects, one individual in the pilot study had the highest (33.5) and one had the lowest (21.7) body

fat percentages of the whole group. Thus, when the body fat results and mental retardation levels of the pilot study group were compared to those of all 18 subjects, the pilot study group appeared to be a good representation of all the subjects in the main study.

Based on the results of the two pilot studies, a constant residual volume value of 1.50 L was used for all subjects in the main study. Also, the use of hydrostatic weighing at total lung capacity without head submersion was the method employed to calculate body density of all subjects in the main study.

Validation of Regression Equations

Results

It was hypothesized that there would be no statistically significant differences between hydrostatic weighing and eight regression equations in the measurement of percent body fat of adult males with (DS). Eighteen subjects volunteered for this study. See Table 3 for a list of their physical characteristics. The statistical package SPSS/PC+V4.0 (Norusis, 1990) was employed to determine same day test-retest correlations for skinfold, circumference, bioelectric impedance, vital capacity, and hydrostatic weighing at total lung capacity without head submersion measurements. There were nine skinfold sites measured which included: biceps, triceps, forearm, pectoralis, subscapular, suprailiac, thigh, calf, and abdomen. The resulting R values for all sites was .99 except the pectoralis, which yielded an R value of .97. There were seven circumference sites measured which included: upper arm, forearm, chest, waist, buttock,

thigh, and calf. The resulting R values for all sites was .99. The resulting R values for the bioelectric impedance, vital capacity, and hydrostatic weighing measurements were all .99. Table 3 provides the means and standard deviations of all the measurements.

Table 3

Anthropometric Characteristics of Subjects in Main Study ($n = 18$)

<u>Variable</u>	<u>Mean</u>	<u>S D</u>	<u>Max Value</u>	<u>Min Value</u>
Skinfold (mm)				
Biceps	7.02	2.07	21.4	4.0
Triceps	13.87	4.27	23.6	6.0
Forearm	6.52	2.26	11.7	4.0
Pectoralis	15.98	6.01	25.0	7.4
Subscapular	26.52	10.09	42.8	11.2
Suprailliac	15.78	9.83	41.8	6.8
Thigh	28.68	9.04	52.8	16.2
Calf	9.77	4.28	14.8	4.6
Abdomen	20.51	8.09	35.4	8.8
Circumferences (cm)				
Upper arm	29.9	3.9	42.5	24.0
Forearm	26.6	2.5	33.5	22.5
Chest	92.3	7.5	115.5	81.0
Waist	92.0	10.8	117.0	74.2
Buttock	97.1	10.4	127.0	85.0
Thigh	54.5	6.2	69.0	46.3
Calf	35.5	3.3	44.5	31.3
Body Density	1.0415	0.0119	0.0202	0.0681
Body Fat (%)	24.6	0.50	33.7	14.0
Age (years)	38.5	12.3	50.0	18.0
Weight (kg)	79.4	17.8	109.9	50.7
Height (cm)	155.1	6.3	165.1	141.0
Vital Capacity (liters)	2.57	0.64	3.43	1.81
Bioelectric Impedance (ohms)	395.3	97.6	487.0	294.0

It should be noted that, although there were very high reliabilities for the skinfold measurements, this method required a series of measurements (five to eight) before the measurements fell into the acceptable range of variability for this procedure. All other procedures in this study required three series of measurements before

acceptable measurements were secured. The reason for this may have been that individuals with DS exhibit extreme hypotonia and this, along with excess body fat, made it difficult for the testers to determine fat from muscle. Since skinfolding requires the tester to "pinch" the body fat away from the underlying muscle, extreme hypotonia would make this task more difficult.

Descriptive statistics were calculated by the computer package SPSS-X to determine the mean, range, standard deviation, and frequency distribution of the measurements derived from each equation. A one-way analysis of variance (ANOVA) with repeated measures of percent body fat was run on the computer package SPSS-X and verified by SAS. The ANOVA was run to determine the significance of differences between the eight regression equations and the criterion measure (hydrostatic weighing) of percent body fat. The omnibus F -test revealed a significant difference between the data obtained from the hydrostatic weighing technique and the regression equations, $F(8, 136) = 16.05, p < .05$.

Mauchly's test for sphericity was performed on the computer package SPSS-X to determine whether the assumption of sphericity had been violated. The result revealed that the assumption had been violated, which increased the chances of Type I errors. In order to offset the possibility of increased Type I errors, the Geisser-Greenhouse conservative F -test was calculated. This test adjusted the F -value upward, to 1 and $1/n-1$ degrees of freedom. Even with the conservative F -value, there was still a statistically significant difference between the data obtained from the hydrostatic weighing technique and the eight regression equations. Therefore a Dunnett's t post-hoc

test was performed to determine which of the equations were significantly different from the criterion measure (hydrostatic weighing). The critical value was $t_{D1} = 2.38$, ($p < .05$). The Dunnett's t post-hoc was selected because it was not extremely conservative, nor was it extremely liberal. It fell in between the two extremes.

Jackson and Pollock (1978)

This regression equation utilizes a number of constant values, measured variables from the sum of three skinfold sites, age, height, and weight. A frequency histogram for this population revealed a normal distribution, with a maximum percent body fat value of 27.4 and a minimum value of 11.8. The mean value was 19.6 percent with a $SD = \pm 4.98$. The Pearson product-moment correlation revealed a correlation of $r = .57$, ($p < .05$) between this equation and hydrostatic weighing.

