VALIDATION OF SELECTED ANTHROPOMETRIC REGRESSION EQUATIONS FOR BODY COMPOSITION ASSESSMENT OF MALE UNIVERSITY ATHLETES IN SOUTH WESTERN NIGERIA

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CERTIFICATION

I certify that this work was carried out by Tunde Adeyinka ADESIPO under my supervision in the Department of Human Kinetics, University of Ibadan, Ibadan, Nigeria.

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DEDICATION

GOD ALMIGHTY, who has been 'very' compassionate to me, is the subject of this work. His Grace will not go unnoticed in my life. I also dedicate this work to my mother, Comfort Kikelomo Adesipo, and my lovely wife Elizabeth Olufunmilayo Adesipo, who has always been my spiritual rock. This piece is also dedicated to Temitope, Adetola, and Oluwatobi, my three children.

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ABSTRACT

Body composition assessment of athletes is acknowledged as basic physiological determinant of athletic health and performance. Assessment of body composition of male Nigerian University athletes, using foreign-derived anthropometric regression equations usually brings with it the issue of precision, accuracy and validity. Previous studies largely focused on developing and validating commonly used equations among foreign athletes, but little research efforts have been directed towards validating these equations on Nigerian athletes using the Underwater Weighing (UWW) criterion. This study, therefore, was carried out to validate the selected anthropometric equations.

The study was anchored to the Theory of Human Body Composition Assessment, while the ex-post facto design was employed. The equations validated were Brozek and Keys (BK) 1951, Sloan and Weir (SW) 1970, Sinning (SI) 1974, Forysth and Sinning (FS) 1975, and Jackson and Pollock (JP) 1979 in order to confirm or refute their respective validity on body composition assessment of male university athletes in Southwestern Nigeria. The multistage sampling procedure was used. Three first generation federal universities in Ibadan, Lagos and Ile Ife) were enumerated, using the intact group of endurance athletes (45), power athletes (45) and control group (45) in each University. The instruments used were UnderWater Weighing equipment, spirometer, health-o-meter scale and skinfold calipher. Underwater measurements were taken following Barton and Cameroon (2009) procedure, while skinfold measurement of abdominal, chest, triceps, subscapular, suprailiac, and thigh were taken following ISAK (2011) protocol. Data were analysed using descriptive statistics, Pearson product moment correlation, t-test, and multiple regression at 0.05 alpha level.

Participants' age was 24.06±2.25 years. There was no significant difference in physical characteristics of height, body weight and body density of endurance athletes, power athletes and control group, but they significantly differed in percent fat and lean body weight. There was moderate, positive, relationship between Body Density (BD) of UWW and BD of BK, SW, SI, FS, but JP(r=0.77) was strongly significantly related. There was positive, relationship between %bf of UWW and %bf of BK(r=0.27), SW(r=0.26), SI(r=0.18), FS(r=0.38) except JP(r=0.72). There was significant difference between BD determined by UWW and BD of BK(t=-12.33), SW(t=-16.21), SI(t=-11.58), FS(t=-7.75) and JP(t=-2.92). There was also a significant difference between %bf of UWW and %bf of BK(t=10.22), SW(t=14.95), SI(t=11.66), FS(t=6.34) and JP(t=8.00). Plotted against validation criteria of Multiple Correlation Co-efficient (R), Constant Error (CE), Total Error (TE), Standard Error of Estimate (SEE), the values obtained were BK(R^2=.103, CE=-0.02, TE=0.002, SEE=0.004), SW(R^2=.103, CE=0.02, TE=.003, SEE=.006), SI(R^2=.138, CE=-0.02, TE=0.002, SEE=0.01), FS(R^2=.209, CE=0.01, TE=0.002, SEE=0.006), JP(R^2 =.208, CE=-0.02, TE=0.002, SEE=0.002). All the examined equations failed the validity test. As a credible alternative this equation was formulated: BD=1.064+0.00392 (X_1)+0.669 (X_2)+0.07761 (X_3).

The anthropometric regression equations of Brozek and Keys, Sloan and Weir, Sinning, Forsyth and Sinning (1975), and Jackson and Pollock, have relationship with, but are significantly different from underwater weighing. All the equations overestimated Body Density and underestimated percent body fat in male University athletes in Southwestern Nigeria. The validated prediction equations should be used with relative caution, while the equation formulated needs to be adopted by Nigerian male athletes.

Keywords: Underwater weighing, Anthropometric regression equations, Validated equation, Percent body fat.

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TABLE OF CONTENTS

Title Page i

Certification ii

Dedication iii

Acknowledgements iv

Abstract v

Table of Contents vii

CHAPTER ONE

INTRODUCTION 1

1.1 Background to the Study 1

1.2 Statement of the Problem 5

1.3 Objective of the Study 7

1.3.1 Specific Objectives of the Study 7

1.4 Research Questions 8

1.5 Hypotheses 8

1.6 Significance of the Study 9

1.7 Delimitations of the Study 10

1.8 Limitations of the Study 10

1.9 Operational Definitions of Terms 11

CHAPTER TWO

LITERATURE REVIEW 13

2.1 Conceptual Framework 14

2.2 Theoretical Framework 16

2.3 Review of Literature 16

2.3.1 Body Composition and its components 17

2.3.2 Methods of determining body composition 21

2.4 Residual Volume in Body Density Determination 33

2.5 Body Composition of Athletic Population 34

2.6 Alteration of Body Composition with Physical Training 36

2.7 Regression Equations in body Composition Predictions 37

2.7.1 Population-specific equations 38
2.8.1 Generalised equation 41
2.8 Regression Equation: Its Validity and Validation 42
2.9 Statistical Considerations in Body Composition Assessment 44
2.10 Standard Error of Estimate 46
2.11 Constant Error 47
2.12 Root Mean Square Error (RMSE) 48
2.13 Development of New Equation for Body Composition Assessment 49
2.14 Empirical review of Literature 50
2.15 Appraisal of Literature Reviewed 51

CHAPTER THREE

METHODOLOGY 53
3.1 Research Design 53
3.2 Population 53
3.3 Sample and Sampling Technique 53
3.4 Research Instruments and Equipment 54
3.5 Validity of the Instrument 56
3.6 Reliability of the Instrument 56
3.7 Ethical Consideration 57
3.8 Procedure for Data Collection 57
3.9 Pilot Study 60
3.10 Data Analysis 60

CHAPTER FOUR

RESULTS AND DISCUSSION OF FINDINGS 62
4.1 Results 62
4.2 Hypothesis Testing 69
4.3 Discussion Findings 105
4.4 Summary for Discussion of Findings 111

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Summary 113

5.2 Conclusions 115

5.3 Recommendations 116

5.4 Contribution to Knowledge 117

5.5 Suggestions for Further Study 117

REFERENCES 118

APPENDIXES 125

LIST OF TABLES

Pages

4.1 Social demographic attributes of the participants 63

4.2 Age and physical characteristics: Comparative statistics 65
4.3 Physiological characteristics: Comparative statistics 67
4.4 Correlation between body density determined by underwater weighing and Brozek and Keys (1951) equation 69
4.5 Independent t-test result of BD determined by underwater weighing and by Brozek and Keys (1951) equation 70
4.6 Correlation between percent body fat determined by Underwater weighing technique and by Brozek and Keys (1951) equation 71
4.7 Independent t-test result of percent body fat by Brozekand Keys (1951) equation 72
4.8 Result of the validation criteria of Brozek and Keys (1951) equation 73
4.9 Correlation between BD by underwater weighing and by Sloan and Weir (1970) equation 75
4.10 Independent t-test result of body density by underwater weighing and by Sloan and Weir (1970) equation 76
4.11 Correlation of Percent body fat correlation determined by underwater weighing technique and Sloan and Weir (1970) equation 77
4.12 Independent t-test result of percent body fat determined by underwater weighing and percent body fat predicted by Sloan and Weir (1970) equation 78

4.13 Result of the validation criteria of Sloan and Weir (1970) equation 79
4.14 Correlation between body density through underwater weighing and body density predicted by Sinning (1974) equation 81
4.15 Independent t-test result of body density determined by underwater weighing Sinning (1974) equation 82
4.16 Correlation of percent body fat by underwater weighing technique and Sinning (1974) equation 83
4.17 Independent t-test result of percent body fat determined by underwater weighing technique and by Sinning (1974) equation 84
4.18 Result of validation criteria of Sinning (1974) equation 85
4.19 Correlation between body density determined by underwater weighing and by Forsyth and Sinning (1975) equation 87
4.20 Independent t-test result of body density determined by underwater weighing and predicted by Forsyth and Sinning (1975) equation 88
4.21 Correlation of %BF determined with underwater weighing technique and Forsyth and Sinning (1975) equation 89
4.22 Independent t-test result of percent body fat determined by underwater weighing technique and predicted by Forsyth and Sinning (1975) equation 90
4.23 Result of validation criteria of Forsyth and Sinning (1975) equation 91

4.24 Correlation between body density determined by underwater weighing and by Jackson and Pollock (1979) equation 93
4.25 Independent t-test result of BD determined by underwater weighing and Jackson and Pollock (1979) equation 94
4.26 Correlation of %BF determined by underwater weighing technique and percent body fat 95
4.27 Independent t-test result of %BF determined by UWT and Jackson and Pollock (1979) equation 96
4.28 Result of validation criteria of Jackson and Pollock (1979) equation 97
4.29 Correlation matrix on relationship between each skinfold thickness site and body density 99
4.30 Regression analysis of relative contribution of each and combination of the predictor variables in predicting body density 101
4.31 Regression analysis on predictive effectiveness of each and combination of the predictor variables in Body density prediction 102
4.32 Developed Prediction Equation 104

LIST OF FIGURES

Page

2.1Conceptual framework of the study 20

CHAPTER ONE

INTRODUCTION

1.1 Background to the study

Body composition is really important in games and sports. In the field of physical and health education, coaches, trainers and exercise physiologists believe that excess fat in the body is detrimental to sports performance, particularly weight bearing skills like walking, running, games and gymnastics. Body composition measurement and prediction has become widely used in a variety of exercise science disciplines (Katch and Katch, 2004).

A variety of approaches have proved successful in properly assessing body fat and lean body mass in individuals. Each of these approaches is founded on its own set of concepts and assumptions. There are two types of assessments: direct and indirect. The direct approach is a direct compositional examination of the human body that can only be done on fresh human cadavers through dissection which produces reliable and valid result (Ackland, Lohman, Borgen and Maughan, 2013). This technique is however restricted to the dead rather than the living. Benke and Wilmore (2004) went further to assert that because of many problems inherent in the compositional dissection of the intact living humans, science has been forced to turn almost exclusively to animals experimentation and indirect human analysis to gain the knowledge which is presently available. In the light of this, several indirect techniques have been developed for practical purposes of body composition assessment in man.

These methods include hydrodensitometry or underwater weighing, anthropometry, which include skinfold thickness, circumferences and diameters measurements, bioelectrical impedance analysis system (BIA), computer tomography (CT) scanning, deuterium oxide dilution, magnetic resonance imaging (MRI), potassium-40 counting image resolution, helium dilution and ultrasound. Each of these methods has limitations, either in terms of convenience and portability required for field use or in accuracy and reliability of results.

The measurement of body composition by densitometry which is most widely used is generally advocated as the method of reference. This approach usually needs the person to be entirely submerged underwater when exhaling maximally to reduce the influence of lung air buoyancy. The underwater weighing technique is based on the use of body density to estimate human body composition. This phenomena, according to Fuller, Lebb, Laskey and Coward (2002), began in the 1930s, when the US Navy was interested in creating a practical method for quantifying body fat in divers who were then involved in test dives to 500ft. Total body fat is calculated from density rather than being measured directly when hydrostatic weighing is utilized. This approach of determining body composition has become the "gold standard" against which other indirect methods are routinely measured. Unfortunately, once a method has been designated as a "gold standard," its flaws are soon ignored and it is given an aura of infallibility (Going, 2006). However, Katch and Katch (2004), Sinning (2010), and Lohman (2011) have all expressed concerns about the accuracy of body composition estimates and the precautions that should be taken when using them.

Anthropometry is the science of measuring the size, weight, and proportions of the human body (Pollock and Wilmore, 2012). Inthe areas of body composition measurement, exercise science and sports medicine; skinfold fat, circumferences and body diameter measures have been utilized (Lohman 2002; Lohman, and Martoell, 2014; Benke and Wilmore 2012). Body density and body fat % can be predicted using the anthropometry approach. It works on the premise that subcutaneous adipose tissue is a good proxy for total body fat. The approach includes using a handy equipment known as skinfold caliper to measure the thickness of subcutaneous fat. Typically, 3 to 12 places are chosen for measurement. Suprailiac, anterior thigh, triceps, and subscapular are the most prevalent sites. The overall fat content of the body is predicted using these 3 to 12 local fat measurements. Once the fat folds have been measured, they are assigned to one of hundreds of different categories to determine the percent body fat. (Elis, 2014). According to Ramirez-Zea, Torun, Martorell and Sten (2006), anthropometry assessment estimates of body composition correlates well with underwater weighing method. Wagner and

Heywood (2015) however opined that in terms of application, the densitometric method is a better and more reliable technique to use than anthropometric techniques. Though in terms of practicality, densitometry method may not be feasible for field tests because of the complexities involves in the utilization of more personnel, expensive equipment and considerable time of use. To summarize, this method requires clear specifications for measurement sites as well as uniform techniques.

Other body composition approaches, such as computer tomography, electrical conductivity, whole-body potassium-40 counting, among others may also be limited by practical limits. The majority of these techniques are prohibitively expensive, complicated, and unsuitable for field research. In order to accurately assess human body composition, scientists have devised separate prediction equations for men and women, young and middle-aged, athletic and non-athletic populations, owing to changes in the distribution of several anthropometric parameters with age and sex. To measure body fat content, most of these equations use skinfolds and anthropometric dimensions. A regression equation is a mathematical formula that allows for the prediction of one dependent variable's values based on the values of one or more independent variables. (Sokal and Rolf, 2013).

According to Katch and Katch (2004), over the last forty years, at least over one hundred regression equations have been developed to evaluate the fat and lean components of the human body. In using anthropometric technique, Brozeks and Keys (1951) presented the first body composition regression equations (Pollock and Wilmore, 2012). Sloan and Weir presented comparable formulae for women of various ages in the early 1960s. Various combinations of skinfold thickness measurements were used to create these equations. Numerous researchers produced new equations for men and women between the middle 1960s and the 1980s. According to Pollock and Wilmore (2012), this is made possible by the computer programs that are readily available to these researchers. With more processing power, analyzing a large number of variables will be easier, so also the choosing of the anthropometric variable combination that produced the highest multiple correlations.

Most of these regression equations tend to be ‘population-specific’ in terms of gender and age. This means that they predict most accurately at the mean of the population in which the data were collected and the equations developed. As subjects differ from the mean, the standard error of measurement increased significantly (Ball, 2005). The more recent trend however has been to develop ‘generalised’ rather than ‘population specific’ equations.

According to Pollock and Wilmore (2012), Durnin and Wormesly (1974) were the first to consider the generalized approach. Proponents of generalized equations claimed that they can handle samples of different ages and reduce huge prediction errors that occur at the extremes of the Body Density (BD) distribution (Sinning and Wilson, 2004). Be it population-specific or generalized equations each of these equations in literature has a certain correlation co-efficient (R) and standard error of estimate (SEE). While some of these equations meet adequate reliability conditions, their application to various samples of subjects may be poor, resulting in significant mistakes in predicting individual values, according to Pollock and Wilmore (2012). The validity co-efficient between predicted and measured BD values for women is r=0.72 to 0.84, while for men it is r=0.85 to 0.89, according to them. When calibrated against criteria estimates with systematic errors, even equations with a very high coefficient of determination (R2) and modest Standard Errors of Estimation (SEEs) might produce erroneous predictions.

Validity is the most significant method of determining the effectiveness of an equation that based on regression. It is one of the most important properties of any instrument because if it does not measure what it is supposed to measure, it will not allow suitable conclusions to be drawn from the results. The amount to which a tool measures what it was supposed to measure is referred to as validity (Thomas and Nelson, 2001). The correlation and associated errors in prediction of BD as directly evaluated by underwater weighing and predicting indirectly from a number of anthropometric measures such as skinfolds and circumferences will be the focus of this study's validity. The focus is on criterion-related validity because the study centers on the degree of relationship between measuring instrument result and criterion score. The criterion is expected to be clearly superior and possess a more direct measure of the attributes or properties under consideration than does the measuring instrument. Therefore, if any prediction equation is used, the assumption is that it has high predictive ability. High Multiple Correlation value coupled with relatively low standard error of estimate are indices of high predictive profile of any equation (Montgomery and Peck, 2002).

Thorland, Johnson, Fagot and Tharp (2004) validated Jackson and Pollock (1979) equation on adolescent athletes and reported an R=0.57 and SEE = 0.0063 for the equation. They also validated Durnin and Womersley (1974) equation and reported an R=0.56 and SEE=0.0063. This validity co-efficient were moderately high but represent shrinkages from values derived from the original samples. Sinning (2001) confirms this, stating that validation of existing equations has often resulted in correlations that are significantly lower than those reported in the initial analysis. As a result, these equations must be cross-validated on new samples other than the ones from which they were obtained. Darman and Goldman (2004) agreed that a given equation's universal applicability could not be assumed without a validation on a separate sample of participants. Peterson, Czerwinski, and Sterrogel (2003) agreed, stating that assessing an equation's accuracy and precision is necessary in order to properly comprehend its strengths and shortcomings.

This study therefore attempts to evaluate some of the existing anthropometric regression equations derived previously for assessing body density and body fat percentage, confirming or refuting their respective validity on a sample of athletes in South Western Nigerian Universities which was notpart of the previous sample used in the formulation of the equations.

1.2 Statement of the Problem

Body composition, particularly fat estimation using densitometric techniques have been undertaken in advanced countries in numerous studies, but the practice is not common in Nigeria. Most physician, coaches, physical educators and exercise physiologists alternatively adopt the relative easier anthropometric method i.e. as in using regression equations.

The validation method includes re-evaluating prediction equations on different samples other than those used in the initial derivation. External validity will reveal the equations' genuineness through its procedure, as well as relative value in properly predicting body fat in new independent samples. The current generalized skinfold thickness formulae were created in a primarily white population. Ball (2005) found variances in fat patterning between blacks and whites, prompting an investigation into whether such generalized equations apply to blacks. There have been various reports of body composition disparities between blacks and whites (Hastuti and Kagawa, Bryne and Hills, 2013). The most well-documented distinction is that blacks have a higher density of lean body mass due to their heavier and denser skeletal mass. Changes in the environment throughout childhood may have an impact on the anatomical distribution of fat in black people. Even densitometry may be erroneous in predicting body composition in blacks due to formulae that assume a constant density of lean muscle mass, which may be adequate for whites but not for black people. Validating existing formulae and establishing a new skinfold statistical method is therefore desirable for more accurate body fatness estimates, particularly in developing nations.

Because the anthropometric approach relies heavily on a small number of skinfold locations, any deviations from the initial validated equation in adipose tissue distribution will have an influence on the prediction. As a result, any difference in adipose tissue distribution from the population used to develop the regression equation should boost the growth of an alternative equation, even though it is recommended that the search for a "perfect" equation for easy identification of an individual's fatness with good accuracy be a continuous process. This will lead us to the question: what is the predictive validity of these regression equations? Systematic mistake occurs when observations continually exaggerate or underestimate the true value. So with these equations being used on Nigerian athletes vis-à-vis University athletes, researchers in body composition assessment in Nigeria might have been committing serious systematic errors.

No study has been conducted, to the best knowledge of the researcher using Nigerians to cross-validate these foreign-derived anthropometric regression equations, whether athletic or non-athletic. As a result, the goal of this research is to test existing equations and establish a % body fat prediction equation based on anthropometric data and the hydrodensitometry methodology as the criterion. The study will also assess the validity of a variety of existing prediction equations in terms of a moderate-to-high co-efficient of determination (R^2), a low SEE, and a high co-efficient of correlation (r).

1.3 Objectives of the Study

Main Objective

The main goal was to evaluate, certify or disprove their authenticity of some of the existing regression equations for predicting body density and percent body fat on a group of subjects (i.e. Nigerian University Athletes) that was completely independent of the previous sample used in the derivation of these equations, and, if any or all of these equations proved unsuitable, to develop a novel statistical approach that will provide more accuracy.

Specific Objectives of the study

(1) To determine the differences, in physical characteristics (height and body weight) of South Western Nigerian male University endurance and power athletes and subjects used by previous researchers who developed the anthropometric regression equations.

(2) To determine the differences, in physiological characteristics of South Western Nigerian male University endurance athletes and power athletes.

(3) To determine the differences, (if any) between BD determined by underwater weighing technique and BD predicted by Sloan and Weir (1970), Jackson and Pollock (1979), Brozek and Keys (1951), Sinning (1974), Forysth and Sinning (1975) prediction equations.

(4) To determine the differences in the physiological variables (%BF, LBW and residual volume) determined by densitometric technique and those estimated by the selected anthropometric-based regression equations predicted by previous researchers using Nigerian male power and endurance athletes.

(5) Identification within adequate standard of error, anthropometric equations that may be used to estimate the body densities of male South WesternNigerian University endurance and power athletes.

(6) To validate the selected regression equations for predicting BD and %BF in male South Western Nigerian University endurance and power athletes.

(7) Development of a prediction regression equation for black athletic population viz-a-viz South West Nigerian male University athletes to estimate BD and percent body fat from selected anthropometric variables.

1.4 Research Questions

The following were answered:

(1) Will there be significant difference in physical characteristics (height and body weight) of male University endurance and power athletes?

(2) Will there be any significant difference in physiological characteristics of male University endurance and power athletes?

1.5 Hypotheses

The following hypotheses were tested:

1. There will be no significant relationship and difference between body density and %BF determined by underwater weighing technique (UWT) and BD and percent body fat estimated by Brozek and Keys (1951) anthropometric-based regression equation.
2. There will be no significant relationship and difference between BD and %BF determined by underwater weighing technique and BD and percent body fat estimated by Sloan and Weir (1970) anthropometric-based regression equation.
3. There will be no significant relationship and difference between BD and %BF determined by UWT and BD and percent body fat estimated by Sinning (1974) anthropometric-based regression equation.
4. There will be no significant relationship between BD and percent body fat determined by underwater weighing technique and BD and %BF estimated by Forysth and Sinning (1975) anthropometric based regression equation.
5. There will be no significant relationship and difference between BD and %BF determined by UWT and by Jackson and Pollock (1979) anthropometric-based regression equation.
6. The anthropometric (skinfold) sites measured for validation of the selected equations will not singularly or in combination provide significant substantial

weights as predictors to generate a new anthropometric regression equation for body composition assessment of male Nigerian University athletes.

1.6 Significance of the Study

This study will provide Nigerian male University athletes in various sports and games, a sort of normative data as regards the awareness of their body composition through the acclaimed ‘reliable’ technique.

This study identified the limitations, constraints and assumptions to be contended with when measuring and interpreting the results of body composition assessment methods in the study. This may help greatly in relatively accurate assessment, since the potential error sources in the methods was highlighted by the study.

Since there is always an inherent error in the best of regression equation this study was able to recommend the amount of caution and the degree of predictive accuracy (i.e. accuracy threshold) at which each equation can be put to use, especially when estimating samples identical with the one used in the original study.

It may also be of a great benefit to Nigerian University Games Association (NUGA) and other Collegiate Sports Associations, in that they could have a criterion in form of a norm for evaluating male athletes prior to and during competition season, adopting the techniques used for measurement in this study.

The study might also help various sports organisations, clubs, sports councils and commissions who wish to undertake body fat determination of athletes on a regular basis. This will ensure the right body composition for different sports in order to optimize their performances.

Finally, the study developed a prediction regression equation for black athletic population viz-a-viz Nigerian athletes to estimate BD and %BF from selected anthropometric variables. Such a race-specific skinfold equation is overdue if one considers the cross-cultural differences in genetic background, socio-economic conditions, health and nutritional status, that may affect the validity of established equations on samples that are different from the ones with which the equations are derived. The novel equation generated can be cross-validated for accuracy on other groups that are similar to the one used in the original study.