This regression equation produced measurements which differed to a statistically significant degree from results produced using hydrostatic weighing for determining the percent body fat of adult males with DS, $t_{D1} = 3.21$, ($p < .05$). A regression analysis revealed a standard error of estimate (SEE) of 4.21 and $R^2 = .33$. These results led to the rejection of the null hypothesis in favor of the alternative hypothesis.

Lohman (1981)

This regression equation utilizes a number of constant values and measured variables from the sum of three skinfold sites. A frequency histogram for this population revealed a normal distribution, with a maximum percent body fat value of 30.9 and a minimum value of 9.6. The mean value was 20.3 percent with a $SD = \pm 6.94$. The Pearson

product-moment correlation revealed a correlation of $r = .55$, ($p < .05$) between this equation and hydrostatic weighing.

This regression equation produced measurements which differed to a statistically significant degree from results produced using hydrostatic weighing for determining the percent body fat of adult males with DS, $t_D^1 = 2.72$, ($p < .05$). A regression analysis revealed an SEE of 5.99 and $R^2 = .30$. These results led to the rejection of the null hypothesis in favor of the alternative hypothesis.

Sloan (1967)

This regression equation utilizes a number of constant values and measured variables from two skinfold sites. A frequency histogram for this population revealed a normal distribution, with a maximum percent body fat value of 45.0 and a minimum value of 14.3. The mean value was 30.12 percent with a $SD = \pm 10.05$. The Pearson product-moment correlation revealed a correlation of $r = .498$, ($p < .05$) between this equation and hydrostatic weighing.

This regression equation produced measurements which differed to a statistically significant degree from results produced using hydrostatic weighing for determining the percent body fat of adult males with DS, $t_D^1 = 3.52$, ($p < .05$). A regression analysis revealed an SEE of 8.98 and $R^2 = .248$. These results led to the rejection of the null hypothesis in favor of the alternative hypothesis.

Kelly and Rimmer (1987)

This regression equation utilizes a number of constant values, measured variables from two circumference sites, height, and weight. A frequency histogram for this population revealed a normal distribution, with a maximum percent body fat value of 35.4 and a

minimum value of 16.2. The mean value was 30.12 percent with a SD = ± 5.31 . The Pearson product-moment correlation technique revealed a correlation of $r = .889$, ($p < .05$) between this equation and hydrostatic weighing.

This regression equation produced measurements which did not differ to a statistically significant degree from results produced using hydrostatic weighing for determining the percent body fat of adult males with DS, $t_D^1 = .46$, ($p < .05$). A regression analysis revealed an SEE of 2.51 and $R^2 = .789$. These results led to the failure to reject the null hypothesis.

McArdle, Katch & Katch (1986)

This regression equation utilizes a number of constant values and measured variables from three circumference sites. A frequency histogram for this population revealed a normal distribution, with a maximum percent body fat value of 40.8 and a minimum value of 16.2. The mean value was 26.61 percent with a SD = ± 7.26 . The Pearson product-moment correlation revealed a correlation of $r = .77$, ($p < .05$) between this equation and hydrostatic weighing.

This regression equation produced measurements which did not differ to a statistically significant degree from results produced using hydrostatic weighing for determining the percent body fat of adult males with DS, $t_D^1 = 1.27$, ($p < .05$). A regression analysis revealed an SEE of 4.75 and $R^2 = .596$. These results led to the failure to reject the null hypothesis.

Durnin and Womersley (1974)

This regression equation utilizes the sum of four skinfold sites and age. A frequency histogram for this population revealed a normal

distribution, with a maximum percent body fat value of 32.0 and a minimum value of 16.2 fat. The mean value was 24.92 percent with a $SD = \pm 4.86$. The Pearson product-moment correlation revealed a correlation of $r = .66$, ($p < .05$) between this equation and hydrostatic weighing.

This regression equation produced measurements which did not differ to a statistically significant degree from results produced using hydrostatic weighing for determining the percent body fat of adult males with DS, $t_D^1 = .19$, ($p < .05$). A regression analysis revealed an SEE of 3.75 and $R^2 = .439$. These results led to the failure to reject the null hypothesis.

Lukaski, Bolonchuk, Hall & Siders (1986)

This regression equation utilizes a number of constant values, measured variables of height and bioelectric resistance. A frequency histogram for this population revealed a normal distribution, with a maximum percent body fat value of 36.6 and a minimum value of 4.7. The mean value was 17.34 percent with a $SD = \pm 7.55$. The Pearson product-moment correlation revealed a correlation of $r = .63$, ($p < .05$) between this equation and hydrostatic weighing.

This regression equation produced measurements which differed to a statistically significant degree from results produced using hydrostatic weighing for determining the percent body fat of adult males with DS, $t_D^1 = 4.84$, ($p < .05$). A regression analysis revealed an SEE of 6.05 and $R^2 = .396$. These results led to the rejection of the null hypothesis in favor of the alternative hypothesis.

Weltman and Katch (1978)

This regression equation utilizes a number of constant values, measured variables of one circumference site, weight, and total body volume. A frequency histogram revealed a normal curve with a maximum percent body fat value of 43.7 and a minimum value of 20.8. The mean value was 29.76 percent with a $SD = \pm 5.99$. The Pearson product-moment correlation revealed a correlation of $r = .13$, ($p < .05$) between this equation and hydrostatic weighing.

This regression equation produced measurements which differed to a statistically significant degree from results produced using hydrostatic weighing for determining the percent body fat of adult males with DS, $tD^1 = 3.29$, ($p < .05$). A regression analysis revealed an SEE of 6.13 and $R^2 = .016$. These results led to the rejection of the null hypothesis in favor of the alternative hypothesis.

The results show that the regression equations utilized in this study, taken as a group, did not yield accurate estimates of percent body fat. The estimates produced by five of the eight regression equations differed to a statistically significant degree when compared to the equation employing the hydrostatic weighing technique for predicting the percent body fat of adult males with DS. These equations were Jackson and Pollock (1978), Lohman (1981), Sloan (1967), Lukaski et al. (1986), and Weltman and Katch (1978). The other three equations—Kelly and Rimmer (1987), McArdle et al. (1986), and Durnin and Womersley (1974)—yielded no statistically significant differences when compared to hydrostatic weighing. A comparison of the body fat equations is presented in Table 4.

Table 4

Comparison of Regression Equations with Hydrostatic Weighing

Equation	%Fat	SD	Correlation	Constant	SEE Error†	Ave. Error
Hydrostatic	24.63	4.99				
Jackson & Pollack* (1978)	19.62	4.98	.57	-5.01	4.21	1.22
Lohman* (1981)	20.39	6.94	.55	-4.24	5.99	1.03
Sloan* (1967)	30.12	10.05	.50	5.49	8.89	1.33
Kelly & Rimmer (1987)	25.35	5.31	.89	.72	2.57	.17
McArdle et al. (1986)	26.61	7.26	.77	1.98	4.75	.48
Durnin & Wommersely (1974)	24.94	4.86	.66	.29	3.75	.07
Lukaski et al.* (1986)	17.34	7.55	.63	-7.29	6.05	1.77
Weltman & Katch* (1978)	29.76	5.99	.13	5.13	6.13	1.24

Note: †Criterion mean score minus predicted mean score

*Statistically significantly different when compared to hydrostatic weighing for predicting percent body fat

Three of the statistically different equations consistently underestimated the percent of body fat. They were Jackson and Pollock (1978), Lohman (1981), and Lukaski et al. (1986). The other two equations which were significantly different—Sloan (1967) and Weltman and Katch (1978)—consistently overestimated the percent of body fat. All three equations not significantly different from hydrostatic weighing (Durnin & Wommersely, 1974; Kelly & Rimmer,

1987; McArdle et al., 1986) predicted slight overestimations of percent body fat.

The variables listed in Table 4 were used to rank-order the body composition equations for their accuracy in predicting percent body fat. The equations were rank-ordered, using the formula of Kelly et al. (1987), as they applied independently to the correlation coefficient, constant error, average error, and standard error of estimate. The factors utilized in this formula are evenly weighted, though error is accounted for three times in the formula. Each equation was given a mean rating with a mean rating of 1.00 denoting a perfect score. Table 5 presents the results of the rank ordering.

Table 5.
Rank Order of Regression Equations

<u>Equations</u>	<u>Mean Rank</u>
Kelly & Rimmer (1987)	1.50
Durnin & Womersley (1974)	1.75
McArdle et al. (1986)	3.00
Jackson & Pollock (1978)	4.50
Lohman (1981)	4.75
Lukaski et al. (1986)	6.50
Weltman & Ketch (1978)	6.75
Sloan (1967)	7.25

Note: A ranking of 1.00 denotes a perfect score. Ranking based on correlation, constant error, average error, and standard error of estimate

According to the results of the ranking procedure, the top three equations were those that did not differ significantly from the hydrostatic equation. The equation of Kelly and Rimmer (1987) was the best predictor of percent fat when compared to hydrostatic

weighing, followed by the equation of Durnin and Womersley (1974) and McArdle et al. (1986), respectively. Interestingly, these results are similar to the results of Dunnett's t post-hoc test. With a critical value of $t_{D^1} = 2.38$ ($p < .05$), the only equations not significantly different were: Durnin and Womersley (1974), $t_{D^1} = .19$, ($p < .05$); Kelly and Rimmer (1987), $t_{D^1} = .46$, ($p < .05$); and McArdle et al. (1986), $t_{D^1} = 1.27$ ($p < .05$).

Discussion

The purpose of this study was to compare eight regression equations to hydrostatic weighing for predicting the percent body fat of adult males with DS. Most individuals with DS continue to be classified as obese or nonobese using measurement tools that lack validation. Body composition measurement techniques, specifically those that make use of regression equations, must be validated with the DS population.

The results of this study revealed that the equations of Kelly and Rimmer (1987), Durnin and Womersley (1974), and McArdle et al. (1986) appear to be the best predictors of body fat for the adult male DS population. Interestingly, two of these equations, Kelly and Rimmer (1987) and McArdle et al. (1986), used circumference measuring techniques, while the Durnin and Womersley (1974) equation employed skinfold variables. Compared with the equations utilizing skinfold variables, the Durnin and Womersley (1974) equation required the most sites to be measured (four). The subjects in this study exhibited extreme hypotonia, so the accuracy of the Durnin and Womersley equation may be due to the fact that more skinfold sites are needed in the regression equation in order to obtain nonsignificant

differences in the estimates of body fat percentage when compared with the results of hydrostatic weighing.