1.7 Delimitation of the Study

These include:

1. The use of ex-post-facto, independent group correlational research design.
2. Selected anthropometric-based prediction equations of Sloan and Weir (1970), Jackson and Pollock (1979), Brozek and Keys (1951), Sinning (1974) and Forysth and Sinning (1975).
3. Two methods of determining body composition, i.e. densitometric evaluation using the hydrostatic weighing technique and anthropometric evaluation using skinfold and girth measurements.
4. Power athletes, comprising sprinters, power swimmers, shot putters, discus throwers, high jumpers, long jumpers and javelin throwers.
5. Endurance athletes comprising endurance swimmers, distance runners, soccer, basketball and handball players and swimmers
6. NUGA athletes from UNILAG (University of Lagos), Universities of Ibadan, and Obafemi Awolowo University Ile-Ife.
7. Body composition variables of weight, absolute fat, relative fat, BD, residual volume, lean body weight and Vital capacity.
8. Descriptive statistics of mean, range and standard deviation, pie-chart, bar-chart, frequency and percentage.
9. Inferential statistics of student-t-test (independent), Analysis of Variance (ANOVA), Pearson-Product Moment Correlation Co-efficient (PPMCC), and Stepwise Multiple Regression Analysis.
10. Residual lung volume estimation from vital capacity measurement during weighing.
11. 6 research assistants who assisted especially in underwater weighing, e.g. as recorders

1.8 Limitations of the Study

Below are the constraints discovered during field work:

1. Under normal circumstances, the water temperature at the period of measurement should be between 33^oc and 36^oc. This was not exactly guaranteed in the

swimming pools used since there was no heating device. However, correction factor for pool temperature was used.

2. The dearth of similar studies and paucity of published normative data in this specialized area in Nigeria limit considerably comparative analysis to available studies on male University athletes from other countries.
3. Subjects who are unfamiliar with immersion in water, and can’t sit fully submerged after a maximal expiration, such as non-swimmers, required a greater degree of habituation in order to give consistent reading. Perseverance of the researcher and dishing out words of encouragement at every stage assisted to overcome this potential limitation. Lifeguards were also placed on standby in case of any eventuality.
4. Since the body composition variables was determined by the indirect methods of densitometry and anthropometry, there might be slight prediction errors resulting from technical and deviation from biological assumptions of subjects. Lohman (2002) reported standards errors of 2.5% and 3.9% for densitometry and anthropometry respectively in predicting percent body fat. Efforts was however made to strive for accuracy of measurement.

1.9 Operational definition of Terms

Densitometry: It is a measurement that estimates Total Body Volume (TBV) based on the amount of water displaced by the body's volume.

Anthropometry: It involves the measurement of size, weight, subcutaneous fat with the human body's proportions using skinfold caliper and broad blade anthropometer.

Regression Equations: A mathematical formula that allows prediction of values of one dependent variable (i.e. the criterion; body density) from known values of one or more independent variables.

Body Density: Ratio of the body weight per unit volume.

Vital Capacity: The highest amount of air an individual may exhale from his lungs after first fully filling them and then fully expiring them.

Lean body weight: This indicates the total body weight minus the weight of the stored fat.

Validity: As per this study, this concerns the correlation and associated errors of prediction between body density as directly determined by densitometric technique and indirectly predicted from a variety of anthropometric measures that includes skinfold and circumferences.

Power athletes: These are athletes whose events demands a single explosive muscular contraction or a several seconds burst of repeated rapid contraction such as sprinters, shot putters, high and long jumpers, discus throwers and javelin throwers.

Endurance athletes: Athletes such as long-distance runners, endurance swimmers, soccer, basketball and handball players whose events and games require a relatively sustained endurance, because of the rhythmic nature of the energy they expended.

Validation: Validation is the process of comparing the model's behavior to that of the real system.

CHAPTER TWO

LITERATURE REVIEW

This study evaluated some of the existing regression equations derived previously for body density and percent body fat prediction. It also confirms or refute the validity of these equations on a sample of subjects (Nigerian male University athletes)using densitometry (underwater weighing) as a criterion measure.

2.1 Conceptual Framework

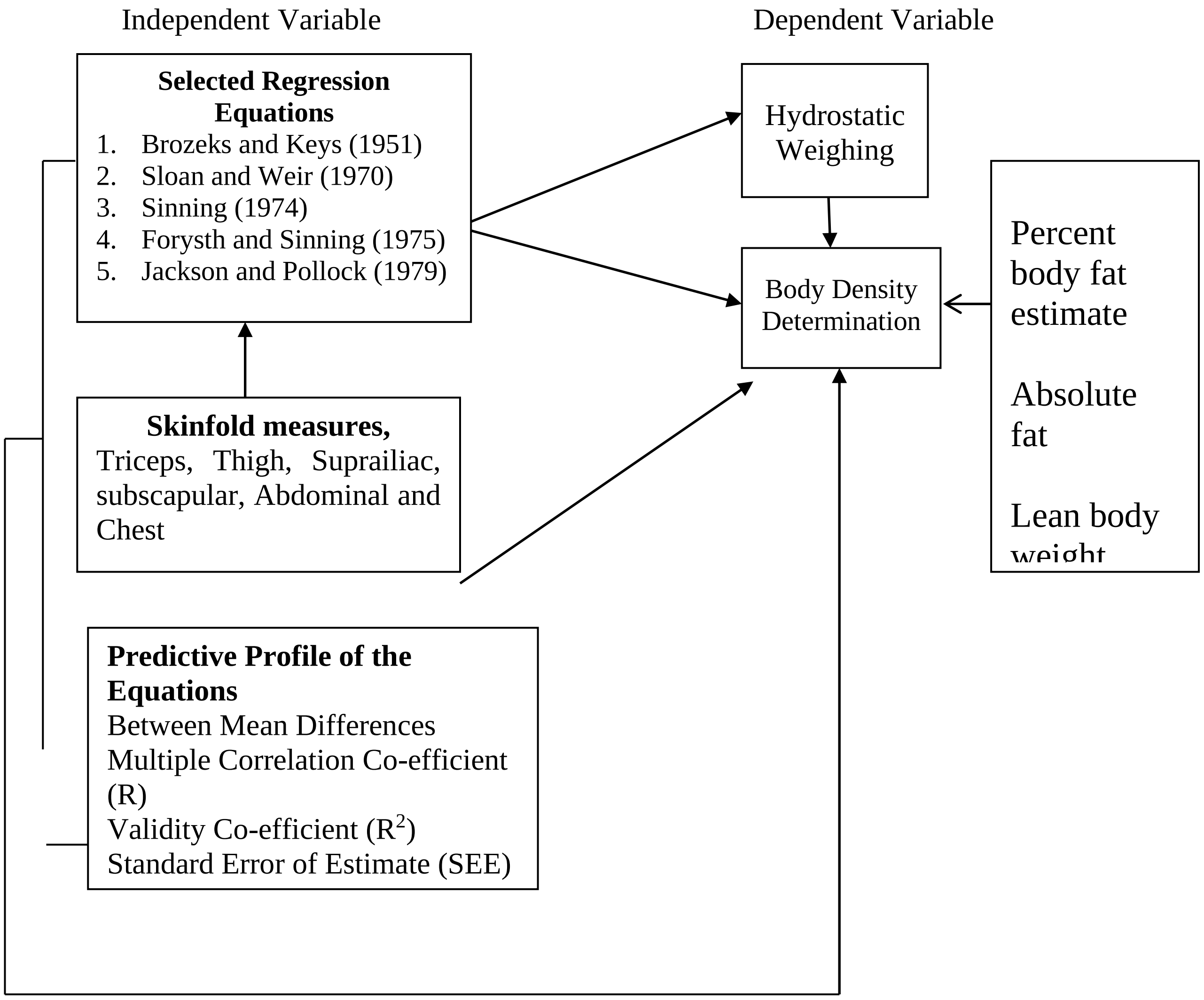

Figure 2.1Conceptual Framework of the Study

Source: Researcher (2016)

A self-developed concept designed to show the relationship between independent variables (selected anthropometric regression equations) and the dependent variable (Body Composition assessment). It was conceptualized to evaluate the anthropometric regressions equations in predicting BD and estimate of %BF in male Nigerian University endurance and power athletes as against BD and %BF directly determined by UWT.

Attribute variables of skinfolds were measured at designated sites i.e. triceps, thigh, suprailiac, subscapular, abdominal and chest skinfolds and slotted into these equations to find out whether the equation will overestimate or underestimate BD and therefore estimated %BF that will be directly determined by the criterion measure i.e. underwater weighing. The predictive validity of the equations were assessed by using the following predictive profile; between mean difference with the criterion measure, multiple correlation co-efficients, (R) validity co-efficient or co-efficient of determination (R^2),SEE and Total error.

2.2 Theoretical Framework of the Study

The theoretical framework introduces and explores the theory that supports the current research problem as well as demonstrating how the research is based on well-established concepts. The notion of human body composition evaluation was used to guide this research. The theory recognizes that whole BD is a result of the densities of the various body components, and that each component's proportion to the whole-body mass must be identified, characterized, and measured. The body is divided into: a fat component (FM) and a fat-free mass (FFM). All remaining substances and tissues, including water, muscle (protein), and bone, make up the FFM. The following five assumptions are made by this two-component body composition model:

i. Fat has a density of 0.90 grams per cubic centimeter.

ii. FFM has a density of 1.100g/cc.

iii. All people have the same fat density and FFM components (water, protein, and minerals).

iv. Within an individual, the densities of the various tissues that make up the FFM are constant, as is their proportionate contribution to the lean component.

v. The only difference between the individual being measured and the reference body is the quantity of fat; the reference body's FFM is considered to be 73.8 percent water, 19.4 percent protein, and 6.8 percent mineral (McArdle, Katch and Katch, 2007).

The two-component model's key benefit enables the measurement of the fat-free body's single constituent. The approach, according to Ackland, Lohman, Sundgot-Borgen, and Maughan (2013), gives a viable way to determine the contents of both the fat and fat-free body. More so, its fundamental drawback is that it does not make independent estimates of different bodily components like muscles and bones. This model, which is the basis for hydrodensitometry or underwater weighing, is extremely useful in research, but it is frequently less useful in ordinary clinical management since it hides significant regional heterogeneity within a global whole-body result.

The accuracy of three-compartment model is more than that of the two-compartment model because it accounts for the biological variability in thefat, protein, and total body water, while the four-component model adds little to the accuracy. Multi-component models in the other hand, describe models of structural, molecular, and fluid, in addition to chemical components. Isotope dilution was used to determine water compartment, DEXA to determine content of inorganic, and protein was determined by neutron activation analysis. A multi-component model is preferable to a two-compartment model because it gives more significant information and additional accurate assessment for those whose total body water and the content of the bone mineral are beyond the projected (or average) values.

Other ways of determining 2-compartments exist, including skinfolds, body impedance analysis, and total body electrical conductivity, all of which share a similar calibration against hydrodensitometry techniques, and each measure is a correlate of Fat and Fat Free Mass. The two-model compartment is used to calibrate prediction equations for fat and FFM. The major measuring technique's accuracy is thus put in the spotlight. Attribute variables of skinfolds are measured at designated sites and slotted into these equations to find out whether the equations will overestimate or underestimate BD and therefore misestimated %BF that will be directly determined by the criterion measure which is the Underwater weighing technique. In terms of theoretical and statistical considerations for the relationship between skinfolds and density, biological factors related with age and sex appear to be limiting generalized skinfold-density equations. Hence there is a need for good standardization of the skinfold method of determination. The anthropometric processes and tools utilized in their application must be identical to those employed in the development of the equations. The skinfold measurement locations must be identical to those utilized, and standardized, and the same calipers must be employed. The prediction equation chosen can have a profound effect on the estimation obtained.

2.3 Review of Literature

2.3.1 Body Composition and Its Components

Buskirk (2006) suggested the following reasons for the study of body composition:

(i) as a research instrument for gender and ethnic differences
(ii) in the description of normal or aberrant growth, development, maturation, and aging.
(iii) to offer physiological variables with reference points.
(iv) as a means of determining physical fitness.
(v) as a resource for athletes preparing for or participating in competition.

Several strategies are available, according to Wells and Fewtrell (2006), each making assumptions that may affect applicability in terms of complexity and ease of usage for various settings. In most cases, a single technique will not be the best option. Bodily composition is not explicitly measured in vivo; instead, it is predicted and estimated based on measurements of body attributes. However, if methodologies are devised and employed in well-defined demographic groupings, such deviations can be minimized. Body composition data is important for athletes since it corresponds with performance and can also reflect 'condition' and 'potential outcomes' (Ackland, Lohman, Sundgot-Borgen and Maughan, 2013). As a result, the authors concluded that anthropometric and body composition data can help with decisions about which sport or event an individual is most likely to succeed in, as well as the development of appropriate training schedules and the control and recovery of those who have sustained sports-related injuries.

(i) Body Fat

There are two depots or storage places for the overall amount of bodily fat. For proper physiologic function, the fat contained in the kidneys, intestines, muscles, marrow of bones,heart, lungs, as well as the liver, spleen, and lipid-rich tissues throughout the central nervous system, is referred to as vital fat. This fat is necessary. Female essential fat includes sex-characteristic fat, according to McArdle, Katch, and Katch (2007). They argued that it is unclear if the fat depot is disposable or functions as a reserve storage facility. Although the specific quantitative amounts of this fat are unknown, the mammary gland and pelvic region are likely key storage places for it. For women with body fat content ranging from fourteen percent to thirty-five percent, the contribution of breast weight to total body fat content was calculated to be no more than 4%. This implies that a considerable proportion of sex-specific fat is contributed by places other than the breast, maybe in the lower body region, which comprises the pelvis and thighs. The store fat, the other primary fat deposit, is made up of fat that has accumulated in the adipose tissue. The fatty tissues that protect the numerous internal organs from harm, as well as the bigger subcutaneous fat volume deposited beneath the skin surface, make up this nutritional reserve. Although males and females have similar proportions of store fat (12 percent in males, 15 percent in females), females have four times the amount of necessary fat, which includes sex-specific fat (McArdle, Katch and Katch, 2010). More than likely, the extra necessary fat is required for childbirth and other endocrine tasks.

Total body fat is derived using hydrostatic weighing where density is employed, and computed from mathematical relations and assumptions when the anthropometric approach is used, according to Katch and Katch (2004). Equations for translating body density to % body fat have been created by researchers. Throughout the human range of fatness, these two equations, Siri (1961) and Brozek, Grande, Anderson, and Keys (1963), produce approximately equal % fat values.

The equations are

Brozek et al: % fat = $\left[\left(\frac{4.570}{\text{BD}}\right) - 4.142\right] \times 100\ \text{kg/m}^3$

Siri: % fat = $\left[\left(\frac{4.950}{\text{BD}}\right) - 4.500\right] \times 100\ \text{kg/m}^3$

Where BD = Body Density Estimate……………………**Equation2.3.1a**

Many people regard the Siri and Brozeketal'smethod of measuring % body fat from body density to be the "best model" for determining body fat. Each one is based on the two model component in which fat tissue has a density of 0.9g/cc and fat-free weight has a density of 1.10g/cc, and bodily water has a constant density. Adults between the ages of 20 and 50 are most likely to fall into this category. The body changes more profoundly during childhood and old age. The density of the fat-free component is affected by changes in body water and bone mineral content as the total body water and mineral content of the elderly and youngsters differ from the values of the 20-50 years old individuals, Lohman (2002) successfully argued that the two-component model has major limits for evaluating the body composition of these extreme groups. His argument was hinged on the fact that changes in the body's mineral content alters the density of fat-free weight, and that the two major sources of differences among individuals in bone mineral content can be traced to genetic and environmental condition. He concluded that some inherit a higher bone mineral content while due to lifestyle, some will develop a higher mineral content.

The fact that Brozek et al (1963) created an equation for the conversion of BD to %BF based on the chemical composition which is very significant,the equation was presented for use among youngnonathletic male population based on cadaver chemical analysis (Brodie, Moscrip and Hutcheon, 2010). When applied to free-living individuals, this body composition prediction using cadaveric skinfold sites raises theoretical problems. Skin compression variability occurs after death as a result of the elastic nature of the skin (Norton, 2009).It should be noted in line with the suggestions of Jackson and Pollock (2010) that the amount of fat in the body is often described as a percentage of fat, or the proportion of the mass of fat to the total body mass as fat, and some may have a larger proportion of fat subcutaneously whilst others may have a larger proportion internally. Similarly, some people may have a larger proportion of subcutaneous fat on the limbs as opposed to the thorax and abdomen.

As regards percentage of fats in athletes, there has been many studies that reported diverse percentages for different athletes in different sports. For example, Sinning and Wilson (2004) reported 8.81% for college wrestlers. Roche, Heymsfield and Lohman (2012) reported 12.2% on male athletes. Jackson and Pollock (2010) reported 8.9% for basketballers, 9.6% for soccer players, 8.5% for swimmers, 15.2% for tennis players, 16.5% for shot-putters and 9.8% for wrestlers. In the same vein, Agbonjinmi and Amusa (2002) reported 10.0% on college men and 7.26% on university soccer players.

(ii) Fat Free Mass/Lean Body Weight

Lean body weight, according to ACSM (2007) is the total body weight minus the weight of the body's stored fat. It expresses lean body mass quantitatively. Benke and Wilmore (2012) defined it as the weight of the body in kilograms exclusive of stored fat. It consists mainly of water, muscle, tissue, skin, bone, organs, minerals, electrolytes and all non-fat tissues. Pollock and Wilmore (2012) stressed that with inactivity, the fat content of the muscle increases, whereas with training, it decreases. This implies that the lean body mass fraction of an individual increases with performance. This, they suggested may be the result of greater protein synthesis and reduced fat breakdown in the skeletal muscle. This protein synthesis and reduction of body fat, caused by increased performance then makes the lean body mass of an individual to increase. This fact is corroborated by Kraemer, Torine and Silvester (2005) who expressly stated that an individual with large lean body mass will also have large muscle mass which means greater force potential.

McArdle, Katch and Katch (2007) maintained that habitual participation in sports and training reduce the body's relative fat level and increase the lean body mass, and that a high lean body mass is desirable in those sports that require strength or strength-related attributes. Rather of being worried with their overall weight, athletes should be focused with their lean body weight, according to Norton (2009). Training programmes should be designed to develop the lean tissue to projected maximum, while maintaining the fat content at relatively low levels.

(iii) Total Body Water

This is the largest body composition in the total body water (TBW). TBW is divided into two fractional components: intracellular fluid and extracellular fluid, the latter of which is further divided into interstitial fluid and plasma volume (Heyward and Wagner, 2004). Due to the lack of water in stored lipids, there appears to be a reciprocal link between body fatness and total body water. According to Behnke and Wilmore (2012), the knowledge of total body water is a useful body composition parameter. Its usefulness to body composition analysis in the broader sense lies in its application in predicting lean body mass and hence fat mass. Indeed, the concept of a constant composition of the lean body mass is essential to most indirect body composition techniques. Thus, if body water can be measured using the electrical resistance of the body, it is possible to derive values for the lean body mass and fat mass.

Other varieties of procedures have been utilized by scientists to determine Total body water. This include deuterium oxide and tritiated water which is an isotopic dilution, antipyrine, urea and alcohol dilution, and newer analytical technique like infrared spectrometric and deuteron photodisintegration (Heyward and Wagner, 2004). However, according to Ackland, Lohman, Sundgot-Borgen, and Maughan (2013), reliance on an indirect approach for TBW assessment may be possible in the future. Going (2006) compared total body water evaluation made with deuterium dilution and bioelectrical impedance measurements, as an example of recent developments. When paired with weight, he discovered that body height squared divided by resistive resistance yields a multiple R of 0.99 with TBW and a standard error of estimation of 1.75L. He did propose, however, that bigger groups should be researched to validate the use of BIA techniques for TBW estimation. Hastuti, Kagawa, Byrne, and Hills (2013) had previously investigated this link and discovered a r of.98. In conclusion, the results imply that the BIA technique may fill a gap in the market for a non-invasive, fairly accurate, and quick TBW assessment.

2.3.2Methods of Determining Body Composition

A fundamental knowledge of the various procedures used to assess body composition is essential. Body composition assessment can be grouped into two,

(i) **Direct Method**

The direct method includes chemical analysis and anatomical analysis.

Chemical Analysis of the Body

Although there had been considerable research dealing with the direct measurement of the body composition in various species of animals, relatively few studies have employed precise chemical technique to analyse human fat content. According to Wells and Fewtrell (2006), such analyses are moment based and arduous, necessitate laboratory instruments that are unique, and present numerous ethical and legal issues in procuring cadavers for research. Norton (2009) attested to this fact when he submitted that few body composition assessments have been conducted directly.

Chemical analysis can only be applied after a person is dead, or cadaver, where the different body tissues can be very carefully dissected. This requires a tremendous amount of time and effort. For these reasons, only a few analyses of human cadavers have been made during the past hundred years. There is always a difficulty in chemical analysis in terms of obtaining permission from relatives or guardians of the dead. It is particularly more difficult to acquire the bodies of healthy persons, whose death is usually assumed sudden and carries with it many legal implications.

Anatomical Analysis

This technique involves gross dissection of the body after which the chemical analysis of the body is done. Only a few investigations on human cadavers have been conducted, and physiologists interested in the fundamental principles underlying gross body composition have largely shunned this method (Brodie, Moscrip and Hitcheon,2010).

(ii) **Indirect Methods of assessing body density, body fat, and other body components**

The problem associated with the direct methods of body compositional analysis in form of restricting the compositional analysis to the dead rather than the living has led to the development of several indirect techniques. These indirect techniques, according to

Heyward and Stolaryzk (2006) have been developed for practical purpose of body composition assessment in both sexes. These techniques include among others;

(i) hydrodensitometry or underwater weighing
(ii) anthropometry
(iii) bioelectrical impedance analysis (BIA)
(iv) magnetic resonance imaging (MRI)
(v) near-infrared interactance
(vi) air-displacement plethysmography
(vii) dual energy x-ray absorptiometry (DEXA)

Hydrodensitometry or Underwater weighing

It is a technique for determining the volume of a person's body. Alternative processes are frequently judged and validated against this procedure, which is regarded as the most dependable of existing ways for estimating body density (Katch and Katch, 2004). To reduce the influence of lung air on buoyancy, the person must be completely submerged underwater and exhale as much as possible. According to Fuller, Lebb, Laskey, and Coward (2002), this occurrence dates back to the 1930s, when the US Navy was interested in creating a practical method for evaluating body fat in divers participating in 500-foot test dives. Archimedes' principles guide the underwater weighing process. It is based on the fundamental premise that a body immersed in a fluid is subjected to a buoyant force, which manifests as a weight loss equal to the weight of the displaced fluid. To put it another way, an object in water must be buoyed up by a force equal to the weight of the water it displaces (McArdle, Katch and Katch 2007). The individual is lowered into a tank or pool, and the difference in weight between air (scale weight) and water is measured. The difference between the scale weight and the underwater weight equals the body volume when trapped air volumes and water temperature are taken into account. Body density is calculated by dividing the mass or weight of the body by the volume of the body.

For best results, instructions to and preparation of the subject before underwater weighing is important. Subjects should be advised to avoid foods that can cause excessive amount of gas to develop in the gastrointestinal tract. Situations that can cause unusual hydration or dehydration should be avoided. There should be no eating or smoking for a least two to three hours before weighing (Ellis, 2014). Pollock and Wilmore (2012) recommended that before beginning the procedure, subjects should be asked to void their bladder and defecate (if need be). Once this has been accomplished, body weight should be measured. If anthropometric measures are to be taken, they should be done next, followed by the underwater weighing. Doing the underwater weighing procedure first and then having the subject dry off changes the texture of the skin and thus, may influence the skinfold fat measurement.

Though Pollock and Wilmore (2012) asserted that the underwater weighing technique is the most accurate laboratory test available to evaluate the total density of the body and its subsequent compositions, it is not without its limitations. The biological and technical sources of mistake in the underwater weighing technique have been thoroughly investigated (Lohman, 2002, Jackson and Pollocks, 2010, Marfell, Olds, Steward and Cater, 2006). They discovered that technical flaws in body density measurement can exacerbate the many sources of biological variance. Some errors have been associated with calculating the percentage fat from body density, that could be linked to the variability and composition of the fat-free body. Such includes

(i) variations in the body's water content that are unrelated to body fatness.
(ii) the protein-to-bone-mineral ratio varies.
(iii) variations in obese tissue density.
(iv) fat content variations.

Hydrostatic weighing techniques, according to Lohman (2002), may have SEE as high as 2.7 percent when used to determine the amount of BF owing to variability in fat-free density among a specific population. The main sources of technical errors in body density measurement have been identified as variations in lung volume residual, which appears to contribute the most error from combined factors of variation in body mass, underwater weighing, and measurement of water temperature (Norton, 2009).

Apart from these limitations, the procedure requires substantial space and equipment, it is time consuming, and requires experts in body composition assessment. Scales not been calibrated, subjects being unable to coordinate the underwater weighing procedure, and oscillations created by water movement are the most common problems associated with reading the underwater scale weight. Pollock and Wilmore (2012) however proffered some solutions to minimize or overcome most of these problems. These include periodic calibration of the scale with known weights, multiple practice trials and a stable, comfortable sit to increase the subject's ability to minimise underwater motion.