The extreme hypotonic condition of the subjects in this study may have been a contributing factor for the large variances found with the equations that incorporated skinfold measurements. Four skinfold equations were utilized in this study (Durnin & Womersely, 1986; Jackson & Pollock, 1978; Lohman, 1981; Sloan, 1967). The only equation not significantly different from hydrostatic weighing for predicting percent body fat was the Durnin and Womersely (1986) equation. Because skinfold measures requires the tester to "pinch" body fat away from underlying muscle tissue, extreme hypotonia would make this a difficult task. This condition, combined with the high percent body fat exhibited by the subjects in this study, increases the difficulty of a delicate procedure.

Three circumference equations (Kelly & Rimmer, 1987; McArdle et al., 1986; Weltman & Katch, 1978) were utilized in this study. The Weltman & Katch (1978) equation was significantly different from hydrostatic weighing when predicting percent body fat. This equation only incorporated one circumference measurement (thigh) and more sites may need to be measured in order to achieve a more accurate prediction of percent body fat.

According to the results of this study the Kelly and Rimmer (1987) equation was the best predictor of percent body fat—for adult males with DS—when compared with hydrostatic weighing. It was interesting to note that measurements of height and weight were incorporated in this equation. It has been argued that equations that utilize measures of height and weight in the prediction of percent

body fat may be in error. Since, individuals with DS have been shown to differ in both height and weight when compared to the nonhandicapped population, then one would think that the Kelly and Rimmer (1987) equation would be a poor predictor of percent body fat for these individuals. This did not happen in this study.

The Kelly and Rimmer (1987) equation was the only equation, in this study, that was developed utilizing mentally retarded subjects. Some of the subjects in the Kelly and Rimmer (1987) study had DS and the development of the Kelly and Rimmer equation would have been influenced by the measurements of height and weight from these subjects. This may help explain why the Kelly and Rimmer (1987) equation had a high correlation $r = .89$ and low SEE = 2.51—when compared to hydrostatic weighing for predicting the percent body fat of adult males with DS—even though measurements of height and weight were utilized in this equation. The use of bioelectrical impedance analysis as a method of predicting percent body fat was explored through the Lukaski et al. (1986) equation. This equation exhibited a significant difference when compared to hydrostatic weighing. One reason for this difference may have been that this equation utilizes the measurement of height. Research has shown that individuals with DS are two standard deviations below their nonhandicapped peers in height (Chumlea & Cronk, 1981; Cronk, 1978). If the Lukaski et al. (1986) equation utilized normative height values from nonhandicapped populations in the design of the equation, this would account for some of the unexplained variance.

Some of the other unexplained variance may be that one or more of the assumptions from Chapter I may have been violated. The use of

skinfolds and circumferences as methods of measuring percent body fat assumes that body fat is evenly distributed through out the body. Another assumption was that tissue densities, determined from twenty cadavers, were representative of the tissue densities found in the DS population. The final assumption was that water content of lean body mass, as determined from six cadavers, was representative of the water content of lean body mass found in the DS population. These assumptions may not hold true for individuals with DS. This would have a direct effect on the correlations between the eight regression equations and hydrostatic weighing when predicting the percent body fat of adult males with DS.

A major concern when attempting to measure the body composition of individuals with DS is whether the individual being measured perceives the chosen technique to be physically intrusive. Bioelectric impedance analysis was the method least intrusive to the individuals in this study. Subjects, lying down with electrodes attached to their hands and feet appeared very relaxed. This procedure caused no physical discomfort. The circumference technique was the next-least imposing. Subjects appeared only slightly concerned during the initial series of measurements. After the first series, the subjects were no longer concerned about the taking of measurements. The skinfold technique caused the greatest amount of anxiety. Each subject exhibited some discomfort during these measurements, which resulted in the need for constant reassurance. Thus, measures of skinfold were the most time-consuming compared with the other two techniques.

Another concern is the amount of time needed to complete testing with each subject. Of the three techniques, bioelectric impedance analysis was the quickest to administer, averaging approximately five minutes; circumference measurements took approximately ten minutes; and measures of skinfold averaged thirty minutes per subject. A minimum of two trials were performed for each procedure. Although the nine skinfold sites and the eight circumference sites would account for some of the longer time it took to secure reliable measurements, it was obvious that most of the extra time during the skinfold procedure was spent reassuring the individuals that everything was all right. Even though measures of skinfold caused some anxiety, none of the subjects asked to stop the testing, nor did they accept invitations from the testers to terminate the tests. All expressed a desire to complete the testing, regardless of the discomfort.

When deciding which measuring technique to employ in predicting the percent fat of adult males with DS, one should consider the amount of time it takes to complete a series of measurements, how physically imposing a particular technique may be, and the accuracy of the technique. There is limited information available concerning the body composition of adult males with DS, especially where hydrostatic weighing is employed. The results of this study will be helpful to researchers and practitioners interested in viable measurement techniques and accurate regression equations for predicting the percent body fat of adult males with DS.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

Introduction

More than one hundred regression equations have been designed over the past thirty years using anthropometric variables to predict body composition in various populations (Lohman, 1981). Many studies have investigated the body composition of adults with mental retardation (Fox, Burkhart & Rotatori, 1983; Kelly & Rimmer, 1987; Kelly, Rimmer & Ness, 1986; Kelly, Rimmer & Rosentswieg, 1987). Very little, however, has been reported concerning the body composition of adults with Down Syndrome (DS) (Bronks & Parker, 1985). Since DS is the most frequent congenital condition associated with mental retardation (MR), there is good reason to investigate accurate methods of predicting the body composition of adults with DS.

The purpose of this study was to compare the accuracy of eight anthropometric regression equations with hydrostatic weighing for predicting the percent body fat of adult males with Down Syndrome (DS). Body fat percentages were predicted for 18 adult males with DS. Skinfold, circumference, and bioelectric impedance analysis data were collected to determine how accurately the regression equations could predict the percent fat of these individuals when compared to hydrostatic weighing. Since hydrostatic weighing involves a number of complex procedures two pilot studies were conducted.

Four subjects participated in the pilot studies. The first pilot was conducted to determine if a constant value of residual volume could be utilized during hydrostatic weighing, or if a measured value, determined by oxygen dilution, needed to be used. The second pilot was performed to determine if hydrostatic weighing at total lung capacity without head submersion could be substituted for the conventional method of hydrostatic weighing.

Paired t -tests revealed no significant differences in either pilot study, $t(3) = .274$, $p < .05$ and $t(3) = .314$, $p < .05$, respectively. Pearson product-moment correlations revealed r values of .99 for both pilot studies. Based on these results a constant residual volume value of 1.50 L and hydrostatic weighing at total lung capacity without head submersion were the procedures utilized in the main research study.

A one-way repeated measures analysis of variance revealed a significant difference between the body fat data obtained from hydrostatic weighing and the regression equations, $F(8, 136) = 16.05$, $p < .05$. Dunnett's post-hoc procedure revealed significant differences in five of the eight equations. Of the three equations that did not yield significantly different results, only the Kelly and Rimmer (1987), $r = .89$, $SEE = 2.51$, $p < .05$, can be recommended for use.

Based on these results, it appears that a constant value of 1.50 L for residual volume and hydrostatic weighing at total lung capacity without head submersion can be utilized when predicting the percent body fat of adult males with DS. This will allow increased numbers of individuals with DS to be hydrostatically weighed. Also, the use of the Kelly and Rimmer (1987) equation will allow researchers and

practitioners to utilize an easy, fast, accurate, and inexpensive method of predicting the percent body fat of adult males with DS.

Findings

It was found, based on the results of this study, that the Kelly and Rimmer (1987) regression equation is the best predictor of percent body fat when compared with hydrostatic weighing for adult males with DS. This finding is encouraging for a number of reasons. First, prediction of percent body fat derived from this equation was not significantly different from those derived from hydrostatic weighing, and had a correlation coefficient of $r = .89$ and a standard error of estimate of 2.51. Second, the equation requires only two circumference measurements, the forearm and the waist. Third, little training or expertise is needed to take circumference measurements. Fourth, this method was among the least physically intrusive. Finally, the circumference measurements were time-efficient, and accurate measurements were easily obtained. The Kelly and Rimmer (1987) regression equation is an acceptable alternative to hydrostatic weighing for the prediction of percent body fat of adult males with DS.

Only two other equations did not produce results significantly different from those of hydrostatic weighing. The second-and-third best predictors of body fat were the equations of Durnin and Womersley (1974) and McArdle, Katch & Katch, (1986), respectively. Although no statistically significant differences were found using these equations, their low correlations and high standard error of estimates (SEE) ($r = .66$, $SEE = 3.57$, $r = .77$, $SEE = 4.75$, respectively) make these

equations questionable alternatives to hydrostatic weighing for predicting percent body fat of adult males with DS. Moreover, the Durnin and Womersley (1974) equation is less appealing, because it employs several invasive skinfold measures. As previously stated, this technique was the most physically intrusive and least comfortable for the individuals being measured, as well as the most difficult technique to perform for people considered experts in body composition measurement.

The remaining equations were statistically significantly different from hydrostatic weighing in their ability to accurately predict the percent body fat of adult males with DS. Because of this—and since they had low correlations, high SEEs, and low R^2 —they can not be recommended for use when predicting the percent body fat of adult males with DS.

Conclusions

The main area of concern—when discussing the percent body fat of adult males with DS—is the confidence that has been placed in the accuracy of the results reported from tissue density studies. If the tissue densities of individuals with DS are different than those reported by Clarys et al., (1984) on nonhandicapped population, then none of the equations examined in this study can be recommended for use in predicting the percent body fat of adult males with DS.

All of the equations are designed to predict percent body fat based on measures obtained through hydrostatic weighing. Hydrostatic weighing predicts total body density and has been shown

to be a good predictor (Durnin & Taylor, 1960; Keys & Brozek, 1953). However, hydrostatic weighing assumes that the results of tissue density studies are representative of the tissue densities of the nonhandicapped population. Maksud (1987) cautions that the calculations of hydrostatic weighing are based on tissue density measurements that are suspect.

It has been assumed that the tissue densities reported by Clarys et al., (1984) are representative of the tissue densities of all people. It is questionable whether the cadavers truly represent the tissue densities of nonhandicapped adults, let alone the tissue densities of adults with DS. According to Maksud (1987), there is good evidence that fat has a relatively constant value across gender, age groups, ethnic groups, etc. but that lean tissue is not constant. Different mineral contents were found in inactive and disabled populations than active populations.