Anthropometry: Skinfolds, circumferences and diameters measurements

Anthropometry is defined as a systematized technique for taking measurements of carefully defined body landmarks and specific subject positions in order to express in a quantitative manner, the dimensions of the body (Katch and Katch, 2004). Measurements of bone and general body diameter, girth or circumferences, and skinfold thickness are all part of the procedure. Anthropometry measurements are approximations used to determine BD and %BF; nevertheless, when utilized with prudence, they can provide relevant and valuable information (Heyward and Wagner, 2004). Anthropometry is the most widely used field method for estimating human body composition, according to Norton (2009), while Jones and Norgan (2014) found that anthropometric and body composition data can help with decisions about which sport or event an individual is most likely to succeed in, as well as the development of appropriate training schedules and the management of those with injuries that are sports-related. The instruments used in anthropometric measurements include broad or narrow blade anthropometer, cloth or steel tape and skinfold calipers.

Anthropometric assessment estimates of body composition correlates accordingly with the method of underwater weighing. Among the several advantages are the fact that the equipment is inexpensive and needs just a little space for a quick succession evaluation. The accuracy of predicting body density from skinfold, circumferences and girth measurement is subject to intertester error. As a result, precise criteria for measurement sites, as well as established methodologies, are critical for this strategy. The reference manual of National Standardization Conference in Airlie, Virginia, USA includes input from 41 experts from various disciplines and include a comprehensive description of over forty anthropometric measures.

Skinfold Measurement in Body composition Assessment

Skinfold thicknesses, often known as 'fat fold' thicknesses, are the thicknesses of double skin folds and subcutaneous adipose tissue at certain bodily locations. The reasoning for skinfold measurement is based on the fact that nearly half of the body's total fat content is stored in fat depots beneath the skin, and that total fat is closely connected to skinfold measurement. Skinfold measurements are used to detect overall fatness and distribution of subcutaneous adipose tissue. The amount of total body fat reflected by the subcutaneous adipose layer varies by age, gender, and population. The idea behind this strategy is that subcutaneous adipose tissue represents total body fat. For example, when total body fat grows, so does the relative proportion of internal fat, resulting in an underestimating of percent body fat at greater levels of fatness if estimates are made.

The utility of skinfold thicknesses, according to Lohman, Roche, and Reynaldo (2008), is twofold. For starters, they give a non-invasive and rather straightforward means of assessing general fatness. The characterization of the distribution of subcutaneous adipose tissue is the second major application of skinfold thicknesses. There is emerging evidence that not all subcutaneous adipose tissue depots are equal in terms of liability or contribution to the obesity-related health risk.

Despite the fact that skinfold measurements are straightforward to do and reasonably repeatable, it is critical to measure from a standardized site and location, however, tiny deviations in location can result in considerable differences in measurement. When utilizing the skinfold caliper, the right side of the body is frequently used. The caliper functions similarly to a micrometer, which is used to measure distance between two locations. To measure skinfold thickness, grab a fold of skin and subcutaneous fat with your thumb and index finger and pull it away from the underlying muscular tissue, following the natural contour of the skinfold. At their site of contact with the skin, the calipers' pincer arms apply constant stress. The thickness of the double layer of skin and subcutaneous tissues is then measured in millimeters using the caliper dial.

The folds are usually made in a vertical plane, with the calipers' blades held vertically. When the natural folds of the skin demand it, you may depart from this position. Individuals who are extremely slim or extremely obese have unique measurement challenges. When employing the skinfold technique, Katch and Katch(2004) noticed that there are some very significant methodological issues to consider. They argued, however, that smart use of basic principles can help to mitigate the severity of the problem. The repeatability of test scores is one of the methodological issues discovered. They did, however, advise that with a lot of expertise and careful attention to anatomical placement and technique, this may be done with a high degree of precision.

According to Katch and Katch (2004), different skinfolds should be assessed in order, then the cycle should be repeated at least two to five times, with the final skinfold score being the average of the results at each site. It is certainly more convenient to remeasure the same spot several times, but this method should not be employed, according to the experts. Fat is compressed when successive fat measures become smaller and smaller; this is most common in 'fleshly' people.

According to Norton (2009), it is preferable to measure the skin while it is dry, because when the skin is moist or wet, the tester may grasp additional skin (fat) and obtain bigger values. Because a movement of bodily fluid to the skin increases skinfold size, measurements should not be done immediately after exercise or when a subject is overheated. It takes practice to consistently grip the same size of skinfold at the same position every time. A result that appears to be too high or too low (typically in comparison to the initial measure) is frequently disregarded or remeasured until the results 'agree' with a predetermined tolerance level.

The error that is common in predicting body fat using skinfold data, according to Lohman (2011), are biological differences in subcutaneous fat proportion (±2.5%), biological variations in subcutaneous fat distribution (±1.8%), and technical measurement mistakes (±0.5%). Based on the distinct level of the error source, ±3.3 percent fat was found to be the overall error, and this was more than the amount claimed for densitometry and on par with many of the more complex indirect approaches. It is possible to detect systematic differences in fat distribution. Whites have bigger skinfolds at limb sites than blacks, especially in males, although the racial differences fade at trunk sites. It is nearly hard to establish which set of skinfold data is "right" because there is no standard by which to compare the results of different scientists from different geographical regions. As with most techniques used for body composition assessment, skinfold measurements have limitations that can lead to inaccurate estimates of subcutaneous fat thickness and, as a result, total body fat for an individual. Just like body composition assessment procedures, skinfold measurements have limitations that can lead to unsuitable subcutaneous fat thickness. Other issues include fatty tissue compression during measurement, as well as the inability to control inter- and intra-subject inconsistency (Gately, Radley and Cooke, 2003).

Circumferences Measurement in Body Composition Assessment

Circumferences are significant metrics for determining the size of the body's cross-sectional and circumferential dimensions. Circumferences, alone or in combination with skinfold measurements performed at the same site or different circumferences, can provide markers of nutritional status and fat patterning, according to Heyward and Stolarcyzk (2006). The cross-sectional areas of adipose can be determined using limb circumferences combined through skinfold values of subcutaneous adipose tissue thicknesses at matching levels. These regions can be used to track adipose tissue and muscle levels and changes during physical rehabilitation if they are calculated using the correct formula.

The tape measure used to measure wrist circumference must be thin enough to fit between the styloid processes of the radius and ulna and the carpals. Circumferences should be recorded with the left hand holding the zero end of the tape above the right hand holding the remaining part of the tape. The positioning of the zero point of a tape can affect measurement reliability both within and between observers. It is sufficient to state that the tape's location for each perimeter is critical, as uneven positioning affects validity and dependability. The measurer's tension on the tape may also have an impact on the measurement's validity and reliability. The tape is wrapped firmly around the body portion for head circumferences, but should be freer enough not to compress the subcutaneous adipose tissue. The measurer should double-check that the tape isn't identifying the skin for these circumferences. In Ojo and Babalola (2018), it was noted that circumference measurement in anthropometry is merely a rough estimate of muscle volume and cannot distinguish between different circumference components. Circumference measurement has low construct validity due to the fact that a combination of bone measures governs it, as well as skin, thickness, body fat, and muscle volume.

Bioelectric Impedance Analysis Technique

The core idea of bioelectrical impedance analysis (BIA) is that electrical conductivity in the body is directly proportional to the fat-free body's tissue (McArdle, Katch and Katch, 2010). Conductivity is higher in fat-free mass than in fat mass because fat-free mass includes practically all of the body's water and electrolytes. In theory, the magnitude of an impedance measurement allows fat-free mass and fat-mass to be distinguished. Bioelectrical impedance approach, according to Dixon, Dietrick, Pierce, Cutrufello, and Drapeau (2005), satisfies the demand for a safe, non-invasive technique that is quick and practical and delivers trustworthy and adequately precise estimates of human body composition outside the laboratory.

The human body's general conductivity is directly linked to lean tissue, and have been validated with criterion methods like skinfold assessment and hydrodensitometry (Keller and Katch, 2005). The technique entails applying adhesive surface electrodes to specific locations on the dorsal surface of the hand and the anterior surface of the ipsilateral foot of a subject who is lying flat on a non-conducting surface with legs abducted, preferably with the thighs not touching, though this may not be possible in highly obsessed subjects. It is critical that there be no metal around the subject that could affect impedance readings (e.g., a metal frame on a hospital bed, metallic jewelry, etc.) because it could affect high frequency measurements (Roos and Jansen, 2005). The applied current is typically in the range of 500µA for single (50KHz) frequency machines and 500µA to 1mA for multifrequency machines (5KHz to 1mHz), and tests can take anywhere from a few seconds to several minutes for a full frequency scan. The raw outputs (resistance and reactance) are normally viewable immediately on the analyzer and then transmitted to a host computer, where dedicated software processes the data.

The changes in body geometry, volume, temperature, and electrolytic concentration have an impact on bioelectric resistance and should be taken into account. Skin temperature, menstrual cycle, use of oral contraceptives, exercise induced hydration, preceding meals, and changing body positions are factors that influences bioelectrical impedance. A variety of equipment for measuring impedance are available, and a number of equations for estimating body composition from impedance readings have been devised. The Standard Error of Estimate of % body fat calculated using various devices and formulae has been observed to range between 2.7 and 6.1 percent when compared to densitometry (Jones and Morgan, 2014).

When using the BIA technique, the individual must not have consumed beverages four hours or less of the test, exercised within 12 hours of the test, or consumed diuretics or alcohol preceding to testing (ACSM, 2007). Because it primarily assesses features of the FFM, BIA analysis is traditionally unsuitable for predicting body fatness in individuals. Single frequency BIA has a high degree of precision, assuming that electrode placement is consistent, and so might be used to assess short-term variations in TBW among individuals. When compared to densitometry, BIA has been demonstrated to dramatically underestimate % body fat in athletes (Dixon et. al 2005). The accuracy of BIA is affected by subject characteristics, procedural skill, the estimated equation utilized, and the device used.

Dual energy X-ray Absorptiometry (DEXA)

This method involves calculating the bone mineral mass by comparing the absorption of two different energies of x-rays. Due to the fact that calculation incorporates tolerance for underlying soft tissue, fat and FFM values are also determined for whole-body scans using instrument-specific algorithms. Originally designed for bone content measurement, particularly the chemical investigation of osteoporosis, it is currently being hailed as a prospective body composition criterion approach. The accuracy with which changes in weight status can be quantified within persons gaining or losing weight is likely to be confused by the change in weight status as well.

After comparing DEXA to other techniques, researchers concluded that it is advisable for use in humans because it has a low standard error of estimation (Norcross and Van Loan 2010, Norcross and Van Loan, Norcross and Van Loan, Norcross and Van Loan It has already been widely utilized by a variety of populations, including children, young women, newborns, males, and athletes, in addition to postmenopausal women. However, according to Jebbs (2013), anyone using DEXA to determine fat mass should keep in mind that the estimated fat is lipid not adipose tissue. Theoretical disparities in imaging modalities would have to be taken into consideration in any validation.

In comparison to other reference and laboratory approaches, dual energy x-ray absorptiometry measurement has various advantages. Firstly, it is easy to administer, fast, precise, and comfortable for most individuals, and because regional measurements are attractive for many population coupled with the fact that measurement is minimally influenced by water fluctuation. However, DEXA does have some limitations, i.e. the scanning bed is not designed for large people, and the machines are large and expensive. DEXA also assumes segment consistency in tissue composition, hydration, and electrolyte content in lean tissue, which is flawed because both water and lipid content of skin, adipose, muscle, and bone tissue vary regionally, according to them.

However, DEXA scan typically registers higher body fat percentages (ranges from 2 to 5%) for total body measurements than other procedure (Norcass and Van Loan, 2010). Although studies done on DEXA has increasingly contribute to the evidence base for medical practices, and results of most validation studies show it to be an accurate tool the measurementfor body composition (Ramananda, Takhellambam and Bidhyapati, 2006).

Near-Infrared Interactance

The principles of light absorption and reflection are used in to create near-infrared interactance (NIR). Infrared light is emitted at specified wavelengths from a light wand or fibre optic probe sited perpendicularly on a body component. A silicon-based detector is used to determine the infrared beam's absorption, which is expressed as two optical densities. Optical density, gender, height, physical activity level, and body weight are used to calculate % body fat in prediction equations (Ackland et al 2012).

Some commercial NIR systems (such as the Futex-5000, -5500, -6,000, -6,100) are portable and require little or no operator training, by that, it is attractive to the health and fitness industry. The tiny body sampling area, however, is a serious drawback.

Although NIR has been found to be reliable for evaluating female athlete body composition (Buskirk, 2012), it does was reported to be of be of more error than other techniques of body composition. In another study, NIR has been demonstrated to overestimate percent fat in young wrestlers approximately up to 14.7 percent (Heymsfield, Wang, and Withers, 2014), and is the least effective method for measuring changes in body composition after resistance and aerobic exercise. As a result, in a healthy and athletic population, NIR is not advised for routine use.

Air-Displacement Plethysmography

Air displacement can be used to determine body volume. The BOD POD (a commercial ADP system) uses a dual chamber plethysmograph to measure body volume by changes in air pressure within the closed-two-compartment chamber (e.g. 450L subject test chamber, 300L reference chamber). It comes with an electronic weighing scale, as well as a computer and software system. The total amount of air displaced is calculated by subtracting the volume of air left in the chamber when it is empty from the total volume of air displaced, which equals body volume (Vescovi, Hilderband, Miller, Hammer and Spiller, 2002).

The procedure includes the following:

a. Individuals' information is entered in the BOD POD computer and calibrated.
b. The subject is properly prepared with minimal clothing e.gsports bras, swimsuits, compression shots, and swim caps.
c. The testee body mass is determined via the digital scale.
d. Sit quietly in the chamber during testing while a minimum of two measurements (150ml of each other) are taken to determine body volume.
e. Thoracic gas volume is measured during normal breathing (i.e. via the panting method or can be predicted via equation.
f. Correct body volume is calculated, body density is determined, and percent body fat is calculated using similar prediction equations.

Safety, speed, comfortability, non-invasiveness, and accessibility for all people are all advantages of air displacement plethysmography over other procedures. However, the expense of purchasing the ADP unit remains a key disadvantage.

Magnetic Resonance Imaging

Magnetic resonance imaging (MRI) is a technique for estimating the volume of adipose tissue rather than its mass. By measuring the absorption and emission of energy in the radio frequency range of the electromagnetic spectrum, the technology creates images based on spatial changes in the phase and frequency of the energy absorbed and emitted. It focuses on hydrogen nuclei, which can be found in either water or fat, and uses this information to distinguish tissue types in 'imaging slices,' which can then be added together to calculate regional tissue volumes (Roberts, Cruiz-Drive and Reid 2003).

The knowledge gained in the research of nuclear magnetic resonance was used to produce magnetic resonance imaging. Nuclear magnetic resonance imaging (NMRI) was the name given to the technology in its early years. However, because the term nuclear was once connected with ionizing radiation exposure, it is now commonly referred to as MRI (Brambilla, Bedgoni and Moreno, 2006). The magnetic resonance imaging technique is a relatively recent technology. In 1973, the first magnetic resonance image was published, and in January 1974, the first cross-sectional image of a living mouse was published. Human studies were published for the first time in 1977. (Published in 2000 by Cambi, Bray, Bouchard, Greenway Johnson and Newton).

Magnetic Resonance Imaging (MRI) is a sophisticated and costly medical imaging technique that has gained popularity in recent years. A powerful main (usually superconducting) magnet, a magnetic field gradient system for signal localization, and a radio frequency system for signal production and processing are all required. Similar to other topographical imaging techniques, MRI scanning provides a data array (MRI picture) that reflects the geographical distribution of the measured physical quantity. MRI provides images of an object's internal physical and chemical properties using externally detected Nuclear magnetic resonance (NMR) signals. Despite the high quality of MRI imaging data, Dixon (2011) warns that comparing results to those obtained through other methods might be difficult. To determine fat mass, you must first figure out how much fat is in adipose tissue and how dense fat is. The latter is more stable, but the former isn't. The fact that MRI can only identify fat mass in adipose tissue is a second concern. Total fat mass vs. adipose tissue mass is measured using techniques other than MRI, such as densitometry, hydrometry, and multi component models. MRI is also relatively costly and in short supply. MRI's key benefit over other techniques is its capacity to assess regional body composition, and it is currently the only accurate and practical tool for evaluating intra-abdominal adipose tissue.

2.4 Residual Volume in Body Density determination

Benke and Wilmore (2004) believed that at the time of weighing,thecapacity of air in the lungs must be estimated, becausea substantial amount of air left in the lungs increases buoyancy, and could results into additional body fat.Wells and Fewtrell (2006) pointed out that variables which constitute potential sources of body density measurement error include body volume, dryland weight, lung volumes, water temperature and gastro-intestinal gases.

Heyward and Wagner (2004) contended that when measuring individual differences in body density, and accuracy is paramount, residual volume needs to be measured rather than estimated. They however showed that the difference in mean body density calculated among groups using the actual and estimated values of residual volume (RV) was less than 0.001gm/ml. Thus, for screening purposes, or when measuring large groups, the estimation of RV would be an acceptable technique. Buskirk (2006) proposed a constant correction factor of 100ml (BTPS) to approximate the air volume of the gastrointestinal tract. Heyward and Stolarczyk (2006) however disagreed with this position, claiming that predicting residual volume rather than measuring it may introduce measurement error in body density determination. Wells and Fewtrell (2006) observed that lung volumes are at least somewhat related to anthropometric characteristics and age. Based on this, they contended that it would be more valid to estimate RV based upon such characteristics rather than simply use a constant value, warning that constant value would theoretically introduce more error of measurement than the prediction equations.

The gender-specific equation using age and height developed on large heterogeneous samples were:

$RV=0.19 \times \text{height (cm)} + 0.0115 \times \text{Age} - 2.24$ (men)

$RV = 0.032 \times \text{height (cm)} + 0.0009 \times \text{Age} - 3.90$ (women)……….**Equation2.4**

Pollock and Wilmore (2012) estimated RV from Vital capacity and reported correlations ranging from 0.88 to 0.95 between body density and residual volume. Heyward (1996) also reported a correlation of 0.84 for men and 0.96 for women for adult fitness sample.

McArdle, Katch and Katch (2010) however asserted that RV is quite variable at any given age, height or vital capacity and may result in errors up to five percent of body fat.

When the individual is submerged in water, the residual volume of the lungs may be reduced. In this case, the hydrostatic force may supplement the greatest force that the expiratory muscles can generate. Increased thoracic blood volume could potentially have a role in the decline (Stout, Eckerson, Housh, Johnsonand Bettis,2005). They also claimed that the hydrostatic pressure could limit the maximal inspiration required to determine the vital capacity while being ineffectual in increasing the maximal expiration required to determine the residual volume.

Residual lung volume can be assessed by:

(i) the close-circuit technique, in which an inert tracer or indicator gas such as nitrogen, hydrogen, or helium is diluted and eventually equilibrated.

(ii) the open-circuit technique, in which nitrogen is "washed out" of the lungs for a period of time while inhaling oxygen.

The shared critical limitation of the two procedures described by McArdle, Katch, and Katch (2010) is that completing a single determination for one person takes a long time. When you factor in the time it takes to prepare the subject and testing equipment, the test itself, and the analysis of the gas samples that result, the methods take anywhere from 15 to 30 minutes altogether. This time element becomes a key limitation when faced with the difficulty of needing to test a large number of participants in addition to the requirement of obtaining a minimum of two determinations for each subject.

2.5 Body Composition of Athletic Population

For better understanding of the complexity of body composition, a knowledge of the build and composition of various type of athletes representing different sports may be helpful.The body built of an individual is determined by genetic factors, food intake and participation in physical activities. The physically active individual is heavier than the inactive ones and also has lower percentage body fat and higher specific gravity.

McArdle, Katch and Katch (2010) opined that the nature of an individual’s lean body mass affects performance in some favoured sports requiring speed, agility, power and strength, since the size of the muscles almost accounts for their increased strength during performance. Athletes that were very slim but hefty due to a well-developed musculature performed better in specific competitive sports activities, according to studies of body composition in certain sports.Benke and Wilmore (2012) found sprinters to be more muscular than distance runners. Ojo (2020) also stressed that with inactivity, the fat content of the muscles increases, whereas with training, it decreases. This implies that the lean body mass fraction of an individual increases with performance, though there is always no further increase in the lean body weight of an athlete after the age of fifty, irrespective of the level of training. In the same vein, an individual with large lean body mass will also have large mass which means greater force potential, though in certain activities, a large lean body mass may be a negative influence on performance.

Habitual participation in sports and training reduce the body's relative fat level and increase the lean body mass, and a desirable high lean body mass in sports that requires strength or strength-related attributes. McArdle, Katch and Katch (2007) was of the opinion that athletes should be concerned with their lean body mass rather than being concerned with overall weight. Training programme should be designed to develop the lean tissue to projected maximum, while maintaining the fat content at relatively low levels. While this would be a desirable approach for an individual,it could be counterproductive for endurance athletes who is forced to move his total body mass horizontally for extend period of timedepending on the need for strength, power and muscular endurance for success in events.

A low relative body fat percentage is thought to be advantageous for success in practically all sports. In activities where the body mass must be moved through space either vertically, as in jumping, or horizontally, as in running, there is a strong negative association between body fat percentage and performance (Katch and Katch, 2004).

Athletes in the same sports, receiving the same training should be seen and treated as individuals. They referred to a study carried out on a number of national and international class female track and field athletes, where a runner and one of the best in her events with high-intensity training and long distance running had over 17% body fat as against her counterpart, below 12% body fat. According to Katch and Katch (2004), it is improbable that this athlete could have decreased her relative body fat to less than 12% without a significant impact on her performance. They concluded that while it is appropriate to establish guidelines such as an acceptable range of body fat for a sport, consideration must be given to and for the exception.

Jebbs and Elia (2003) concludes that relative body fat is not only lower in athletes when compared with non-athletes, the optimum value is different from sport to sport, being lowest in the energy-demanding long duration sports, and highest in technique and power events which do not require sustained energy production for a long duration.

2.6 Alteration of Body Composition with Physical Training

Habitual participation in sports and training reduce the body's relative fat level and increase the lean body mass. Body composition can undergo substantial alteration with physical training. The magnitude of the changes in body composition with training appears to be especially related to the total energy expenditure associated with the activity (Baumgatner and Jackson, 2013). Thus, in energy demanding sports like distance runs, the adaptive changes in body composition are high. Exercise and training of desirable intensity can also lead to substantial weight gains. These gains, however, appear to be predominantly, if not totally increases in lean body weight, and a substantial loss in body fat.

Sokal and Rolf (2013) conducted a longitudinal study of seven female gymnasts and found that there was a direct correlation between the intensity of training and alteration in body composition. With intense training, body density increased, reflecting a loss in relative body fat, and skinfold thickness decreased. During the periods of rest or reduced activity, these changes were reversed. Heyward (1996) evaluated body weights and skinfolds thicknesses on basketball and hockey players before and after a season of play in their respective sports, although weight remained relatively stable, there were rather major decrease in subcutaneous skinfold fat. In a similar study of football players, Baumgatner and Jackson (2013) reported no change in body weight, substantial decreases in skinfold thicknesses, and significant increases in estimated body density, indicating an overall decrease in total body water and an increase in fat-free weight resulting from a season of training. Lending credence to this widely assumed position, Sinning (2010) studied five middle-aged men who ran three times per week, a minimum of 30 minutes per session for a total of 16 weeks. Compared with a group of 5 sedentary controls, the experimental group lost 4.5kg of body weight, 3.6kg of body fat, and 0.9kg of fat-free weight.

There have been several studies that have also evaluated the effects of weight training in either a standard or a circuit format on alterations in body composition. Brodie (2008) conducted a 10-week weight training programme, 2 days per week for 40 minutes per day, involving 47 women and 26 men. Neither group changed total body weight, but both groups decreased absolute body fat by 1.2kg and 0.9kg and relative body fat by 1.9 and 1.3% and increased fat-free weight by 1.1 and 1.2kg in the women and men respectively. Circuit-weight training has also been shown to alter body composition. Gabett(2007) circuit-weight trained men and women subjects 3 days per week, approximately 30 minutes per day for a period of 10 weeks. Although increases were found in fat-free weight of 1.7 and 1.3kg for men and women respectively, there were no significant changes in body weight, and only the women exhibited a significant decrease in relative body fat (-1.8 percent).