Because DS is a chromosomal disorder there are a number of physical differences between the nonhandicapped and DS populations. Many studies have shown that individuals with DS are shorter in stature (Bronks & Parker, 1985; Rarick & Seefeldt, 1974; Roche, 1965), and differ in body weight (Benda, 1949; Brousseau, 1928; Cronk, 1978) than the nonhandicapped population. Therefore, it is not difficult to see why there is concern about the tissue densities of individuals with DS as compared to the tissue densities of the twenty five cadavers reported in Clarys et al., (1984).

Until research can be performed to determine the tissue densities of adults with DS, researchers—examining body composition—must make do with the measurement techniques that

are available to them. For this study hydrostatic weighing was considered the best available predictor of percent body fat.

There are numerous health risks associated with obesity. Accurate measurement techniques are needed to determine whether obesity is a characteristic associated with DS. For example, weight reduction programs are currently being employed among the DS population to reduce obesity levels. The problem with these programs is that the methods being used to determine obesity (height and weight charts and triceps skinfold alone) have exhibited poor validity when used with the nonhandicapped population. Some of these methods can produce errors as great as 150 percent (Katch & Micheal, 1969).

A major area of concern is the percent body fat at which an individual with DS should be, in order to be classified as not obese. Society is pushing for normalization of mentally retarded (MR) individuals in all facets of daily life. Many of these programs have paved the way for a greater acceptance of MR individuals into society. Being both mentally retarded and obese presents a dual handicap and reduces access to social interaction with nonhandicapped peers (Chumlea & Cronk, 1981; Rotatori, Switzky & Fox, 1983). But, trying to reduce the body fat of an individual with DS to a level society has estimated to be average (approximately 15 percent for adult, nonhandicapped males) may have adverse effects and be very difficult to achieve.

Individuals with DS have a genetic disorder. It may be that these individuals are predisposed to higher percentages of body fat than the nonhandicapped individual. If this is so, then trying to reduce the

percent body fat of individuals with DS—to the average established for non handicapped individuals—would be equivalent to trying to stretch them to the average height established for nonhandicapped adults. It can not be done without injury to the individual. Besides the adverse effect this attempt of body fat reduction would have on the individual with DS, conventional methods of body fat reduction—namely diet and exercise—may be difficult to implement with the DS population.

Issues of concern are the poor nutritional and exercise behaviors of adults with DS. The principle rule in fat reduction is to increase caloric expenditure above caloric intake. Poor nutritional and exercise behaviors are developed at an early age, when the easiest way to keep the child with DS quiet and occupied is to sit the child in front of a television with food. Here the child is sedentary—burning very few calories—while increasing the caloric intake. This will lead to increased body fat.

Another area of concern is that many people with DS are born with congenital heart defects. Developing exercise programs that would decrease body fat may not be possible for the individual with a congenital heart defect. The best method to reduce body fat for the person with a congenital heart defect is through a sound nutritional program. The difficulties associated with developing a sound nutritional program for individuals with DS are numerous.

Finally, people need to take into account the interests of the individual with DS. It may be that eating is one of the few pleasures the individual with DS is experiencing and exercising is not something of interest. It is the individual with DS's perception of quality of life that needs to be considered. If, the person with DS has a health

problem associated with a high percent body fat, then programs to reduce the body fat need to be undertaken—even when the individual with DS does not desire to do so—because the individual may not comprehend the importance of such a program. But, if body fat reduction programs are developed so that the individual with DS can appear more like the average person, then the individual with DS must be allowed to choose to participate in such programs.

Factors such as possible predisposed high percent body fat; poor nutritional and exercise behaviors; congenital heart defects, and the individual with DS's perception of quality of life, all combine to make the reduction of body fat a difficult procedure for individuals with DS.

The first aspect for determining appropriate levels of body fat for individuals with DS is to identify accurate techniques for measuring the body composition of these individuals. This study provides practical information for researchers and practitioners that will help identify accurate methods of measuring body composition of adult males with DS. To date, this is the only research involving individuals with DS that compares the accuracy of the most frequently utilized methods of measuring body composition with hydrostatic weighing. Since hydrostatic weighing is considered the "gold standard" in body composition measurement, the results of this study will help alleviate concerns associated with using measurement techniques other than hydrostatic weighing for predicting percent body fat of adult males with DS.

Recommendations

The results of this study indicated that only one regression equation (Kelly & Rimmer, 1987) is an acceptable alternative for hydrostatic weighing in predicting the percent body fat of adult males with DS. The following are recommendations for future research studies in the area of body composition of adults—male and female—with DS:

1. Further research is needed comparing the use of a constant residual volume to an actual measured value and its effect on body density and body fat during hydrostatic weighing
2. Further research is needed comparing hydrostatic weighing with the head not submerged with the conventional method in predicting body density and body fat is needed.
3. Replications of the present study need to be conducted to help expand the numbers of individuals with DS tested.
4. A correlation between retardation level and percent body fat of adults with DS needs to be investigated.
5. A correlation between age and percent body fat of adults with DS needs to be explored.

6. The effect of living situation (i.e., Institution, group home, family) on body fat percentages of adults with DS needs to be examined.
7. Average levels of body fat percentages for adults with DS need to be developed.
8. A cross-validation study involving another group of adult males with DS needs to be performed.

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APPENDICES

APPENDIX A

**Oregon State University
Application For Approval Of The Human Subjects Board**

Principal Investigator* _____

Department _____

Present or Proposed Source of Funding _____

Type of Project _____ Faculty Research Project

_____ Graduate Student Thesis Project*

(Student's Name _____)

The following information should be attached to this form. All material, including this cover sheet, should be submitted IN DUPLICATE to the Research Office, Ads A312. Feel free to call x3437 if you have any questions.

1. A brief description of the methods and procedures to be used during this research project.
2. A list of the risks and/or benefits (if any) to the subjects involved in this study.
3. A copy of the informed consent document and a description of the methods by which the informed consent will be obtained.
4. A description of the method by which anonymity of the subjects will be maintained.
5. A copy of any questionnaire, survey, testing instrument, etc. (if any) to be used in this project.
6. If this is part of a proposal to an outside funding agency, attach a copy of the proposal.

Signed _____ Date _____

Principal Investigator

*Note: Graduate Student Thesis projects should be submitted by the major professor as Principal Investigator.

Chairman's Summary of ReviewTitle: Body composition of Down syndrome populationProgram Director: John M. Dunn

Recommendation:

☒ XX Approval *
☐ Provisional Approval
☐ Disapproval
☐ No action

* The informed consent forms obtained from each subject need to be retained for the long term. Archives Division of the OSU Department of Budgets and Personnel Service is willing to receive and archive these on microfilm. At present at least, this can be done without charge to the research project. Please have the forms retained in archives as well as in your files.

Remarks: _____

Date: Feb. 28, 1989Signature Redacted for privacy

If the recommendation of the committee is for provisional approval or disapproval, the program director should resubmit the application with the necessary corrections within one month.

MENTAL HEALTH DIVISION

2575 BITTERN STREET N.E., SALEM, OREGON 97310-0520

July 13, 1989

Steven E. Ovalle
903 N.W. 27th
Corvallis, Oregon 97330

Dear Mr. Ovalle:

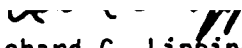
We have reviewed your Master's Degree study to validate eight regression equations that predict the percent of body fat of adult males with Down Syndrome. We also noted that this study has been approved by the Human Subjects Committee of Oregon State University and by the Research Committee of Fairview Training Center.

We find that your study also meets our standards for research to be conducted with clients in Mental Health Division funded programs in community settings. You may use this letter to demonstrate MHD approval of your study as you approach residential providers of services for persons with developmental disabilities to identify up to 21 males between the ages of 18 and 50 with Down Syndrome.

Best wishes to you. We will be interested in the outcome of your work.

Sincerely,

Redacted for privacy


Richard C. Lippincott, M.D.
Assistant Director, Human Resources
Administrator for Mental Health

RCL:jdp

APPENDIX B**Informed Consent**

1. The proposed study involves research into the field of body composition measurement. The purpose of the study is to validate eight regression equations that predict percent body fat with hydrostatic weighing for adult males with Down Syndrome. The total time expected to complete the necessary measurements is approximately one hour. A list of the procedures to be used in this study is provided on the following pages.
2. A light pinching sensation may cause brief and slight discomfort during skinfold measurements. There may also be some minor discomfort while submerged, at residual volume, during hydrostatic weighing.
3. The subject may benefit by learning his body fat percentage, and then decide if he needs to lower that value. High percentages of body fat have been associated with a number of health hazards.
4. The subject's confidentiality will be maintained by using an identification number in place of his name.
5. Any questions about the study may be directed to, and will be answered by, Steven Ovalle or John M. Dunn through the Department of Physical Education at Oregon State University, 754-2176.
6. The subject is free to withdraw at any time.
7. The experimenter will provide an oral presentation of the informed consent and procedures.
8. My signature on this form indicates that I understand that the subject will participate in the study, but may withdraw at any time. I have been informed of the nature of the study and the subject identified will not be revealed without my permission.

Parent/Guardian_____ Date_____

Subject_____ Date_____

Informed Consent

To Whom it May Concern:

My name is Steven Ovalle and I am a graduate student at Oregon State University. I am currently pursuing a Masters degree in the area of Movement Studies For The Disabled and have several years experience working with people who have various handicapping conditions, including Down Syndrome. I am particularly interested in researching the validity of eight regression equations used to predict body fat percentages of adult males with Down Syndrome.

In order to correctly classify a person as obese and then prescribe an appropriate weight reduction program, valid techniques for predicting body fat need to be assured. The methods used in this study to predict body fat include: Hydrostatic Weighing, Skinfold Measurements, Circumference Measurements, Bioelectric Impedance Analysis and Height and Weight.

Hydrostatic Weighing: The subject will be submerged up to the neck in water with his head out and holding in a maximal inhalation. The subject will be allowed an opportunity to explore this procedure himself. The experimenter and a tester will provide assistance to the subject whenever needed.

Skinfold Measurement: This procedure involves the use of a skinfold caliper that exerts a small constant pressure which may cause a slight pinching sensation. This procedure will not leave any marks on the subject.

Circumferences Measurements: This procedure involves the use of a cloth measuring tape. There are no discomforts associated with this procedure.

Bioelectrical Impedance Analysis: This procedure involves a very small (50Hkz) electrical current passed through the subject from an electrode on the wrist to one on the ankle. This current is so small that it causes no pain and the subject can not feel it.

The subject will be allowed to explore all of the equipment before actual measurements are taken and assistance will be provided whenever needed. This should reduce subject fear and anxiety about the procedures.

Confidentiality of all information collected will be ensured by using an assigned number for identification of each subject. The data will be accessible only to the investigator directly involved in this study.

I will be happy to discuss any part of this study with you or answer any questions. If you would like to know more about this study or visit the testing facilities, please contact me at 258-8121 or 753-3230, or call John M. Dunn at 754-2176.