As a result of the cited references, one may confidently conclude that exercise training causes significant changes in body composition. Exercise training appears to result in moderate total body weight loss, moderate to large body fat loss, and small to moderate gains in lean body mass. The degree of these changes is proportional to the frequency, intensity, and duration of activity, as well as the length of the research. Although body weight often drops over three months or longer, it is not uncommon for body weight to fluctuate little during the first few months of training. This lack of significant change in the initial stages of an exercise program is mostly due to changes in body composition, i.e., body fat decreases accompanied by equal gains in fat-free weight. Lean weight varies very little as the exercise program is extended beyond three months, and body weight decreases now begin to represent genuine changes in body fat.

2.7 Regression equations in body composition predictions

A regression equation is a mathematical model that allows the values of one dependent variable to be predicted based on the values of one or more independent variables (Sokal and Rohlf 2013). According to Katch and Katch (2004), over the last forty years, at least over one hundred regression equations have been developed to evaluate the fat and lean components of the body. A regression equation may be 'population specific' or 'generalised' equation.

2.8Population-Specific Regression Equations

Population specific equations is defined as an equation derived from a given population that do not apply to other populations because of biological factors that influence the relation of an anthropometry to total body fatness (Behnke and Wilmore 2012). Also the characteristics of the sample under study do not apply to other samples in terms of methodological factors. Such methodological factors include sampling procedure (most body composition studies involve non-random samples), sample size, variables selected in a given study, measurement description and procedures used, criterion variable selected for estimating percentage of fat, and statistical analysis procedures used to develop the prediction equations.

In an attempt to quantify body fat from skinfold measurements, Jackson and Pollock (2010) noted certain constraints connected with population specific formulas and linear regression models. They noticed that the slope of the regression lines between young adult males and exceptionally lean world class runners was not parallel in a sample of men of various ages. In rare circumstances, research has revealed a curvilinear link between skinfold measurements and body density. They went on to say that the discrepancies in slopes and intercepts could be due to this non-linear relationship. As a result, they devise a number of formulas based on a quadratic relationship and the age function.

The selected population-specific regression equations for this study include:

i) **Brozeks and Keys (1951)**

BD = 1.1017 – 0.000282 subscapular SF – 0.00736 chest SF – 0.000583 Triceps SF…………………………………………… **Equation 2.8a**

According to Pollock and Wilmore (2010), this was the first body composition regression equation. It was derived originally by using 159 University student with a mean age of 20.4 years. The authors used mainly skinfold fat measurement in three sites namely, subscapular, chest and triceps to evaluate young and middle-aged men body densities. The equation has a multiple correlation co-efficient (R) of 0.88 and a standard Error of Estimate of .0007. The initial body density mean value of the sample was 1.0777g/ml with a standard deviation of 0.014kg.ml^{-1}.

(ii) **Sloan and Weir (1970)**

BD = 1.1043 – 0.00132 Thigh SF – 0.00131 subscapular SF………**Equation 2.8b**

The equation has a multiple correlation co-efficient R = 0.71 and a Standard Error of Estimate (SEE) - 0.0108 (Sinning and Wilson, 1984). Skinfold fat measurements at only two sites namely, thigh and subscapular were used. It was derived with male athletes ages 18-26 years. A vertical skinfold of the anterior midline of the thigh, in between the inguinal ligament and the top of the patella, and a subscapular skinfold running downward and laterally in the natural fold of the skin from the inferior angle to the scapular provided, according to the authors, will be the best method in young men (aged 18-26 years).

(iii) **Sinning (1974)**

BD = 1.1080 – 0.00168 subscapular SF – 0.00127 abdominal SF….**Equation 2.8c**

The equation was derived with 50 University athletes aged 19 to 22 years. A multiple correlation co-efficient; 0.975 and a SEE; 0.0076 was reported for the equation by Thorland et. al (1984). It used skinfold fat measurements from only two sites namely subscapular and abdominal skinfolds as anthropometric sites for the equation.

(iv) **Forsyth and Sinning (1975)**

BD = 1.03525-0.00156 subscapular SF+.00207 bitrochanter diameter-0.0148 abdominal SF………………………..**Equation2.8d**

The equation was originally derived with fifty University male athletes ages 19-29 years. Their mean body density was 1.072g/ml with a standard deviation of 0.010. Thorland, Johnson, Fagot and Tharp (2004) reported an R=0.76 and SEE=0.0051 for the equation.

Pollock and Wilmore (2012) however reported an R of 0.84 and SEE of 0.006 for the same equation. These equations tend to be ‘population specific’ in terms of gender and age. According to Katch and Katch (2004), they predict most accurately at the mean of the population in which the data were collected and the equation developed. Dixon (2011) remarked that a major limitation of population specific equations lies in the fact that equations developed on one group are biased when applied to subjects who differ in gender, age and fatness. This was corroborated by Lohman (2001) who noted that equations developed on younger subjects underestimate the body density of older subjects. When gender-specific equations were applied to the opposite sex, the prediction error was consistently above 0.025g/ml, or 11 % for fat.

Not only are the population-specific equation sensitive to differences in age, gender and degree of fatness, but they are also subject to error regarding a basic assumption that hydrostatically determined body density is curvilinear rather than linear.

Salmat, Shance, Salamat, Khoshali and Asgari (2015) reported that two of the selected population-specific equation used two skinfold sites (Sloan and Weir (1970) and Sinning (1978).Brozeks and Keys (1963)) used three sites like Forysth and Sinning (1975). The main difference was that Forysth and Sinning (1975) included trochanter diameter as a variable in addition to two skinfolds. Each author might have selected his sites based on certain criteria like correlation of the sites with other measures of body fatness, good reliability and perceived representation of trunk and limb subcutaneous fat. According to Katch and McArdle (2003), the validity co-efficient and SEE for regression equations using only skinfold and only circumferences or diameter are nearly same. The majority of the population-specific equations were shown to have poor applicability when applied to a different sample of subjects, resulting in substantial mistakes in calculating individual values (Pollock and Wilmore, 2012). They predict most accurately at the population mean for which the data was collected and the equation developed. As the subjects differ from the mean, the standard error of measurement increases significantly.

2.8.1 Generalized equation

The development of 'generalized' rather than 'population-specific' equations has become more popular in recent years. According to Pollock and Wilmore, Durmin and Womersley were the first to consider generalized approach.

The selected generalized regression equation for this study is

BD-1.1093800-0.008269 chest+abdomen+thighSF+.00016 Triceps+Thigh+Suprailiac SF^{2}-0.0002574age, ………..**Equation 2.8.1a**

(R = 0.81, SEE = 0.0077)

The equation was created using 403 American Volunteers ranging in age from 18 to 61 years old. Researchers' access to digital computers and step - wise regression computer programmes enhanced computing capacity and made it possible to assess a large number of variables and select the anthropometric variable combination that created the highest correlation value. Jackson and Pollock (1999) argued that age has been shown to account for body density variation beyond that accounted for by skinfold fat, so they incorporated age in the equation. The Durnin and Wormesley equation also took age into account by creating distinct equations for different age groups in the original sample.

Generalized equations are designed to offer an acceptable estimation of body density and fat for a wide age range and fatness. Proponents of generalized equation argued that population-specific equations used linear regression models to develop their equations when research has actually shown that relationship between skinfold fat and body density may be curvilinear (Jackson and Pollock, 1999). Thorland, Johnson, Fagot and Tharp (2004) observed that if an equation is based upon linear combination of individual anthropometric measures, the potential for inter-tester bias may be increased. Such inter-tester variability may be reduced when the sum of several measures are used in a prediction equation and that relationship between skinfold thickness and body density were best described by quadratic functions.

The general technique allows one equation to replace an equation that has population specificity without compromising forecast accuracy. They are more applicable to body types and a wide range of age than population-specific tests. They also reduce substantial prediction mistakes that arise at the body density distribution's extremes. However, there may be some debate over whether the newer generalized equations has higher advantage over the previous ones. According to Sinning and Wilson (2004), the following two factors may have lowered the advantages of newer equations over older ones in every sample investigated.

(i) The age of the analyzed sample may be quite uniform, with little variation.

(ii) When the skinfolds were plotted versus body density, there may not be any apparent curvilinearity.

Katch and Katch (2004) recently addressed many limitations restricting the general usage of regression equations, demonstrating that:

(i)different prediction equations derive from diverse populations.

(ii) significant sources of heterogeneity arise from the various ways of determining body density in order to predict body fat.

(iii) different investigators use different methods to measure skinfolds.

With these considerations in mind, Jackson, Pollock, and Ward (2000) concluded that the universal application of any equation or formula cannot be assumed without a validation on a separate group of participants.

2.8.2 Regression Equation: its validity and validation

A statistical model that identifies the exact link between the predictor and the outcome variables can be referred to as regression equation. With a model regression equation, one can anticipate the outcome with a narrow margin of error. A typical model or equation represent in this linear form

$$Y_1 = b_0 + b_1X_1 + b_2X_2 + \cdots + \sum i$$ ………….**Equation 2.8.2a**

In this model, Y stands for an outcome variable, while X1 and X2 stand for the predictor variables that go along with it. There is a numerical relationship between the predictor and the outcome in the equation. If the predictor has a zero value, the term b_0 reflects the model's intercept. It could be compared to a baseline or control points. The terms b_1 and b_2 denote the numerical relationship that exists between the predictor variable and the outcome. These are referred to as regression coefficients. The degree to which a test measures what it is designed to assess is a typical definition of validity. However, Thomas and Nelson (2001) looked at these typical criteria and concluded that they don't account for the reality that there are multiple types of test validity. According to them, prospective test users should not ask the question "is this test valid for the purpose for which I intend to use it?" rather than "is this test valid?" Validity is a critical characteristic of any instrument because if an instrument does not measure what it is intended to measure, then it will not permit appropriate inferences to be made from its result.

The correlation and related standard error of estimate between body density as directly evaluated by underwater weighing and indirectly anticipated from a number of anthropometric parameters such as skinfolds, circumferences, and bone diameters is defined as validity in the context of this study. Validity is defined by Kleinbaum and Kupper (2012) as the appropriateness, purposefulness, correctness, and utility of the inferences made by a researcher based on the data obtained. Validation, according to them, is the act of gathering and analyzing evidence to support such inferences. The validity of an instrument is based on the conclusions made about its unique usage, not the instrument itself. Roland (2017) claimed that existing equations must be validated because the multiple correlation (R) of an equation does not guarantee that a particular regression equation would reliably predict individual scores in a second random sample from the population under study. The assumption is that any prediction equation used has a high predictive validity. The 'worth' of initial prediction equation is determined by the amount of the correlation co-efficient amongst predicted and observed scores, as well as the standard deviation of the distinct scores. Every validation study must account for the likelihood of inter-investigator discrepancies in skinfold measurement techniques. Methodological differences in validation and cross-validation research, according to Sinning and Wilson (2004), may be as relevant as theoretical differences in cross-validation studies. It's also worth noting that variances in cross-validation findings could be related to changes in criterion measurement methodologies.

The link between skinfolds, BD and fatness was thoroughly examined by Lohman (2002). He acknowledged that generalized equations that results in the influence of age on body fat distribution are needed, but he also stressed the importance of cross-validation when using specialized samples. Each equation must be validated and evaluated independently. Thorland, Johnson, Fagot, and Tharp (2004), for example, cross verified both generic curvilinear and certain linear models and they discovered diverse curvilinear equations were not equally good in calculating BD. The standard error appears to provide the robust evidence in cross-validation of equations in terms of accuracy and validity especially when cross-validated on a second sample. The equation is more accurate and valid if the standard errors are near to each other. The standard deviation of the projected density value should be supplied in addition to the standard error (Brodie, Miscrip and Hutcheon, 2010).

2.9Statistical Considerations for Body Composition Assessment

(i) **Multiple Regression**

A key purpose of regression analysis is to isolate the link between each of the independent and the dependent variable. When all of the other independent variables are held constant, a regression co-efficient is the mean change in the independent variable for each one unit change in an independent variable. Multiple regression is a strategy that allows researchers to discover the greatest combination of two or more variables to discover a connection between a criteria variable and another variable (Ferguson, 2010).

A regression equation can also be used to investigate or explain the causal link between variables, such as to answer the following question:

(i) What variable(s) perform best in predicting the outcome?

(ii) What will be the effect of the performance of the predictor variable(s) when the effect of the other variables is controlled for?

In a multiple linear regression, more than one independent variable is included in the model. It looks into how two or more variables interact to influence the dependent variable. Multiple regression's strength rests in the fact that it separates the effects of variables that are acting at the same time. A multiple regression analysis' statistical purpose is to create a linear equation model that determines the best weighted linear combination of independent variables in the research for predicting the criterion variable. The specific weight (contribution) allocated to each independent variable in the model is relevant to the other independent variables in the analysis since the model configures the predictors together to maximize prediction accuracy. Building multiple regression models is usually the last stage of data analysis in most projects. Many factors can be included in these models, which can work alone or in tandem to explain variance in the dependent variable. The ability to document collective efforts, i.e. the interplay of factors on expected outcomes, is one of the most significant advantages of regression analysis. They can also determine how much variance in the dependent variable can be assigned to the model variables, as well as how much variation is left unexplained.

The outcome of a multiple regression analysis is determined by the predictor variables chosen and the order in which they are input. Changing the variables, or the order in which they appear, alters the amount of additional variation that each contributes. Multiple Regression's popularity arises from its versatility and the amount of information it provides on the relationships between variables. It can be used to examine data from any of the primary quantitative research designs, including causal-comparative correlational, experimental. It can handle data that is interval, ordinal, or categorical. It calculates the magnitude as well as the statistical significance of the association between variables.

(ii) Multiple Correlation

The multiple correlation coefficient (R) results in an equation that predicts a criterion dependent variable by combining one or more independent variables (e.g. skinfolds, girths, diameter, height, weight, etc) (BD and lean body weight). For analyzing both group and individual data, each equation has its own level of precision. In most cases, the variables with the highest correlation with the criterion are included in the model. If one wants to predict something, the magnitude of the obtained co-efficient must be much higher, usually at least 0.70. (Ferguson, 2010). Correlation coefficients of this magnitude are almost impossible to obtain from a single predictor variable, but they can be obtained by combining multiple predictor variables using the multiple regression technique.

Montgomery and Peck (2002) suggested the use of 'R^2' of prediction as a measure of predictive ability. Negative values of R^2 of prediction will indicate that the predictions are worse than using the sample means. A large positive number (close to 1.0) indicates a good fit. Pearson r is a bivariate correlation indicator that expresses the size of a relationship. The multiple correlation co-efficient, represented as 'R,' is the index of correlation when two or more independent variables are employed. R, unlike "r," has no negative values. R is a number that ranges from 0.00 to 1.00 and indicates the strength of the link between numerous independent factors and a dependent variable, but not the direction of the relationship. However, indicating direction would be meaningless because X may be positively associated to Y_1 and X_2 could be adversely related to Y. When the R statistic is squared, it shows how much of the variance in Y is explained by the independent variable's cumulative simultaneous influence. The co-efficient of determination is another name for R_2. The computation of R_2 provides a direct method of measuring the prediction equation's accuracy. When the independent variables have low correlations among themselves, R tends to be bigger. It is important to note that correlational studies do not establish cause and effect in and of themselves. However, if two variables have a large enough link, it is possible to predict a score in one of them if the other variable's score is known.

2.10 Standard Error of Estimate

The regression analysis creates a sampling distribution of sort, the standard deviation of which is called the standard error of estimate. In using regression equation to make predictions, the estimate will not match exactly the actual value of Y, rather the Y predicted value will be somewhat different than an actual value, the difference is called the error of prediction.

The difference between Y predicted value and actual Y values are also known as residuals. When all the prediction errors from the model are placed in a distribution, the mean and the standard deviation of the entire group can be calculated. The Standard Error of Estimate (SEE) is the standard deviation of all the prediction errors at the stage of derivation of the equation, when there is a large correlation, the unexplained variance will be very small and will therefore result in a small SEE. However when the original correlation is weak, there will be a greater amount of unexplained variance. This will result in large standard error of estimate.

The standard error of regression, is the average distance between the observed values and the regression line. It conveniently demonstrates how inaccurate the regression model is when the response variable's units are used. The smaller the value, the closer the observation is to the fitted line (regression). In contrast, a large standard error of estimate implies that the data are dispersed widely about the regression line and that the regression equation will not yield a precise estimate. When using a regression model to make predictions, determining the standard error of regression may be more significant than determining the coefficient of determination (R_2).

2.11 Constant Error

A constant error is a source of error in a scientific experiment that causes measurements to continuously diverge from their variable values, either greater or lower than their temporal value. Unlike random mistakes, which cause measurements to depart by varying amounts (either higher or lower than their time values), constant errors only generate one type of variance.

Constant mistakes are difficult to spot since they don't change no matter how many times an experiment is performed, assuming that the experimental circumstances and apparatus don't change. Furthermore, despite the fact that persistent errors impart a constant bias into the mean or median of experimental data, no statistical examination of the data can discover one.

It's worth noting the distinction between a precise and an accurate measurement. A measuring scale with inaccurate divisions, or graduations, will yield a detailed measurement, but one with a continual error induced by the inaccuracy of the results. This type of constant error can be avoided by performing the experiment on a known quantity for which the exact outcome is already known, and then applying any necessary corrections to unknown values. Certain measuring instruments, such as ammeters, voltmeters, stop clocks, and thermometers, may have a 'zero error,' which is a form of constant error.

Whether it's due to the difficulties of collecting accurate measurements or equipment issues, completely avoiding error is nearly impossible. To address this problem, scientists do their utmost to classify errors and quantify any uncertainty in their measurements. Consistent errors, on the other hand, can be recognized and eradicated in a variety of methods. When the experimental results are compared to those produced by someone else using a different process or other equipment, a consistent mistake may be discovered. Similarly, it may be essential to tweak or calibrate one's process or equipment, or both, to achieve the desired result. A measuring instrument can change the physical quantity it is supposed to measure under specific circumstances. The voltmeter becomes a main component of the circuit when it is connected to a circuit with low current or high voltage, and has an impact on the voltage measurement. In the context of this study, Constant error (CE) is the sub mean difference derived from the subtraction of the body density estimated from body density measured through hydrostatic weighing.

2.12 Root Mean Square Error (RMSE)

Examining the model's residual standard error generated on the test data is an excellent way to judge model predictive ability. The square root of the mean squared prediction error value is used to calculate the residual standard error. It calculates the model's average prediction error while forecasting a future observation's outcome. The RMSE should be as low as possible. The root-mean-square deviation (RMSD) is a commonly used measure of the discrepancies between values (sample or population values) predicted by a model or an estimate and values observed. The RMSD is used to combine the magnitudes of prediction errors for different data points into a single predictive power measure.

The Root Mean Square Error (RMSE) is calculated thus:

$$\sqrt[RMSE]{\frac{\sum(observed - predicted)^2}{n - p - 1}}$$

Where n = the number of observation

p = number of the predicted variables…………… **Equation 2.12a**

2.13 Development of New Equation for body Composition Assessment

Questions may be asked; why a new equation? The reason is basically this. These equations were created for mostly white population, and it is unknown whether they are valid for black people. There have been several reports of body composition disparities between blacks and whites. The most well-documented variation is an increase in lean body mass density (Wilmore, Costil and Kenny, 2008). As Sokal and Rolf (2013) demonstrate, hydrodensitometry will incorrectly estimate body composition in blacks due to equations that assume a constant density of lean body mass, which may be adequate for whites but not for blacks. Skinfolds have been criticized for being used to evaluate body fatness. The population in which the equation was created, and the equation's validity in different populations have all been the targets of criticism for the skinfold prediction equation. Katch & Katch (2004); Sinning (2010); Lohman (2011) and Jebb (2013) have all voiced concerns about the accuracy of body composition estimates and the care to take when utilizing them. This is because current equations' validation and cross-validation have often shown correlations that are far lower than those stated in the original study (Dixon 2011). When calibrated against criteria estimates with systematic errors, even equations with a high coefficient of determination (R_2) and small SEE might produce erroneous predictions. According to Johnston (2002), the utility of a prediction equation is determined by its ability to be applied to a new set of people. Researchers can never be certain that a prediction equation they build will operate correctly when applied to a new group of people's criteria scores. The success of a prediction equation with a new group is usually determined by how similar the new group is to the group that developed the prediction equation originally. This procedure will provide information about the equation's genuine external validity.

There is need to validate any derived equation on other samples. Merely to calculate errors of estimate in the sample used for optimization is no validation, and one should not accept such data as indicative of probable result using that equation in another setting. Damon and Goldman (2004) came to the conclusion that the universal applicability of a given equation or formula cannot be assumed without testing it on a separate group of people. The authors, on the other hand, claimed that every equation developed during a validation study must be validated as well. The hunt for a perfect prediction equation to predict a high degree of accuracy of an individual's fatness should be an ongoing activity, according to Katch and Katch (2004).

2.14Empirical Review of Literature

Empirical Review on Regression Equation for estimating body density and percent body fat

Thorland, Johnson, Fagot and Tharp (2004) compared 17 equation for estimating body density through skinfolds, circumferences, as well as diameters in adolescent male athletes and fifteen equations for adolescent female athletes. Linear and quadratic forms have acceptable accuracy for female athletes. The validity co-efficient were low to moderately high (R^2=0.29-0.67) and represented shrinkage from values derived on the original samples in all equations. This is corroborated by Sinning (2010) that cross validation of existing equations have generally resulted in a correlation substantially below those reported in the original investigation. Of the 17 equations compared, only Forysth and Sinning (1975) equation yielded a distribution similar in variance to that of actual body density scores. In the same vein, the authors also cross-validated fifteen selected equations on adolescent female athletes, the validity co-efficient derived were low to moderately high (R^2=0.31-0.67), but in only twelve of the fifteen equations were these values less than in the original samples. Only the equation of Jackson, Pollock and Ward (2000) yielded a distribution of predicted body density scores with a standard deviation similar to that of the actual body density score. Jackson and Pollock (1978) cross-validated their equations on ninety-five adults men from the same population, and high multiple correlation (R=0.904 to 0.920) as well as low SEE($\pm$0.0085 to 0.0076) similar to that of the original group was reported.

Sinning and Wilson (2004) conducted validation studies using 265 male athletes and 79 female athletes. Of a total of 21 equations, only those of Jackson and Pollock (1984) gave estimates of percentage body fat which does not differ significantly from values obtained by hydrostatic weighing. Overall, the equations tended to over-estimate the percentage of body mass as fat in men.

Sinning and Wilson (2004) validated nine generalized and specific equations which include Durning and Womersley (1984), Jackson, Pollock and Ward (1986), Wilmore and Behnke (1969) and Katch and McArdle (1999). With the exception of Jackson, Pollock and Ward (1986) equation, all other equations underestimated body density ranging from 0.012 to 0.001gm/cm^3.

Wilmore, Girandola and Moody (2002) evaluated the validity of four previously derived equations i.e. Brozek and Keys (1951), Pascale, Grossman and Sloane (1956), Sloan (1967) and Wilmore and Benke (1969), and found out that all the four prediction equations demonstrated a good degree of validity for their samples when compared with the original samples and their values were significantly related to the criterion measure.

Coker (1986) validated some selected equations on the criterion measure of hydrostatistically derived body density values. Only six out of the ten estimated body densities compared favourably with criterion body density and were found to be statistically significant. Of all the body densities estimated from the six selected anthropometric regression equations, the mean difference of all but one i.e. Forysth and Sinning (1975) was found to be statistically not significant. Equations of Brozeks and Keys (1951), Sloan and Weir (1974), Sinning (1974), Jackson and Pollock (1979) overestimated body density while the equation of Durning and Womersley (1974) underestimated body density.

2.15Appraisal of Literature Reviewed

Pertinent and related literature of various researchers and many authors were reviewed. The essence of the two theoretical basis for the study (i.e. the two-component model, and the multi-component models) were discussed. Body composition components and methods of determining and assessing them (i.e. both direct and indirect methods) were comprehensively reviewed.

Authors and researchers position on body composition of athletic population and alteration of these body composition with training was reviewed. The place of regression equations (both population specific and generalized equations) in body composition predictions was reviewed as well as the imperative of validating these equations to test their predictive accuracy. The need for and development of new regression equation was reviewed as well as statistical considerations involved in validation of existing equations and development of new ones. Some empirical studies on validation of existing regression equation was also extensively reviewed.

CHAPTER THREE

METHODOLOGY

This study is designed to validate selected anthropometric equations and densitometric technique in body composition assessment on Nigerian male University endurance and power athletes.

3.1 Research Design

Ex-post-facto, independent group correlational research was used in this study. The design is a means of eliciting potential antecedents of past events that cannot be controlled, engineered, or managed by the investigator. Ex-post-facto research, according to Kerlinger (2000), is when the independent variable or variables have already occurred, and the variables are evaluated in retrospect for probable relationships with and effects on the dependent variable or variables. The design was selected because the variables to be measured are attribute variables that occur naturally and were not being manipulated by the researcher. Moreover, the participants are from an intact group which precludes randomly assigning them to either experimental or control group.

3.2 Population

This embraced all male endurance and power athletes of the Universities in South Western Nigeria.

3.3 Sample and Sampling Techniques

The sample size was one hundred and thirt-five (135) participants. A multistage sampling technique was used to select the participants for this study. Also, a non-probability sampling of purposive sampling procedure was used at some stages.

Stage 1: Simple random technique was used to select one out of the six geo-political zones in Nigeria.

Stage 2: Purposive sampling technique was also used to select and consider the three ‘first generation’ Federal Universities in the South-Western Nigeria, i.e. University of Ibadan, Oyo State, University of Lagos, Lagos State, Obafemi Awolowo University, Osun State.

Stage 3: Purposive sampling technique was used to choose participants who met the inclusion criteria (i.e. being a University athlete who is a member of the respective sports and games team and have represented the universities in at least one edition of the NUGA Games) from these three Federal Universities.

Stage 4: Purposive sampling technique was used to select the sports and games where the attributes could be measured from the participants i.e. high jump, long jump, javelin throwing, discuss throwing, shot putting, sprints, power swimming, endurance swimming, long distance running, soccer, basketball and handball).

With these stages completed, 45 power athletes, 45 endurance athletes and 45 non-athletes controls were selected as participants from the three Universities.

3.4 Research Instrument and Equipment

The research involved basically the use of densitometric technique (underwater weighing) and anthropometric measures to assess body composition of Nigerian male University athletes. The instruments listed and described below were used for the two methods.

(1) Densitometry (Hydrostatic Weighing Equipment)

The researcher constructed a suspending device for the underwater weighing which conformed with the models designed and tested by Burton and Cameroon (2009). The suspending apparatus consisted of the following parts.

(i) A wooden platform painted with oil paint to prevent differential water soaking in between measurements.

(ii) Two vertical iron bars linked together by a transverse iron bar to prevent collapse of the verbal bars during measurement.

(iii) S-Hooks was used for the attachment of the suspending apparatus to the diving board at the shallow end of the pool.

(iv) A pulley-system which facilitated lowering and lifting of subjects in and out of the pool was used. This suspending apparatus will be attached to the S-Hook under a salter scale model 235PBW made in England which is graduated from 0kg-25kg. It has a knob for zero correction (Refer to the appendix where there is a picture of the equipment).

All other instruments listed below are standardized and they possess the basic characteristics of standardized instrument as requested by Gay (1980) which include specifications, direction for scoring and interpretation.

Spirometer

Spirometer (with printer) model 796-0-234 manufactured by Nautilus Scientific, U.K. was used to measure vital capacity from which residual volume was estimated. It provides easy and accurate measurement of the lung vital capacity. It is light weight and fits easily into the hand.

Thermometer

Calibrated in ‘F’ (degree farenheith) and ‘C’ (degree centigrade), model 24-4 manufactured by Nautilus Scientific, U.K. was used to take the temperature of the pool at the time of the underwater weighing.

(2) Anthropometric Measurements

(1) Healthometer Scale (Bean Scale Model 8002)

This is an accurate, easy-to-read scale which is graduated in metric units from 0kg to 160kg. This was manufactured by Continental Scale Corporation, Bridgeview, Illionos, U.S.A. It is calibrated in 100gm units. This was used to measure height and weight in air and out of water.

(2) Lange Skinfold Caliper

A well calibrated Lange Skinfold Caliper with Cat No 3003 with standard constant press jaw of 10g/mm^2, manufactured by Cambridge Scientific Industries, U.S.A. 1986 was used for the measurements of the skinfold thickness with the dial read to the nearest 0.5mm. The instrument was designed for simple, accurate measurements of skinfold thickness to determine percent body fat. According to Amusa and Igbanugo (1999), it is designed for laboratory use and well established for use in body composition studies.

(3) Measuring Tape

A flexible glass-reinforced tape measure manufactured by County Technology Inc, Grays Mills, W154631, 1990 was used in measuring circumferences. The instrument is guaranteed not to stretch or tear with normal use. It is calibrated in both inches and centimeters and it is 150cm (60 inches) long with $^1/_8$ inch and 1mm sub-divisions.

3.5 Validity of the Instrument

It is important to validate instruments to test the manufacturer’s claims on their performance characteristics and to guarantee that any internal malfunctioning in the equipment will not negatively affect the quality of the result.

An instrument has validity when it measures what it purports to measure. The instruments employed in the study are all standardized and have different levels of validity attached to them. They also possess the important characteristics of a standardized instrument as requested by Gay, (1980), which are specification, direction for scoring and interpretation. However, instruments were cross checked and tested to ensure that the instruments measured what they are intended to measure, and in good working condition. Thomas and Nelson (2001) stated that the validity of an instrument is very important to the researcher to be able to predict and determine the exactness of the correctness of what it is intended to measure.

3.6 Reliability of the Instrument

Reliability is the basic attitude in a research procedure (Burns and Grove, 2005). Reliability of instruments depends on whether the instructions are complied with, testing procedure and method of scoring are consistently reported and must be viewed in terms of its measurement error and its influence on different levels of ability within the group (Thomas and Nelson, 2001). To obtain the consistency and repeatability of the instruments, successive trials were conducted to ensure that the result can be trusted. The researcher, in the course of the trial runs, was able to determine the observed true and error scores of each instrument, and because he was the only one that took the measurement, the inter rater reliability was guaranteed.

3.7 Ethical Consideration

The approval was obtained following the due process laid by the Ethical Review Committee of University of Ibadan in conjunction with Collaborative Institutional Training Initiative (CITI PROGRAM) as well as the Ethics and Research Committee of the Obafemi Awolowo University. Both electronic and hard copies of the research proposal indicated the participants' dossiers.

3.8 Procedure for Data Collection

The researcher introduced himself to each institution authorities with an introductory letter from the Head of his Department at the University of Ibadan. After all the procedures were taken, the purpose of the study was explained to the participants, theywere enlightened about the study and they gave their consent.

(i) **Test Location**

All the measurements were taken within the Exercise Physiology and Human Performance Laboratory of the respective Universities and the Underwater weighing performed at the swimming pool of the universities.

(ii) Physical characteristics of weight and height were taken first and followed by anthropometric measurements and underwater weighing in that order. Measurements on each participant was taken in one day, in the morning, before breakfast and exercise, in the following order.

Demographic Measurements

Age: Participants' age was recorded to the nearest birthday according to the participants file records

Height: Height was measured using the stadiometer portion of the Health-o-meter scale. The participants removed their shoes and stood erect, feet together with heels, buttocks, upper back and rear of the head in contact with the stadiometer bar. The movable bar of the stadiometer was then adjusted to the subject's vertex which is the most superior part of the head when the head is held looking straight. The height was recorded in centimeters (cm) to the nearest 0.1cm.

Weight in air: weight in air was determined using the weighing portion of the Health-O-meter scale. Participants were in minimal amount of clothes (swimming suit or short) and stood bare-footed on the Health-O-meter. The weights on the two poise bars of the machine were then adjusted until the correct weight of the subject was obtained. The weight in air was recorded in kilogram (kg) to the nearest 0.1 kilograms.

Anthropometric Measurements

The anthropometric method used to estimate BD and determine %BF in the study is skinfold measurements. All measurements were taken on the right side of the body with the subject standing in a fully relaxed position. Three readings were taken and the mean of the three readings was recorded as the actual skinfold thickness (Amusa and Igbanugo, 1999). The procedure for skinfold measurement involve grasping firmly the fold between the index finger and the thumb, ensuring that the two layers of skin and the underlying fat were included, but not the muscle, the caliper perpendicular to the fold at approximately 1.0cm from the thumb and the index finger. Care was taken to ensure that the fold followed its natural stress line as it is lifted. The calipers grip was released so that the full tension is exerted on the skinfold. The caliper was applied about 1.0cm away from the finger of the researcher. At least five seconds pass between reading the calipers in order to account for the compressibility of fats. All measurements were taken by the researcher, and in accordance with the International Society for Advancement of Kinathropometric (ISAK) protocol.

The sites measured are as follows:

Skinfold

a.(i) **Chest skinfold (mm)**: This is the diagonal fold halfway amid the fore axillary line and the nipple.

(ii) **Triceps skinfold (mm)**: A vertical fold in the posterior midline of the upper arm midway between the scapular and ulnar acromion and olecranon processes.

(iii) **Subscapular skinfold (mm)**: This will be taken from an oblique fold on a lateral and downward line at the inferior angle of the scapular.

(iv) **Abdominal skinfold (mm)**: A vertical fold, about 3.0cm lateral to the midpoint, of and adjacent to the umbilicus, and 1.0cm inferior to it, but not including the umbilical tissue.

(v) **Thigh skinfold (mm)**. This will be measured from a vertical fold on the anterior aspect (on the ventrum) of the thigh, midway between the inguinal crease and the proximal border of the patella.

(vi) **Suprailiac Skinfold (mm):** Measured in the midaxillary line immediately superior to the iliac crest. The caliper jaws are applied about 1cm from the fingers holding the skinfold, and the thickness is recorded to the nearest 0.1cm.

Hydrostatic Measurements

Details of the procedure involved in underwater weighing and vital capacity determination was given to the participants. They were reassured about their safety in water as life-saving guards stood-by during the period, in case of any emergency. Participants were advised to avoid foods six hours to the period of measurement, refrain from exercises, for a 12-hour period before assessment, and empty their bowel and bladder. Three readings were taken for vital capacity and the highest value recorded to compute the residual volume.

Residual volume estimation via Vital capacity: The participants seated on a chair, made of wooden platform on a transverse bar, attached to the two vertical iron bars inside the pool. Participants had a deep breath for a few seconds, and then exhaled completely as hard as they can into the spirometer.

The participants were then lowered into the pool through a pulley device for submersion. As he was being lowered, he was exhaling. The exhalation resulted into air bubbles on the surface of the water. The underwater weight was recorded at the time when the top of the head clears the surface and at the end of exhalation when no more air bubbles can be observed on the surface of the water and the dial of the weighing scale stops moving. The same procedure was repeated six times for each participant. The mean of the last three readings was taken as the underwater weight as the previous trials served to familizarise the participants with the pool and the procedure. After the last trial, each participant was asked to remove his swimming suit or short, which was weighed along with the submerged suspending apparatus. The weight value was then subtracted from the value derived when weighing underwater to reflect the ‘actual’ hydrostatic weight.

3.9 Pilot Study

A try-out procedure is essential in developing a sound research plan. A pilot study was conducted by the researcher using five male power athletes and five male endurance athletes of the University of Ilorin (who are not part of the study) to familiarize the tester with the measuring equipment and procedure for measurement.

The pilot study was carried out (at the swimming pool and gymnasium of University of Ilorin) to see if any refinement would be necessary in methods and procedures of the main study.

3.10 Data Analysis

For the purpose of analysis, descriptive statistics of mean, range, pie chart and bar chart and standard deviation was used to describe the data collected from the participants. Inferential statistics of:

(i) Student t-test independent group was used to compare the mean values of variables (underwater weighing (criterion) and anthropometric-based predictions). Effect size ‘Cohen’ ‘d’ was calculated based on information in the SPSS printout.

(ii) Analysis of variance, F-ratio was used to determine the significant differences in the selected variables among the different groups (power athletes and endurance athletes) and the control group. Scheffe-post hoc multiple comparison method was applied when F statistics indicates significant difference to determine which of the means were significantly different from the other.

(iii) Pearson-Product Moment Correlation Co-efficient (PPMCC) was used to show the degree and strength of the relationship between Body density (DV) and the predictor variables (IV), the intercorrelation among the independent variables, and to determine how accurately selected regression equations predicted body composition variables of the study sample (i.e. validity co-efficient).

(iv) Stepwise-Multiple Regression Analysis was used to determine the relative contribution of each and various combination of the independent variables (anthropometric measurements) in predicting the dependent variable (body density) in the new regression equation derived by the study. (All analysis was undertaken with the use of SPSS Statistical Software Version 19 (SPSS Inc. Chicago).

A significance level of 0.05 was applied to all statistical procedure.

CHAPTER FOUR

RESULTS AND DISCUSSION OF FINDINGS

4.1 Results

The study was carried out to evaluate some of the existing anthropometric regression equations derived previously for predicting body density and percent body fat confirming or refuting their respective validity on male University athletes, which was entirely independent of the original sample used in their derivation.

Find the Socio-demographic attributes of the participants (N=135) on the next page.

Table 4.1: Social Demographic Attributes of the Participants (N= 135)

Variable	Power Athletes Group	Endurance Athletes Group	Non-athletes Group
	n= 45 f(%)	n= 45 f(%)	n= 45 f(%)
Age(yrs**)**			
18-21	21(46.7)	18(40)	20(44.4)
22-25	14(31.1)	15(33.3)	13(28.9)
26-29	10(22.2)	12(26.7)	12(26.7)
Height(cm)			
150-160	18(40)	18(40)	17(37.8)
161-170	16(35.5)	15(33.5)	16(35.5)
171-180	11(24.5)	12(26.7)	12(26.2)
Weight (kg)			
55-65	17(37.8)	11(24.5)	10(22.2)
66-76	18(40)	24(53.3)	20(44.5)
77-87	10(22.2)	10(22.2)	15(33.3)

Table 4.1 shows the Age, height and weight of the participants, 46.7%, 40% and 44.4% of the power athletes, endurance athletes and non-athletes respectively are within the age of 18-21 years, likewise, 14(31.1%), 15(33.3%) and 13(28.9%) of the groups listed above are within the age of 22-25 years. However, 10(22.2%), 12(26.7%) and 12(26.7%) of the power athletes, endurance athletes and non-athletes respectively are within the age of 26-29 years. As regards height, 18(40%), 18(40%) and 17(37.8%) of power athletes, endurance athletes and non-athletes respectively are within 150-160cm. 16(35.5%), 15(33.3%) and 16(35.5%) of the power Athletes, endurance Athletes and non-athletes (control group) respectively have between 161-170cm. Likewise,11(24.50%), 12(26.7%) and 12(35.5%) of the group as listed above are within the height of 171-180cm. The weight of 17(37.8%), 11(24.5%) and 10(22.2%)power athletes, endurance athletes and non-athletes respectively falls within 55-65kg. In the same vein, the three groups as listed above have 18(40%), 24(50.3%) and 20(44.5%) of the participants weighing between 66-76kg. However, 10(22.2%), 10(22.2%) and 15(33.3%) of the power athletes, endurance athletes and non-athletes respectively weighed between 77-87kg

Research Q1: Will there be any significant difference in physical characteristics (height and body weight) of male University endurance and power athletes?

Table 4.2: Age and Physical Characteristics: Comparative Statistics

Variables	**Endurance Athletes n=45**			**Power Athletes n-45**			**Non-athletes n=45**			**F**	**Sig.**
	$\overline{x}$	Std Deviation	Range	$\overline{x}$	Std Deviation	Range	$\overline{x}$	Std Deviation	Range		
Age (yrs)	24.33	2.39	21-29	23.82	2.10	18-28	24.53	2.40	22-28	3.02	.065
Height (cm)	164.87	6.68	156-177	166.62	5.95	148-194	168.67	7.65	164.5-196.0	3.11	.051
Body weight (kg)	68.36	4.38	55-78	69.18	3.26	65-79	71.78	6.95	56-90	2.52	0.60

F; 0.05>3.22 df(2,88)

Table 4.2 showed the comparative statistics of physical characteristics of age, height and body weight of endurance and power athletes.

The mean age of endurance athletes was 24.33±2.39 with a range of 21-29 years while that of power athletes was 23.80±2.10 and a range of 18-28 years. The non-athletes have a mean of 24.53±2.40 with a range of 22-28 years.

The p-value of 0.065 shows no significant difference in the age of power athletes and endurance athletes, and when the two groups were also compared with non-athletes.

The mean height of endurance athletes was 164.87cm ± 6.68 with a range of 156-177cm while that of power athletes was 166.62cm ± 5.95 and a range of 148-174cm. The non-athletes have a mean height of 168.67 ± 7.68 with a range of 164.5-196.0cm. The p-value of 0.051 indicates that there was no significant difference between the height of endurance athletes and power athletes at 0.05 significant level.

The mean body weight for endurance athletes was 68.36kg±4.38 with a range of 55-78kg while that of power athletes stood at 69.18kg±3.26 and a range of 65-79kg. The non-athletes have a mean weight of 71.78kg ± 6.75 and ranged from 56-90kg. The power athletes weigh 0.25% more than the endurance athletes and 2.5% than the non-athletes.

The p-value of 0.060 showed that there was no significant difference in body weight between endurance athletes and power athletes. Comparatively, there was no significant difference in physical characteristics of height and weight including age between Nigerian male University endurance and power athletes.

Research Q2: Will there be any significant difference in physiological characteristics (body density, percent body fat and lean body weight and residual volume of male University endurance and power athletes.

Table 4.3: Physiological Characteristics: Comparative Statistics

Variables	Endurance Athletes n=45			Power Athletes n-45			Non-athletes n=45			F	Sig.
	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range		
BD	1.072	0.005	1.066-1.078	1.069	.006	1.063-1.074	1.073	0.005	1.066-1.084	2.85	.125
%BF	13.47	1.53	9.70-15.54	14.50	1.99	9.53-17.35	15.22	1.68	11.40-18.50	14.85	.000
LBW (kg)	60.44	4.79	49.76-67.53	63.01	5.30	50.52-70.11	59.80	4.97	49.65-64.10	5.17	.001
Residual Volume (cc)	1430.96	82.45	1248.00-1560.33	1424.93	65.04	1248.07-1620.55	1350.11	111.11	1.080.28-1525.10	1.72	.000

F=0.05>3.22;df (2,88)

Using underwater weighing technique, the mean body density for endurance athletes was 1.072g/ml ± 0.005 and a range of 1.066g/ml to 1.075g/ml while that of power athletes was 1.069g/ml±0.006 with a range of 1.063-1.074g/ml. The non-athletes have a mean body density of 1.073g/ml ± 0.005 and a range of 1.066g/ml-1.084g/ml. The p-value of .125 is greater than 0.05, meaning no significant difference between the groups.

The mean percent body fat for endurance athletes was 13.47%±1.53 and a range of 9.70% to 15.54% while that of power athletes was 14.50% ± 1.99 and a range of 9.53% to 17.55%. The non-athletes have a mean %BF of 15.22% ± 1.68 and a range of 11.40% to 18.50%. The p-value of .000 at 0.05 significant level showed a significant difference in %BF between the endurance athletes and the power athletes.

The Scheffe post-hoc comparison showed a significant mean difference between endurance and power athletes, F=5.67, between power athletes and non-athletes, (F=3.50) which was significant F(2,88)<3.35.

The mean lean body weight for endurance athletes was 64.44kg ± 4.79 ranging from 49.76kg-67.53kg with that of the power athletes at 63.01kg ± 5.30 with a range of 50.52kg to 70.11kg. The non-athlete have a mean value of 59.80kg ± 4.97 with a range of 49.65 to 64.10kg. The p-value was .001 with an F-ratio of 5.17 which was higher than the table value of 3.22 at 0.05 level of significance. This implied a significant difference among the groups. The Scheffepost hoc comparison showed a significant difference between endurance and power athletes F=3.40 p=0.055 between power athletes and non-athletes, F=8.04, p=0.012 which was significant F(2,88) = 3.35.

The mean residual volume’s estimated value for endurance athletes was 1430.96cc ± 82.45 and a range of 1248.00cc to 1560.33cc. Power athletes mean residual volume value was 1424.93cc ± 65.04 and a range of 1248.07cc to 1620.55cc. The non-athletes have a residual volume estimation value of 1350.11cc ± 111.11 and a range of 1080.28cc to 1525.10cc.

The p-value was .000 indicating no significant different between the endurance athletes and the power athletes at 0.05 significant level. However, comparison of the two groups with non-athletes showed significant difference. Scheffe post hoc analysis indicated an F ratio of 11.72 which is greater than the critical value of 3.22 that showed significant difference between the groups and non-athletes.

4.2 Hypothesis Testing

Ho 1

There will be no significant relationship and difference between body density and percent body fat determined by underwater weighing technique and by Brozek and Keys (1951) anthropometric-based regression equation.

Table 4.4: Correlation between Body Density determined by Underwater Weighing and Brozek and Keys (1951) equation

Descriptive Statistics

Variable	N	Mean	Std Dev	SEM
Body Density (UWW)	90	1.0708	.00342	.000510
Body Density (Brozek and Keys)	90	1.0803	.00424	.000632

Correlations

		Body Density (UWW)	Body Density (BK)
Body Density (UWW)	Pearson Correlation	1	.0306
	Sig (2-tailed)		.000
	N	90	90
Body Density (BK)		.306	1
		.000	
		90	90

Table 4.5: Independent t-test result of Body Density determined by Underwater Weighing and Brozek and Keys (1951) equation.

Group Statistics

Variable	N	Mean	Mean Diff	SEM	SD
Body Density (UWW)	90	1.0708	.0095	.00077	.00342
Body Density (BK)	90	1.0803			.00424

Independent Sample Test

T	df	Sig (2 tailed)	Lower	Upper
-12.335	88	.000	.59126	5.38210

Table 4.6: Correlation between Percent Body Fat determined by Underwater Weighing Technique and Brozek and Keys (1951) equation

Descriptive Statistics

Variable	N	Mean	SD	SEM
Body Density (UWW)	90	13.01	1.69	0.2527
Body Density (Brozek and Keys)	90	8.48	1.82	0.2718

Correlations

		Percent Fat (UWW)	Percent Fat (BK)
Body Density (UWW)	Pearson Correlation	1	.271
	Sig (2-tailed)		.000
	N	90	90
Body Density (BK)		.271	1
		.000	
		90	90

Table 4.7: Independent t-test result of Percent Body Fat determined by Underwater Weighing and Brozek and Keys (1951) equation.

Group Statistics

Variable	N	Mean	Mean Diff	SEM	SD
Body Density (UWW)	90	13.01	4.53	.02526	4.26
Body Density (B.K.)	90	8.48			4.20

Independent Sample t-test

T	Df	Sig (2 tailed)	Lower	Upper
10.221	88	.000	.32164	3.57260

Table 4.8 Result of the Validation Criteria on Brozek and Keys (1951) equation

Equation	$\bar{x}$		t-test		r	R^2	CE	TE	SEE
	B.D	%fat	B.D	%fat					
Underwater weighing	1.070±0.004	13.07±1.69	-12.335	10.220	.323	.104	-0.017	0.0019	0.0042
Brozek& Keys (1951)	1.092±0.004	8.48±1.82							

SEE = Standard Error of Estimate; TE = Total Error; CE = Constant Error

The 4.4 showed Pearson Product Moment Correlation co-efficient ‘r’ that there was moderate, positive but non-significant correlation between body density determined by underwater weighing technique and by Brozek and Keys (1951) equation ($r=.306$ $p>0.05$). P value was greater than 0.05 level of significance.

Table 4.5 showed that there was significant difference between the mean value of body density determined by underwater weighing technique and body density determined by Brozek and Keys (1951) equation ($t = -12.335 > df = 88$, $p>0.05$). Effect size $d=0.72$ at $p>0.05$). The size of the effect size was large.

Table 4.6 showed the Pearson Product Moment correlation co-efficient (R) that there was a weak, positive but non-significant correlation between percent body fat estimated by underwater weighing technique and percent body fat estimated by Brozek and Keys (1951) equation ($r=0.271$ $p > 0.05$). P-value was greater than 0.05 level of significance.

In table 4.7 it was shown that there was a significant difference between percent body fat estimated by underwater weighing and percent body fat estimated by Brozek and Keys (1951) equation (t-cal = 10.221 > t-crit = 2.045, $p > 0.05$. Effect size $r=0.83$, $p>0.05$). The size of the effect size was large.

Table 4.8 showed the result of the validation of Brozek and Keys (1951) equations on male university athletes. The validity co-efficient was low ($R^2=0.103$) and represent shrinkage from values derived on the original sample in the equation (0.382). Absolute value of constant error was -0.017g/ml^2 corresponding to 2.43% fat. Standard error of estimate (SEE) value was 0.0042g/ml^{-1-} and Total error which accounted for the effect of both constant error and SEE was 0.0019 corresponding to 2.04% fat.

Summarily, there was a weak, positive but non-significant relationship between body density and percent body fat determined by underwater weighing and body density and percent body fat estimated by Brozek and Keys (1951) equation resulting in significant difference between body density and percent body fat determined by underwater weighing and body density and percent body fat determined by Brozek and Keys (1951) equation. This implied that the null hypothesis which stated that there was no significant relationship and difference between body density and percent body fat determined by underwater weighing and body density and percent body fat estimated by Brozek and Keys (1951) anthropometric-based regression equation was rejected.

Hypothesis 2

There will be no significant relationship and difference between body density and percent body fat determined by underwater weighing technique and body density and percent body fat estimated by Sloan and Weir (1970) anthropometric-based regression equation.

Table 4.9: Correlation of Underwater Weighing and Sloan and Weir (1970) equation prediction of Body Density

Descriptive Statistics

Variable	N	Mean	Std Dev	Std error Mean
Body Density (UWW)	90	1.0708	.00342	.000510
Body Density (SW)	90	1.0834	.00038	.000573

Correlations

		Body Density (UWW)	Body Density (BK)
Body Density (UWW)	Pearson Correlation	1	.321
	Sig (2-tailed)		.309
	N	90	90
Body Density (BK)	Pearson Correlation	.321	1
	Sig (2-tailed)	.309	
	N	90	90

Table 4.10: Independent t-test result of Body Density determined by Underwater Weighing and Sloan and Weir (1970) equation

Group Statistics

Variable	N	Mean	Mean Diff	SEM	SD
Body Density (UWW)	90	1.0708	0.0126	.000510	.00342
Body Density (B.K.)	90	1.0834			.00038

Independent Sample Test

T	Df	Sig	Lower	Upper
-16.215	88	.000	.28406	2.17246

Table 4.11: Correlation of Percent Body Fat determined by UW and Sloan and Weir (1970) equation

Descriptive Statistics

Variable	N	Mean	Std Dev	Std Error Mean
Body Density (UWW)	90	13.01	1.69	0.2527
Body Density (SW)	90	8.75	1.69	.2437

Correlations

		Percent fat (UWW)	Percent fat (BK)
Percent body fat (UWW)	Pearson Correlation	1	.256
	Sig (2-tailed)		.090
	N	90	90
Body Density (BK)		.256	1
		.090	
		90	90

Table 4.12: Independent t-test result of Percent Body Fat determined by Underwater Weighing and by Sloan and Weir (1970) equation.

Group Statistics

Variable	N	Mean	Mean Diff	SEM	SD
Body Density (UWW)	90	13.01	4.26	0.3033	4.26
Body Density (BK)	90	8.75			3.07

Independent Sample Test

T	df	2 tailed	Lower	Upper
14.948	88	.000	.56480	5.23185

Table 4.13 Result of the Validation Criteria on Sloan and Weir (1970) equation

Equation	$\bar{x}$		**t-test**		**r**	R^2	**CE**	**TE**	**SEE**
	B.D	**%fat**	**B.D**	**%fat**					
Underwater weighing	1.070±0.004	13.07±1.69	-16.215	14.948	.321	.103	-0.015	.0027	.0058
Sloan and Weir (1970) equation	1.084±0.003	8.75±1.69							

Table 4.9 showed Pearson Product Moment Correlation Co-efficient (r) that there was a moderate, positive but non-significant correlation between body density determined by underwater weighing technique and body density predicted by Sloan and Weir (1970) equation (r=0.321 p>0.05). P-value was greater than 0.05 level of significance.

Table 4.10 showed a significant difference between the mean value of BD determined by underwater weighing technique and body density determined by Sloan and Weir (1970) equation (t-cal=-16.215df=88, p>0.05. Effect sized=0.94 at p>0.05). the size of the effect was large.

Table 4.11 showed the Pearson Product Moment Correlation co-efficient (r) that there was a weak, positive but non-significant correlation between %BF estimated by underwater weighing technique and percent body fat estimated by Sloan and Weir (1970) equation (r=0.256). P-value was greater than 0.05 level of significance.

In table 4.12 it was shown that there is significant difference between %BF estimated by underwater weighing and percent body fat estimated by Sloan and Weir (1970) equation (t-cal=14.948df=88, p>0.05, Effect size d=0.91, p>0.05). The size of the effect size was large.

Table 4.13showed the result of the validation of Sloan and Weir (1970) equation on male university athletes. The validity co-efficient was low (R^2=0.103) and represent shrinkage from values derived on the original sample in the equation (0.510). Absolute value of constant error was -0.015 corresponding to 2.38% fat. Standard error of estimate (SEE) value was 0.0058g/ml^{-1} and Total error which accounted for the effect of both constant error and SEE was 0.0027 corresponding to 2.12 fat.

Summarily, there was a weak, positive non-significant relationship between BD and %BF determined via underwater weighing and BD and percent body fat estimated by Sloan and Weir (1970) equation resulting in significant difference between body density and %BF determined by UWT and BD and %BF determined through Sloan and Weir (1970) equation. The implication of this is that the hypothesis was therefore, rejected.

Hypothesis 3

There will be no significant relationship and difference between body density and percent body fat determined by underwater weighing technique and by Sinning (1974) anthropometric based equation.

Table 4.14: Correlation between Body Density determined by Underwater Weighing and Body Density predicted by Sinning (1974) equation.

Descriptive Statistics

Variable	N	Mean	S.Dev	SEM
Body Density (UWW)	90	1.0708	.00342	.000510
Body Density (SI)	90	1.0819	.00584	.000832

Correlations

		Body Density (UWW)	Body Density (BK)
Body Density (UWW)	Pearson Correlation	1	.372
	Sig (2-tailed)		.669
	N	90	90
Body Density (SI)		.372	1
		.669	
		90	90

Table 4.15: Independent t-test result of Body Density determined by Underwater Weighing and by Sinning (1974) equation.

Group Statistics

Variable	N	Mean	Mean Diff	SEM	SD
Body Density (UWW)	90	1.0708	.01111	.00100	.00342
Body Density (SI)	90	1.0819			.00256

Independent Sample Test

T	df	Sig	Lower	Upper
-11.581	88	.000	.34618	3.32143

Table 4.16: Correlation of Underwater weighing and Sinning (1974) equation prediction of Percent Body Fat

Descriptive Statistics

Variable	N	Mean	Std Dev	Std error Mean
Percent body fat (UWW)	90	13.01	1.69	0.2527
Percent Body Fat (SI)	90	8.27	1.65	0.2463

Correlations

		Percent Fat (UWW)	Percent Fat (SI)
Percent body fat (UWW)	Pearson Correlation	1	.181
	Sig (2-tailed)		.000
	N	90	90
Percent body fat (SI)		.181	1
		.000	
		90	90

Table 4.17: Independent t-test result of Body Percent Body fat by Underwater Weighing and Sinning (1974) equation.

Group Statistics

Variable	N	Mean	Mean Diff	SEM	SD
Percent body fat (UWW)	90	13.01	4.74	0.1140	4.26
Percent body fat (SI)	90	8.27			3.92

Independent Samples Test

T	df	Sig (2 tailed)	95% Confidence Interval of the difference	
			Lower	Upper
11.664	88	.000	.32961	3.18410

Table 4.18 Result of Validation Criteria on Sinning (1974) equation

Equation	$\bar{x}$		**t-test**		**R**	**R^2**	**CE**	**TE**	**SEE**
	BD	**%fat**	**BD**	**%fat**					
Underwater weighing	1.070±0.004	13.07±1.69	-11.581	11.664	.372	.138	-0.012	.0021	0.0045
Sinning (1974)	1.081±.0055	8.27±1.65							

Table 4.14 showed Pearson Product Moment Correlation co-efficient (r) that there was a moderate, positive but non-significant correlation between body density determined by underwater weighing technique and by Sinning (1974) equation ($r=0.372$ $p>0.05$). P-value was greater than 0.05 level of significance.

Table 4.15 showed that there is significant difference between the mean value of body density determined by underwater weighing technique and body density determined by Sinning (1974) equation (t-cal= -11.581 df=88, $p>0.05$. Effect size $d=0.90$ at $p>0.05$). The size of the effect was large.

Table 4.16 showed the Pearson Product Moment Correlation co-efficient (r) that there was a weak, positive but non-significant correlation between %BF estimated by underwater weighing techniques and percent body fat estimated by Sinning (1974) equation (r-0.181 $p>0.05$) p-value was greater than 0.05 level of significance.

Table 4.17 reflected that there is significant difference between %BF estimated by underwater weighing and percent body fat estimated by Sinning (1974) equation (t-cal=11.664df=88, >0.05, Effect size $d=0.91$, $p>0.05$). The size of the effect size was large.

In table 4.18, the result of the validation of Sinning (1974) equation on male university athletes was shown. The validity co-efficient was low ($R^2 = 0.138$) and represent shrinkage from values derived on the original sample when the equation was generated (0.97). Absolute value of constant error was -0012g/ml corresponding to 2.26% fat. Standard error of estimate (SEE) value was $0.0045g/ml^{-1}$ and Total error which accounted for the effect of both constant error and SEE was 0.0021 corresponding to 2.02% fat.

Summarily, there was a weak, positive but non-significant relationship between BD and %BF determined by underwater weighing and BD and %BF estimated by Sinning (1974) equation resulting in significant difference between body density and percent body fat determined by underwater weighing and body density and percent body fat estimated by Sinning (1974) equation. The implication of this is that the null hypothesis was rejected.

Hypothesis 4

There will be no significant relationship and difference between body density and percentage body fat determined by underwater weighing technique and body density and percent body fat estimated by Forsyth and Sinning (1975) anthropometric-based equation.

Table 4.19: **Correlation between Body Density determined by Underwater weighing and by Forysth and Sinning (1975) equation.**

Descriptive Statistics

Variable	N	Mean	Std Dev	Std error Mean
Body Density (UWW)	90	1.0708	.00342	.000510
Body Density (FS)	90	1.0793	.00638	.000921

Correlations

		Body Density (UWW)	Body Density (FS)
Body Density (UWW)	Pearson Correlation	1	.348
	Sig (2-tailed)		.865
	N	90	90
Body Density (FS)	Pearson Correlation	.348	1
	Sig (2-tailed)	.865	
	N	90	90

Table 4.20: Independent t-test result of Body Density determined by Underwater Weighing and Forysth and Sinning (1975) equation.

Variable	N	Mean	Mean Diff	SEM	SD
Body Density (UWW)	90	1.0708	.0085	.00109	.00342
Body Density (B.K.)	90	1.0793			.00731

T	df	Sig (2 tailed)	Lower	Upper
-7.747	88	.000	.20445	2.1431

Table 4.21: Correlation of Percent Body Fat determined by Underwater Weighing and Forysth and Sinning (1975) equation.

Variable	N	Mean	Std Dev	Std error Mean
Percent body fat (UWW)	90	13.01	1.69	0.2527
Percent body fat (FS)	90	8.41	1.63	0.2441

Correlations

		Percent fat (UWW)	Percent fat (FS)
Percent body fat (UWW)	Pearson Correlation	1	.384
	Sig (2-tailed)		.021
	N	90	90
Percent body fat (FS)		.384	1
		.021	
		90	90

Table 4.22: Independent t-test result of Percent Body Fat determined by Underwater Weighing and Percent Body Fat Predicted by Forsyth and Sinning (1975) equation.
Group Statistics

Variable	N	Mean	Mean Diff	SEM	SD
Percent body fat (UWW)	90	13.01	4.60	0.3125	4.26
Percent body fat (FS)	90	8.41			3.78

Independent Sample Test

T	df	Sig (2 tailed)	Lower	Upper
6.341	88	.000	.46103	4.32145

Table 4.23: Result of Validation Criteria on Forsyth and Sinning (1975) equation

Equation	$\bar{x}$		t-test		R	R^2	CE	TE	SEE
	B.D	**%fat**	**B.D**	**%fat**					
Underwater weighing	1.070±0.004	13.07±1.69	-7.747	6.341	.348	.121	-0.012	.0020	0.0055
Sinning (1974)	1.079±.0055	8.41±1.63							

Table 4.19 showed Pearson Product Moment Correlation Co-efficient (r) that there was a moderate, positive but non-significant correlation between body density predicted by Forsyth and Sinning (1975) equation ($r=0.348$ $p>0.05$), p-value was greater than 0.05 level of significance.

Table 4.20 showed that there is significant difference between the mean value of body density determined by Forsyth and Sinning (1975) equation and by underwater weighing (t-cal=-7.749>df=88, $p>0.05$. Effect size $d=0.902$ at $p>0.05$). The effect size was large.

Table 4.21 showed the Pearson Product Moment Correlation Co-efficient (r) that there was a moderate, positive but non-significant correlation between %BF estimated by underwater weighing and %BF estimated by Forsyth and Sinning (1975) equation ($r=0.384$ $p>0.05$) p-value was greater than 0.05 level of significance.

In table 4.22, it was clearly shown that there is significance difference between percent body fat estimated by underwater weighing and percent body fat estimated by Forsyth and Sinning (1975) equation (t-cal =6.341>df=88, $p>0.05$, Effect size $d=0.91$, $p>0.05$).

Table 4.23 which showed the result of the validation of Forsyth and Sinning (1975) equation on male university athletes, the validity co-efficient was low ($R^2=0.121$) and represent shrinkage from value derived on the original sample when the equation was generated (0.68). Absolute value of constant error was -0.012g/ml corresponding to 2.26% fat. Standard error of estimate (SEE) value was 0.0058g/ml^{-1} and Total error which accounted for the effect of both constant error and SEE was 0.0020 corresponding to 2.00% fat.

Summarily, there was a moderate, positive but non-significant relationship between BD and %BF determined by underwater weighing and body density/percent body fat estimated by Forsyth and Sinning (1975) equation resulting in significant difference between body density and percent body fat determined by underwater weighing and body density/percent body fat estimated by Forsyth and Sinning (1975) equation. The implication of this is that the null hypothesis was therefore, rejected.

Hypothesis 5

There will be no significant relationship and difference between body density and percent body determined by underwater weighing technique and body density and percent body fat estimated by Jackson and Pollock (1979) anthropometric equation.

Table 4.24: Correlation between Body Density determined by Underwater Weighing and by Jackson and Pollock (1979) equation.

Descriptive Statistics

Variable	N	Mean	Std Dev	Std error Mean
Body Density (UWW)	90	1.0708	.00342	.000510
Body Density (JP)	90	1.0782	.00538	.000821

Correlations

		Body Density (UWW)	Body Density (FS)
Body Density (UWW)	Pearson Correlation	1	.765
	Sig (2-tailed)		.013
	N	90	90
Body Density (JP)	Pearson Correlation	.765	1
	Sig (2-tailed)	.013	
	N	90	90

Table 4.25: Independent t-test result of Body Density determined by Underwater Weighing and by Jackson and Pollock (1979) equation.

Group Statistics

Variable	N	Mean	Mean Diff	Std Dev.	SEM
Body Density (UWW)	90	1.0708	.0074	.00342	.00105
Body Density (JP)	90	1.0782		.00693	

Independent Sample Test

T	df	Sig (2 tailed)	95% Confidence Interval of the Difference	
			Lower	Upper
-1.920	88	.000	.65032	6.51484

Table 4.26: Correlation of Percent Body Fat determined by Underwater Weighing and predicted by Jackson and Pollock (1979) equation.

Descriptive Statistics

Variable	N	Mean	Std Dev	Std error Mean
Percent body fat (UWW)	90	13.01	1.69	0.2527
Percent body fat (JP)	90	10.51	1.78	0.2654

Correlations

		Percent fat (UWW)	Percent fat (JP)
Percent body fat (UWW)	Pearson Correlation	1	.719
	Sig (2-tailed)		.000
	N	90	90
Percent body fat (JP)	Pearson Correlation	.719	1
	Sig (2-tailed)	.0001	
	N	90	90

Table 4.27: Independent t-test result of Percent Body Fat determined by Underwater Weighing and by Jackson and Pollock (1979) equation.

Group Statistics

Variable	N	Mean	Mean Diff	SEM	SD
Percent body fat (UWW)	90	13.01	2.50	0.2926	4.26
Percent body fat (JP)	90	10.51			4.15

Independent Sample Test

T	Df	Sig (2 tailed)	95% Confidence Interval of the Difference	
			Lower	Upper
11.664	88	.000	.56320	5.21496

Table 4.28: Result of Validation criteria on Jackson and Pollock (1979) equation

Equation	$\bar{x}$		t-test		R	R^2	CE	TE	SEE
	BD	**%BF**	**BD**	**%BF**					
Underwater weighing	1.070±0.004	13.07±1.69	-2.920	10.221	.457	.208	-0.016	.0017	0.0015
Jackson and Pollock (1979)	1.078±.0053	10.51±1.78							

Table 4.24 showed Pearson Product Moment Correlation Co-efficient (r) that there was a strong, positive and significant correlation between body density predicted by Jackson and Pollock (1979) equation ($r=0.765$ $p>0.05$).

Table 4.25 showed that there is significant difference between the mean value of body density determined by Jackson and Pollock (1979) equation and the body density determined by underwater weighing (t-cal=-2.920 >df=88, $p>0.05$. Effect size $d = 0.993$ at $p>0.05$). The effect size was large.

In Table 4.26, Pearson Product Moment Correlation Co-efficient (r) showed a strong, positive and significant correlation between percent body fat estimated by underwater weighing and percent body fat estimated by Jackson and Pollock (1979) equation ($r = 0.719$ $p>0.05$).

Table 4.27 showed that there is significant difference between percent body fat estimated by underwater weighing and percent body fat estimated by Jackson and Pollock (1979) equation (t-cal=11.664>df=88 $p>0.05$. Effect size $d=0.905$ $p>0.05$).

Table 4.28 showed that result of the validation of Jackson and Pollock (1979) equation on male University athletes; the validity co-efficient was low ($R^2 = 0.208$) and represent shrinkage from the value derived on the original sample when the equation was generated (0.81). Absolute value of constant error was -0.16g/ml corresponding to 2.17% fat. SEE value was 0.0015g/ml^{-1} and Total error was 0.0017 corresponding to 1.86% fat.

Summarily, though there was a strong, positive significant relationship between body density and %BF determined by underwater weighing and body density/percent body fat estimated by Jackson and Pollock (1979) there is significant difference between BD and percent body fat determined by underwater weighing and body density/percent body fat estimated by Jackson and Pollock (1979) equation.The implication of this is that the null hypothesis was rejected.

Hypothesis 6

The anthropometric (skinfold) sites measured for validation of the selected equations will not singularly or in combination provide significant substantial weights as predictors to generate a new anthropometric regression equation for body composition assessment of male Nigerian University endurance and power athletes.

Table 4.29: Correlation Matrix on Relationship between each Skinfold Thickness and Body Density

Variables	Body Density	Subscapular	Abdominal	Suprailiac	Chest	Triceps	Thigh
Body Density	1.0						
Subscapular	-.345	1.0					
Abdominal	.291	0.13	1.0				
Suprailiac	.253	.231	.545**	1.0			
Chest	.447*	.177	.335	.370	1.0		
Triceps	.394*	-0.51	.347	1.87	.651**	1.0	
Thigh	-.039	.352	.527**	.337	.480**	.574**	1.0
Mean	1.07						
SD	0.004						

* significant at 0.01 level

** significant at 0.05 level

As indicated in Table 4.29, there was a significant relationship between each of chest Skinfold (SF) and Triceps SF and Body Density i.e. Chest SF (r = 0.447), Triceps SF (r = 0.394), while subscapular SF, abdominal SF, SuprailiacSF and Thigh SF has no constructive significant relationship with body density. Also from the Table, the Chest and Triceps skinfolds have the highest intercorrelation value of 0.65 while abdominal and subscapular skinfolds have the lowest value of 0.13. However, among the six predictor variables used in the equation, the pairwise correlation ranged from a low value of 0.51 (Triceps and Subscapular skinfolds) to a high value of 0.65 (chest and triceps skinfolds).

Table 4.30: Regression Analysis of Relative Contribution of each and Combination of the Predictor Variables in Predicting Body Density

Model	Unstandardized Coefficient		Standardized Co-efficient	T	Sig.	Collinearity Statistics	
	B	Std Error	Beta; β			Tolerance	VIF
Constant	1.09	0.012		86.042	.001	1.000	1.000
Thigh/Suprailiac/Triceps	8.587	0.001	.295	1.63	.001	.827	1.209
Thigh/Suprailiac/Triceps/Age	8.489	0.006	.404	1.55	.001	1.000	.827
Thigh/Subscapular/Triceps/Age	7.581	.008	.359	1.08	.262	.829	1.209
Abdominal/Suprailiac	8.448	0.009	.469	0.72	.001	.756	1.415
Chest/Triceps/Thigh	0.001	0.004	.476	1.07	.009	,846	1.203
Subscapular	-0.001	0.004	-.392	-2.10	.047	.748	1.301
Age	0.000	0.006	.056	0.07	.868	.040	1.201

Table 4.30 above showed (a) the unstandardized co-efficient for each predictor variable which is the predicted increase in the value of the criterion-variable for a 1 unit increase in that predictor (while controlling for the other predictors) and (b) the standardized Beta (β) coefficients which gives a measure of the contribution of each variable to the model in terms of standard deviations. The ‘t’ and Sig (p) values give an indication of the impact of each predictor variable.

Table 4.31: Regression Analysis on Predictive Effectiveness of each and Combination of the Predictor Variables in Body Density Prediction

Model Summary

R	R^2	Adjusted R-Square	SEE
0.841	.706	.701	.003838

Model	Sum of squares	Df	M^2	F	Sig.
Regression	121.350	6	20.225	21.864	.000
Residual	21.272	83	0.925		
Total	142.622	89			

Table 4.31 shows that predictor variables of Thigh, Suprailiac, Triceps, Subscapular, Thigh, Chest and Age were jointly significant as predictors of body density; F(6,83) = 21.864, R=0.841, R^2 = 706, Adjusted R^2 = 701, $p<0.05$) having 70.6% of the variations accounted for in the whole model by the independent variables. This implied that the sum of Thigh, Suprailiac and Triceps Skinfolds with Age, the sum of abdominal and triceps and thigh skinfolds cumulatively has an impact on body density prediction in this study, and since the p-value of the ANOVA is less than 0.05, it implied that the model fit the data. Therefore the hypothesis which stated that the anthropometric (skinfold) sites measured for validation of the selected equations will not singularly or in combination provide significant substantial weights as predictors to generate a new anthropometric regression equation for body composition assessment of male Nigeria University endurance and power athletes is thereby rejected.

Arising from the rejection of the hypothesis, and the fact that the validated selected equations proved invalid, the developed prediction equation on Nigerian Male University athletes is:

Table 4.32: Developed Prediction Equation

$$\boxed{BD = 1.064+0.0392\ (X_1) + 0.0469\ (X_2) + 0.0476\ (X_3)}$$

Where X_1 = Subscapular SF

X_2 = Sum of abdominal and suprailiac SF,

X_3 = Sum of Chest, Triceps and Thigh SF……………..**Equation 5.1a**

N.B.: The values are generated from the standardized co-efficient β on Table 8.

4.3 Discussion of Findings

The findings were explored and put in the context of other researches in the field. Contextualizing the result within the literature covered showed how the findings fit the existing knowledge. Attempts were also made to explain some fresh insights about the problem based upon evidence-based interpretation of the findings i.e. what they contribute and what consequences they have for theory and practice.

From related studies especially those that were used to derive regression equations, it was observed that the mean age of 24.33 and 23.80 obtained in this study was either lower or higher. For example Jackson and Pollock (1978) reported a mean age 32.6± 10.8 years, Katch and McArdle (2003) reported a mean age 19.3 years on College men while Durning and Womersley (1974) reported an age range of 17-27 years with a mean of 24.3 years. In the same veinBrozek and Keys (1963) derived their equation from athletes with age range from 18-26years, while Sloan and Weir (1970) also derived their equation from male athletes ages 18-26 years.

Pollock and Wilmore (1990) considered age as a vital factor of body density derivation of population specific regression equations. The authors asserted that population-specific regression equations predict most accurately at the means of the population in which the data were collected and the equation developed, as subjects differ from the mean (age inclusive), the standard error of measurement increases significantly.This might have prompted Jackson and Pollock (1978) in developing a generalized equation to add age into the predictive equation, which according to them will justify the changes in the proportion of %fat and body density.

As regards body weight, comparing the means from the group in the present study with those of other related studies, it was observed that it was greater than 61.3kg recorded by Coker (1986) for male University sportsmen. The mean value was however lower than 79.6 ± 10.6kg recorded by Wilmore, Grandola and Moody (2002) for their group. Other authors like Wells and Fewtrell (2006) reported a mean weight of 78.05kg on footballers used in their study in body composition of thirty six backliners and receivers. The value was also lower than the reported mean of 98.56kg and 75.50kg recorded on professional male basketball and soccer players respectively (Wilmore and Benke,2009).

This is however expected since most of the studies on body composition were done in European countries and America where the average weight is relatively higher.

The reported mean body density of 1.072g/ml and 1.069g/ml for endurance and power athletes respectively is comparable to that reported by Smith and Mansfield (2004) whose similar population (University football players) exhibited body density of 1.068g/ml. It is slightly higher than the 1.068g/ml reported by Durning and Womersly (2004). Thorland, Johnson, Tharp and Fagot (2004) derived in adolescent male athletes, a body density value of 1.080g/ml and 1.078g/ml of wrestlers. Both values are higher than this present's study value.

According to Nevil, Metiosis, Jackson, Waing, Thorton, and Gallazher(2008), body density prediction error and variability could be due to either error or variability in the hydrostatic weighing procedure adopted, natural variability in the body density of different samples being considered or a combination of these factors. What accounted for the differences in the value derived in this study and the ones compared may also be the estimation method used to derive the value of residual lung volume. According and Jackson and Pollock (1978), if accuracy is going to be a major concern, the underwater weighing method with measured residual lung volume should be the method of choice. They contended that using predicted residual lung volume rather than measuring it makes the underwater weighing less accurate, with the Standard Error increasing from 1% to 3.5% body fat. Residual volume should normally be measured by an open circuit nitrogen washout technique or a close circuit oxygen helium dilution method, asserted Pollock and Wilmore (1990).

Percent body fat for the subjects ranged from 9.70% to 17.55%. The value is lower than the one reported by Benke and Wilmore (2004) Leadg, O'Neill, Sohum, Toomey and Jakeman (2013) which were 17.89% and 18.6% for males of approximately the same age, and considerably above the mean values of 10.9% and 10.8% reported Lohman (2006) and Sokal and Rolf (2013). This apparent discrepancy is probably a result of the inherent differences between the samples presented in these studies rather than error in the procedure. Moreover, black athletes have also been found to be leaner than their white counterparts (Wilmore and Beknke, 2009). So a relatively lower percent body fat is expected when using the same age group samples.

Baumgartner and Jackson (2013) were of the opinion that the percent body fat of athletes depends on the athlete’s gender and event performed. Highly trained athletes, such as distance runners, will typically have very low body fat levels. For example, the average percent body fat of world–class distance runners is quite low, averaging around 8% for males and ranging from 12% to 15% for women. For most people who do not exercise to the level of elite athletes, this may appear to be an impossibly low level. Ranurez-zea,Torun, Martorel and Sten (2006) suggested that athletes should be seen and treated as individuals. The authors referred to a study carried out on a number of national and international class female track and field athlete, where a runner and one of the best in her event with high intensity training and long distance running had over 17% body fat as against her counterparts below 12% body fat. According to the authors, it is improbable that this athlete could have decreased her relative body fat to less than 12% without a deleterious impact on her future performance. It can be concluded that relative body fat value is not only lower in athletes when compared to non-athletes, the optimum value is different from sports, to sports being lowest in the energy demanding-long duration sports and highest in technique and power events which do not require sustained energy production for a long duration.

Vital capacity was used in theestimation of theresidual volume based on the formula of Sinning (1975) i.e.Rv = 0.24 x Vc (BTPS) for males. This estimated method was not similar to those used by these authors i.e. Wilmore and Benke (2009) who measured residual lung with the close circuit oxygen dilution method, Sinning and Wilson (2004) who measured residual volume outside the water tank using the helium dilution, Roche, Hemysfield, Wang and Withers (2013) who measured residual volume by using nitrogen-dilution method.

The estimated method was also not similar to the ones used by Brodie, Moscrip and Hutchson (2016) and also Sinning (2010) who used open circuit oxygen system and open circuit nitrogen dilution method respectively to determine subjects’ residual volume. It is worthy of note to recognize the fact that if accuracy is going to be the major concern as suggested by Baumgartner and Jackson (2013), the choice procedure should be underwater weighing. According to the authors, using predicted or estimated residual lung volume rather than measuring it makes the underwater weighing method less accurate with the standard error increasing from 1% to 3.5% body fat. Therefore it was concluded that there was no significant difference between endurance athletes and power athletes in age, height, body weight, body density and residual volume, while there was significant difference in their values in percent body fat and lean body weight.

The study revealed no significant relationship between BD determined by underwater weighing and body density estimated by the five selected regression equations. Sloan and Weir (1970) overestimate the subjects' body density by a mean of 0.0130g/ml. Jackson and Pollock (1979) equation overestimate the subject's body density by a mean of 0.009g/ml. Brozek and Keys (1963) equation overestimate the subjects body density by a mean of 0.0095g/ml while Forysth and Sinning (1975) overestimated body density by a mean of 0.0081g/ml. The outcome of this study is in line with the submission of Oppliger, Clark and Nelson (2000) that validation and cross-validation of existing equations generally resulted in correlations substantially below those reported in the original investigation.

The study also revealed that percent body fat estimated by Sloan and Weir (1970), Sinning (1974), Forysth and Sinning (1975), Brozek and Keys (1963) have no significant relationship with %BF determined by underwater weighing technique whereas Jackson and Pollock (1979) equation does. The finding is not strange as Durning and Womersley (1974) also underestimated percent body fat in men and women when compared with the four model component, with mean underestimation of 3.1% and 2.4% fat respectively. The result is in contradiction with the submission of Katch and McArdle (2003), and Jackson and Pollock (1978), who asserted that when anthropometric measurement are precisely and accurately taken and adequate equation(s) is (are) applied, using such measurements as variables, high correlation and high reliability and validity coefficient have been demonstrated between the estimated and true values of body composition. However, because this study did not measure residual lung volume, the findings must be interpreted with caution, as the uncertainties associated with predicting residual lung volume reduce the validity of the percent body fat criterion, lowering the correlations between the criterion and predicted volumes (Katch and Katch 1980).

Each of the five body densities estimated was compared with the BD determined using underwater weighing techniques, it was observed from the table that the mean differences of four out of the five estimated body densities are significantly different from the mean of hydrostatic weighing derived criterion. The four body densities were those derived from equations of Brozek and Keys (1951), BD = 1.08389g.ml with "t value' of 16.215, Sloan and Weir (1970), BD = 1.84g/ml with t-value of 11.581, Sinning (1974) BD = 1.084g/ml with 't' value of 11.581, Forysth and Sinning, 1.079 g/ml with t value of -7.747, only the mean of equation of Jackson and Pollock (1979) was statistically not significant when compared with the mean of criterion measure i.e. BD = 1.078 g/ml with 't' value of 1.920.

All 't' values of the body densities were found to be statistically significant at the significance level of 0.05, except only one that was found to be statistically insignificant at the same level of significance. With the exception of Jackson and Pollock (1979) equation value of 1.078gm /cm^3, the other four equations either underestimates or overestimate body density, for example, Brozek and Keys (1951) equation overestimated body density of subjects by a mean of 0.015gm/cm^3.

Various body densities values were derived using underwater weighing technique by authors of the selected regression equations in their original studies. Forysth and Sinning (1974) recorded 1.078 g/ml while Jackson and Pollock (1978) had 1.058g/ml for their original studies. These values were either higher or lower than the value derived in this study. However, some of them were comparable with the results obtained in the present study e.g. Benke and Wilmore (1974) obtained a body density of 1.065gm/ml while Wilmore and Benke (2009) obtained a body density of 1.067g/ml while using 133 men ages 16 – 36 years. The two are comparable with the value of 1.070 g/ml derived for this study.

Percent body fat for the subjects range from 8.27% to 10.51%. The figures are lower than the one reported by Benke and Wilmore (2004). Norton (2009 and Kraemer, Torine and Silvester (2015) which were 15.5%, 18.3% and 14.3% respectively for males of approximately the same age, and considerable above the mean values of 8.10% and 9.21% reported by Hastiuti and Kagawa (2013) and Ramirez-Zea, Torun, Martorelli and Sein (2006) respectively. This apparent discrepancies is probably a result of the inherent difference between the samples presented in these studies rather than a basic error in experimental procedure. Moreover black athletes have also been found to be leaner than their white counterparts (Dietrik, Pierce, Cutrufello and Drapeau, 2005), so a relatively lower percent body fat is expected when using the same age group samples.

On validation of the selected regression equations, Burton and Cameron (2009) contented that even equation with very high coefficient of determination (R^2) and small SEE may produce erroneous predictions when calibrated against criterion estimates that have systematic errors. The result of the correlation is also in consonance with the position of Ferguson (2010) who maintained that if the multiple regression weights calculated in one sample are applied to a second sample, the correlation between the weighted predictors and criterion in the second sample will be less than the multiple correlation originally calculated on the first sample. By implication, failure to demonstrate statistically unbiased relationship may be due to inadequate statistical power, often as a consequence of an insufficient difference between mean value of BD and percent body fat determined by underwater weighing and BD estimated by the selected equation with a relatively large effect sizes. The mean difference ranges from -0.012 to -0,016g/ml,. when the mean density values are converted to percent fat by the use of Brozek et. al (1963) formula, the mean difference between actual and predicted values deviate from 2.96 to 3.67% from the criterion value of 13.01% fat. However, Jackson and Pollock (1979) equation comes closest to predicting the actual mean value (1078g/ml compared to the criterion value of 1.070g/ml). Standard Error of estimate ranged from 0.0015 – 0.0058g/ml. However, Total Error which accounted for the effects SEE ranged from 0.0027 to 0.0039g/ml corresponding to 2.18% – 3.84%.Validity coefficient (R^2) were low to moderately low (R^2 = 0.10 – 0.21) which represent shrinkage from values derived on the original samples on all equations.

The mean differences, correlation coefficient, regression analysis, and SEE were used to assess the accuracy of each of the selected equations. High multiple correlation value coupled with relatively low Standard Error of Estimate are indices of high predictive profile of any equation (Montgomery and Peck, 2002). Wagner, Leadra and Pedro (2017) submitted that the magnitude of the correlation coefficient among predicted and observed scores, in addition to the standard deviation of the different scores tells the ‘worth’ of the original estimated equation. The closer the standard errors the more accurate and valid is the equation, which is not the case with Sloan and Weir (1979), Sinning (1974), Brozekand Keys (1951), Forysth and Sinning (1975) equations, but relatively better with Jackson and Pollock (1979) equation in that Jackson and Pollock equation yielded a distribution variance closer to that of actual body density value.

To consider an equation as valid, the validation criteria recommended by Shenoy, Shrivata, Sandhu, Maihotra and Gupta (2015) should be used. That is, the result obtained by the equation tested and the criterion method should not present significant differences, standard error of estimate should be less than 3.5 and finally R^2 should be greater than 0.7. Of striking interest is the fact that the selected generalized equation of Jackson and Pollock (1979) also overestimate body density and underestimate percent body fat. This is a clear negation of the submission of Jackson and Pollock (1970) that generalized equations will eliminate the need for new prediction equations for those specific population groups not yet studied.

The concept of generalized equation is sound and appealing but with findings of this study, the generalized equation does not show superior predictive accuracy than the selected population specific equation. This is obvious in the similarity of the correlation co-efficient and standard error of estimate from validating these equations. Two factors in this study may have reduced the advantages of newer generalized equation. Firstly, the age of the study sample was quite homogenous, ranging from 18 – 29 years (Table 1). Secondly, there was no apparent curvilinearity when the skin folds were plotted against body density. The samples were more homogenous in fatness (SD = 0.005 – 0.006), eliminating extreme fatness where the curvilinearity is especially evident.

4.4Summary for Discussion of Findings

Overall, there was no single anthropometric equation validated which satisfied all the cross-validation criteria suggested by previous investigators, however, the linear equation of Jackson and Pollock (1979) resulted in an extremely small constant error and an appropriate standard deviation of the percent body density values only the equation gave estimates not significantly different from underwater weighing.

As a result, practitioners should carefully choose and employ only equations that have been created and cross-validated for specific ethnic populations. To verify the accuracy and application of previously published prediction equations for black populations, more study is needed. This position is confirmed by Aristzabal, Restrepo and Garcia (2018) in their research where it was emphasized that anthropometric equations should not be applied to a population different from its derivation without previously validating them.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATION

5.1 Summary

Anthropometric regression equations are frequently employed to analyze body composition in both individuals and large populations. Nearly all these equations have been validated in some developed countries, although in some instances it might may not be appropriate for diverse racial groups or population based on disparities in body composition. The study therefore evaluate some of these existing equations derived previously for predicting BD and %BF confirming or refuting their respective validity on male university athletes, although, it was completely unrelated to the original sample used in their derivations. Literatures reviewed focused on the conceptual model and theoretical framework and also empirical review of several related literature relating to anthropometric regression equations and validation was carried out. The study used ex-post facto independent group correlational research design. One hundred and thirty-five (forty-five each for endurance athletes, power athletes and control) served as samples. Underwater weighing (criterion measure) and anthropometric measures at various sites were used for body composition assessment, using standardized instruments with various ranges of validity and reliability.

Descriptive statistics of mean and inferential statistics of independent t-test, Analysis of Variance, Pearson Product Moment Correlation and Stepwise Multiple Regression Analysis were used for the analysis of the data. Alpha level was set at 0.05 for all tests. The study provided answers to three research questions and tested six hypotheses.

The findings of the study revealed no significant difference in physical characteristics of height, body weight, body density and residual volume while there was significant difference in the values of %BF and lean body weight of power and endurance athletes. There was weak, positive but non-significant relationship between BD determined by underwater weighing technique and body density estimated by the five selected regression equations. There was also either weak or moderate positive but non-significant relationship between %BF estimated by underwater weighing technique and percent body fats estimated by four of the five equations except Jackson and Pollock (1979) equation. There was significant difference between body density determined by densitometric technique and those estimated by the five anthropometric based regression equations. There was also significant difference between percent body fat determined by underwater weighing and percent body fat determined by the five selected equations. The results obtained were discussed by comparing the findings of the study with those of related past studies. Literature was appropriately cited to corroborate the results obtained in this study.

An anthropometric regression equation was developed for use of male university athletes in Nigeria, viz;

BD = 1.064 + 0.0392 (X_1) + 0.0469 (X_2) + 0.0476 (X_3) ………….**Equation 5.4a**

where X_1 = subscapular SF, X_2 = sum of abdominal and suprailiac SF, X_3 = sum of chest, triceps and thigh SF

5.2 Conclusions

The following conclusions were reached as a result of this study:

1. There was no significant difference in physical characteristics of height, body weight, body density and residual volume of endurance athletes and power athletes, but they differ in physiological characteristics of percent body fat and lean body weight.
2. There was weak, positive but non-significant relationship but a significant difference between BD and percent body fat determined by underwater weighing technique and body density and percent body fat estimated by Brozek and Keys (1951) anthropometric-based regression equation.
3. There was weak, positive but non-significant relationship but a significant difference between BD and %BF determined by underwater weighing technique and body density and percent body fat estimated by Sloan and Weir (1970) anthropometric based regression equation.
4. There was weak, positive but non-significant relationship but a significant difference between BD and percent body fat determined by underwater weighing technique and body density and %BF estimated by Sinning (1974) anthropometric-based regression equation.
5. There was weak, positive but non-significant relationship but a significance difference between body density and percent body fat determined by underwater weighing technique and body density and percent body fat estimated by Forysth and Sinning (1975) anthropometric-based regression equation.
6. There was significant relationship and significant difference between body density and percent body fat determined by underwater weighing technique and BD and percent body fat estimated by Jackson and Pollock (1979) anthropometric based regression equation.
7. The anthropometric (skinfold) sites measured for validation of selected equation were singularly and in combination provide significant substantial weights as predictors to generate anthropometric regression equation for body composition assessment of male university athletes in Nigeria in a novel manner.

5.3 Recommendations

These include:

1. Prediction equations should be used with relative caution until further study on an entirely different samples of subjects either confirm or refute their validity. Finding the original source for the equations' derivation and critically examining the data supplied to identify the optimum equation for a specific demographic may be required.
2. In choosing equation(s) for any population whatsoever, it is recommended that one with high validity and reliability co-efficient should be employed. Also the population must be similar to those in the original study from which the equation(s) was/were developed if accurate result is desired.
3. The intercept of these equations may be recast to reflect the mean density of the study male athletes as this would adequately take into consideration the denser lean body mass and skeletal weights of black athletes.
4. For body composition assessment of male University endurance and power athletes, the selected anthropometric regression equations should be preferably used in this ‘worthy’ order i.e. the quadratic form equation of Jackson and Pollock (1979), Sinning (1974), Forysth and Sinning (1975), Sloan and Weir (1970) and Brozek and Keys (1951) equations.
5. The proposed prediction equation (i.e. $BD = 1.064 + 0.0392(X_1) + 0.0469(X_2) + 0.0476(X_3)$ where X_1=subscapular SF; X_2=Sum of abdominal and suprailiac SF, X_3 = sum of chest, Triceps and Thigh SF which has the following characteristics of using acceptable reference method to obtain criterion measure for body density, high multiple correlation between the reference measure and estimated scores ($R>0.80$) and a small prediction SEE of 0.0062 is recommended for use on male university endurance and power athletes. However, it will need a cross-validation suggestively with two compartment model and four compartment model before it is accepted for widespread use.

5.4 Contributions to Knowledge

1. In this study evidences has been provided concerning the true external validity and 'worth' of the five selected population-specific and generalized equations i.e. the body composition predictive ability of each of the equations.
2. The study was able to cross validate therefore evaluate these selected foreign derived anthropometric regression equations using Nigerian athletic population.
3. The study developed body density and percent body fat prediction equation using the variables from anthropometric with underwater weighing technique as a criterion measure; i.e.

$$\mathbf{BD = 1.064+0.0392(X_1)+0.0469(X_2) + 0.0476(X_3)}$$

Where X_1 = Subscapular skinfold

X_2 = Sum of abdominal and suprailiac skinfolds

X_3 = Sum of chest, triceps and thigh skinfolds

However, there is the need to subject these quadratic equation to cross-validation process to ensure its general acceptability.

5.5 Suggestions for further studies

1. Replication could be done on female University endurance and power athletes.
2. Cross-validation of the study's derived equation on an independent sample of athletic population. More study will be desirable to determine the validity of this prediction equation in other populations.
3. The quest for a flawless prediction equation that will simplify individuals fatness should be a constant research endeavor.

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APPENDIX I

Informed Consent Form

Validation of Selected Anthropometric Regression Equations for Body Composition Assessment in NigerianMaleUniversity Endurance and Power Athletes

1. This study is being conducted by Mr. Tunde Adeyinka ADESIPO of the University of Ibadan.
2. I have been informed that the purpose of this research is to evaluate some of the existing anthropometric regression equations derived previously exiting anthropometric regression equations derived previously for predicting body density and percent body fat, confirming or refuting their respective validity on a sample of subjects (Nigerian University athletes) which was entirely independent of the original sample used in the derivation of these equations.
3. I understand that the study will use purposive sampling technique to select participant in this study, who will be in these three years; 45 power athletes, 45 endurance athletes, and 45 (non-athletes) as the control group. The research will involve basically the use of densitometric technique (underwater weighing) and anthropometric measures to assess participants' body composition.
4. All the measurements will be taken within the Exercise Physiology/Human Performance Laboratory of the respective Universities and the underwater weighing performed at the swimming pools of the Universities.
5. I understand there may be foreseeable risk or discomfort to me if I agree to participate in the study. Such discomfort may include submerging myself underwater for measurement of underwater weight.
6. I understand that the possible benefits of my participation in the research include being instrumental to the development of an anthropometric regression equation to assess body composition of male Nigerian University athletes.
7. I understand that the results of the research study may be published but that my name or identity will not be revealed. In order to maintain confidentiality of my records, all information collected in this study will be given code numbers and no name will be recorded.

8. I have been advised and understand that the research work in which I will be participating does not involve more than minimal risk and that in case of any minor or major injury, I can expect to receive first aid treatment or major treatment (as the case may be) at the University's clinic or Health centre and the researcher will bear the cost.
9. I have been informed that I will be compensated for my participation with a customized research sport wear, but will not be paid any fees for participating in this research.
10. My participation in this research is entirely voluntary, and I have been made to understand that I can withdraw from the research at any time at no adverse cost to me personally.
11. I have been informed that any question I have concerning the research study or my participation in it, before or after my consent will be answered by the researcher.
12. I understand that in case of injury, if I have questions about my rights as a participant in this research, or I feel I have been placed at risk, I can contact the Chair, Ethical Review Committee of University of Ibadan.
13. I have read the above information. The nature, demands, risks and benefits of the project have been explained to me. I knowingly assume the risks involved, and understand that I may withdraw my consent and discontinue participation at any time without penalty or loss of benefit to myself.

I signing this consent form, I am no waiving any legal claims, rights or remedies. A copy of this consent form will be given to me.

Subject's signature ______________________________ Date _________________

Name _________________________________ Games/Sport_____________________

Witness Signature (if applicable _________________) Date ___________________

14. I certify that I have explained to the above individual the nature and purpose, the potential benefits, and possible risks associated with participation in this research study, have answered any questions that have been raised, and have witnessed the above signature.

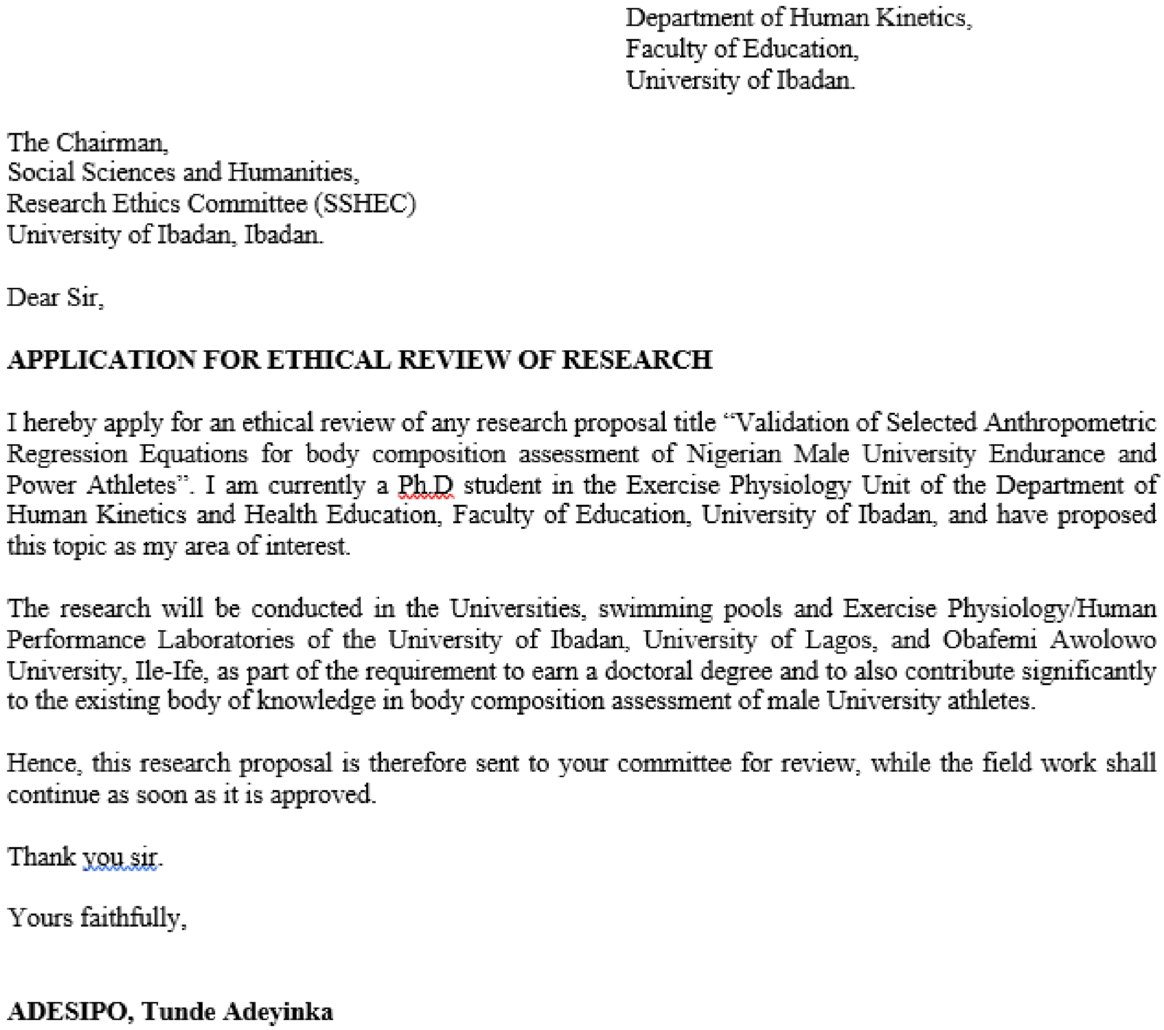
15. These elements of informed consent confirm to the assurance given by the Ethical Review Committee of the University of Ibadan to the Department of Human Kinetics and Health Education to protect the rights of human subjects.

16. I have provided the participant a copy of the signed consent document.

Signature of researcher ___________________________ Date________________

APPENDIX II

APPLICATION FOR ETHICALS



Department of Human Kinetics,
Faculty of Education,
University of Ibadan.

The Chairman,
Social Sciences and Humanities,
Research Ethics Committee (SSHEC)
University of Ibadan, Ibadan.

Dear Sir,

APPLICATION FOR ETHICAL REVIEW OF RESEARCH

I hereby apply for an ethical review of any research proposal title "Validation of Selected Anthropometric Regression Equations for body composition assessment of Nigerian Male University Endurance and Power Athletes". I am currently a Ph.D student in the Exercise Physiology Unit of the Department of Human Kinetics and Health Education, Faculty of Education, University of Ibadan, and have proposed this topic as my area of interest.

The research will be conducted in the Universities, swimming pools and Exercise Physiology/Human Performance Laboratories of the University of Ibadan, University of Lagos, and Obafemi Awolowo University, Ile-Ife, as part of the requirement to earn a doctoral degree and to also contribute significantly to the existing body of knowledge in body composition assessment of male University athletes.

Hence, this research proposal is therefore sent to your committee for review, while the field work shall continue as soon as it is approved.

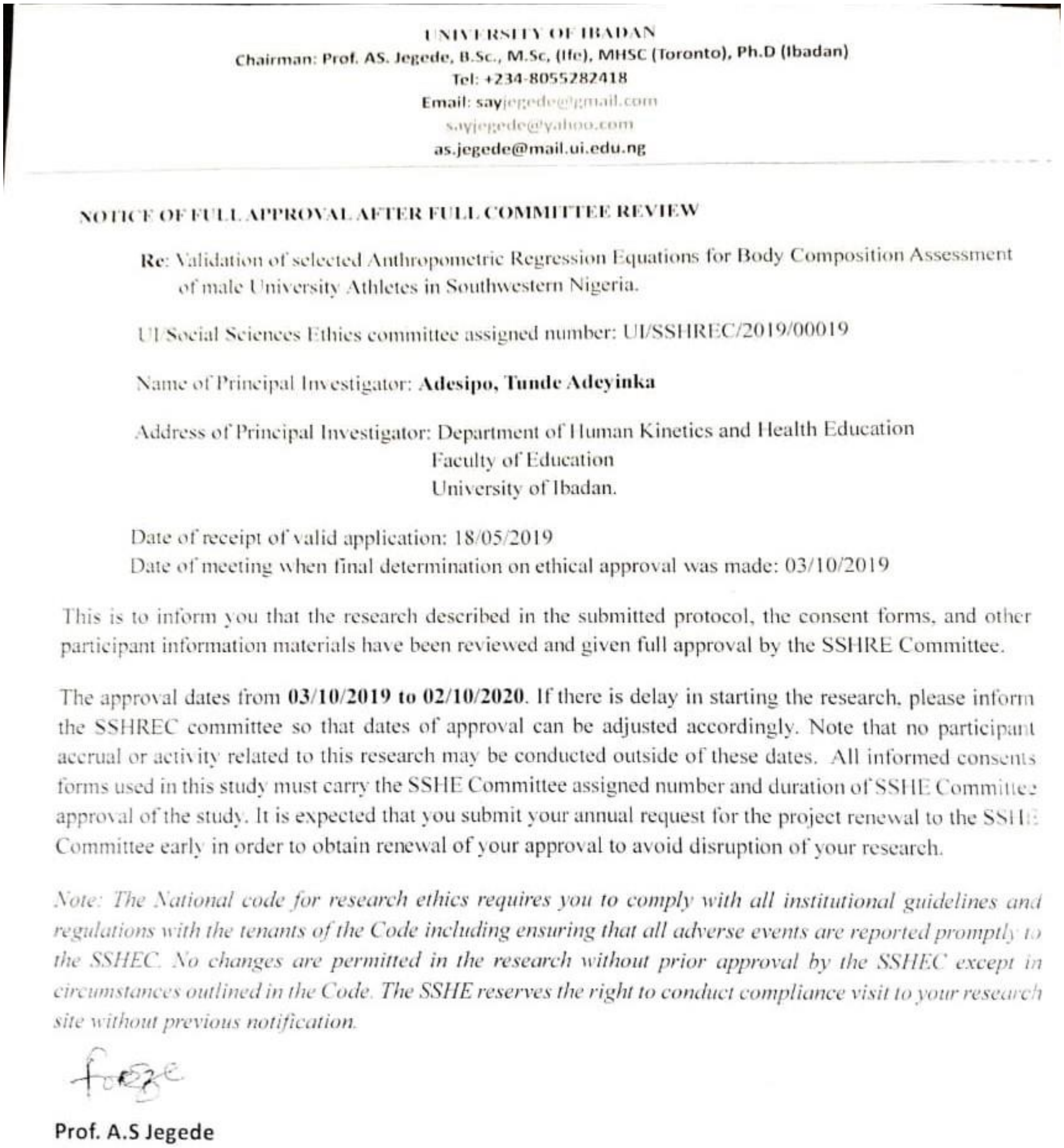
Thank you sir.

Yours faithfully,

ADESIPO, Tunde Adeyinka

APPENDIX III

ETHICAL APPROVAL



UNIVERSITY OF IBADAN
Chairman: Prof. AS. Jegede, B.Sc., M.Sc, (Ife), MHSC (Toronto), Ph.D (Ibadan)
Tel: +234-8055282418
Email: sayjegede@gmail.com
sayjegede@yahoo.com
as.jegede@mail.ui.edu.ng

NOTICE OF FULL APPROVAL AFTER FULL COMMITTEE REVIEW

Re: Validation of selected Anthropometric Regression Equations for Body Composition Assessment of male University Athletes in Southwestern Nigeria.

UI/Social Sciences Ethics committee assigned number: UI/SSHREC/2019/00019

Name of Principal Investigator: **Adesipo, Tunde Adeyinka**

Address of Principal Investigator: Department of Human Kinetics and Health Education
Faculty of Education
University of Ibadan.

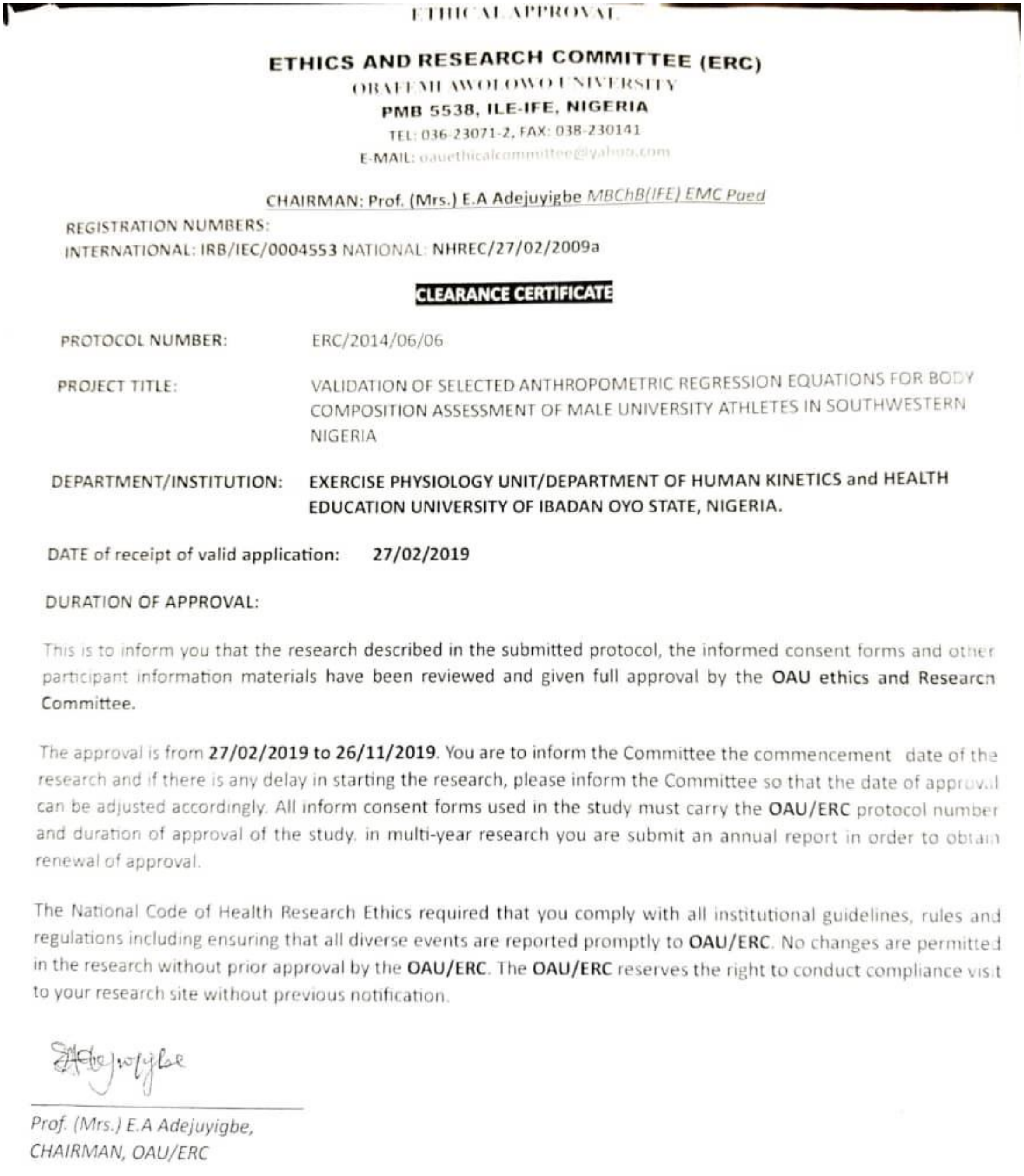
Date of receipt of valid application: 18/05/2019
Date of meeting when final determination on ethical approval was made: 03/10/2019

This is to inform you that the research described in the submitted protocol, the consent forms, and other participant information materials have been reviewed and given full approval by the SSHRE Committee.

The approval dates from **03/10/2019 to 02/10/2020**. If there is delay in starting the research, please inform the SSHREC committee so that dates of approval can be adjusted accordingly. Note that no participant accrual or activity related to this research may be conducted outside of these dates. All informed consents forms used in this study must carry the SSHE Committee assigned number and duration of SSHE Committee approval of the study. It is expected that you submit your annual request for the project renewal to the SSHE Committee early in order to obtain renewal of your approval to avoid disruption of your research.

Note: The National code for research ethics requires you to comply with all institutional guidelines and regulations with the tenants of the Code including ensuring that all adverse events are reported promptly to the SSHEC. No changes are permitted in the research without prior approval by the SSHEC except in circumstances outlined in the Code. The SSHE reserves the right to conduct compliance visit to your research site without previous notification.

Prof. A.S Jegede



ETHICAL APPROVAL

ETHICS AND RESEARCH COMMITTEE (ERC)

OBAFEMI AWOLOWO UNIVERSITY
PMB 5538, ILE-IFE, NIGERIA
TEL: 036-23071-2, FAX: 038-230141
E-MAIL: oauethicalcommittee@yahoo.com

CHAIRMAN: Prof. (Mrs.) E.A Adejuyigbe *MBChB(IFE) EMC Paed*

REGISTRATION NUMBERS:
INTERNATIONAL: IRB/IEC/0004553 NATIONAL: NHREC/27/02/2009a

CLEARANCE CERTIFICATE

PROTOCOL NUMBER: ERC/2014/06/06

PROJECT TITLE: VALIDATION OF SELECTED ANTHROPOMETRIC REGRESSION EQUATIONS FOR BODY COMPOSITION ASSESSMENT OF MALE UNIVERSITY ATHLETES IN SOUTHWESTERN NIGERIA

DEPARTMENT/INSTITUTION: **EXERCISE PHYSIOLOGY UNIT/DEPARTMENT OF HUMAN KINETICS and HEALTH EDUCATION UNIVERSITY OF IBADAN OYO STATE, NIGERIA.**

DATE of receipt of valid application: **27/02/2019**

DURATION OF APPROVAL:

This is to inform you that the research described in the submitted protocol, the informed consent forms and other participant information materials have been reviewed and given full approval by the **OAU ethics and Research** Committee.

The approval is from **27/02/2019 to 26/11/2019**. You are to inform the Committee the commencement date of the research and if there is any delay in starting the research, please inform the Committee so that the date of approval can be adjusted accordingly. All inform consent forms used in the study must carry the **OAU/ERC** protocol number and duration of approval of the study. in multi-year research you are submit an annual report in order to obtain renewal of approval.

The National Code of Health Research Ethics required that you comply with all institutional guidelines, rules and regulations including ensuring that all diverse events are reported promptly to **OAU/ERC**. No changes are permitted in the research without prior approval by the **OAU/ERC**. The **OAU/ERC** reserves the right to conduct compliance visit to your research site without previous notification.

EAdejuyigbe

Prof. (Mrs.) E.A Adejuyigbe,
CHAIRMAN, OAU/ERC

APPENDIX IV

Computation

The study used the computational procedure adopted by Sinning (2000) using Behnke and Wilmore (2009) formula

$$BD = \frac{Wa}{\left[\frac{Wa - Ww}{Dw}\right]} - RV + 100ml$$

Where Wa = weight of participants in air (gms)

Ww = weight of participants in water (gms)

Dw = density of water at the temperature taken during underwater weighing

Rv = Residual volume in cc, as estimated from vital capacity

Residual volume will be estimated from Vital Capacity using the formular of Sinning (1975).

$$RV = 0.24 \times Vc\ (BTPS) \text{ for males.}$$

The 100ml value is added to residual lung volume to adjust for gas bubbles in the gastrointestinal tract (Benke and Wilmore 1974).

Percent body fat will be computed using the formula of Brozek, Grande, Anderson and Keys (1963)

$$\left[\left(\frac{4.570}{BD}\right) - 4.142 \quad x\ 100\right]$$

$$\text{Lean Body Weight} = \text{Body wt} - \frac{\%\text{fat x body wt}}{100}$$

The reliability co-efficient of the fomular is 0.99.

$$\text{Absolute Fat} = \text{Weight} \quad x\ \frac{\text{percent body fat (kg)}}{100}$$

Selected Regression Equation

1. Brozek and Keys (1951) men ages 18-26 years

$BD = 1.1017 – 0.00028$ subscapular SF – 0.000736 chest SF – 0.000583 Triceps SF

$R = 0.88$ $SEE = 0.007$

2. Sloan and Weir (1970) – male athletes 18-26 years

$BD = 1.1043 – 0.00132$ Thigh SF – 0.00131 subscapular SF.

$R = 0.71$, $SEE = 0.0108$

3. Sinning (1974) – College athletes

BD = 1.1080 – 0.00118 subscapular SF – 0.00127 abdominal SF

R = 0.98, SEE = 0.0076

4. Forysth and Sinning (1975) – Male athletes 19-29 years

BD = 1.0353 – 0.00156 subscapular SF + 0.00207 bitrochanter diameter – 0.0148 abdominal SF

5. Jackson and Pollock (1979) – Generalized equation for men

BD – 1.1093800 – 0.0008267 chest + abdominal + thigh SF^2 + 0.0000016 Triceps + thigh + Suprailiac SF^2 – 0.002574 Age

R = 0.81, SEE = 0.0077

The information on the measurement of various skinfold in these equations and determination of body density will be used to calculate the participants percent body fat.

APPENDIX V

UNDERWATER WEIGHING: MEASUREMENT AND COMPUTATIONAL PROCEDURES

A. Weight in air ________________kg

B. Weight in air ________________kg
   1. Gross weight in water ________________kg
   2. Tare Weight (weight of submerged apparatus) ________________kg
   3. Net underwater weight (1 minus 2) (10 trials)

C. (i) Water Temperature _______________ °C
   (ii) Water density ____________________ g/cc

D. Residual lung volume plus gastrointestinal volume
   1. Vital capacity (vc) ________________litres
   2. Corrected vital capacity (VC BTPS) ________________litres
   3. Residual volume (RV) ________________litres
   4. Volume of gas in intestinal tract (VGI) (add 100ml) ________________litres
   5. Total volume (RV + VGI) ________________litres

E. Weight of equivalent volume of waters
   (RV + VGI)

F. Corrected body weight under water
   (wt in water (B) + weight of equivalent volume of water (0) ___________kg

G. Volume of body = weight in air (A) – Weight in water (B^3) ___________kg

H. Specific gravity (density of body) ___________g/cc to 5 decimal places

$$\frac{\text{Weight in air (A)}}{\text{Volume of body (F)}}$$

I. Fraction of body weight as fat (fat weight ___________

$$= \frac{4.570 - 4.142}{BD}$$

J. Percent Body fat (Fat weight (H) x 100) ___________%

K. Fat-free weight – weight in air (A) – fat wt (H) ___________kg

APPENDIX VI

ANTHROPOMETRIC MEASUREMENTS

Name:………………………………………………………………………………

Height:……………………………………………………………………………..

Sport:………………………………………………………………………………

Age:……………………………………………………………………………...

Weight:……………………………………………………………………….....

Vital Capacity:……………………………………………………………………

	1	**2**	**3**	**Mean Values**
Skin folds (mm)				
Chest				
Triceps				
Subscapular				
Abdominal				
Thigh				
Supraillium				
Circumferences (mm)				
Abdominal				
Calf				
Diameter				
Britrochanter				
Chest				

Plate 1; Measurement of Suprailiac skinfold thickness

Plate 2: Measurement of subscapular skinfold thickness

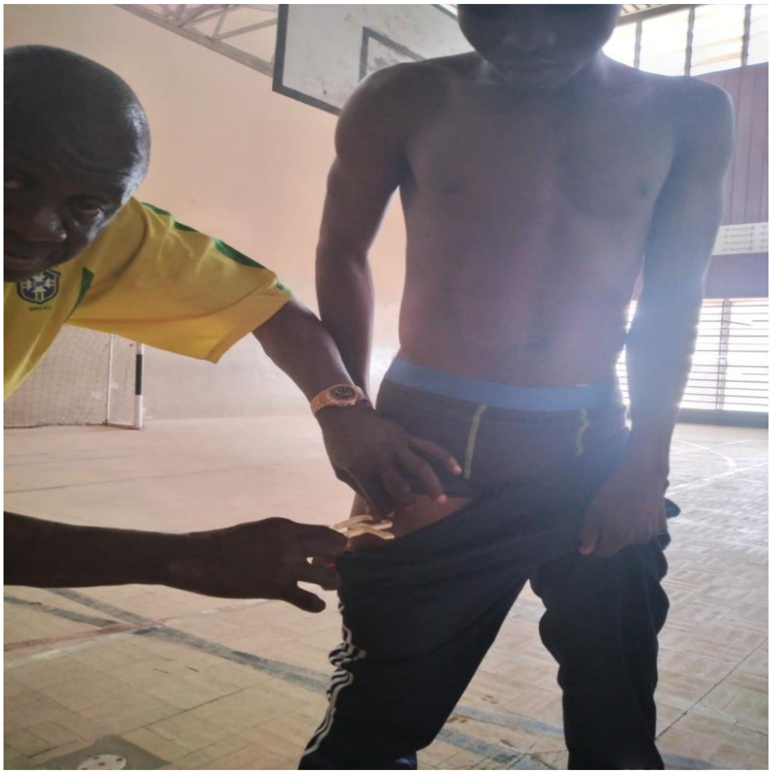


Plate 3; Measurement of Thigh Skinfold Thickness

Plate 4: measurement ofsuprailiac skinfold thickness

Plate 5; A group of non-athletes (control group)

Plate 6; A group of male University Power Athletes

Plate 7: A group of University Male Endurance Athletes

Plate 8: Measurement of Abdominal Skinfold Thickness

Plate 9; Measurement of Subscapular Skinfold Thickness

Plate 10: A picture of the under water weighing equipment

Plate 11; Underwater weighing Equipment inside the pool

Plate 12: An athlete getting prepared for underwater weighing.

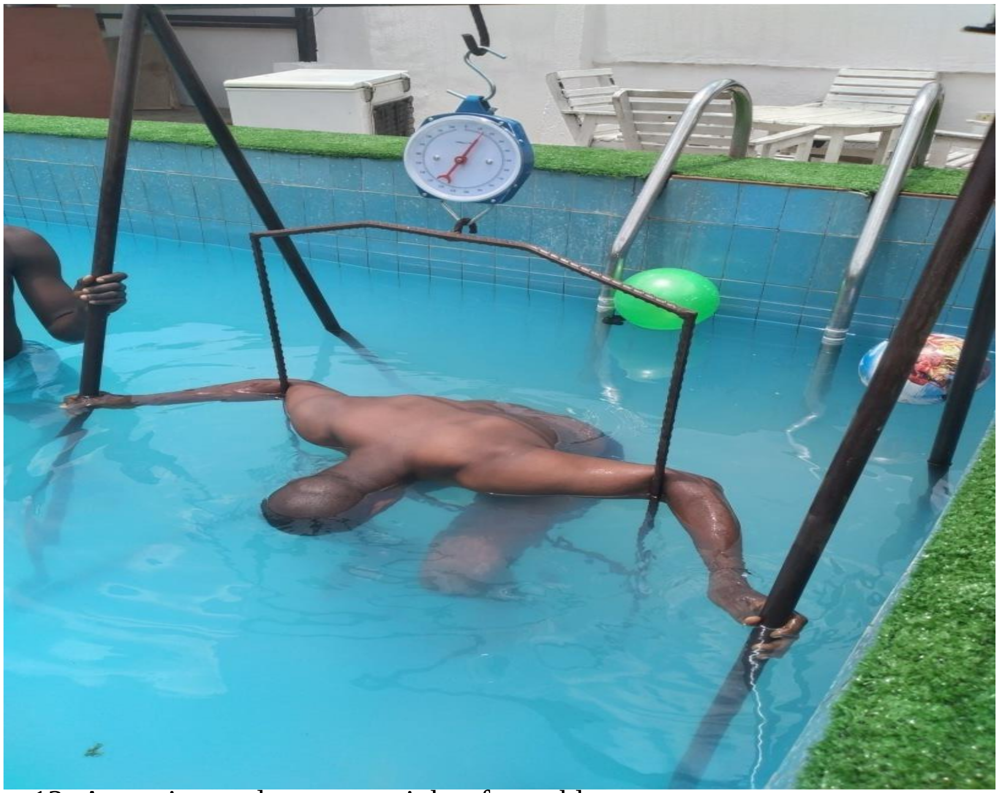


Plate 13; Assessing underwater weight of an athlete.

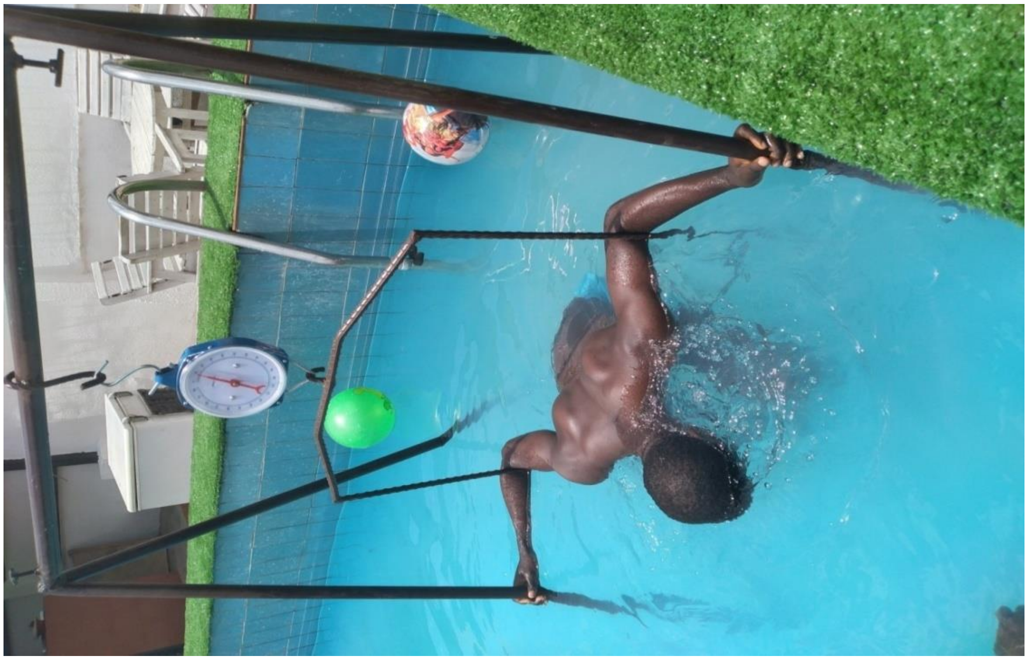


Plate 14: Assessing underwater weight of an Athlete.