Thank you for your assistance.

Sincerely,

Steven E. Ovalle
Health and Physical Education
OSU Womans Building
Corvallis, OR. 97330.

_____ Yes I will serve as a volunteer for your study.

_____ No I feel I would not be an appropriate volunteer for your study.

Informed Consent

To Whom it May Concern,

My name is Steven Ovalle and I am a graduate student at Oregon State University. I am currently pursuing a Masters degree in the area of Movement Studies For The Disabled and have several years experience working with people who have various handicapping conditions, including Down Syndrome. I am particularly interested in researching the validity of eight regression equations used to predict body fat percentages of adult males with Down Syndrome.

Hydrostatic Weighing is considered the most valid procedure for predicting body fat. A pilot study will be conducted to determine which method of hydrostatic weighing will be used during the research study.

The first method of hydrostatic weighing will have the subject fully submerged under water while forcing out as much air as possible, then waiting under water about 3 seconds for an accurate weight to be recorded. This will be repeated 10 times.

The second method will have the subject submerged in water up to the neck while inhaling and holding as much air as possible, then waiting about 3 seconds for an accurate weight to be recorded. This will be repeated 5 times.

A second pilot study will be performed measuring residual volume. Residual volume is the amount of air left in the lungs after a forced maximal expiration. The method used in the pilot study to measure residual volume will be helium dilution. The subject will be breathing a predetermined amount of helium and room air through a closed circuit breathing apparatus. A constant flow of oxygen will be supplied to maintain the subjects breathing volumes. After about 5 minutes of breathing the helium the subject will perform a forced maximal exhalation and the test is over.

The subject will be allowed to explore all of the equipment before actual measurements are taken and assistance will be provided whenever needed. This should reduce subject fear and anxiety about the procedures.

Confidentiality of all information collected will be ensured by using an assigned number for identification of each subject. The data will be accessible only to the investigator directly involved in this study.

I will be happy to discuss any part of this study with you or answer any questions. If you would like to know more about this study or visit the testing facilities, please contact me at 258-8121 or 753-3230, or call John M. Dunn at 754-2176.

Thank you for your cooperation.

Sincerely,

Steven E. Ovalle
Health and Physical Education
OSU Womans Building
Corvallis, OR. 97330.

_____ Yes I will serve as a volunteer for your
study.

_____ No I feel I would not be an appropriate
volunteer for your study.

APPENDIX C**Data Sheet #1**

Subjects ID# _____ Sex_____ Age_____ Date_____

Home____ Inst.____

MR Level: Mild____ Moderate____ Severe____ Profound____

Skinfold Measurements

	Series #1	Series #2	Series #3	Mean
Biceps	_____mm	_____mm	_____mm	_____mm
Triceps	_____mm	_____mm	_____mm	_____mm
Forearm	_____mm	_____mm	_____mm	_____mm
Pectoralis	_____mm	_____mm	_____mm	_____mm
Subscapular	_____mm	_____mm	_____mm	_____mm
Suprailliac	_____mm	_____mm	_____mm	_____mm
Thigh	_____mm	_____mm	_____mm	_____mm
Calf	_____mm	_____mm	_____mm	_____mm
Abdomen	_____mm	_____mm	_____mm	_____mm

% Body fat_____ Body density_____

Residual Volume

A. Constant Residual Volume = 1500ml

B. Measured Residual Volume: Oxygen dilution

Trials: 1._____ 2_____ 3_____ Mean_____

Data Sheet #2**Circumference Measurements**

	Series #1	Series #2	Series #3	Mean
Upper Arm	_____cm	_____cm	_____cm	_____mm
Forearm	_____cm	_____cm	_____cm	_____mm
Chest	_____cm	_____cm	_____cm	_____mm
Waist	_____cm	_____cm	_____cm	_____mm
Buttocks	_____cm	_____cm	_____cm	_____mm
Thigh	_____cm	_____cm	_____cm	_____mm
Calf	_____cm	_____cm	_____cm	_____mm

% Body fat _____ Body density _____

Subjects ID# _____ Weight _____kg Height _____cm

Bioelectrical Impedance Analysis

	Series #1	Series #2	Series #3	Mean
Resistance	_____ohms	_____ohms	_____ohms	
_____ohms				

% Body fat _____ Fat Weight _____lb/kg

% Body Water _____ Total Body Water _____lb/kg

Lean Body Weight _____lb/kg

Data Sheet #3**Hydrostatic Weighing**

HW Trials: 1.____ 2.____ 3.____ 4.____ 5.____
 6.____ 7.____ 8.____ 9.____ 10.____

HW= Ave. of last 3 trials____kg - tare wt.____=____kg

Tare wt. ____kg Body density ____

Water temp ____C % Body fat ____

Water density ____kg/l Fat wt. ____

Lean body wt. ____

Db = wt. %BF = $(4.570/Bd - 4.142) \times 100$
 (wt.- HW)
 (DH20) - RV

HW at Total Lung Capacity Head Not Submerged

HWTLCCHNS Trials: 1.____ 2.____ 3.____ 4.____
 5.____

HWTLCCHNS =
 Ave. of middle 3 trials____kg - tare wt.____ = ____kg

Vital capacity____l Measured RV____l Const. RV____ml

Body density ____ % Body fat ____

Fat wt. ____ Lean body wt. ____

Comments: