FIELD METHODS OF ACCURATELY DETERMINING THE PERCENT BODY FAT OF MALE JOCKEY APPRENTICES AT THE SOUTH AFRICAN JOCKEY ACADEMY, THE WEIGHT-MAKING TECHNIQUES REPORTED AND THE RISK OF EATING DISORDERS

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ABSTRACT

Background: The South African Jockey Academy (SAJA) apprentices need to meet handicapping requirements for body weight. To avoid various deleterious weight-making practices, which increase the risk of occupational injury, excess body fat has to be eliminated while maintaining an acceptable fat-free mass. A practical, affordable and accurate measurement of percent body fat (%BF) is therefore essential.

Objectives: To determine the most appropriate field techniques to measure %BF when euhydrated and dehydrated; weight-making practices reported; and risk of eating disorders.

Methods: Seventeen male apprentices' (mean age 18.7 ± 1.7 years) %BF was calculated when both dehydrated and euhydrated, using equations extrapolated from body mass index (BMI), skinfold measurements and bioelectric impedance analysis (BIA) and compared to euhydrated deuterium dilution (eDD) (reference method). A lifestyle questionnaire and the EAT-26 questionnaire investigated weight-making methods and the risk of eating disorders.

Results: Mean BMI was 19.2 ± 1.2 kg/m^2. Mean %BF according to the reference method was 9.51 ± 2.85 % and 88% were underfat. Both BMI and BIA were not as accurate as skinfold measurements. The Slaughter, Lohman, Boileau, Horswill, Stillman, Van Loan & Bemben (1988) skinfold equation and the Durnin & Womersley (1974) skinfold equation using Brozek et al. (1963) were the only methods with acceptable levels of bias in both hydration states. Restricting food intake (75%), daily weighing (69%), keeping busy to avoid eating (44%) and exercising (44%) were the most commonly reported chronic weight-making methods. The most common acute weight-making methods were hot baths (50%), sauna (37.5%) and wearing plastic to sweat during exercise (31%). The mean EAT-26 score was 4.87 ± 5.84.

Conclusion: When dehydrated, the Slaughter *et al.* (1988) equation for those under 18 years or the Durnin & Womersley (1974) skinfold equation for those above 16 years was recommended for measuring %BF of the SAJA. The weight-making techniques were similar to those of professional jockeys although not as diverse. The risk of eating disorders was low.

PREFACE

This dissertation was written between February 2016 and December 2017 under the supervision of Dr Chara Biggs using data collected from the male jockey apprentices training at the South African Jockey Academy in Summerveld between June and September 2016.

Signed: ___________________________ Date: __________________

Emma Illidge (candidate)

As supervisor of the candidate, I agree to the submission of this dissertation.

Signed: ___________________________ Date: __________________

Dr Chara Biggs (supervisor)

DECLARATION OF ORIGINALITY

I, Emma Louise Illidge, declare that:

1. The entirety of the work contained in this dissertation is my original work, except where otherwise stated.

2. This dissertation, or any part of it, has not been submitted for any degree or examination at any other university.

3. Where other sources have been used they have not been copied and have been properly acknowledged.

4. This dissertation does not contain text, graphics or tables copied and pasted from the internet, unless specifically acknowledged, and the source being detailed in the dissertation and in the relevant reference section.

Signed: ____________________________ Date: ____________________

Emma Illidge (candidate)

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LIST OF ABBREVIATIONS

%BF – Percent body fat

2-C model – Two compartment model

3-C model – Three compartment model

3D – Three dimensional

4-C model – Four component model

ADP – Air displacement plethysmography

AN – Anorexia nervosa

BD – Body density

BIA – Bioelectric impedance analysis

BMC – Bone mineral content

BMD – Bone mineral density

BMI – Body mass index

BN – Bulimia nervosa

CT - Computed Tomography

DPA – Dual photon absorptiometry

DSM - Diagnostic and Statistical Manual of Mental Disorders

DXA – Dual-energy X-ray absorptiometry

EA – Energy availability

EAT-26 – Eating attitudes test (consisting of 26 questions)

ECF – Extracellular fluid

FBC – Full blood count

FFM – Fat-free mass

FFMI – Fat-free mass index

FM – Fat mass

FMI – Fat mass index

IAEA - International Atomic Energy Agency

ICF – Intra-cellular fluid

ISAK - International Society for the Advancement of Kinanthropometry

LOA – Limits of agreement

MRI - Magnetic Resonance Imaging

MF-BIA – Multi-frequency bioelectrical impedance analysis

NHRASA – National Horse Racing Authority of South Africa

RED-S – Relative energy deficiency in sport

RDI – Reference daily intake

RMR – Resting metabolic rate

SAJA – South African Jockey Academy

SAT – Subcutaneous adipose tissue

SEE – Standard error of estimate

SF-BIA – Single frequency bioelectric impedance analysis

SS – Short stature

TBW – Total body water

U&E – Urea and electrolytes

UK – United Kingdom

USA – United States of America

USG – Urine specific gravity

UWW – Underwater weighing

YRBS – Youth Risk Behaviour Survey

CHAPTER 1: INTRODUCTION, THE PROBLEM AND ITS SETTING

1.1 IMPORTANCE OF THE STUDY

Horse racing in South Africa makes a significant contribution to the national economy. The industry is controlled by two bodies: Phumelela Gaming and Leisure Limited, which controls racing in the Free State, Northern Cape, Eastern Cape and Gauteng, and Gold Circle, which controls racing in the Western Cape and Kwazulu-Natal. In 2016, the two bodies contributed 2.465 billion rand to the gross domestic product (GDP) and provided employment for more than three thousand people (Gold Circle, 2017, Phumelela, 2017).

Horse racing relies on a handicapping system, meaning that each horse being ridden in a given race is assigned a specific weight to carry, according to the ability of the horse. If the weight of the kitted jockey plus saddle immediately prior to the race exceeds this, it is unlikely that they will be given the ride. It is easier for the jockey to 'make' a heavier weight than to lose weight before racing, therefore it is critical to maintain an optimal low weight all year round. Jockeys and apprentices often resort to various deleterious techniques of rapidly losing weight in order to 'make' weight for a race, which increases the risk of occupational injury (Wilson, Fraser, Sharma, Eubank, Drust, Morton & Close, 2013a). To avoid this, surplus weight in the form of body fat should be eliminated while maintaining the bone and muscle mass important for the health and performance of the jockey. An accurate, practical and affordable measurement of percent body fat (%BF) is therefore useful.

The South African Jockey Academy (SAJA) currently uses skinfold measurements to calculate %BF, a method with a great potential for error (Parker, Reilly, Slater, Wells & Pitsiladis, 2003). Bioelectric impedance analysis (BIA) is an alternative method of body fat analysis that has not been validated in the jockey apprentice population before but may have advantages over the skinfold method because it requires less training and is not influenced by inter-observer variability (Fu & Stone, 1994; Ostojic, 2006). Equations have also been developed to estimate %BF from body mass index (BMI) (Deurenberg, Weststrate & Seidell, 1991c), which involves measurements that are routinely measured at the SAJA, therefore it could provide a very practical and inexpensive alternative to other field methods. This method has also not been validated in the jockey or apprentice population.

These methods however may be influenced by fluid changes in the body (Saunders, Blevins & Broeder, 1998) which is a concern, as common strategies of making weight for races involve manipulation of hydration status (Labadarios, Kotze, Momberg & Kotze, 1993; Leydon & Wall, 2002; Moore, Timperio, Crawford, Burns & Cameron-Smith, 2002a; Dolan, O'Connor, McGoldrick, O'Loughlin, Lyons & Warrington, 2011; Wilson, Drust, Morton & Close, 2014). It is therefore necessary to validate these methods in the apprentice population against a reference method for measuring %BF, such as deuterium dilution (DD) (Parker *et al.*, 2003) in order for the apprentices to ensure an optimal %BF which can reduce the need for detrimental weigh making strategies.

Very little literature involving South African jockeys or apprentices exists to date. Only two such studies exist. Labadarios *et al.* (1993) described the %BF and weight-making practises in a descriptive study involving 93 South African male flat jockeys, although %BF was measured using only the skinfold method and no reference method. Krog (2015) also described the %BF and weight-making practises of 21 male flat jockey apprentices training at the SAJA, although %BF was measured using only BIA.

1.2 STATEMENT OF RESEARCH PROBLEM

The SAJA apprentices require an accurate, practical and affordable measurement of %BF due to pressures related to weight-restriction in the industry. The accuracy of three field methods of measuring %BF (BMI, skinfolds and BIA) had not been validated against a reference method in the apprentices at the SAJA before. Dehydration may also have an impact on the accuracy of the methods. The use of various weight-making techniques involving dehydration and food restriction as well as the risk of developing eating disorders is of concern in the professional jockey population and should also be assessed amongst the apprentices.

1.3 TYPE OF STUDY

This was a cross-sectional, descriptive study, with minor intervention made with regards to ensuring euhydration.

1.4 OBJECTIVES

1.4.1 To determine the hydration status prior to intervention of the male apprentice jockeys at the SAJA by urinalysis.

1.4.2 To accurately determine the mean %BF of the apprentices using the reference method DD.

1.4.3 To classify the height-for-age, BMI, %BF, FMI and FFMI of the apprentices.

1.4.4 To validate the accuracy of three methods of body composition analysis (BMI, skinfolds and BIA) in measuring %BF to the reference method DD, in male apprentice jockeys at the SAJA when euhydrated and dehydrated.

1.4.5 To investigate the association between weight satisfaction of the apprentices and their %BF, age, height, weight, BMI, fat mass index (FMI) and fat-free mass index (FFMI).

1.4.6 To investigate the use of various weight-making techniques of the apprentices using a lifestyle questionnaire.

1.4.7 To investigate the apprentices' risk of developing eating disorders such as anorexia nervosa (AN) and bulimia nervosa (BN) using the EAT-26 questionnaire.

1.5 HYPOTHESES

1.5.1 The mean BMI of the apprentices would be close to the minimum cut-off range for normal BMI with a high prevalence of underweight.

1.5.2 The mean fat-free mass (FFM) of the apprentices would be normal.

1.5.3 The %BF values would indicate scope for reduction of body fat in all of the apprentices included.

1.5.4 Using BMI to calculate %BF will not provide accurate %BF results in both the euhydrated and dehydrated states and would be significantly impacted by dehydration.

1.5.5 Regression equations using skinfold measurements would significantly underestimate %BF in both the euhydrated and dehydrated states and that dehydration would significantly impact all of the skinfold measurements and %BF values.

1.5.6 Bioelectric impedance analysis would be the most comparable to DD (reference method), in both the euhydrated and dehydrated state, but would be significantly impacted by dehydration.

1.5.7 Weight dissatisfaction would be significantly associated with a higher body weight, BMI and %BF.

1.5.8 The prevalence of chronic and acute weight-making behaviours of the apprentices studied would be similar to that of the previous study on apprentices at the SAJA (Krog, 2015) and implicate necessary intervention.

1.5.9 There would be a high risk of developing eating disorders such as AN and BN.

1.6 STUDY PARAMETERS

All male jockey apprentices enrolled at the SAJA in Kwa-Zulu Natal between June and September 2016 were invited to participate in the study.

1.7 STUDY ASSUMPTIONS

1.7.1 It was assumed that the investigators performing measurements would do so meticulously and according to protocol.

1.7.2 It was assumed that all apprentices would answer the questionnaires honestly, objectively and with clear understanding after explanation and any necessary clarification.

1.8 DEFINITION OF TERMS

Acute dehydration – Water loss that occurs within a short period of time and is primarily due to vomiting and diarrhoea associated with illness, sweat loss, or other uncommon situations that cause fluid deprivation or fluid loss (Kenefick, Cheuvront, Leon & O'Brien, 2012).

Acute weight-making techniques – Techniques used to lose weight over a very short period of time, for example, by dehydration (Dolan *et al.*, 2011).

Bioelectric impedance analysis – A method of body composition analysis that applies prediction models derived from regression analysis to the measured impedance of the human body to an electric current to estimate TBW and FFM (Sun, Chumlea, Heymsfield, Lukaski, Schoeller, Friedl, Kuczmarski, Flegal, Johnson & Hubbard, 2003).

Body density – A measurement that is determined by weighing the body in air and in water, or by dividing the body weight by body volume, that permits calculation of the proportions of fat and lean body tissue (Bender, 2009).

Body mass index – An approximate measure of overweight and obesity, calculated by dividing body weight in kilograms by the square of height in metres (Flegal, Shepherd, Looker, Graubard, Borrud, Ogden, Harris, Everhart & Schenker, 2009).

Chronic dehydration – Dehydration that persists for more than a day, usually as a result of inadequate fluid intake (Kenefick *et al.*, 2012).

Chronic weight-making techniques – Techniques used to sustain weight loss over an extended period of time, for example, by energy restriction (Dolan *et al.*, 2011).

Dehydration - In this study, this term pertains to a condition of hypertonic hypovolemia brought about by the net loss of hypotonic body fluids (Kenefick *et al.*, 2012).

Energy availability – The energy left over for body functions after exercise energy expenditure had been subtracted from dietary energy intake and is expressed in kilojoules per kilogram fat-free mass (kJ/kg FFM) (Manore & Thompson, 2006). For example, if a 60 kg athlete consumed 8000 kJ and expends 1000 kJ through exercise, their EA will be 117 kJ/kg.

Euhydration – A "normal," narrow fluctuation in body water content with a urine specific gravity (USG) of 1.020 g/ml or less, without a change in body mass greater than one percent (Kenefick *et al.*, 2012).

Fat-free mass – Body mass which does not consist of fat, including that of internal organs, bone, muscle, water and connective tissue (Ackland, Lohman, Sundgot-Borgen, Maughan, Meyer, Stewart & Müller, 2012).

Fat mass index – An approximate measure of whether an individual is overfat, calculated by dividing body fat mass in kilograms by the square of height in metres (Bahadori, Uitz, Tonninger-Bahadori, Pestemer-Lach, Trummer, Thonhofer, Brath & Schaflinger, 2006).

Flat horse racing – Flat races consist of a run with no obstacles and ranges from distances of five to 20 furlongs - one furlong being 201 metres (Warrington, Dolan, McGoldrick, McEvoy, MacManus, Griffin & Lyons, 2009).

Four compartment model – A body composition model which divide the body components on either a chemical level into fat mass, protein, water and other or anatomically into adipose tissue, skeletal tissue, muscle and connective tissue and other (Ackland *et al.*, 2012).

Handicap – In the context of horseracing, it is the total weight impediment allocated to a horse for a given race weight to equalize their chances to win. This includes the jockey, his/her riding gear, the saddle, and any other added weight which the horse must carry (Krog, 2015).

Heavy ride – A race meeting ride wherein the horses are handicapped at near the maximum weight, which in South Africa is 62 kg, allowing the jockeys to ride at higher weights (Krog, 2015).

Jockey apprentice - A jockey in training. To enter the academy, the applicant must be 16 to 20 years old, 1.5 to 1.6 metres tall and weigh 38 to 47 kilograms. He or she must win 50 race rides as an apprentice in order to receive a professional jockey license. The apprenticeship typically lasts five years (The South African Jockey Academy, 2007c).

Jump horse racing – Jump races consist of a run which is at least 3.2 km long, throughout which the horse must jump a number of fences or hurdles (Warrington *et al.*, 2009).

Light ride - A race meeting ride wherein the horses are handicapped at near the minimum weight, which in South Africa is 52 kg, which might necessitate rapid weight loss before the ride (Krog, 2015).

Making weight - The practice of rapid weight loss shortly before competition in order to meet the allocated weight requirement (Wilson *et al.*, 2014).

Mild dehydration - Also known as minimal dehydration. Dehydration classified by a body weight change of one to three percent or a USG of 1.010 to 1.020 g/ml (Casa, Armstrong, Hillman, Montain, Reiff, Rich, Roberts & Stone, 2000).

Moderate dehydration – Also known as significant dehydration. Dehydration classified by a body weight change of three to five percent or a USG of 1.021 to 1.030 g/ml (Casa *et al.*, 2000).

Multi-frequency bioelectrical impedance analysis – Bioelectrical impedance analysis that involves electrical currents flowing at different frequencies to evaluate fat-free mass and total body water, as well as to differentiate measures for intra-cellular and extracellular fluid (Kyle, Bosaeus, De Lorenzo, Deurenberg, Elia, Gómez, Heitmann, Kent-Smith, Melchior & Pirlich, 2004a).

Professional jockey – An athlete who races horses as a profession. In South Africa, a jockey apprentice must be awarded a jockey licence from the National Horseracing Authority (NHA) of South Africa after riding a minimum of 50 winners as well as complete an apprenticeship at the SAJA or one of its satellites, which typically lasts five years, in order to qualify as a professional jockey (Krog, 2015).

Relative energy deficiency in sport – TA syndrome which characterised by impaired physiological functioning caused by relative energy deficiency, and includes but is not limited to impairments of metabolic rate, menstrual function, bone health, immunity, protein synthesis and cardiovascular health (Mountjoy, Sundgot-Borgen, Burke, Carter, Constantini, Lebrun, Meyer, Sherman, Steffen & Budgett, 2014).

Resting metabolic rate - The rate of energy expenditure which is required at complete rest for all cellular function, to maintain the systems of the body and to regulate body temperature (Livingstone, 2008).

Salt baths – A method of acute weight-loss by dehydration whereby salts, such as Epsom salts, are added to a hot bath to induce sweating and osmotic dehydration (Wilson *et al.*, 2014).

Severe dehydration - Also known as significant dehydration. Dehydration classified by a body weight change of six percent or more or a USG greater than 1.030 g/ml (Casa *et al.*, 2000).

Single frequency bioelectrical impedance analysis – Bioelectrical impedance analysis that involves an electrical current that flows at a single frequency (usually 50 kHz) between electrodes to measure fat-free mass and total body water (Kyle *et al.*, 2004a).

Sweat suits – An outfit, usually made from plastic, used to induce acute weight-loss by means of dehydration by sweating (Dolan *et al.*, 2011).

Three compartment model - A body composition model which divides the body components into fat mass, bone mineral and other (Ackland *et al.*, 2012).

Two compartment model - A body composition model which divides the body into fat mass and FFM (Ackland *et al.*, 2012).

Urine specific gravity – A method of assessing hydration status by measuring the density of a sample of urine in comparison to pure water, which has a density of 1.000 g/ml (Armstrong, 2005).

1.9 SUMMARY

This was the first study to investigate the accuracy of field methods to measure %BF in the jockey apprentice population and in South African jockeys using a reference method. Accurate measurement of %BF is pertinent to the jockey apprentices as they need to keep their weight as low as possible without compromising FFM, which will affect bone health, balance and metabolic rate. This emphasis on weight in horse-racing necessitates investigation of the prevalence of weight-making techniques which could be detrimental to the apprentices' health, as well as their risk of eating disorders.

1.10 DISSERTATION OUTLINE

This dissertation is laid out as follows:

Chapter 1: Introduction, the problem and its setting

Chapter 2: Review of related literature

Chapter 3: Methodology

Chapter 4: Results

Chapter 5: Discussion

Chapter 6: Conclusion and recommendations

CHAPTER 2: REVIEW OF RELATED LITERATURE

2.1 INTRODUCTION

Horse racing in South Africa is an important contributor to the national economy and the jockeys are a critical component to the industry. The pressures concerning weight control can have dire consequences for the jockeys' health and performance which require attention.

Horse racing relies on a handicapping system, and, in South Africa, these handicaps range from 52 to 62 kg, according to the horse's ability. The handicap weight includes that of the saddle, other riding gear and the jockey. The jockey must ensure that his/her weight plus that of the gear meets specification in order to be employed to ride. It is easier to 'make' a heavier weight than to lose weight immediately before a race as lead weights can be added to the saddle and/or heavier gear can be used, therefore it is optimal to maintain a low weight all year round. Excess weight in the form of body fat must be eliminated while maintaining a healthy bone and muscle weight, in order to avoid the use of deleterious weight-making techniques, which increase the jockey's risk of occupational injury (Wilson, Chester, Eubank, Crighton, Drust, Morton & Close, 2012a; Wilson *et al.*, 2013a). An accurate measurement of body fat, reflected as %BF is therefore essential.

The SAJA apprentices face similar pressures regarding weight to that of the professionals. The SAJA currently measures %BF using skinfolds, which presents a great potential for error (Ruiz, Colley & Hamilton, 1971; Kispert & Merrifield, 1987; Moreno, Joyanes, Mesana, González-Gross, Gil, Sarría, Gutierrez, Garaulet, Perez-Prieto, Bueno & Marcos, 2003) due to its ease of use and the availability of the necessary equipment and on-site biokineticist trained in the techniques of the International Society for the Advancement of Kinanthropometry (ISAK). Bioelectric impedance analysis is an alternative method with less risk of error (Ostojic, 2006) which has not yet been validated in apprentice jockeys. Equations have also been developed to estimate %BF from BMI (Deurenberg *et al.*, 1991c), making this another very practical and inexpensive alternative. As jockeys/apprentices utilize dehydration as a technique of weight control (Labadarios *et al.*, 1993; Leydon & Wall, 2002; Moore *et al.*, 2002a; Dolan *et al.*, 2011; Wilson *et al.*, 2014), the methods of using skinfolds, BIA and BMI to measure %BF needed to be validated as each may be impacted by dehydration (Saunders *et al.*, 1998; Demirkan, Kutlu, Koz, Özal, Güçlüöver & Favre, 2014).

This literature review discusses the weight-making techniques used by jockeys/apprentices and their possible effects on health and performance. It evaluates the suitability of using BMI, skinfolds and BIA to estimate %BF in the jockey apprentice population, taking into consideration their unique lifestyle and physique.

2.2 BACKGROUND TO HORSE RACING

Horse racing as a sport is reported to have originated in the 12th century when English knights brought back Arab horses upon returning from their crusades. These horses had been domesticated by nomadic tribesmen of Central Asia. The Arab stallions were bred with the English mares to produce the Thoroughbred, a breed with greater strength and endurance. Initially, only nobility would place bets on races between Thoroughbred horses, until eventually, during Queen Anne's reign (1702 to 1714), horse racing (also known as the Sport of Kings) became a full spectator sport (Huggins, 2014). The Jockey Club was created in 1750 to govern the sport (The Jockey Club, 2017).

Currently there are two major types of horse racing, flat racing and jump racing (also referred to as steeple chase or national hunt). Flat racing focuses on speed and stamina only, whereas jump racing includes hurdles (Warrington *et al.*, 2009). In South Africa, flat racing is the only type of event that takes place therefore, all South African apprentices train to be professional flat jockeys. As such, this literature review will focus on data concerning flat jockeys.

2.3 THE JOCKEY APPRENTICE

The SAJA is the only training academy in Southern Africa, therefore all apprentices in in this region must go through the SAJA. The SAJA trains approximately 30 apprentices at any given time, most of whom train at the base campus in Summerveld in KwaZulu Natal while the others train at the satellite campuses in Johannesburg, Port Elizabeth and Cape Town. To enter the academy, the applicant must be 16 to 20 years old, 1.5 to 1.6 m tall and weigh 38 to 47 kg. They undergo a bone age X-ray, where the left wrist is X-rayed on the axis of Greulich and Pyle in order to calculate bone age in contrast to chronological age. They also do a fitness test with a biokineticist to ensure that they meet fitness standards. Basic visual screening with a registered optometrist is done to rule out those who need glasses or have bad eyesight. Full blood count (FBC) and urea and electrolyte (U&E) blood tests are also done to test for medical conditions. Finally, they undergo a basic psychometric test to establish a personality profile, which will help the recruitment panel to gain insight into those who are more suited (Sr D Butt 2017, personal communication, 26 June).

As an apprentice, they must win 50 race rides in order to receive a professional jockey license. The apprenticeship typically lasts five years. The first year apprentices have riding lessons for approximately the first six to eight months at SAJA. These lessons involve strength and conditioning sessions under the instruction of a biokineticist. When the riding masters feel that the apprentice is ready, they will begin work riding at the training tracks, as well as supervised intensive training on a mechanical horse called the Equicizer™. When the apprentice is thought to have reached the required level of riding proficiency, which is usually after 3 years, they ride qualifying races, along with senior apprentices and professional jockeys (The South African Jockey Academy, 2007b).

2.3.1 A day in the life of a jockey apprentice

Work riding starts at 5 am and ends at 9 am at one of the two training centres, Summerveld or Ashburton. The apprentices arrive back at the academy at around 9h30 am to shower, dress and eat breakfast in the academy dining hall. For those who still attend school, lessons are from 10h30 am to 3 pm with a lunch break from 1 pm to 1h30 pm. Those that no longer attend school might attend race meetings during the week. After school, the apprentices attend to stable duties and/or receive riding lessons. They have 30 minutes free time before supper in the dining hall at 5h30 pm, followed by homework time at 6h30 pm. There is 30 minutes to one hour quiet time before lights out at 8h30 pm for first years or 9 pm for older apprentices (The South African Jockey Academy, 2007b).

During the weekends, the apprentices usually have one day off, but will otherwise continue work riding and attend race meetings if allowed. Race meetings are held daily throughout South Africa, including Cape Town, Kimberly, Port Elizabeth, Johannesburg as well as KwaZulu Natal, where the SAJA is based. Every week approximately three race meetings are hosted in KwaZulu Natal alone. The apprentices are flown between cities to race, with the most skilled apprentices travelling the most. An apprentice can attend between one and seven race meetings per week depending on their skill and/or experience (The South African Jockey Academy, 2007b).

During school holidays, work riding and life at the academy continues, although the apprentices do not have lessons then. They are also allowed two weeks a year to go home (The South African Jockey Academy, 2007b).

2.3.2 Merit handicapping

Merit handicapping has a crucial role to play in the lifestyle of jockeys and apprentices. Thoroughbred horses are handicapped for weight during each race in an attempt to "level the playing field" and therefore provide a more interesting competition. In South Africa, horses are handicapped on merit by the National Horse Racing Authority of Southern Africa (NHRASA). The handicap is earned by the measurement of the horse's previous performances using a system compatible with that of international standards (The National Horse Racing Authority of Southern Africa, 2016). The horses that have historically performed better are handicapped more severely and will therefore be assigned to carry heavier weights. In South Africa, the minimum handicap is a riding weight, for both professional jockeys and apprentices, of 52 kg and the maximum is 62 kg (Krog, 2015).

As the handicap weight includes the jockey, their riding gear and saddle, the jockey needs to weigh two to four kilograms less than that of the handicap in order to be employed for the ride. If their combined weight is less than that of the handicap, lead weights (referred to as dead weight) up to approximately 2 kg can be added to the saddle just prior to the race and heavier gear including the saddle and boots can be used to make up the outstanding weight. If the jockey is too heavy on the day prior to the race, they will have to rapidly lose weight, usually by means of saunas, exercising in sweat suits and/or fluid restriction. This process of rapidly losing weight is commonly referred to as "making weight".

Apprentices also have to "make" weight to meet handicap requirements. To compensate for their inexperience, they are given a "claiming allowance" of a maximum of 4 kg in SA when riding in their initial qualifying races. In effect therefore an apprentice jockey would ride at 4 kg lighter than a professional jockey for the same ride. This means that they will be allowed to ride at handicaps which they would not typically be able to make with their weight, gear and the saddle combined. For example, if an apprentice weighs 46 kg and the handicap of the horse is 52 kg, the apprentice can "claim" a total of 4 kg in addition to the weight of their riding gear and saddle (± 2kg). This encourages the trainers to use the inexperienced apprentices as the weight advantage could override their inexperience. The allowance is reduced to 2.5 kg when the apprentice accumulates 10 wins. After 40 wins, no claim can be made (Krog, 2015). The pressure to maintain a lower weight therefore increases as the apprentice gains experience.

Jockeys/apprentices are weighed immediately prior to and after each race. The two weights may not differ by more than 500g (National Horse Racing Authority of South Africa, 2016). They may ride several races on a given race day and their weight requirements for each horse often differs. It is easier to "make" a heavier weight by placing lead weights under their saddle or riding with heavier gear such as heavier saddles. Trainers prefer not to put up a lot of dead weight as it is believed that live weight balances a horse better, although an experimental study found no significant differences between the impact of an experienced rider and an equivalent weight of lead on the workload or locomotion of nine trained Dutch Warmblood horses (Sloet van Oldruitenborgh-Oosterbaan, Barneveld & Schamhardt, 1995). Making a lighter weight presents a greater challenge, which generally involves various deleterious weight-making techniques.

2.4 WEIGHT-MAKING TECHNIQUES

Horse racing differs from other weight category sports, such as boxing, light weight rowing and wrestling, as there is no "off-season" and racing may take place seven days a week (Warrington *et al.*, 2009). There is therefore insufficient time to recover in between race meetings and the jockeys are consistently required to make weight or achieve low weights.

Various deleterious methods, both acute and chronic, have been used to achieve the low weights required by handicapping (Wilson *et al.*, 2013a). These methods are typically culturally driven amongst the jockeys as they have been passed down by previous generations (Labadarios *et al.*, 1993; Moore, Timperio, Crawford, Burns &

Cameron-Smith, 2002b; Wilson *et al.*, 2014) and therefore have no significant scientific basis.

Acute weight-making techniques refer to techniques used to lose weight over a very short period of time, usually for the purpose of making weight for a specific handicap prior to a race. Common methods primarily involve dehydration (saunas, sweat suits, diuretics and laxatives) and food and fluid restriction (Labadarios *et al.*, 1993; Leydon & Wall, 2002; Moore *et al.*, 2002b; Cotugna, Snider & Windish, 2011; Dolan *et al.*, 2011; Wilson *et al.*, 2014). The amount lost will depend on the handicapping requirement, for example, if the jockey weighs 56 kg and needs to ride light at 52 kg, then he/she will lose more than 4 kg to meet the requirement, taking into account the weight of the saddle and gear.

To ensure sustained weight loss over an extended period of time and maintain a low body weight, the jockey/apprentice will employ chronic weight-making techniques. These include excessive exercise, food restriction, sporadic eating, the use of laxatives and appetite suppressants as well as forced vomiting (Wilson *et al.*, 2014). A combination of acute and chronic weight-making techniques are employed.

King & Mezey (1987) interviewed ten professional English jockeys (jump and flat) aged 21 to 35 years and reported that all (100%) used saunas and exercised strenuously, 90% restricted food intake, 80% used sweat suits, 70% used laxatives, 60% used diuretics, 20% used appetite suppressants and 10% reported vomiting as means to make weight. Binge eating was reported by 60%, although other studies did not report on binge eating. Only one study has investigated weight-making methods used by professional flat jockeys in South Africa. Labadarios *et al.* (1993) conducted a descriptive study involving 93 South African male flat jockeys and found that 75% smoked cigarettes regularly, 77% restricted food and fluid intake, 70% used saunas, 70% used diuretics, 48% exercised in sweat suits, 48% used appetite suppressants, 27% used hot baths and 27% used laxatives in order to control and/or make weight. The use of diuretics and laxatives to make weight for jockeys was banned internationally in 1999, however studies have reported the use of such substances by jockeys for weight-making purposes since (Leydon & Wall, 2002; Moore *et al.*, 2002b; Dolan *et al.*, 2011). Nine years after Labadarios *et al.* (1993), a descriptive study that included 116 Australian flat jockeys (91 male and 25 female), 11 of which were apprentices, found that 76% exercised, 75% skipped meals, 68% used saunas, 48% smoked cigarettes, 39% used diuretics, and 26% used laxatives in order to make or control their weight (Moore *et al.*, 2002a). The study did not differentiate between the strategies used by professional and apprentice jockeys. In New Zealand, Leydon & Wall (2002) investigated the weight-making practises of nine apprentice and nine professional jockeys (male and female) and reported that 67% restricted food intake, 56% used saunas, 56% restricted fluids, 28% took hot baths, 22% exercised, 17% used laxatives and 22% used other methods in order to make weight. Twenty-eight percent also reported using laxatives in an attempt to lose weight in the past.

When the reports of the apprentice jockeys were isolated, the results were similar: 67% used saunas, 67% restricted food intake, 56% restricted fluid intake, 33% exercised, none used diuretics or laxatives and 22% used other methods to make weight at the time of the study. Weight-making techniques were more prevalent in the male participants than the females. Dolan *et al.* (2011) interviewed 21 male professional Irish jockeys (flat and jump) with a mean age of 27.3 years and found that 86% used the sauna, 81% exercised to sweat and 71% restricted food intake as means to make weight. Cotugna *et al.* (2011) interviewed 20 American professional flat jockeys, aged 21 to 54 years, and reported that 60% used the sauna, 40% exercised, 35% restricted food intake, 10% vomited after eating and 5% restricted fluid. Fifteen percent reported not using any techniques to make weight. The same study found that the most common pattern of daily intake on race days was eating very little (coffee, energy drinks, a piece of fruit, a granola bar) until after racing and then consuming a large meal for dinner. When not racing, only 50% consumed three regular meals per day and 10% reported eating similarly to race days with a larger quantity of food at each eating time. An experimental study, which tested the effects of acute dehydration on physical and cognitive function, involving eight professional jockeys, six of which were jump and two flat, reported that all (100 %) dieted and exercised in sweat suits, 75% used the sauna, 62% restricted food and fluids, 37% used hot or salt baths, 25% fasted and 50% used other methods to make or lose weight (Wilson, Hawken, Poole, Sparks, Bennett, Drust, Morton & Close, 2013b). This study included a majority of jump jockeys who may face less pressure to lose weight due to higher minimum weight requirements. Cullen (2014) conducted a descriptive study which investigated the weight-making habits of 33 retired male flat jockeys from

Ireland during their career and found that all (100%) reported restricting energy intake, 97% exercised excessively, 91% restricted fluid, 79% used hot baths, 73% used saunas, 61% used diuretics, 61% used laxatives, and 6% vomited as a means to make weight for races. A recent study involving 20 male professional jockeys based in Hong Kong, found from a questionnaire that 26% used saunas, 20% restricted fluid intake, 20% wore plastic clothing, 16% exercised excessively, 15% exercised to sweat and 4% vomited in order to make or control weight (O'Reilly, Cheng & Poon, 2017).

Very little literature has been published regarding the practices of jockey apprentices in South Africa. Krog (2015) studied 21 male flat jockey apprentices training at the SAJA and found that 67% restricted food intake, 48% exercised to sweat and 43% used saunas suggesting that some of the traditionally used methods of the professionals had been passed down to the apprentices. Additionally, 81% reported avoiding situations with food, 71% followed their own diet, 67% would skip lunch and 52% would keep busy to avoid eating.

As the most common techniques of both acute and chronic weight loss in the jockeys and apprentices involved dehydration and food restriction, it is important to explore the prevalence and implications of these techniques.

2.4.1 Dehydration

Acute weight loss by dehydration is a frequently used method. Warrington *et al.* (2009) conducted a descriptive study which assessed the hydration status of seventeen flat jockeys and ten jump jockeys using USG (TS400 refractometer). They reported mild dehydration (mean USG 1.022 g/ml) for both flat and jump jockeys on a non-race day using a cut-off value of 1.020 g/ml (Sawka, Burke, Eichner, Maughan, Monatin & Stachenfeld, 2007) indicating that the professional jockeys were chronically dehydrated. Dehydration increased significantly on an official race day (mean USG 1.028 g/ml) with severe dehydration (USG >1.030 g/ml) reported in 54% of the 11 flat jockeys (Case, Armstrong, Hillman, Montain, Reiff, Rich, Roberts & Stone, 2000).

A cross-sectional observational study including 47 male American flat jockeys reported mild dehydration (mean USG of 1.021 g/ml) on typical race days but found that those with a high USG (>1.028 g/ml) had body weights significantly heavier than those with a USG <1.028 g/ml (54.2 kg vs. 52.1 kg; $p=0.001$) (Benardot, Thompson, Hutchinson, Roman, Hedrick & Reynaud, 2008). Higher USG readings were significantly associated with heavier body weights in male jockeys, as heavier jockeys are more inclined to resort to dehydration strategies to 'make' a desired weight. This reinforces the need for accurate measurements of %BF to assist in healthy weight control and reduce the need for these techniques as the %BF will determine the lowest body weight the jockey can attain without compromising FFM.

In addition to presenting a number of detrimental consequences to the jockey/apprentices' health and performance (Dolan, Cullen, McGoldrick & Warrington, 2013; Wilson *et al.*, 2013b; García-Trabanino, Jarquín, Wesseling, Johnson, González-Quiroz, Weiss, Glaser, Vindell, Stockfelt & Roncal, 2015), a state of dehydration may impact the accuracy of weight and body fat measurement (Thompson, Thompson, Prestridge, Bailey, Bean, Brown & McDaniel, 1991; Saunders *et al.*, 1998; Pialoux, Mischler, Mounier, Gachon, Ritz, Coudert & Fellmann, 2004). The impact of dehydration in jockey/apprentices on the reliability of various methods of measuring body composition must therefore be assessed.

2.4.2 Food restriction

Restricting food intake is another popular method of controlling weight (King & Mezey, 1987; Labadarios *et al.*, 1993; Moore *et al.*, 2002a; Leydon & Wall, 2002; Dolan *et al.*, 2011; Cotugna *et al.*, 2011; Cullen, 2014; Krog, 2015; O'Reilly *et al.*, 2017) which may present detrimental consequences to the physical and psychological health of the jockeys.

2.4.2.1 Relative energy deficiency in sport

Restricting food intake, restricts energy consumption, which can result in an insufficient energy availability (EA). Krog (2015) reported a low mean calculated EA of 113.28 kJ/kg FFM in the SAJA apprentices over two training days and one rest day, which is less than the recommended 125 kJ/kg FFM for male athletes (Sundgot-Borgen, Meyer, Lohman, Ackland, Maughan, Stewart & Müller, 2013). A more comprehensive term for the syndrome previously known as 'Female Athlete Triad', was introduced by the International Olympic Committee (IOC): 'Relative Energy Deficiency in Sport' (RED-S), due to the complexity of the syndrome and the fact that male athletes are also affected (Mountjoy *et al.*, 2014). It refers to impaired physiological function including, but not limited to, bone health, protein synthesis, immunity, metabolic rate, menstrual function and cardiovascular health caused by relative energy deficiency. Relative energy deficiency is a deficiency of energy relative to the balance between dietary energy intake and energy expenditure required for health and activities of daily living, growth and sporting activities, which connotes that low energy availability can occur even in the scenario where energy intake and total energy expenditure are balanced (Mountjoy, Sundgot-Borgen, Burke, Carter, Constantini, Lebrun, Meyer, Sherman, Steffen & Budgett, 2015).

2.4.2.2 Bone health

A healthy EA is particularly important for young athletes like apprentice jockeys as peak BMD for males typically occurs before the age of 20 years (Cvijetić Avdagić, Colić Barić, Keser, Cecić, Šatalić, Bobić & Gomzi, 2009; Berger, Goltzman, Langsetmo, Joseph, Jackson, Kreiger, Tenenhouse, Davison, Josse & Prior, 2010).

Leydon & Wall (2002) reported that 44% of the flat jockeys were osteopenic. This was attributed to insufficient calcium intake as a result of food restriction as 58% of the males consumed less than 60% of the recommended daily intake (RDI) of calcium according to their seven-day weighed food records. Warrington *et al.* (2009) found that 53% of flat jockeys were osteopenic and 12% had osteoporosis, which was suggested to be a result of insufficient EA.

This is of concern due to the high risk of injury from falling in horse racing. Waldron-Lynch, Murray, Brady, McKenna, McGoldrick, Warrington, O'Loughlin & Barragry (2010) reported a mean frequency of 3.2 fractures per rider (at the current point in their career) in a sample of 27 professional male jockeys (17 flat and 10 jump) with a mean age of 25.5 years. Both professional and apprentices flat racing jockeys were reported to have a 44% rate of injury per fall, which is significantly higher than that of jump jockeys, according to a meta-analysis reporting falls, injuries and concussions in jockeys between 2006 and 2007 (Rueda, Halley & Gilchrist, 2010).

Psychological consequences, such as abnormal eating behaviours can also either precede or be the result of RED-S (Mountjoy *et al.*, 2015).

2.4.2.3 Abnormal eating behaviours

Due to chronic food restriction, abnormal eating behaviours associated with an increased risk of developing eating disorders such as AN and BN are of concern in the horse racing industry. The Eating Attitudes Test (EAT-26) questionnaire has been utilised in several studies to assess the risk of developing eating disorders in jockeys (Garner & Garfinkel, 1979; King & Mezey, 1987; Leydon & Wall, 2002; Caulfield & Karageorghis, 2008; Wilson, Pritchard, Papageorgiou, Phillips, Kumar, Langan-Evans, Routledge, Owens, Morton & Close, 2015)

King & Mezey (1987) reported a significantly higher mean EAT-26 score of 14.9 for the male English jockeys studied when compared to age-matched controls, which implied a high risk of AN and BN. However, the EAT-26 cut-off score to indicate risk of eating disorders is 20. Although the number with an EAT-26 score greater than 20 was not reported, no cases of eating disorders were diagnosed according to a further full psychiatric and eating interview. Leydon & Wall (2002) reported a lower mean score of 13.5 in the male and female professional New Zealand jockeys, however 20% had an EAT score of 20 or more. Using the EAT-26 questionnaire, Caulfield & Karageorghis (2008) investigated the eating attitudes of 41 professional male jockeys based in the United Kingdom. Both jump and flat jockeys were included but the ratio was not specified. Descriptive data was collected at three different weights. At their lightest or minimum weight, which necessitated acute weight loss by methods commonly used to make weight for a "light" ride, the mean EAT-26 score was 8.56. At their optimal weight, which was described as when the jockey felt he was healthy and not wasting, the mean EAT-26 score was 6.78. Finally, at a relaxed weight, which was during a time that the jockey was not required to lose or maintain weight as no "light" rides were impending, the mean score was 6.17. Statistically significant differences were found between the mean scores at the different weights. Twenty percent (8/41) scored more than twenty, six of which only scored 20 or more at their lightest weight, and were thus categorised as at risk of eating disorders. These participants were advised to seek psychological support as recommended by Garner & Garfinkel (1979). An intervention study by Wilson *et al.* (2015) measured the EAT-26 scores of nine professional flat (eight male and one female) and five professional male jump jockeys in England before and after an individually prescribed six-week diet and exercise intervention which aimed to reduce body fat while maintaining FFM. Before the intervention, the mean EAT-26 score was 14.8. This was non-significantly reduced to 11.0 after the intervention. Twenty-nine percent scored 20 or above, indicating risk of eating disorders. By comparing these studies, it can be seen that the results are all in agreement with one another, with the exception with that of Caulfield & Karageorghis (2008).

Although no eating disorders were diagnosed in these studies, despite the high prevalence of disordered eating, eating disorders in males, specifically male athletes who are encouraged to maintain low body weights, may be underreported. This may be due to the gender bias in the Diagnostic and Statistical Manual of Mental Disorders, fourth edition (DSM-IV) criteria for eating disorders, which indicates that amenorrhoea is a specification for AN (Strother, Lemberg, Stanford & Turberville, 2012; Mitchison, Hay, Griffiths, Murray, Bentley, Gratwick-Sarll, Harrison & Mond, 2017). Additionally, underreporting may result from shame associated with the stereotype that eating disorders afflicts only females and male homosexuals (Murray, 2017). Underreporting of symptoms of eating disorders is not uncommon in athletes due to poor credibility of efforts to ensure confidentiality (Joy, Kussman & Nattiv, 2016).

It is therefore important to assess the impact of food restriction on the apprentices' risk of eating disorders as well as to be able to measure %BF accurately so that weight can be controlled appropriately to minimize these consequences

2.5. PERCENT BODY FAT OF JOCKEYS AND APPRENTICES

There may be scope for the jockeys to reduce their %BF in order to make weight for races using a healthier, more sustainable approach instead of resorting to weight-making techniques which may pose risks to their health. The mean %BF of male flat jockeys measured by dual x-ray absorptiometry (DXA) has been reported to be significantly lower than that of male professional jump jockeys according to Warrington *et al.* (2009) (8.99 % versus 10.42 %) and Dolan, Crabtree, McGoldrick, Ashley, McCaffrey & Warrington (2012a) (8.26 % versus 13.84 %, measured by DXA). Wilson *et al.* (2013a) however reported no significant differences (13.0 % versus 11.5 %, measured by DXA). Nevertheless, this literature review will focus on the %BF of male flat jockeys.

Little data exists on the %BF of jockey apprentices. The descriptive study by Leydon & Wall (2002) reported a non-statistically significant higher mean %BF in male jockey apprentices (12.3%) compared to male professionals (10.7%), according to DXA. It is however important to note that of the 11 apprentices, only two were male and of the nine professionals, only four were male. Therefore the sample size can be considered too small to be an accurate representation of average male professional and apprentice jockey %BF. The study suggested that the %BF of apprentices is comparable to that of professionals, considering the lack of data on apprentices.

Krog (2015) estimated the %BF of 21 male apprentices at the SAJA using BIA (BODYSTAT®1500 MDD, Bodystat Ltd) and reported a mean %BF of 12.2 %.

The results of studies published on the %BF of jockeys are summarised in Table 2.1. The mean %BF represented appear to be similar, with the exception of that of O'Reilly *et al.* (2017). The relative difference may be a consequence of using the skinfold equation by Durnin & Womersley (1974) equation instead of DXA. Labadarios *et al.* (1993) and Dolan *et al.* (2013) also used skinfolds, however, Labadarios *et al.* (1993) did not disclose which equation was used and Dolan *et al.* (2013) used the Withers, Craig, Bourdon & Norton (1987) equation.

Table 2.1: Studies reporting percent body fat of jockeys and apprentices [a]

Study	Sample size	Age (years)	Method used	%BF
		Apprentices		
Leydon & Wall (2002)	2	20.5 ± 3.8	DXA	12.3 [b]
Krog (2015)	21	18.0 ± 1.4	BIA (BODYSTAT®1500 MDD)	12.2 ± 2.5
		Professional jockeys		
Labadarios *et al.* (1993)	93	28.8 [b]	Skinfold [c]	11.0 [b]
Leydon & Wall (2002)	4	23.5 ± 4.3	DXA	10.7 [b]
Warrington *et al.* (2009)	17	26.7+7.6	DXA and skinfolds [d]	9.0 ± 2.5 (DXA) 7.9 ± 1.7 (skinfolds)
Dolan, McGoldrick, McCaffrey, O'Connor, May, Fitzpatrick & Warrington (2009)	16	24.1 ± 8.6	DXA and skinfolds [d]	11.0 ± 5.4 (DXA) 7.8 ± 1.3 (skinfolds)
Dolan *et al.* (2012a)	14	25.9 ± 3.3	DXA	8.3 ± 2.9

Study	Sample size	Age (years)	Method used	%BF
Dolan, McGoldrick, Davenport, Kelleher, Byrne, Tormey, Smith & Warrington (2012b)	20 [e]	25.9 ± 3.3	DXA	11.4 ± 5.6
Wilson, Sparks, Drust, Morton & Close (2012b)	9 (protocols 1-3) [f] 6 (protocol 4)	24 ± 3.1 (protocols 1-3) 26 ± 3.7 (protocol 4)	DXA	11.3 ± 2.2 (protocols 1-3) 11.7 ± 2.8 (protocol 4)
Wilson *et al.* (2013a)	19	27 ± 5	DXA	13.0 ± 3
Dolan *et al.* (2013)	9	24 ± 7	Skinfolds [d]	9.0 ± 1.4
O'Reilly *et al.* (2017)	20	29.3 ± 7.8	Skinfolds [g]	5.8 ± 2.6

%BF: Percent body fat
[a] All male flat jockeys, unless otherwise specified.
[b] SD not given.
[c] Unspecified skinfold equation involving four unspecified skinfold sites was used.
[d] Withers *et al.* (1987) equation used to predict body density. Siri (1956) equation used to estimate %BF from body density.
[e] Both flat and jump jockeys included. Ratio of jump and flat not specified.
[f] Professional jump jockeys included only. This study involved four protocols used to assess the energy expenditure in elite jockeys during a simulated race riding and a working day.
[g] Durnin & Womersley (1974) equation used to predict %BF.

2.6 IMPORTANCE OF ACCURATE MEASUREMENT OF PERCENT BODY FAT

The accurate assessment of %BF is important in the jockey population for appropriate weight loss and to optimize performance (Wilson *et al.*, 2012a).

Although it is essential for a jockey to have a lower body weight for racing, it is important to maintain a healthy body composition. The body is composed of fat mass (FM) and FFM. Fat-free mass consists of water, muscle, connective tissue, organ and bone mass (Ackland *et al.*, 2012). Jockeys should aim to maintain an optimal level of FFM during weight loss, making loss of fat mass favourable. Therefore accuracy with measurement is important to ensure that the loss is not FFM.

2.6.1 Importance of fat-free mass

Higher levels of FFM have been associated with better postural balance (Alonso *et al.*, 2012) which could assist the jockey to remain stable and maintain control while riding and reduce the risk of falls. This is important as flat horse racing is associated with a high risk of falls, injuries and subsequent fractures (Rueda *et al.*, 2010; Waldron-Lynch *et al.*, 2010). Maintaining a healthy BMD is also important to prevent fractures as a result of a fall. Dolan *et al.* (2012a) measured the BMD of 58 male participants (14 flat jockeys, 16 jump jockeys, 14 elite amateur boxers and 14 age, gender and BMI-matched controls) using DXA and concluded that FFM is the primary significant positive predictor of BMD.

Fat-free mass is positively correlated with resting metabolic rate (RMR) (Cunningham, 1991), therefore maintaining FFM is also essential to sustained weight loss, an important consideration for the jockey. Cunningham (1991) proposed the only general equation based on FFM to estimate RMR. This has been validated in athletes in comparison to 11 RMR prediction equations including that of Harris & Benedict (1918), Owen, Holup, D'Alessio, Craig, Polansky, Smalley, Kavle, Bushman, Owen & Mozzoli (1987), Mifflin, St Jeor, Hill, Scott, Daugherty & Koh (1990), Thompson & Manore (1996) and Lohman, Harris, Teixeira & Weiss (2000). Kim, Kim, Kim, Park & Kim (2015) recommended the use of the Cunningham (1991) for athletes as it has the closest correlation to indirect calorimetry. The accurate measurement of FFM therefore will assist the accurate estimation of RMR. In turn this is important in order to appropriately prescribe daily energy intake in order to achieve or maintain a specific body mass.

Therefore, maintenance of healthy levels of FFM in jockeys/apprentices may reduce the risk of falls and fractures and assist in weight control.

2.6.2 Importance of fat mass

Jockey/apprentice's need to reduce their %BF to the minimum acceptable range which does not present a risk to their health. Essential fat is found in the bone marrow, lungs, heart, kidneys, liver, muscles, intestine and central nervous system. There is no known amount of essential fat for adolescent males. The amount of essential fat required by healthy active adult men is four to six %BF or ~2.5 kg according to Friedl, Moore, Martinez-Lopez, Vogel, Askew, Marchitelli, Hoyt & Gordon (1994). This was based on the results of an experimental study involving 55 healthy young men (mean age 24.6 years) who underwent an eight-week army combat training course which involved a very low energy intake and strenuous exercise, resulting in a 15.7 % weight loss. Once the men reached a %BF of four to six percent, which was measured using DXA, subsequent weight loss was due to loss of FFM. Essential fat therefore is protected by FFM which is expended for energy when storage fat is depleted (Norgan, 1997a).

However, an amount of storage fat is important to prevent the catabolism of FFM for energy. Gallagher, Heymsfield, Heo, Jebb, Murgatroyd & Sakamoto (2000) proposed a healthy %BF range of eight to 20 percent for all males aged 20 to 39 years according to a four component (4-C) model. This range corresponded to a BMI of 18.5 to 25 kg/m^2 in 613 young African American and Caucasian males aged 20 to 39 years. Borrud, Flegal, Freedman, Li & Ogden (2011) established %BF-for-age percentiles according to DXA for children aged eight to 20 years which correspond to that of the BMI-for-age percentiles. There is no established minimum %BF for jockeys or apprentices.

Accurate measurements of %BF are therefore necessary to ensure that the minimal optimal fat mass is maintained for performance and health while protecting the FFM.

2.7 METHODS OF MEASURING PERCENT BODY FAT

Changes in body weight alone fail to reflect favourable or unfavourable changes in %BF as a result of dietary and training interventions. The selection of an appropriate method of body composition analysis to measure %BF for a specific population depends on the availability of funds and the importance of accuracy relative to cost and practicality (Heyward, 2001).

Accurate measurement of body composition requires techniques that describe the constituent components of the body. These components can be described as chemical, where components are separated according to their molecular properties, for example lipids and proteins, or they can be described as anatomical, which separates components according to the type of tissue, for example adipose tissue.

Models of body composition analysis include four compartment (4-C) models, which either divide components on a chemical level into fat mass, protein, water and other or anatomically into adipose tissue, skeletal tissue, muscle and connective tissue and other; three-component models (3-C), dividing the body into fat mass, bone mineral and other; and two-component (2-C) which simply divides the body into fat mass and FFM. Four-component models are the most reliable due to the variability in the density of the components of FFM (Ackland *et al.*, 2012). The techniques of analysis vary in accuracy and practicality. Techniques of directly measuring fat mass, such as cadaver dissection, multi-component models and medical imaging including Magnetic Resonance Imaging (MRI) and Computed Tomography (CT), are the most accurate but present a number of limitations including cost, time, feasibility and unnecessary radiation exposure. These methods have been used validating other more feasible laboratory methods (Ackland *et al.*, 2012).

2.7.1 Laboratory methods

Laboratory or indirect methods include isotope dilution (hydrometry) such as DD, DXA, densitometry including underwater weighing (UWW) and air displacement plethysmography (ADP), ultrasound and three-dimensional (3D) photonic scanning (Ackland *et al.*, 2012). These methods have been validated against the direct reference methods (cadaver dissection) and are therefore highly accurate yet expensive and impractical for regular use. They are therefore referred to as reference or "gold standard" methods (Ackland *et al.*, 2012). To date, DXA is the only reference method that has been used to measure the body composition of jockeys (Warrington *et al.*, 2009; Waldron-Lynch *et al.*, 2010; Dolan *et al.*, 2011; Dolan *et al.*, 2012a; Dolan *et al.*, 2013; Wilson *et al.*, 2013a; Wilson *et al.*, 2014).

2.7.1.1 Duel X-ray Absorptiometry

Dual X-ray absorptiometry is a laboratory method used to predict %BF by estimating an R_{ST} value, which is the ratio of soft tissue attenuation at two photon energies: 40 keV and 70 keV (Wang, Heymsfield, Chen, Zhu & Pierson, 2010). It was developed from dual photon absorptiometry (DPA) which uses a 153-Gd radionuclide source, however DXA provides total body scans with enhanced precision and less radiation exposure in significantly less time (Mazess, Barden & Hanson, 1990). It involves less exposure to radiation than MRI and CT scans, however caution is still recommended against using on multiple occasions (Ackland *et al.*, 2012). Total body bone mineral content (BMC) correlates highly with actual skeletal mass and with total body calcium by neutron activation analysis in vivo (Heymsfield, Wang, Lichtman, Kamen, Kehayias & Pierson, 1989; Mazess, Barden, Bisek & Hanson, 1990) because calcium is a constant fraction (about 38%) of the mineral component, or calcium hydroxyapatite. Lohman *et al.* (2000) concluded that the estimates of %BF from DXA are within one to three percent from reference methods but that a five percent change in the water content of FFM affects estimates of %BF by one to 2.5 percent, therefore euhydration is essential for accurate measurement. Euhydration needs to be ensured before DXA is used to measure %BF in jockeys due to their tendency to be chronically dehydrated.

2.7.1.2 Deuterium Dilution

Deuterium dilution, the laboratory technique used as the reference method for the measurement of %BF in this study, has not previously been used in the jockey population. The technique uses deuterium, a stable isotope of hydrogen, ingested as deuterium oxide, to measure total body water (TBW) and so estimate FM and FFM (International Atomic Energy Agency, 2010). The technique has been validated against reference standards using 3-C and 4-C models in healthy subjects and is accepted as a reference method (Fuller, Jebb, Laskey, Coward & Elia, 1992). It is a costly method as it relies on the purchase of deuterium oxide as well as expensive laboratory equipment and technical expertise, however the technique was used in this study as the local expertise, deuterium oxide and appropriate laboratory facilities were available. The technique assumes a constant hydration of 72 to 73%, therefore variations in hydration status as for DXA can confound the results (Wang, Deurenberg, Wang, Pietrobelli, Baumgartner & Heymsfield, 1999; Ackland *et al.*, 2012).

2.7.2 Field methods

Field methods are most commonly used to measure and monitor body composition for sport and health purposes, due to their ease of use and low cost (Ackland *et al.*, 2012).

These include the measurement of skinfolds and BIA. Body mass index can also be considered a field method to estimate %BF. The accuracy of these methods varies according to sample population as well as conformity to standardised techniques (Wells & Fewtrell, 2006).

2.7.2.1 Body Mass Index

Body mass index is a commonly used equation to classify individuals according to adiposity, for example, obese, overweight, normal or underweight. Equations have been developed to estimate %BF from BMI. Deurenberg *et al.* (1991c) derived an equation from the results of a descriptive study involving 521 males and 708 females in the Netherlands, aged seven to 83 years, using UWW as the reference. The equation produced for adults older than 15 years was:

%BF = 1.20 x BMI + 0.23 x age (years) - 10.8 x sex (males = 1, females = 0) - 54

Gallagher *et al.* (2000) later derived an age and gender-specific equation from the results of a descriptive study conducted in the United States of America (USA), the United Kingdom (UK) and Japan from a sample of 1013 non-athletic adult women and 613 adult men of various ethnicities (African America, Asian and Caucasian) using a 4-C model involving DXA, deuterium and tritium dilution and UWW as the references. However, the mean age of the males included was 51.4 (black), 46.7 (Asian) and 48.1 (white) years which did not match that of the jockey apprentices and this equation was therefore excluded.

The strength of the relationship between BMI and %BF has been argued. A descriptive study by Meeuwsen, Horgan & Elia (2010b), involving 11 582 male and 12 044 female Scottish non-athletic subjects ranging from 18 to beyond 70 years of age, demonstrated a nonlinear association between BMI and %BF measured by single frequency two compartment BIA (BODYSTAT®1500). The relationship between BMI and %BF was curvilinear or quadratic, meaning that the association weakened as the BMI decreased. The correlation was weak for males in the BMI range 20 to 25 kg/m^2, into which the jockey/apprentices fall (Krog, 2015), and only showed a strong correlation for males with a BMI greater than 25 kg/m^2. A cross-sectional study involving 287 males (192 athletes from various sports and 95 controls) and 191 females (87 athletes and 104 controls) assessed the relationship between BMI and %BF determined by skinfold measurements. A weak relationship between BMI and %BF was found for both athletes and controls (Nevill, Stewart, Olds & Holder, 2006).

It is important to consider the effect of height on the accuracy of BMI and other regression equations for %BF analysis, since height is used as a variable in some (Lukaski, Bolonchuk, Hall & Siders, 1986; Segal, Van Loan, Fitzgerald, Hodgdon & Van Itallie, 1988; Boulier, Fricker, Thomasset & Apfelbaum, 1990; Heitmann, 1990; Deurenberg, Van der Kooy, Leenen, Weststrate & Seidell, 1991b; Houtkooper, Going, Lohman, Roche & Van Loan, 1992; Lohman, 1992; Organ, Bradham, Gore & Lozier, 1994; De Lorenzo, Iacopino, Andreoli & Petrone De Luca, 1998; Kyle, Genton, Karsegard, Slosman & Pichard, 2001; Sun *et al.*, 2003). By necessity of their profession, flat jockeys are required to be of short stature (SS). Mean heights of between 1.59 to 1.68 m have been reported amongst professional jockeys (Labadarios *et al.*, 1993; Leydon & Wall, 2002; Moore *et al.*, 2002b; Dolan *et al.*, 2009; Warrington *et al.*, 2009; Cotugna *et al.*, 2011; Dolan *et al.*, 2012a; Dolan *et al.*, 2012b; Wilson *et al.*, 2012b; Dolan *et al.*, 2013; Wilson *et al.*, 2013a; Jackson, Sanchez-Santos, MacKinnon, Turner, Kuznik, Ellis, Box, Hill, Javaid & Cooper, 2017; O'Reilly *et al.*, 2017). This is similar to the height of apprentice jockeys which ranged from 1.58 to 1.67 m (Leydon & Wall, 2002; Moore *et al.*, 2002b; Cullen, Dolan, McGoldrick, Brien, Carson & Warrington, 2015; Krog, 2015; Silk, Greene, Baker & Jander, 2015). The mean height of South African young adult males aged 15 to 24 years (1.69 m, range 1.678 -1.693) according to the South African National Health and Nutrition

Examination Survey (SANHANES) of 2012 (Shisana, Labadarios, Rehle, Simbayi, Zuma, Dhansay, Reddy, Parker, Hoosain & Naidoo, 2014).

To date, no studies have investigated the impact of SS on the validity of methods to measure %BF. A descriptive study by López-Alvarenga, Montesinos-Cabrera, Velázquez-Alva & González-Barranco (2003) in Mexico compared the %BF according to BIA of 58 SS individuals with 58 BMI-matched controls of normal stature. Short stature was defined as women with a height less than or equal to 1.5 metres and men less than or equal to 1.6 metres. The mean %BF of the SS individuals was significantly higher ($p = 0.04$) than that of the controls (López-Alvarenga *et al.*, 2003). This reinforces the need to validate methods of measuring %BF that involve height as a variable, such as BMI and BIA, in the jockey apprentice population.

To date, no studies have assessed the relationship between BMI and %BF in jockeys or apprentices. It is important to determine the accuracy of BMI to predict %BF in jockey apprentices as this could provide a very practical and inexpensive alternative to other field methods.

2.7.2.2 Skinfold measurements

Skinfold measurements are a practical, quick and cost-effective method of measuring body composition (Ackland *et al.*, 2012). They are commonly used to assess body composition in sport and was the current method to measure %BF at the SAJA. This method involves the measurement of skinfold thickness at specific body sites.

Raw skinfold thickness measurements, and the sum thereof, may be used to assess and monitor body fatness, which is an indicator of nutritional status in both athletes and non-athletes (Wells & Fewtrell, 2006). This technique simply allows one to assess whether there has been a loss or gain in fat mass, but cannot be validated for specific populations. In order to derive %BF values, population-specific regression equations, which have been validated against reference methods, must be applied.

The use of regression equations involve the substitution of skinfold measurements, or sum thereof, into an equation to estimate either %BF or body density (BD), which can be translated into %BF using the following equations:

For white adults: Siri (1961): $\%BF = (4.95/BD - 4.50) \times 100$ or

Brozek, Grande, Anderson & Keys (1963): %BF = (4.57/BD − 4.142) × 100

These equations assume that FM has a density of 0.9007 g/cm^3 and FFM has a density of 1.1 g/cm^3. They also assume constant proportions and densities of the components of FFM: water (73.8% and 0.9937 g/cm^3), protein (19.4% and 1.34 g/cm^3) and mineral (6.8% and 3.038 g/cm^3) for all individuals (Brozek *et al.*, 1963). However, these may vary according to race and age.

For black adults, the following equations have been recommended:

Schutte, Townsend, Hugg, Shoup, Malina & Blomqvist (1984): %BF = [(4.374/BD) - 3.928] x 100 or

Wagner, Heyward, Kocina, Stolarczyk & Wilson (1997): %BF = [(4.858/BD) - 4.394] x 100

However, in studies where BD equations have been proposed without considering race (Durnin & Rahaman, 1967; Forsyth & Sinning, 1973; Durnin & Womersley, 1974; Withers *et al.*, 1987; Deurenberg, Pieters & Hautvast, 1990), both the Siri (1961) and Brozek *et al.* (1963) were recommended to translate BD onto %BF. Slaughter, Lohman, Boileau, Horswill, Stillman, Van Loan & Bemben (1988) also recommended Siri (1961) for both blacks and whites.

Skinfold measurements are popular due to the low cost and ease of use (Ackland *et al.*, 2012). However, there is an assumption that there is a fixed relationship between subcutaneous adipose tissue (SAT) at specific skin sites and total body fat. This relationship has been found to be influenced by age and sex (Durnin & Womersley, 1974), race (Vickery, Cureton & Collins, 1988; Wagner & Heyward, 2000) and adiposity (Beddoe & Samat, 1998). The impact of dehydration should also be considered. Accuracy is also affected by the measurement technique of the observer and interobserver variability, the number of sites measured (Hume & Marfell-Jones, 2008) as well as the equations used (Sinning, Dolny, Little, Cunningham, Racaniello, Siconolfi & Sholes, 1985).

2.7.2.2.1 <u>The impact of age and sex</u>

Durnin & Womersley (1974) demonstrated that different regression equations for skinfolds need to be used in order to achieve acceptable variability for males and females, as well as different age groups, as the regression lines produced for BD relative to skinfold thickness were significantly different for the different age groups and sexes. This means that a given skinfold corresponds to a significantly different BD between males and females and different age groups. It was also implied that a greater proportion of BF content is situated internally as opposed to subcutaneously in females as a given skinfold corresponded to a significantly lower BD. This was supported by Himes, Roche & Siervogel (1979), who showed that there was a significantly greater variability in skinfold compressibility in males compared to females in a sample of 69 adolescents and young adults.

Slaughter *et al.* (1988) and Deurenberg *et al.* (1990) also showed how BD measured by skinfolds varied according to maturation status using the classification described by Marshall & Tanner (1968) which is based on the extent of hair covering the pubic region in six stages (p1 to p6). Separate equations were proposed for pre-pubertal (p1 to p2), pubertal (p3 to p4), post-pubertal (p5 to p6) and adult (p6 onwards) subjects (see table 2.2). However, in the study by Slaughter *et al.* (1988), this only applied when the combination of the triceps and subscapular skinfolds was used to calculate BD. When the combination of the triceps and calf skinfolds was used instead, there was no significant effect of maturation. This combination actually proved to account for greater variance and a lower standard error of measurement (SEE). Deurenberg *et al.* (1990) did not include subjects classified as adults according to Marshall & Tanner (1968). The mean age of the post-pubertal males in this study was 17.5 and the maximum age was 20 years.

2.7.2.2.2 <u>The impact of race</u>

Vickery *et al.* (1988) compared %BF measured using the seven skinfold equation by Jackson & Pollock (1978) with UWW, in a sample of 140 black and 179 white male subjects aged 18 to 32 years. The skinfold equation calculated a significantly higher BD for the black subjects compared to the white subjects, yet the skinfold measurements were not significantly different. These results suggest that race has a significant impact on the prediction of BD from skinfolds in young males. The study proposed the use of separate regression equations to calculate BD from the same seven skinfolds (triceps, subscapular, chest, mid-axilla, supra-iliac, abdomen and thigh) in black and white males. The individual skinfolds significantly influenced by race were the chest, abdomen and thigh. Slaughter *et al.* (1988) reported that the impact of race was only significant when the combination of the triceps and subscapular skinfolds was used to calculate BD. When the combination of the triceps and calf skinfolds was used instead, there was no significant effect of race. In contrast, Evans, Rowe, Misic, Prior & Arngrimsson (2005) also proposed a new equation that included race as a variable due to the significant impact of race on %BF determined by skinfolds. The proposed equations included either seven skinfolds (subscapular, triceps, chest, mid-axilla, supra-iliac, abdominal and thigh) or three skinfolds (abdominal, thigh and triceps).

Many studies have derived skinfold equations from white subjects only (Sloan, 1967; Katch & McArdle, 1973; Lohman, 1981; Lean, Han & Deurenberg, 1996; Rodriguez, Moreno, Blay, Blay, Fleta, Sarria & Bueno, 2005; Peterson, Czerwinski & Siervogel, 2003), whereas other studies that have produced valid skinfold equations did not consider race as a variable (Durnin & Rahaman, 1967; Forsyth & Sinning, 1973; Durnin & Womersley, 1974; Jackson & Pollock, 1978; Withers *et al.*, 1987; Deurenberg *et al.*, 1990; Van der Ploeg, Gunn, Withers & Modra, 2003).

2.7.2.2.3 <u>The impact of adiposity</u>

Beddoe & Samat (1998) assessed the variability of %BF measured by four skinfolds using the Durnin & Womersley (1974) equation in a sample of 33 males and 35 female using hydrometry (tritium dilution) and neutron activation as a reference. Significantly greater variation between the two methods was found in individuals with higher %BF according to the reference method. This suggests that there is a more constant relationship between subcutaneous fat and total body fat in leaner individuals, making the skinfold method more accurate for measuring %BF in leaner individuals. This reflects in favour of this method in the jockey apprentice population as they do not have high levels of %BF.

2.7.2.2.4 <u>The impact of dehydration</u>

The impact of hydration status on the prediction of %BF from skinfolds was evaluated using three skinfold sites (triceps, subscapular and abdomen) and the equation by Lohman (1981) was assessed on 66 male wrestlers with a mean age of 20.2 years (Utter, Goss, Swan, Harris, Robertson & Trone, 2003) and 114 male wrestlers aged 15 to 17 years (Demirkan *et al.*, 2014). Both studies reported no significant difference between %BF calculated in a euhydrated state (mean USG 1.019 g/ml and 1.016 g/ml for Utter *et al.* (2003) and Demirkan *et al.* (2014) respectively); and a dehydrated state (mean USG 1.027 g/ml and 1.028 g/ml for Utter *et al.* (2003) and Demirkan *et al.* (2014) respectively). Utter *et al.* (2003) reported mean %BF values of 12.4 % and 12.2 % for euhydration and dehydration respectively, and Demirkan *et al.* (2014) reported 8.8 % and 9.1 % for euhydration and dehydration respectively.

Dolan *et al.* (2013) used the Withers *et al* (1987) and Siri (1961) equations to estimate %BF in a sample of nine professional male jockeys in Ireland (five jump and four flat) in an intervention study on the effects of dehydration on physiological and cognitive function. The results showed a non-significant decrease in %BF according to skinfold measurements from 9.0 % at baseline to 8.9 % after four percent weight loss by dehydration.

The literature regarding the impact of hydration status on the %BF determined by skinfold measurements therefore suggests that there is no significant impact of dehydration on the measurement of %BF from skinfolds. To date, no data exists for the impact of hydration status on the accuracy of estimating %BF from skinfold measurements in jockeys, therefore it was important to test this.

2.7.2.2.5 The impact of measurement technique

Strict adherence to a measurement protocol is also essential to obtaining reliable results. Ruiz *et al.* (1971) investigated the variation of triceps skinfold measurements in males aged 40 years and older when the measurement site was displaced by 2.5cm vertically in 124 subjects and horizontally in 120 subjects, when the depth of the bite changed (either deeper or more superficial than the standard technique) in 62 subjects, and when the skinfold was either held or released when the measurement was read in 123 subjects. The study reported highly significant differences in triceps skinfold thickness as a result of horizontal and/or vertical displacement of the calliper site as well as the size of the bite, but no significant difference when the skinfold was either held or released when the measurement was read. This study signified the importance of a standardised technique. In 1986, the ISAK was formed in Glasgow. This International society established a closely-defined protocol, as well as an exam-based certification course, for practitioners and instructors (International Society for the Advancement of Kinanthropometry, 2001) which is reported to reduce intra-tester error by seven-fold (Ackland *et al.*, 2012). A cross-sectional quantitative study by Hume & Marfell-Jones (2008) on the impact of a one cm variation from the standard ISAK skinfold sites in a sample of ten males aged 27.9 years reported significant differences in skinfold measurement values for 70% of the points measured. The ISAK technique has been used in a recent study on jockeys (Silk *et al.*, 2015) and was used in this study.

2.7.2.2.6 <u>The impact of inter-observer variability</u>

Literature regarding the impact of inter-observer variability on increased error in measurement is controversial when trained investigators use a standardised technique. Kispert & Merrifield (1987) investigated the variability of measurements at three skinfold sites in ten males (triceps, chest and subscapular) and ten females (triceps, abdomen and supra-iliac) by eight investigators and reported no significant differences between the measurement values at each sites nor for the sum of the skinfolds. Conversely, the study by Hume & Marfell-Jones (2008) reported significant differences between the measurements of the two investigators.

Although the evidence regarding inter-observer variability for skinfold measurements is ambiguous, measurements in this study were carried out by the same investigator who was ISAK trained to eliminate potential variability.

2.7.2.2.7 <u>Regression equations</u>

A number of regression equations have been produced in order to calculate %BF from skinfold measurements. Most equations calculate BD, which then needs to be translated into %BF from either the Siri (1961) or Brozek *et al.* (1963). The choice of equation should be population specific, as it has been discussed that age, sex, race and adiposity can affect variability, therefore it is necessary to investigate the equation's which have been used and validated in the jockey/apprentice population.

2.7.2.2.8 <u>Regression equations used in the jockey population</u>

The biokineticist at the SAJA currently uses the four-skinfold equation which was retrieved from (Topend Sports Network, 2015) and attributed to Jackson & Pollock (1985). The selection of this equation was based on the fact that it takes age into account, however more recent equations also include age as a variable (Peterson *et al.*, 2003; Van der Ploeg *et al.*, 2003; Vickery *et al.*, 1988; Withers *et al.*, 1987). The equation could not be sourced from the publication by Jackson & Pollock (1985). One of the authors, Dr A.S. Jackson (udde@me.com), who is affiliated with the University of Houston, was contacted and confirmed that this equation was developed by himself and the late Mr Michael Pollock, of the University of Wisconsin. Although the equation could still not be found in any of their publications (as the reputable Jackson & Pollock (1978) equations use either three or seven skinfold sites) the equation was used in this study as it was in use at the time at the SAJA.

Labadarios *et al.* (1993) measured four skinfold sites, namely the triceps, biceps, subscapular and supra-iliac, to determine the %BF of professional male flat jockeys in South Africa, although neither the equation or measurement standards were specified No reference method was used as a comparison and hydration status was not measured.

Warrington *et al.* (2009) measured the %BF of 17 professional male flat jockeys and ten professional male jump jockeys in Ireland using both DXA and seven skinfold measurements (biceps, triceps, subscapular, supra-iliac, abdominal, mid-thigh and medial calf) and the equation by Withers *et al.* (1987) to calculate BD and the Siri (1961) equation to translate into %BF. Note that this equation was derived from the 1987 dataset, but not published in full in the original study. The skinfold protocol was not specified. The jockeys were tested for hydration status and measured on a non-race day. The mean USG (1.022 g/ml) on the non-race day, indicating moderate dehydration (Casa *et al.*, 2000). Statistical analysis showed that there was no significant difference between %BF values for flat jockeys measured by DXA (8.99 %) and skinfolds (7.88 %), indicating that skinfold measurements using the Withers *et al* (1987) equation was comparable to DXA in the jockey population.

Similarly Dolan *et al.* (2009) used the Withers *et al* (1987) equation with the Siri (1961) equation versus DXA in a sample of 41 weight category athletes (29 professional jockeys and 12 boxers) in Ireland. Skinfold measurements were taken in accordance with the American College of Sports Medicine (ACSM) (2006) guidelines, however hydration status was not assessed. They reported significant differences between the %BF values determined by each method although the difference between DXA and skinfold values when only the flat jockeys were included was not significant. Dolan *et al.* (2013) also used the Withers *et al* (1987) and Siri (1961) equations to estimate

%BF of the nine male professional jockeys in Ireland. Euhydration was ensured prior to measurement however no reference method was used in this study. Withers *et al.* (1987) measured the triceps, biceps, subscapular, chest, supra-iliac, abdominal, frontal thigh and medial calf skinfolds against UWW in a sample of 207 male athletes participating in various sports with a mean age of 24.2 years and developed a regression equation using skinfold measurements at four sites (abdominal, front thigh, medial calf and juxta-nipple) as well as two circumferences, neck and ankle. A seven skinfold equation, involving the biceps, triceps, subscapular, supra-iliac, abdominal, medial calf and frontal thigh, was adapted from this data.

Finally, O'Reilly *et al.* (2017) predicted the %BF of 20 professional male flat jockeys in Hong Kong using four skinfold sites, namely biceps, triceps, subscapular and supra-iliac and the equation by Durnin & Womersley (1974). It can be noted, that O'Reilly *et al.* (2017) produced notably lower results for %BF than the previously mentioned studies. No reference method was used in this study. The Durnin & Womersley (1974) equation was developed from the skinfold and UWW data of 209 male and 272 female non-athletes aged from 16 to 72 years The lower %BF values given by O'Reilly *et al.* (2017) are supported by Piers, Soares, Frandsen & O'dea (2000) who also demonstrated significantly lower estimates of %BF using the Durnin & Womersley (1974) equation when compared to DD in a sample of 117 male and females age 19 to 77 years.

The only regression equations to date used in the published studies on jockeys have been that of Durnin & Womersley (1974) and Withers *et al.* (1987) in combination with the Siri (1961) equation and the Withers *et al.* (1987) equation has been shown to be comparable to DXA by Warrington *et al.* (2009).

2.7.2.2.9 Regression equations not yet used in jockeys

Various regression equations have been developed to estimate %BF from skinfold measurements which have not as yet been used in jockey studies, but which may be suitable to the jockey population (Table 2.2).

Table 2.2: Potential regression equations for skinfold measurements in male jockeys

Author	Sample	Mean age (years)	Race	Sites used	Reference method	SEE (g/ml)	Equation
Sloan (1967)	50 (male)	18 – 26 [a]	White	Two (thigh and subscapular)	UWW	n/s	BD = 1.1043 – 0.0013(thigh) – 90.00135(subscapular)
Durnin & Rahaman (1967)	105 adult (60 male) 86 adolescent (48 male)	22 ± 3.2 (adult male) 14.7 ± 0.8 (adolescent male)	n/s	Four (biceps, triceps, subscapular, supra-iliac)	UWW	0.0067 (adult male) 0.0083 (adolescent male)	12 - 17 BD = 1.1533-0.0643(LOG sum four skinfolds) 18 - 30 BD = 1.1610-0.0632(LOG sum four skinfolds)
Katch & McArdle (1973)	122 (53 male)	19.3 ± 1.5 (male)	White	Three (triceps, subscapular, abdominal) One circumference (forearm)	UWW	0.0072	BD = 1.10986 – 0.00083(triceps) – 0.00087(subscapular) – 0.00098(abdominal) + 0.00210(forearm circumference)
Forsyth & Sinning (1973)	50 (male athletes)	19 – 22 [a]	n/s	Two (triceps, abdominal)	UWW	0.006	BD = 1.103 – 0.00168(subscapular) – 0.00127(abdominal)
Durnin & Womersley (1974)	481	16 – 72 [a]	n/s	Four (biceps, triceps, subscapular, supra-iliac)	UWW	0.0065 – 0.0113	17 – 19 years: BD = 1.162 – 0.063(sum four skinfolds) 20 – 29 years: BD = 1.1631 – 0.0632(sum four skinfolds)

Author	Sample	Mean age (years)	Race	Sites used	Reference method	SEE (g/ml)	Equation
Jackson & Pollock (1978)	n_1 = 308 male n_2 = 85 male	$n_{1:}$ 32.6 ± 10.8 $n_{2:}$ 33.3 ± 11.5	n/s	3SF: Three (chest, abdominal, thigh) or 7SF: Seven (chest, mid-axilla, triceps, subscapular, abdominal, supra-iliac, thigh)	UWW	3SF: 0.0077 7SF: 0.0078	3SF: BD = 1.1041 – 0.00083(sum three skinfolds) + 0.0000016(sum three skinfolds)^2 7SF: BD = 1.112 - 0.00043499(sum three skinfolds) + 0.00000055(sum three skinfolds)^2 - 0.00028826A
Lohman (1981)	61 [b]	"college-age" [c]	White	Three (triceps, abdominal, subscapular)	UWW	0.0047	BD = 1.0982 – 0.000815 (sum three skinfolds) + 0.0000084 (sum three skinfolds)^2
Jackson & Pollock (1985)	n/a	n/a	n/s	Four (abdominal, triceps, thigh, supra-iliac)	UWW	n/a	%BF = 0.29288(sum four skinfolds) – 0.0005(sum four skinfolds)^2 + 0.15845A – 5.76377
Withers *et al.* (1987) [d]	207 (male)	24.2 ± 4.7	n/s	Seven (biceps, triceps, subscapular, supra-iliac, abdominal, calf, thigh)	UWW	0.00537	BD = 1.0988 - 0.0004(sum seven skinfolds)
Slaughter *et al.* (1988)	310 (174 male)	8 - 18	Black and white [e]	Two (triceps and calf) [f]	4-C model (DD, UWW, photon absorptiometry)	3.9%	Male: %BF = 0.0735(sum two skinfolds) + 1
Vickery *et al.* (1988)	n_b = 140 male n_w = 179 male	n_b: 21.7 ± 3.8 n_w; 22.4 ± 3.5	140 black and 179 white	Seven (chest, mid-axilla, triceps, subscapular, abdominal, supra-iliac, thigh)	UWW	0.0063	BD = 1.112785 – 0.00031133 (sum seven skinfolds) + 0.00000009748 (sum seven skinfolds)^2 – 0.000321428A – 0.00709929Ra_1

Author	Sample	Mean age (years)	Race	Sites used	Reference method	SEE (g/ml)	Equation
Deurenberg *et al.* (1990)	n = 378 (170 male)	PrP (n = 114): 11.3 ± 0.16 P (n = 35): 13.8 ± 0.21 PoP (n = 21): 17.5 ± 0.39	n/s	Two (biceps and triceps) or Four (biceps, triceps, supra-iliac, subscapular)	UWW	0.0013 – 0.0028	2SF: BD = 1.1132 – 0.0410(LOG sum two skinfolds) 4SF: BD = 1.1324 – 0.0429(LOG sum four skinfolds)
Lean *et al.* (1996)	n = 147 (63 male)	40.1 ± 13.1 R: 16.1 – 65.4 (male)	White	One skinfold (triceps) and one circumference (waist)	UWW	3.2	Male: %BF = 0.353(waist circumference) + 0.756(triceps skinfold) + 0.235A
Stewart & Hannan (2000)	n_1 = 82 male athletes n_2 = 24 male athletes	n_1: 28.1 ± 7.5 n_2: 29.0 ± 7.0	n/s	Five (abdominal, chest, forearm, calf, thigh, supra-iliac)	DXA	RMSE: 2.9%	%BF = [105.2Wt + 189.5(abdominal) + 345.2(chest) - 521.1(forearm) + 215.9(calf) + 258.3(thigh) + 293(supra-iliac) - 8334.4]/Wt x 100
Peterson *et al.* (2003)	n = 681 (365 male)	n_1: 36.2 ± 11.0 R:18.0 –55.4 n_2: 35.2 ± 14.6 R:18.0 – 55.6	White	Four (triceps, subscapular, supra-iliac, thigh)	4-C model (DXA, UWW, DD)	RMSE: 4.6% (male)	Male: %BF = 20.94878 + 0.1166A - 0.11666Ht + 0.42696(sum four skinfolds) - 0.00159(sum four skinfolds)^2

Author	Sample	Mean age (years)	Race	Sites used	Reference method	SEE (g/ml)	Equation
Van der Ploeg *et al.* (2003)	n = 79 male	35.0 ± 12.2	n/s	6SF: Six (subscapular, biceps, abdominal, thigh, calf, mid-axilla) or 3SF: Three skinfolds (mid-axilla, calf, thigh), One circumference (waist), One breadth (femur)	4-C model (DXA, UWW, DD)	RMSE: 1.8% (6SF) RMSE: 2.2% (3SF)	6SF: %BF = -0.00057(sum six skinfolds)^2 + 0.298Σ(sum six skinfolds) + 0.078A – 1.13 3SF: %BF = -0.00258(sum three skinfolds)^2 + 0.558(sum three skinfolds) + 0.118A + 0.282(waist girth) – 2.1(femur breadth) – 2.34
Evans *et al.* (2005)	n = 132 athletes (78 male)	20.7 ± 2.0	88 black and 94 white	7SK: Seven (subscapular, triceps, chest, mid-axilla, supra-iliac, abdominal, thigh) or 3SK: Three (abdominal, thigh, triceps)	4-C model (DD, UWW, photon absorptiometry)	RMSE: 3.76% (7SK) RMSE: 3.66% (3SK)	Male: 7SK: %BF = 10.566 + 0.12077(sum seven skinfolds) – 8.057 – 2.545Ra_2 3SK: %BF = 8.997 + 0.24658(sum three skinfolds) – 6.343 – 1.998Ra_2

All skinfolds refer to skinfold thickness in milimetres (mm). All circumferences measured in centimetres (cm).
SEE: Standard error of estimate. UWW: Underwater weighing. n/s: Not specified. BD: Body density. n_1: Validation sample. n_2: Cross-validation sample. n/a: Not applicable - Jackson & Pollock (1985) conducted a review on previous skinfold studies. %BF: Percent body fat. A: Age (years). PrP: Prepubescent (male). P: Pubescent (male). PoP: Postpubescent (male). Ad: Adult (male). n_b: Black sample. n_w: White sample. Ra_1: Race, where white = 2 and black = 1. R: Range. RMSE: root mean square error. Wt: Weight (kg). 4-C model: four-component model. Ht: Height (cm). 6SF: Equation by author/s involving six skinfold measurements. 3SF: Equation by author/s involving three skinfold measurements. 7SK: Equation by author/s involving seven skinfold measurements. Ra_2: Race, where white = 0 and black = 1.

[a] Mean age not given.

[b] Validation sample – Study also reviewed previous regression equations.

[c] Neither mean age nor age range given.

[d] Equation given was derived from the 1987 dataset, but not published in full in the original study.

[e] Ratio of white and black subjects not specified.

[f] This skinfold combination was not significantly influenced by maturation or race.

Various studies have cross-validated these equations against each other. Sinning *et al.* (1985) evaluated against UWW the accuracy of 21 skinfold equations, including that of Sloan (1967), Katch & McArdle (1973), Forsyth & Sinning (1973), Durnin & Womersley (1974), Jackson & Pollock (1978) and Lohman (1981), to calculate the BD and %BF of 265 male athletes, age 18 to 26 years. Only the equations by Jackson & Pollock (1978), which involved either seven skinfolds (chest, mid-axilla, triceps, subscapular, abdomen, supra-iliac, thigh) or three skinfolds (chest, abdomen, thigh),showed no significant difference from the reference method of UWW. The equations by Sloan (1967), Katch & McArdle (1973) and Lohman (1981) also produced estimations with an acceptable error.

Peterson *et al.* (2003) developed their own skinfold equation using a 4-C model (DXA, DD and UWW) in a sample of 274 male and 230 female subjects and then cross-validated it with the equations by Durnin & Womersley (1974) and Jackson & Pollock (1978) in a sample of 86 males and 91 females (Peterson *et al.*, 2003). Peterson *et al.* (2003) maintained that the Durnin & Womersley (1974) equation underestimated %BF in men and women. The newly proposed equation by Peterson *et al.* (2003) produced estimations that did not differ significantly from that of the reference method.

Rodriguez *et al.* (2005) compared 14 commonly used equations to predict %BF from skinfolds, including that of Durnin & Womersley (1974), Slaughter *et al.* (1988), Deurenberg *et al.* (1990) and Lean *et al.* (1996), to DXA in a sample of in 238 white adolescents (167 females and 113 males), aged 13.0 to 17.9 years. The study found that only the Slaughter *et al.* (1988) equation showed nonsignificant differences against DXA in adolescent males. No studies to date have validated these equations for use in jockeys or jockey apprentices.

The Sloan (1967), Durnin & Rahaman (1967), Forsyth & Sinning (1973), Durnin & Womersley (1974), Lohman (1981), Jackson & Pollock (1985), Slaughter *et al.* (1988), Deurenberg *et al.* (1990), Peterson *et al.* (2003) and Evans *et al.* (2005) equations are used to measure %BF of the jockey apprentices in this study as these equations include only the seven skinfolds (biceps, triceps, subscapular, supra-iliac, abdominal, thigh and calf) currently measured at the SAJA for the purpose of body composition measurement.

2.7.2.2.10 Quality of equipment

The type of calliper has been found to have a significant impact due to the pressure exerted on the skinfold (Ball, Swan & Altena, 2006). High quality metal callipers such as the Lange and Harpenden have been found to be the most accurate as they are able to apply constant pressure throughout the range of measurement (Heyward & Wagner, 2004). Lange callipers are used in this study.

The accuracy of using skinfold measurements to estimate %BF is highly influenced by the technique, inter-observer variability and choice of equation. Only the equation by Withers *et al.* (1987) has been validated in a jockey/apprentice population, although it may be influenced by dehydration. This necessitates the validation of various equations for use in the jockey apprentice population.

An alternative field method, of similar cost but requiring less training and is less susceptible to inter-observer variability, would be extremely valuable for the jockey apprentice population.

2.7.2.3 Bioelectrical Impedance Analysis

Bioelectrical impedance analysis is another portable, quick, cost-effective and non-invasive method of measuring %BF with less inter-observer variability than skinfold measurements, thus making it a more practical method (Ostojic, 2006). Bioelectrical impedance analysis uses the impedance of a conductor (the human body), which is the opposition to the flow of an alternating electric current comprising of both resistance (R) and reactivity (Xc), at a specific frequency/frequencies to calculate %BF from body volume and length (Brodie, Moscrip & Hutcheon, 1998). The most common methods of BIA include single-frequency (SF-BIA), where the electrical current flows at a single frequency (usually 50 kHz) between electrodes to measure FFM and TBW, and multi-frequency (MF-BIA), which uses different frequencies to evaluate FFM, TBW, as well as to differentiate measures for intra-cellular (ICF) and extracellular fluid (ECF) (Kyle *et al.*, 2004a). The advantage of MF-BIA over SF-BIA is that MF-BIA is reported to be more accurate for the measurement of TBW in conditions in which body water compartmentalization (ICF and ECF balance) is altered from the normal state, for example renal failure (Gudivaka, Schoeller, Kushner & Bolt, 1999; Martinoli, Mohamed, Maiolo, Cianci, Denoth, Salvadori & Iacopino, 2003). However it has recently been found that MF-BIA does not provide more accurate results than SF-BIA when used to measure %BF in variable hydration statuses (Donadio, Halim, Caprio, Grassi, Khedr & Mazzantini, 2008). Single-frequency devices such as the BODYSTAT®1500 MDD used in this study, are more affordable than MF-BIA devices and has been used to measure the body composition of apprentice jockeys training at the SAJA for research purposes (Krog, 2015).

The accuracy of BIA for measuring %BF is influenced by the age and sex (Deurenberg, Van der Kooy, Leenen, Weststrate & Seidell, 1991a; Lohman, 1992), race (Sun *et al.*, 2003) adiposity (Segal *et al.*, 1988; Gray, Bray, Gemayel & Kaplan, 1989), hydration status (Saunders *et al.*, 1998) of the individual measured, the choice of machine (Ghosh, Meister, Cowen, Hannan & Ferguson, 1997) and adherence to procedural techniques. Procedural techniques have been established by the European Society for Parenteral and Enteral Nutrition (Kyle, Bosaeus, De Lorenzo, Deurenberg, Elia, Gómez, Heitmann, Kent-Smith, Melchior & Pirlich, 2004b).

These include, but are not limited to, calibration of electrical equipment, correct placement of electrodes, subject in a supine position on a non-conductive surface and subject fasting for eight hours prior to measurement (Kyle *et al.*, 2004b). Height may also be a confounding factor. These factors are used to select an appropriate population-specific BIA equation (Kyle *et al.*, 2004a).

2.7.2.3.1 <u>The impact of age and sex</u>

Deurenberg *et al.* (1991a) developed regression equations for BIA from a sample of 827 male and female subjects aged seven to 83 years using UWW as a reference. The study reported that age and sex significantly impacted the accuracy of %BF measured by BIA compared to UWW therefore these variables were included in the equations produced.

Lohman (1992) conducted a similar study involving 685 male and female subjects aged 18 to 70 years and also reported significant effects of age and sex on accuracy when BIA was compared to UWW. Separate equations were proposed for each age group (18 to 29 years; 30 to 49 years; 50 to 70 years) and for each sex within each age group.

2.7.2.3.2 The impact of race

Sun *et al.* (2003) tested BIA equations for calculating FFM in a sample of 1034 white (412 male and 622 female) and 279 (114 male and 156 female) black subjects aged, 12 to 94 years using a 4-C model (UWW, DD, DXA). It was found that race-combined equations tended to under-predict FFM in black males by 2.1 kg and females by 1.6 kg, and over-predict FFM in white males by 0.4 kg and females by 0.3 kg. Based on these results, race- and sex-specific equations were developed and cross-validated in a sample of 440 white (182 male and 258 female) and 85 black (26 male and 59 female) subjects to produce acceptable SEE values.

2.7.2.3.3 The impact of adiposity

Segal *et al.* (1988) conducted a descriptive study involving 1069 male and 498 females aged 17 to 62 years with %BF ranging from three to 56% according to UWW. Fat-free mass was measured using SF-BIA and it was found that BIA significantly overestimated FFM in obese subjects with a %BF greater than 42%. A separate regression equation was derived for obese subjects.

Gray *et al.* (1989) reported similar findings in a sample of 87 adults with %BF varying from 8.8 to 59% when comparing SF-BIA to UWW and also derived a separate equation for obese subjects.

Since jockeys and apprentices are not obese, this factor will not influence the results of predicting %BF from BIA.

2.7.2.3.4 The impact of dehydration

Measurement of %BF by BIA is known to be affected by hydration status. An intervention study by Saunders *et al.* (1998), involving 15 athletes (11 men and 4 women) aged 19 to 56 years, found that exercise-induced dehydration, as indicated by a 3% loss of normal body mass, caused a significant reduction in %BF when measured by single-frequency BIA (Valhalla Scientific 1990B, San Diego, CA) analyser. This is a concern in the jockey/apprentice population as common strategies of making weight for races involve manipulation of hydration status (Labadarios *et al.*, 1993; Leydon & Wall, 2002; Moore *et al.*, 2002a; Dolan *et al.*, 2011; Wilson *et al.*, 2014) and jockeys are reported to be chronically dehydrated, even on non-race days when %BF would typically be measured (Warrington *et al.* (2009).

Thompson *et al.* (1991) conducted an intervention study which investigated the impact of dehydration (as indicated by a mean 2.81% loss of body mass following a combination of exercise and sitting in a steam room) on the %BF measured by SF-BIA in a sample of ten males aged 18 to 44 years. The equation used was not specified. A significant decrease in %BF as measured by BIA was reported when comparing baseline to dehydration.

2.7.2.3.5 Choice of machine

The BODYSTAT®1500 is a relatively affordable SF-BIA device that measures %BF by using the tetrapolar hand-to-foot technique at a single frequency. Ghosh *et al.* (1997) validated the BODYSTAT®1500 machine against DXA in a study involving 160 participants, including healthy adults and adolescents as well as hospital patients, and reported satisfactory limits of agreement.

The machine has been compared to various other SF-BIA devices, including the RJL system which also uses the tetrapolar hand-to-foot technique, the Tanita TBF410 GS model which uses the bipolar foot to foot technique, the Omron BF300 which uses the bipolar handheld technique and the Omron BF511 which uses the tetrapolar handheld technique, as well as the skinfold equations by Pařízková (1977) and Slaughter *et al.* (1988) (Smye, Sutcliffe & Pitt, 1993; Stewart & Hannan, 2000; Vetrovska, Vilikus, Klaschka, Stranska, Svacina, Svobodova & Matoulek, 2014).

Smye *et al.* (1993) compared four whole-body SF-BIA systems (Holtain, RJL, BODYSTAT®1500 and EZcomp) on two separate occasions in a sample of 21 healthy subjects (nine female and 12 male) aged 20 to 57 years and found no significant difference between the %BF values obtained from the BODYSTAT®1500, RJL and EZcomp but significant differences between the BODYSTAT®1500 and Holtain. Limited conclusions can be drawn from this study as no reference method was used to validate the BIA results.

The previously described study by Stewart & Hannan (2000), involving 82 male athletes reported that fat mass predicted by skinfolds using the equations by Durnin & Womersley (1974) and Jackson & Pollock (1978) produced a lower SEE (1.7 kg) that that of BIA using the RJL machine and equations by Lohman (1992) and Lukaski *et al.* (1986) (2.8 kg). Since the BODYSTAT®1500 is reported to have a similar accuracy to that of RJL, it can be deduced that skinfold measurements using the equations by

Durnin & Womersley (1974) and Jackson & Pollock (1978) could be more accurate than the BODYSTAT®1500.

In a descriptive study involving 42 male children with a mean age of 12.9 years, %BF was measured by BIA using the Tanita TBF410 GS model and the BODYSTAT®1500. The results were compared to that of a 3-C model, involving ADP (BOD POD) and DD, as the reference method. The study reported that both BIA machines significantly overestimated %BF when compared to the reference method (Parker *et al.*, 2003).

Markham & Fountaine (2011) compared the accuracy of predicting %BF using the BODYSTAT®1500 and Omron machines in a sample of 24 (15 male and 9 female) track and field athletes with a mean age of 20.13 years using the BOD POD as a reference. The study reported significantly higher %BF values measured by the BODYSTAT®1500 when compared to both the BOD POD and the Omron in the male subjects, indicating that the Omron was more reliable.

Vetrovska *et al.* (2014) compared the accuracy of %BF measurements using the Tanita TBF 410 GS, BODYSTAT®1500 and Omron BF 300 machines as well skinfold measurements using the equation by Pařízková (1977) against DXA in a sample of 130 females with a mean age of 46.8 years stratified by BMI. They found that all methods, except for Omron, significantly underestimated %BF when compared to DXA for participants with a BMI less than 25 kg/m^2 (30/130) and that there was a significant difference between values measured by the Omron and BODYSTAT®1500 machines in this group. The skinfold method underestimated %BF for all BMI groups. Overall, it was found that all methods produced values significantly different to that of DXA, with Omron being the most similar.

In summary the BODYSTAT®1500 machine significantly overestimates %BF when compared to the reference methods APD, DD and DXA.

2.7.2.3.6 <u>The impact of height</u>

Although there is no evidence in the literature that states that height directly influences the accuracy of BIA, it is established that BIA equations are inaccurate at extremes of height (Kyle *et al.*, 2004b). The BIA equations are based on $V = p \times S^2/R$; where V is the conductive volume, p is the specific resistivity of the conductor, S is stature (height) and R is whole-body resistance (Houtkooper, Lohman, Going & Howell, 1996). As jockeys are small in stature, and the equations for BIA include height as a variable it would be reasonable to hypothesise that height may be a confounding factor.

2.7.2.3.7 Regression equations

Various equations have been developed to estimate %BF from impedance, none of which have been validated in a jockey/apprentice population. The manufacturers of the BODYSTAT®1500 refused to disclose the regression equation used by their computer software. It was important to determine whether other BIA equations were more appropriate for the jockey apprentice population. Studies which have published equations considered suitable for the jockey apprentice population, on the basis of being validated in an age- and gender-appropriate population with an acceptable SEE, are summarised in Table 2.3.

The BODYSTAT®1500 is not phase-sensitive, which means it measures impedance (Z) at a frequency of 50 KHz only, and does not measure R and X values separately. A phase-sensitive machine is required to measure these values separately and Z and R values are not recommended to be used interchangeably (Preedy, 2012). This presents a challenge when substituting measurements from the BODYSTAT®1500 into other regression equations as most involve R instead of Z.

Table 2.3: Potential regression equations for bioelectrical impedance measurements in male jockeys

Author/s	Sample size	Mean age (years)	Race	Reference method	SEE (kg)	Equation	BIA Machine
Lukaski *et al.* (1986)	114 (47 male)	26.9 ± 8.0 (male) R: 18 – 50	n/s	UWW	2.51	$FFM = 0.756Ht^2/R_{50KHz} + 0.11Wt + 0.107X_{50KHz} - 5.463$	RJL-101
Segal *et al.* (1988)	1567 (1069 male)	17 – 62 [a]	n/s	UWW	2.47 [b]	FFM (male) [b] $= 0.0006636Ht^2 - 0.02117R_{50KHz} + 0.62854Wt - 0.1238A + 9.33285$	RJL-101
Gray *et al.* (1989)	87 (25 male)	41 ± 1 R:19 – 74	n/s	UWW	r: 0.97 [c]	FFM (male) $= 0.00139Ht^2 - 0.0801R_{50KHz} + 0.187Wt + 39.83$	RJL-101
Van Loan, Boileau, Slaughter, Stillman, Lohman, Going & Carswell (1990)	150 (75 male)	18 – 32 [d]	n/s	3-C model (UWW, DD)	2.5	FFM (male) $= 0.51Ht^2/R_{50KHz} + 0.33Wt + 1.69 + 3.66$	RJL-101

Author/s	Sample size	Mean age (years)	Race	Reference method	SEE (kg)	Equation	BIA Machine
Heitmann (1990)	139 (male and female)	35 – 65 [e]	n/s	4-C model (DD, TBK)	3.6	FFM (male) = $0.279Ht^2/R_{50KHz} + 0.245Wt + 0.231Ht - 0.077A - 14.94$	RJL-103
Boulier *et al.* (1990)	202 (81 male)	27.8 ± 11.7 R:12 – 71	n/s	UWW	2.6	FFM (male) = $6.37 + 064Wt + 0.4Ht^2/Z_{1MHz} - 0.16A - 2.71$	IMP BO-1
Deurenberg *et al.* (1991)	661 (male and female)	16 – 83 [e]	n/s	4-C model (DD, UWW)	2.6	FFM = $-12.44 + 0.34Ht^2/R_{50KHz} + 0.1534Ht + 0.273Wt - 0.127A + 4.56$	RJL-101
Lohman (1992)	153 (male)	18 – 29 [e]	n/s	UWW	2.9	FFM = $0.47634Ht^2/R_{50KHz} + 0.295Wt + 5.49$	Valhalla
Houtkooper *et al.* (1992)	$n_1 = 94$ $n_2 = 131$ (male and female)	10 – 19 [f]	White	4-C model (DD, UWW)	2.1	FFM = $0.61Ht^2/R_{50KHz} + 0.25Wt + 1.31$	RJL-101

Author/s	Sample size	Mean age (years)	Race	Reference method	SEE (kg)	Equation	BIA Machine
Organ *et al.* (1994)	200 (96 male)	35.2 ± 9.6 (male) R: 21-64	White	4-C model (UWW, DD)	2.8	FM = -4.2422 + 0.7368Wt – 0.0482Ht + 0.117A + 0.0393upperlimbR_{50KHz} + 0.511trunkR_{50KHz} + 0.0654lowerlimbR_{50KHz} – 0.2561lowerlimbXc	N/A
De Lorenzo *et al.* (1998)	35 (20 male)	9.7 ± 1.0 R: 7.7 - 13	n/s	DXA	1.0	FFM = 2.33 + 0.588Ht^2/Z_{50KHz} + 0.211Wt	RJL-101
Piers *et al.* (2000)	117 (51 male)	36.0 ± 18.0 (male) R: 19 – 77	n/s	DD	n/r	FFM = 0.98FFM_{He} + 1.019MAC – 1.009X_b – 24.709	RJL-101
Kyle *et al.* (2001)	343 (202 male)	R: 22 – 94 [g]	White	DXA	1.8	FFM (male) = -4.104 + 0.518Ht^2/R_{50KHz} + 0.231Wt + 0.13Xc – 4.229	Xitron

Author/s	Sample size	Mean age (years)	Race	Reference method	SEE (kg)	Equation	BIA Machine
Sun *et al.* (2003)	1801 (712 male)	WMV: 41.9 ± 20.1 BMV: 48.3 ± 19.3 WMCV: 30.1 ± 14.3 BMCV: 37.2 ± 15.2 R: 12 – 94	355 black and 1474 white	4-C model (UWW, DD, DXA)	3.9 (male)	FFM (male) = -10.678 + 0.652Ht^2/R$_{50KHz}$ + 0.262Wt + 0.015R$_{50KHz}$	RJL-101

SEE: Standard error of estimate. n/s: Not specified. R: Range. UWW: Underwater weighing. Ht: Height. R_{50KHz}: Resistance at a frequency of 50 KHz. Wt: Weight. $X_{50\ KHz}$: Reactance at a frequency of 50 KHz. FFM: Fat-free mass. RJL-101: RJL System model 101. DD: Deuterium dilution. TBK: Total body potassium. RJL-103: RJL system model 103. Z_{1MHz}: Impedance at a frequency of 1MHz. IMP BO-1: I'Impulsion system. Z_{50KHz}: Impedance at a frequency of 50 KHz. n_1: validation sample. n_2: cross-validation sample. Valhalla: Valhalla system. FM: Fat mass. DXA: Dual X-ray Absorptiometry. n/r: not reported. FFM_{He}: FFM derived from Heitmann (1990) equation. MAC: mid-arm circumference in millimetres (mm). X_b: biceps skinfold thickness in mm. Xitron: Xitron system. WMV: White male validation sample. BMV: Black male validation sample. WMCV: White male cross-validation sample. BMCV: Black male cross-validation sample. Z_{50KHz}: Impedance at a frequency of 50 KHz.

[a] Mean age given for males at four separate laboratories (labs) - Lab A (n = 96): 32 ± 9; Lan B (n = 99): 26 ± 8; Lab C (n = 490): 34 ± 8; Lab D (n = 404): 32 ± 7.

[b] For males with a %BF less than 20%.

[c] No SEE given as equation was not cross-validated.

[d] Mean age given for males at three separate labs - Lab AZ (n = 48): 24.2 ± 3.8; Lab IL (n = 51): 21.9 ± 2.4; Lab CA (n = 51): 25.8 ± 3.3.

[e] Mean age not given.

[f] Mean age given for subjects in validation sample and cross-validation samples – Validation sample (n = 94): 12.3 ± 1.2; Wright State University (n = 68): 11.9 ± 1.4; University of Arizona (n = 25): 12.5 ± 1.3; Western Human Nutrition Research Centre (n = 38): 15.7 ± 1.6.

[g] Mean age of sample not given. Subjects were divided into age groups: 20 – 29 years (n = 21); 30 – 39 years (n = 77); 40 – 49 years (n = 36); 50 – 59 years (n = 15); 60 – 69 years (n = 11); 70 – 79 years (n = 30); 80 years and older (n = 12).

Studies have also assessed accuracy of some of these regression equations by either cross-validation or analysis of SEE, which indicates accuracy. Piers *et al.* (2000) conducted a descriptive study on 117 healthy Australian adults, including males and females with ages ranging from 19 to 77 years, to evaluate the reliability of equations by Heitmann (1990), Lukaski *et al.* (1986) and Segal *et al.* (1988), against DD as a reference method. It was reported that all three equations produced significantly different results for %BF when compared to the reference method. A modified version of Heitmann, which included biceps skinfold thickness and mid upper arm circumference, was then developed by Piers *et al.* (2000) to produce results that were not significantly different to DD.

Kyle *et al.* (2004a) evaluated the reliability of a number of equations developed since 1990 which are commonly used to estimate FFM and body fat mass in terms of SEE. Houtkooper *et al.* (1996) suggested that an ideal SEE would be less than 2.5 and an acceptable SEE of less than 3.0 for men when evaluating the suitability of an equation. The equations were classified according to outcome values, which were either FFM or fat mass (FM). Most of the equations that can be considered suitable for use in the jockey apprentice population predict FFM, which can then be used to calculate FM by subtracting the FFM from total body mass. The equations evaluated in the study by Kyle *et al.* (2004a) are described in ascending order of SEE.

The equation by Kyle *et al.* (2001), which was validated against DXA in a sample of 343 healthy adults age 18 to 94 years, was found to have the lowest SEE (1.8) and was therefore the most accurate. This equation estimates FFM from R and X values (Kyle *et al.*, 2001). The next most accurate was the equation by Boulier *et al.* (1990) with a SEE of 2.6, which necessitates the use of Z values from a frequency of 1 MHz, and Deurenberg *et al.* (1991a) with the same SEE. For directly determining FM only, the equation by Organ *et al.* (1994) had an acceptable SEE of 2.8. This was determined using a device that measures segmental BIA, meaning that impedance values for each segment of the body, for example trunk, are measured. The variables required for this equation cannot be measured by the BODYSTAT®1500 as it measures whole-body impedance only. Lohman (1992) developed an equation for predicting FFM with an acceptable SEE of 2.9. Sun *et al.* (2003) developed from a sample of 1829 male and female subjects aged 12 to 94 years using a multi-component model involving UWW, DD and DXA as a reference, giving an SEE of 3.9 for the male sample. According to Houtkooper *et al.* (1996), this is an unacceptably high SEE for the male population.

Interestingly, the study by Kyle *et al.* (2004a) did not evaluate the equation to predict FFM by Houtkooper *et al.* (1992). This equation was derived from both UWW and DD in a sample of 94 healthy male and female subjects age 10 to 19 years, and then cross-validated in a three other samples including 131 subjects from the same population. This study demonstrated a SEE of 2.1 for the equation from cross-validation, making it the second most reliable equation for SF-BIA for use in the jockey apprentice population.

2.7.2.4 The prediction of percent body fat by bioelectrical impedance analysis compared to skinfolds

It is of importance to this study that the accuracy of BIA and skinfolds for the measurement of %BF be compared as neither method has been validated in the jockey apprentice population. Comparisons of the two methods have included the skinfold equations by Durnin and Womersley (1974) , Jackson & Pollock (1978) and Lohman (1981), as well as BIA equations by the Valhalla and RJL machines (equations cannot be disclosed) Lukaski *et al.* (1986), Lohman (1992) and Houtkooper *et al.* (1992).

Jackson, Pollock, Graves & Mahar (1988) compared the reliability of %BF values predicted by SF-BIA using the equation by Lukaski *et al.* (1986) and the seven-skinfold equation by Jackson & Pollock (1978) compared to UWW as a reference method in a sample of 132 healthy male and female subjects with mean age of 36.7 years for the male subjects. The results indicated a greater inter-observer variation in skinfold methods when compared to BIA, however BIA produced a greater SEE than the skinfold method when compared to UWW.

Fuller *et al.* (1992) compared %BF values predicted by SF-BIA using the equation provided by the Valhalla machine used (equation cannot be disclosed) and four skinfolds using the equation by Durnin & Womersley (1974) against a four component model involving DXA, UWW and DD, in a sample of 28 healthy adults (12 women and 16 men) aged 18 to 59 years. The mean age of the participants was 32.9 years which is substantially higher than that of the jockey apprentices at the SAJA. The study reported that skinfolds produced more reliable values than BIA. Although, it must be noted that this study sample size is relatively small and the skinfold measurements were carried out by a single observer, therefore preventing inter-observer variation which would have been more likely in a larger population over time.

Stewart & Hannan (2000) reported that fat mass predicted by skinfolds using the equations by Durnin & Womersley (1974) and Jackson & Pollock (1978) produced a lower SEE (1.7) that that of SF-BIA using the RJL machine and the equations by Lohman (1992) and Lukaski *et al.* (1986) (2.8) in 82 male athletes. Dual X-ray Absorptiometry was used as a reference method.

The previously described study by Parker *et al.* (2003) also compared %BF as measured by skinfolds using the equation by Slaughter *et al.* (1988) to the 3-C model. Although BIA using the Tanita TBF410 GS model gave inaccurate results, nonsignificant differences were reported between the skinfold method and the reference method.

Hetzler, Kimura, Haines, Labotz & Smith (2006) investigated the level of agreement between SF-BIA using equations by RJL, Lukaski *et al.* (1986) and Houtkooper *et al.* (1992) to the skinfold equations by Jackson & Pollock (1978) and Lohman (1981) to determine minimal wrestling weight in 208 wrestlers, aged 13 to 18 years, as previously described. Significant differences were reported between values determined BIA using Lukaski *et al.* (1986) and both skinfold equations as well as between Houtkooper *et al.* (1992) and Jackson & Pollock (1978) but not Lohman (1981). No significant differences were found between RJL and either of the skinfold equations. No reference method was used in this study.

Demirkan *et al.* (2014) measured the %BF of 114 male wrestlers aged 15 to 17 years by the skinfold method using the Lohman (1992) equation as well as BIA using the Tanita BC- 418 device. Skinfold measurements produced significantly lower values for %BF (8.8 % for euhydration and 9.1 % for dehydration) than BIA (9.0 % for euhydration and 10.8 % for dehydration). No reference method was used.

It is clear that further validation of both methods for the apprentices is required as there is no data available for this population.

2.8 CONCLUSION

It is evident that deleterious techniques including chronic weight-making methods, such as food restriction, excessive exercise, smoking and the use of laxatives and appetite suppressants, as well as acute weight-making methods, including fluid restriction and dehydration by using saunas, exercising in sweat suits, taking hot or salt baths and the use of diuretics, are part of the jockey culture. These habits have been inherited by the jockey apprentices at the SAJA.

These habits negatively impact the physiological health, such as BMD, and psychological health, in terms of the risk of eating disorders of the jockeys reducing. This study investigates the apprentices' risk of abnormal eating behaviours.

Accurate prediction of %BF is important to assist the apprentices with healthy weight control, by ensuring that FFM is not lost during weight loss, and preventing the apprentices from reducing their %BF to dangerously low levels.

Reference methods for frequently measuring %BF, such as DXA and DD, are not appropriate due to cost, impracticality and possible risk of excessive radiation exposure (DXA). Field methods such as BMI, BIA and skinfold measurements are more suitable. These methods may be impacted by dehydration which presents an issue in the jockey population as they are reported to be chronically dehydrated. It is therefore important to evaluate the impact of dehydration on the accuracy of these methods in the jockey apprentice population.

The advantages and disadvantages of each method seem to be equal, in terms of cost, practicality and the impact of demographic factors and hydration status. Using BMI to calculate %BF may be affected by the apprentices' SS. The skinfold method is not affected by SS as equations do not use height as a variable. The skinfold method does however require a substantial amount of training. Bioelectric impedance analysis may be affected by height as it is used as a variable in most BIA equations. This method requires much less, if any, training than the skinfold method.

Assessment of the accuracy of these three methods in this unique population, and the impact of dehydration, would therefore be useful for improving the weight-control practices of the apprentices.

CHAPTER 3: METHODOLOGY

3.1 INTRODUCTION

This chapter discusses background information on the study site (SAJA), the study design, study population and sample, methods and materials used, statistical analysis, reduction of bias and ethical considerations.

3.2 BACKGROUND INFORMATION ON THE STUDY SITE

The SAJA, situated in Summerveld, is the only institution in SA that offers both an academic and practical apprentice programme to qualify professional jockeys. It was established in 1958 and has extended to two satellite training centres in Cape Town and Port Elizabeth. The academy and these satellites are run by Gold Circle. There is an additional training centre based in Gauteng that is funded and administered by The Racing Trust. Apprentices begin their initial training at the Academy in Summerveld and are fed through to the other three training centres once they are competent at riding in races (The South African Jockey Academy, 2007a).

3.3 STUDY DESIGN

This was a cross-sectional, descriptive study including all male apprentice jockeys training at the SAJA in 2016. However, it can be noted that the study did involve some intervention as a hydration protocol was used to ensure euhydration for euhydrated measurements.

The study aimed to determine the accuracy of three methods of body composition analysis (BMI, skinfold method and BIA) when euhydrated and dehydrated compared to DD. It also investigated the weight-making techniques and the risk of developing eating disorders such as AN and BN.

A cross-sectional study involves the assessment of a population, which is represented by the study sample, at a single point in time. It is used to estimate the prevalence of a specific outcome/s in the population of interest. It typically involves survey research, such as questionnaires, which is a cost-effective method of data collection (Creswell, 2013).

The advantages include cost-effectiveness, timely data collection, the ability to control for multiple confounders, the ability to assess multiple outcomes at once and the use of individualised data (Thiese, 2014). A disadvantage is that temporality cannot be demonstrated, meaning that causation cannot be proven as both exposure and outcome are measured at the same time (Thiese, 2014).

A descriptive study is used to describe the characteristics of a population without manipulating the environment. It can therefore be used to identify patterns but not causation (Shields & Rangarajan, 2013).

The advantages are that there are relatively small ethical implications as the environment is not manipulated, although this study involved some intervention by the use of a hydration protocol; it is effective in the analysis of non-quantified topics and issues, and it offers the opportunity to observe a phenomenon in a completely natural or unchanged environment, as well as integrate both qualitative and quantitative methods of data collection (Dudovskiy, 2016). The disadvantage is that it is of low internal validity as it cannot be used to identify cause and effect (Dudovskiy, 2016).

A cross sectional descriptive design was appropriate for this study due to its low cost and timeliness and because it was not the intention of the study to identify causation. The study design allowed for the comparison of methods of measuring %BF, weight-making techniques and risk of eating disorders at the SAJA and did not require any manipulation of the environment or apprentices.

3.4 STUDY POPULATION AND SAMPLE SELECTION

Total population sampling was used in this study and all male jockey apprentices training at the Summerveld campus of the SAJA between June and September 2016 were invited to participate. Those that met the inclusion criteria were included.

3.4.1 Inclusion criteria

Male jockey apprentices enrolled in the apprenticeship program at the SAJA Summerveld campus during the duration of data collection were included in the study.

3.4.2 Exclusion criteria

Female apprentices were not included due to the small sample of female apprentices. Apprentices who left the academy or obtained their professional license during data collection were excluded from analysis. Apprentices with known disorders that could impact water balance, such as renal failure, and body composition, such as dwarfism or any amputations would have been excluded.

3.5 OUTCOME VARIABLES

These included demographics (age and race); USG, anthropometry (weight, height, BMI, skinfolds including biceps, triceps, subscapular, supra-iliac, abdominal, thigh and calf skinfolds), impedance values obtained from the BODYSTAT®1500 machine, and the Fourier-transform infrared spectroscopy results obtained from the DD technique in both a dehydrated and euhydrated state; the responses to the use of various weight-making and weight-control techniques according to the lifestyle questionnaire; and the EAT-26 scores of the apprentices.

3.6 CONFOUNDING VARIABLES

There were no confounding variables.

3.7 STUDY MATERIALS AND METHODS

Urine specific gravity, anthropometric measurements, BIA and DD were measured by the research team at 5am following an overnight fast on a rest day, which was usually a Sunday. These measurements were taken on two separate days: once when dehydrated, following no protocol to ensure dehydration, and again when euhydrated, following a euhydration protocol. Ensuring dehydration required no intervention in this population. The apprentices arrived at the first measurement session with a USG indicating dehydration due to chronic dehydration. Should they have arrived euhydrated on the first measurement session, a dehydration protocol would have been implemented for the next session, however this was not necessary.

3.7.1 Urine specific gravity

Urine specific gravity has previously been shown to be an accurate and reliable measure of hydration status (Bartok, Schoeller, Randall Clark, Sullivan & Landry, 2004; Armstrong, 2005; Oppliger, Magnes, Popowski & Gisolfi, 2005). Urine specific gravity was measured using a digital hand held pocket refractometer (ATAGO PAL-10S) prior to anthropometric measurements, BIA and DD.

A midstream urine sample was important for consistency and accuracy (Armstrong, 2005). To collect a midstream urine sample, the apprentices were required to first pass a small amount urine into the toilet and then, without stopping the urine flow, catch enough urine to quarter fill the sterile sample bottle provided. The sample bottle cap was replaced, the bottle washed and was given immediately to the fieldworker for analysis.

The fieldworker wore surgical gloves during testing. Prior to calibration, the device was switched on. To calibrate the device, it was set to zero before every test was done. Approximately 0.3 ml of tap water was placed on the prism surface of the device before zero-setting. Once “AAA” was displayed on the screen, the prism was wiped with two-ply tissue paper, water was applied and the zero button was pressed again. Once the screen displayed 1.000, confirming the zero setting, the prism was wiped clean again with tissue paper. Approximately 0.3 ml of the urine sample was then placed on the prism surface using a plastic spoon and, after about three seconds, a USG reading was obtained. This process was repeated and an average of the two readings was recorded on the data collection sheet (Appendix A). If the two readings differed by more than 0.001 g/ml, a third reading was taken and an average of the two closest readings was used.

The readings were interpreted according to the guidelines prescribed by Armstrong, Maresh, Castellani, Bergeron, Kenefick, LaGasse & Riebe (1994) and Casa *et al.* (2000), which classifies euhydration as a USG less than or equal to 1.020 g/ml (Armstrong *et al.*, 1994), a USG greater than 1.020 g/ml up to 1.030 g/ml as significant or moderate dehydration and a USG greater than 1.030 g/ml as serious or severe dehydration (Casa *et al.*, 2000).

3.7.2 Anthropometry measurements

3.7.2.1 *Weight*

A portable Seca 437 scale (50 g to 150 kg) was used to determine weight. The scale was calibrated prior to the study by SA Scales and was regularly checked during the study using a known 5 kg calibration weight (Avery) and placed on a stable level surface. The apprentices were weighed in their underwear after urination and having fasted overnight. The scale was first switched on and when 0.00 appeared the apprentices were instructed to step onto the centre of the scale, with their weight evenly distributed on both feet, and look directly ahead (Norton & Olds, 1996). Their weight was recorded on the data collection sheet (Appendix A). They were then asked to step off the scale. The scale was zeroed and the apprentice reweighed. If the readings differed by 100 g, the apprentice was weighed a third time and the average was taken of the two closest readings.

3.7.2.2 *Height*

The apprentices were asked to remove their shoes, socks and any head gear and then to stand on the baseboard of the stadiometer with their back against the stadiometer (height rod Seca 217, 20 to 205 cm) so that they were facing forward (Norton & Olds, 1996). They were instructed to stand erect with their feet together and flat on the centre of the base plate and their arms hanging naturally by their side. The back of their head, upper back, buttock and heels were in contact with the stadiometer. The fieldworker positioned their head in the vertical Frankfort plane. The apprentices were asked to deeply inhale and the headpiece was lowered onto their vertex. The reading was recorded in the data collection sheet (Appendix A). They were then asked to exhale. The measurement was repeated. If there was a difference of 0.2 cm, the reading was repeated a third time and the average of the two closest readings was used. For apprentices aged 19 years and younger, their height-for-age was classified according to the WHO (2007) Z-scores, as indicated in table 3.1.

<u>Table 3.1:</u> WHO (2007) growth indicator classification for children (19 years and younger)

<table>
<tr><th rowspan="2">Z score</th><th colspan="4">Growth Indicators</th></tr>
<tr><th>Length/height-for-age</th><th>Weight-for-age</th><th>Weight-for-length/height</th><th>BMI-for-age (5 to 19 years)</th></tr>
<tr><td>Above 3</td><td>Very tall – rarely a problem – maybe endocrine disorder</td><td rowspan="3">May be a growth problem but rather assess using weight for length/height or BMI-for-age</td><td>Obese</td><td>Obese</td></tr>
<tr><td>Above 2</td><td>Normal</td><td>Overweight</td><td>Obese</td></tr>
<tr><td>Above 1</td><td>Normal</td><td>Possible risk of overweight</td><td>Overweight</td></tr>
<tr><td>0 (median)</td><td>Normal</td><td>Normal</td><td>Normal</td><td>Normal</td></tr>
<tr><td>Below -1</td><td>Normal</td><td>Normal</td><td>Normal</td><td>Normal</td></tr>
<tr><td>Below -2</td><td>Stunted</td><td>Underweight</td><td>Wasted</td><td>Wasted</td></tr>
<tr><td>Below -3</td><td>Severely stunted</td><td>Severely underweight</td><td>Severely wasted</td><td>Severely wasted</td></tr>
</table>

3.7.2.3 *Body mass index calculations and equations*

The BMI was calculated by dividing their weight in kilograms (kg) by their height in meters squared (m^2) as below.

BMI (kg/m^2) = weight (kg)/height squared (m^2)

The BMI of the apprentices aged 19 years and younger was classified according to the WHO (2007) Z-scores as indicated in Table 3.1. A BMI less than 18.5 kg/m^2 is classified as underweight, with 17.0 to 18.49 kg/m^2 indicating mild thinness or malnutrition, 16.0 to 16.9 kg/m^2 indicating moderate thinness or malnutrition and less than 16 kg/m^2 indicating severe thinness or malnutrition.

The BMI of the apprentices aged 19 years and older was classified according to Ralph, Garrow & James (2000) as indicated in Table 3.2.

Table 3.2: Body mass index classification for adults (19 years and older) (Ralph *et al.*, 2000)

Classification	**BMI (kg/m^2)**
Underweight:	
Severe malnutrition	<16.0
Moderate malnutrition	16.0 - 16.9
Mild malnutrition	17.0 - 18.5
Normal weight	18.5 – 24.9
Overweight:	
Pre-obese	25.0 - 29.9
Obese:	
Obese class I	30.0 – 34.9
Obese class II	35.0 – 39.9
Obese class III	≥40.0

The equation by Deurenberg *et al.* (1991c) was used to calculate %BF from BMI, as seen in Table 3.3. The BMI equation by Gallagher *et al.* (2000) was considered to calculate %BF however the mean age of the males included was 51.4, 46.7 and 48.1 years for black, Asian and white groups respectively, which does not match that of the jockey apprentices.

Table 3.3: Equation used to calculate percent body fat from body mass index

Name	**Age (years)**	**Equation**

Deurenberg *et al.* (1991c)	≥15	%BF = 1.20BMI + 0.23A - 10.8S – 5.4

BMI: Body mass index (kg/m^2). A: Age (years). S: Sex, where male = 1 and female = 0.

The Deurenberg *et al.* (1991c) equation has not been validated in the jockey or apprentice population. Body mass index requires a simple calculation involving measurements which are measured routinely at the SAJA. It may therefore be a practical and inexpensive alternative to measuring %BF at the SAJA if proven to be accurate.

3.7.3 Skinfold method

The skinfolds method is a portable, quick and cost-effective method of measuring %BF (Ackland *et al.*, 2012). It is currently used to measure %BF at the SAJA and has also been used in several studies involving jockeys (Labadarios *et al.*, 1993; Dolan *et al.*, 2009; Warrington *et al.*, 2009; Dolan *et al.*, 2013; O'Reilly *et al.*, 2017).

Labadarios *et al.* (1993) did not specify the skinfold equation applied to four skinfold measurements, namely the triceps, biceps, subscapular and supra-iliac. Dolan *et al.* (2009), Warrington *et al.* (2009) and Dolan *et al.* (2013) used the Withers *et al.* (1987) equation, involving seven skinfolds (biceps, triceps, subscapular, supra-iliac, abdominal, mid-thigh and medial calf) to predict BD and the Siri (1956) equation used to estimate %BF from BD. O'Reilly *et al.* (2017) used the Durnin & Womersley (1974) equation involving four skinfold measurements (biceps, triceps, subscapular, supra-iliac), however the equation used to translate BD into %BF was not specified.

The skinfold method is based on the assumption that there is a fixed relationship between subcutaneous adipose tissue (SAT) at specific skin sites and total body fat (TBF) (Ball *et al.*, 2006). This relationship has been found to be influenced by age and sex (Durnin & Womersley, 1974), which is why most regression equations include these variables, as well as race (Vickery *et al.*, 1988; Wagner & Heyward, 2000), adiposity (Beddoe & Samat, 1998) and dehydration (Konings, Kooman, Schonck, van Kreel, Heidendal, Cheriex, van der Sande & Leunissen, 2003; Demirkan *et al.*, 2014). Accuracy is also affected by the measurement technique of the observer, interobserver variability, the number of sites measured (Hume & Marfell-Jones, 2008) as well as the equations used (Sinning *et al.*, 1985).

The skinfold measurements in the current study were all taken by the same biokineticist (Mrs Tarryn Mason, tarrynsneydsajeri@gmail.com) trained in the techniques of the International Society for the Advancement of Kinanthropometry (ISAK) in order to control for inter-observer variability and to ensure that the measurements were reliable. For all measurements using the measuring tape (Mabel), the measurer's eyes were at the same level as the tape to avoid any error of parallax.

Metal callipers (Lange) were used, as seen in figure 3.1, and were calibrated by Ross Calibration Services (rosco1@lantic.net) prior to data collection.

Figure 3.1: Lange metal callipers

The following technique was applied to measure all skinfolds once the site had been located and marked (as described in sections 3.8.3.1 to 3.8.3.7):

The nearest edge of the calliper contact faces were applied one centimetre away from the edge of the thumb and finger. The nearest edge of the calliper contact faces were applied one centimetre away from the edge of the thumb and finger. The calliper was held at 90° to the surface of the skinfold site and the measurement was read vertically above the fold two seconds after the full pressure of the calliper was applied. The skinfold was then released. The measurement was repeated. If there was a difference of 1 mm in the readings, a third measurement was taken and the mean of the two closest readings were used (Marfell-Jones, Stewart & De Ridder, 2012). The measurements were recorded on the data collection sheet (Appendix A).

Each skinfold measurement was marked and measured as follows:

The images provided were used with the permission of Professor Kevin Norton (kevin.norton@unisa.edu.au), the secretary-general of ISAK.

3.7.3.1 *Triceps skinfold*

The apprentice was asked to stand erect, with arms at his side and palms facing forward in the correct anatomical position. The biokineticist stood behind and on the right side of the apprentice. The acromiale and radiale landmarks were first located and marked.

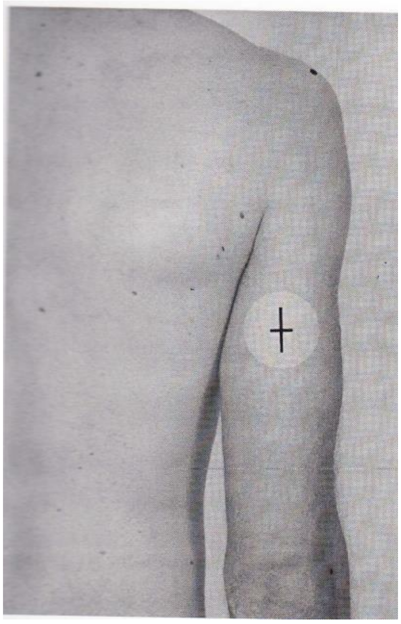
The biokineticist palpated along the spine of the scapula to the corner of the acromion, which is the start of the lateral border which usually runs anteriorly, slightly superiorly and medially. To confirm the location of the most lateral part of the border (the most lateral aspect), the straight edge of a pencil was applied to the lateral and superior margin of the acromion. The top margin was then palpated superiorly in line with the most lateral aspect and the acromiale site was marked with a dot on the superior point using a felt tip pen, as seen in figure 3.2 (Marfell-Jones *et al.*, 2012).

She then palpated downward into the lateral dimple of the right elbow to find the space between the capitulum of the humerus and the head of the radius. A dot was marked perpendicular to the long axis of the forearm, at the most lateral part of the proximal radial head, as seen in figure 3.2. This is the radiale landmark (Marfell-Jones *et al.*, 2012).

The distance between the acromiale and radiale landmarks on the right arm was measured using a measuring tape (Mabel) with the arm relaxed and extended by the side and the mid-acromiale-radiale site was marked with a horizontal line. This mark was projected around to the posterior and anterior surfaces of the arm as a horizontal line. The mark on the anterior surface would be used to mark the biceps skinfold site.

The triceps skinfold site was marked over the most posterior part by intersecting the projected line with a vertical line in the middle of the arm when viewed from behind (Marfell-Jones *et al.*, 2012), as illustrated in figure 3.2.

Figure 3.2: Triceps skinfold site® (ISAK, 2011)

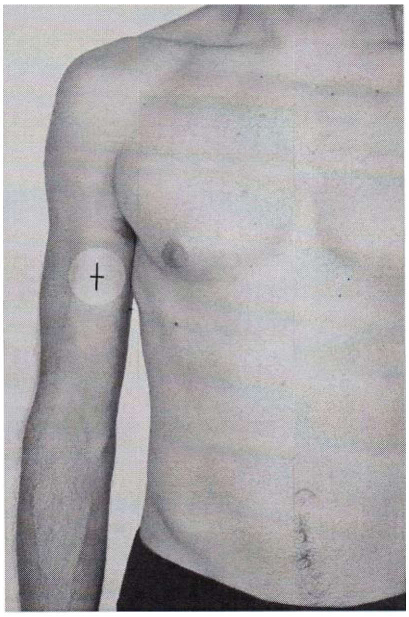


To measure the triceps skinfold thickness, the apprentice first assumed a relaxed standing position with the left arm hanging by the side and the right arm relaxed with the shoulder joint slightly externally rotated and elbow extended by the side of the body. The skinfold was picked up on the marked horizontal line, parallel to the long axis of the arm.

3.7.3.2 *Biceps skinfold site*

The biceps skinfold site was marked by intersecting the line projected on the posterior surface from the mid-acromiale-radiale site with a vertical line in the middle of the muscle belly with a felt tip pen when viewed from the front (Marfell-Jones *et al.*, 2012), as illustrated in Figure 3.3.

Figure 3.3: Biceps skinfold site® (ISAK, 2011)

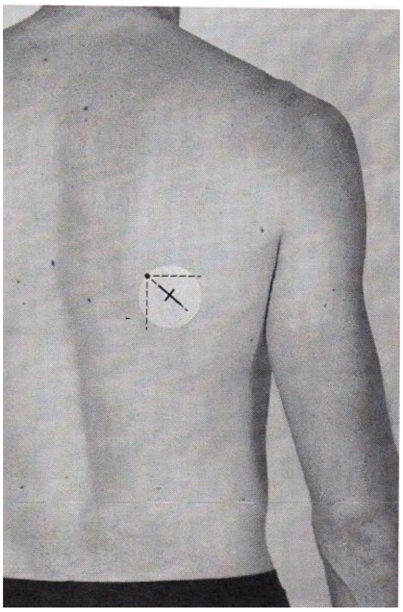


To measure the biceps skinfold thickness, the apprentice remained in the same anatomical position as for the triceps skinfold measurement. The skinfold picked up was parallel to the long axis of the arm.

3.7.3.3 *Subscapular skinfold*

The apprentice remained in the anatomical position. The inferior angle of the scapula was palpated with the left thumb and the undermost point, called the subscapulare, was marked with a dot with a felt tip pen. A line was drawn from the subscapulare mark laterally downward at a 45° angle. Another line was drawn perpendicular to this at a point 2 cm from the subscapular (Marfell-Jones *et al.*, 2012). This mark is illustrated in Figure 3.4.

Figure 3.4: Subscapulare® skinfold site (ISAK, 2011)

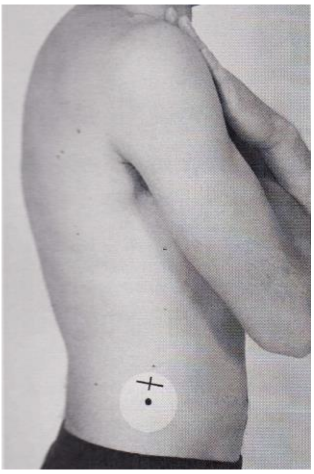


To measure the subscapular skinfold thickness, the apprentice assumed a relaxed standing position with the arms hanging by the sides. The line of the skinfold was determined by the natural fold lines of the skin. The skinfold was picked up on the marked horizontal line, parallel to the long axis of the arm.

3.7.3.4 *Supra-iliac skinfold site*

The apprentice was asked to stand in a relaxed position with the left arm hanging by the side and the right arm abducted to the horizontal. The iliocristale was first located by palpating the top of the iliac crest horizontally with the tips of the fingers to find the superior aspect of the crest. A dot was drawn at the level of the crest, vertically below the midpoint of the axilla, as seen in Figure 4.4. The biokineticist placed her left thumb on the tip of the iliocristale and raised the skinfold superior to the mark, between the thumb and index finger of the left hand. The centre of the raised skinfold was then marked with a cross (Marfell-Jones *et al.*, 2012). This is illustrated in figure 4.5.

Figure 3.5: The supra-iliac skinfold site (ISAK, 2011)

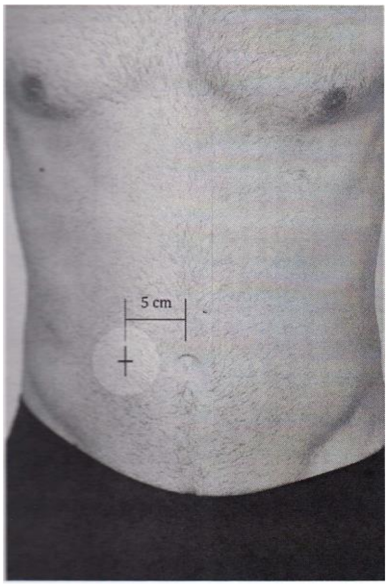


To measure the supra-iliac skinfold thickness, the apprentice assumed a relaxed standing position with the left arm hanging by the side and the right arm either abducted or placed across the trunk. The line of the skinfold picked up ran slightly downward posterior-anterior, as determined by the natural fold lines of the skin.

3.7.3.5 *Abdominal skinfold site*

The apprentice remained in the anatomical position. The abdominal skinfold site was marked with a cross five cm to the right hand side of the omphalion, which is the midpoint of the navel (Marfell-Jones *et al.*, 2012), as illustrated in Figure 4.6.

Figure 3.6: Abdominal skinfold site® (ISAK 2011)

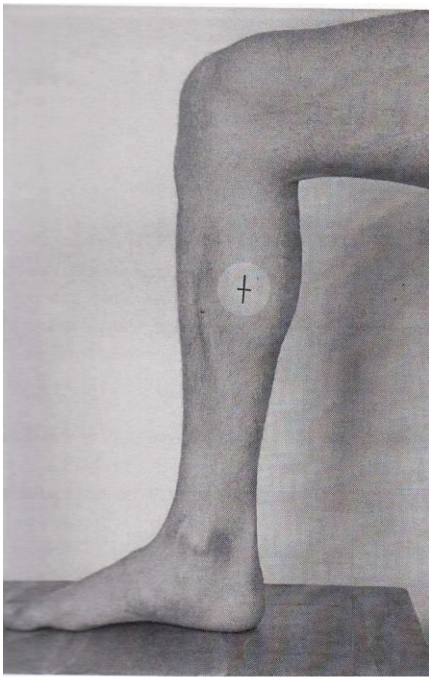


To measure the abdominal skinfold thickness, the apprentice assumed a relaxed standing position with the arms hanging by the sides. The skinfold picked up was vertical. Care was taken to ensure the initial grasp was firm and broad since often the underlying musculature is poorly developed which may result in an underestimation of the thickness of the subcutaneous layer of tissue.

3.7.3.6 *Medial calf skinfold site*

The apprentice stood with his foot raised and placed on a platform so that the calf was perpendicular to the thigh. The maximal girth of the calf was located and marked by manipulating the position of the measuring tape with the middle fingers in a series of up or down measurements. A short horizontal line was marked on the most medial aspect of the calf on the inside of the leg at the level of the maximal girth. A vertical line was then marked on the medial aspect of the calf to indicate the skinfold site (Marfell-Jones *et al.*, 2012). This mark is illustrated in Figure 4.7.

Figure 3.7: Medial calf skinfold site® (ISAK, 2011)

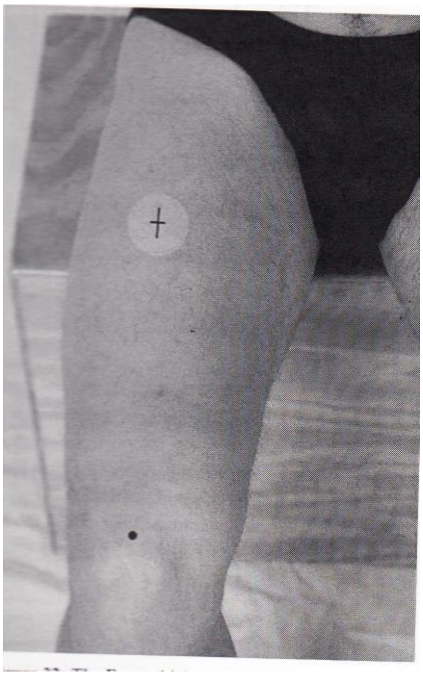


To measure the medial calf skinfold thickness, the apprentice assumed a relaxed standing position with the arms hanging by the sides and the right foot placed on a platform. The right knee was bent at about 90°. The skinfold pick up was parallel to the long axis of the leg. The nearest edge of the calliper contact faces were applied one centimetre away from the edge of the thumb and finger.

3.7.3.7 *Frontal thigh skinfold*

The apprentice was asked to assume a seated position with the torso erect and arms hanging by the sides. To measure the patellare, the biokineticist palpated the patella from the lateral and medial sides, working up to the superior border. The posterior surface was palpated through the patellar tendon. With the thumb nail of the biokineticist at the posterior border, the apprentice then flexed his knee to 90 º and the patellare site was marked with a dot, as seen in Figure 4.7. The biokineticist then stood facing the right side of the apprentice on the lateral side of the thigh. The measuring tape was placed on top of the right thigh with one end on the patellare and the other end on the inguinal point, which is the crease at the angle of the trunk and the anterior thigh. The distance between the two landmarks was measured and a short horizontal line made at the midpoint. Another line was drawn perpendicular to the horizontal line in the midline of the thigh. Caution was taken to avoid following the curvature of the surface of the skin with the measuring tape (Marfell-Jones *et al.*, 2012). The site is illustrated in Figure 4.8.

Figure 3.8: Front thigh skinfold site® (ISAK, 2011)



To measure the frontal thigh skinfold thickness, the apprentice assumed a seated position at the front edge of a seat with the torso erect and the arms hanging by the sides. The knee of the right leg was bent at a right angle. The biokineticist stood facing the right side of the apprentice on the lateral side of the thigh. The skinfold was raised one centimetre above the marked site.

3.7.3.8 *Equations to calculate percent body fat from skinfold measurements*

The skinfold measurements were substituted into various equations to calculate the %BF (Table 3.4). The biokineticist at the SAJA currently uses the four-skinfold equation which was retrieved from Topend Sports Network (2015) and attributed to Jackson & Pollock (1985), as it is the only equation that directly calculates %BF while including exact age as a variable in the equation. Although the equation cannot be found in the publication by Jackson & Pollock (1985), the reference to this equation has been confirmed by one of the authors, Dr A.S. Jackson (udde@me.com).

Table 3.4: Equations used to calculate percent body fat from skinfolds

Author/s	Recommended age range (years)	Equation [a]
Sloan (1967)	18 – 26	BD = 1.1043 – 0.001327(thigh) – 1.001310(subscapular)
Durnin & Rahaman (1967)	12 - 17	BD = 1.1533-0.0643(LOG sum biceps, triceps, subscapular, supra-iliac)
	18 - 30	BD = 1.1610-0.0632LOGΣ(biceps, triceps, subscapular, supra-iliac)
Forsyth & Sinning (1973)	19 – 22	BD = 1.103 – 0.00168(subscapular) – 0.00127(abdominal)
Durnin & Womersley (1974)	17 – 19	BD = 1.162 – 0.063(LOG sum biceps, triceps, subscapular, supra-iliac)
	20 – 29	BD = 1.1631 – 0.0632(LOG sum biceps, triceps, subscapular, supra-iliac)
Lohman (1981)	"college-age" [b]	BD = 1.0982 – 0.000815(sum triceps, abdominal, subscapular) + 0.0000084(sum triceps, abdominal, subscapular)^2
Jackson & Pollock (1985)	18 – 61	%BF = 0.29288(sum abdominal, triceps, thigh, supra-iliac) – 0.0005(sum abdominal, triceps, thigh, supra-iliac)^2 + 0.15845A – 5.76377
Withers *et al.* (1987)	15 – 39	BD = 1.0988 - 0.0004(sum triceps, biceps, subscapular, supra-iliac, abdominal, medial calf, thigh)
Slaughter *et al.* (1988)	8 – 18	%BF = 0.735(sum triceps and calf) + 1
Deurenberg *et al.* (1990)	7 – 20 [c]	2SF: BD = 1.1132 – 0.0410(LOG sum biceps and triceps)
		4SF: BD = 1.1324 – 0.0429(LOG sum biceps, triceps, supra-iliac, subscapular)
Peterson *et al.* (2003)	18 – 56	%BF = 20.94878 + 0.1166A - 0.11666Ht + 0.42696(sum triceps, subscapular, supra-iliac, thigh) - 0.00159(sum triceps, subscapular, supra-iliac, thigh)^2
Evans *et al.* (2005)	18 - 26	%BF = 8.997 + 0.24658(sum abdominal, thigh, triceps) – 6.343 – 1.998Ra

BD: Body density. n/a: Not applicable – race was not specified. %BF: Percent body fat. A: Age (years). Wt: Weight (kg). Ht: Height (cm). 3SF: Equation by author/s involving three skinfold measurements. 7SK: Equation by authors/s involving seven skinfold measurements. Ra: Race, where white = 0 and black = 1.

[a] Skinfolds measured in mm.

[b] Age range suggested is 18 to 24 years. Mean age was 20.4 years for the cross-validation sample with no standard deviation given.

[c] Equation used was recommended for post-pubescent males. Mean age of this group was 16.8 ± 36 (Deurenberg *et al.*, 1990).

Slaughter *et al.* (1988) and Deurenberg *et al.* (1990) proposed different skinfold equations according to maturation status using the classification described by Marshall & Tanner (1968) which is based on the extent of hair covering the pubic region in six stages (p1 to p6). Separate equations were proposed for pre-pubertal (p1 to p2), pubertal (p3 to p4), post-pubertal (p5 to p6) and adult (p6 onwards) subjects (see table 2.4). In the study by Slaughter *et al.* (1988), the mean age of the post-pubertal male subjects was 15.8 years and the mean age of the adult male subjects was 23.1 years, which would be age groups relevant to the jockey apprentices. Deurenberg *et al.* (1990) did not include subjects classified as adults according to Marshall & Tanner (1968). The mean age of the post-pubertal males in this study was 17.5 years and the maximum age was 20 years. For this reason, the equations indicated for post-pubertal males were applied to the apprentices younger than 20 years as maturation status was not measured. Slaughter *et al.* (1988) proposed equations for different maturation stages between ages eight and 18 years, however, it was found that maturation had no significant effect on %BF when the tricep and calf skinfolds were used instead of the subscapular and calf. For this reason, the equation using the tricep and calf was used.

All equations were only applied to the apprentices that fell into the recommended age group and compared to the mean value of the same group according to the reference method (DD).

The apprentices were divided into two age groups for the Durnin & Rahaman (1967) and Durnin & Womersley (1974) equations and the equations were applied according to age group.

The BD equations by Sloan (1967), Durnin & Rahaman (1967), Forsyth & Sinning (1973), Durnin & Womersley (1974), Lohman (1981), Withers *et al.* (1987) and Deurenberg *et al.* (1990) were translated into %BF using the BD equations by Siri (1961) and Brozek *et al.* (1963), as follows:

Siri (1961): $\%BF = (4.95/BD - 4.50) \times 100$

Brozek *et al.* (1963): $\%BF = (4.57/BD - 4.142) \times 100$

3.7.4 Bioelectric impedance analysis

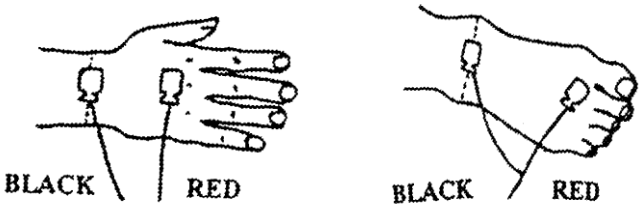
Bioelectric impedance analysis is another portable, quick and cost-effective method of measuring %BF, yet it is less invasive than the skinfold method, requires less training, and is not influenced by inter-observer variability (Ostojic, 2006). However, the accuracy of BIA for measuring %BF is more susceptible to the impact of fluid and electrolyte changes (Saunders *et al.*, 1998), which is a concern in the jockey apprentice population.

Bioelectrical impedance analysis uses the impedance of a conductor (the human body), which is the opposition to the flow of an alternating electric current comprising of both resistance (R) and reactivity (Xc), at specific frequency/frequencies to calculate %BF from body volume and length (Brodie *et al.*, 1998). Single-frequency BIA (SF-BIA) is a common method of BIA where the electrical current flows at a single frequency between electrodes to measure FFM and total body water (TBW) (Kyle *et al.*, 2004a). The BODYSTAT®1500 machine used in this study is an affordable SF-BIA device that uses a frequency of 50 kHz. Ghosh *et al.* (1997) validated the BODYSTAT®1500 machine against DXA in a study involving 160 participants, including healthy adults and adolescents as well as hospital patients, and reported satisfactory limits of agreement. The BODYSTAT®1500 has previously been used to measure the body composition of apprentices training at the SAJA for research purposes (Krog, 2015) although it has not been validated in the jockey population against a reference method.

The standard operating procedures (SOP) for the BODYSTAT®1500 were followed. The BODYSTAT®1500 uses Lock-in Signal Conversion Technology, meaning it cannot be self-calibrated. The calibrator supplied with the machine was used to independently verify that the unit remained in calibration prior to each day of data collection.

The apprentice removed any socks or gloves that would cover the electrode placement sites and any jewellery or metal accessories that could have interfered with the measurement. They then lay down on a plinth table in the supine position with no parts of the body touching one another. The skin on the back of the right hand and foot was cleaned with an alcohol swab in order to remove excess oil and sweat which might have influenced the reading due to reduced contact with the skin surface. BODYSTAT Ltd. electrodes were placed on the right hand (one behind the knuckle of the middle finger and one on the wrist next to the ulna head) and foot (one behind the second toe next to the big toe and one on the ankle at the level of and between the medial and lateral malleoli), as seen in Figure 4.8.

Figure 3.9: Diagram of electrode placement on right hand and foot (BodyStat, 2007)



The crocodile clips on the black cables were attached to the metal tab strip of the electrodes on the wrist next to the ulna head and ankle and the clips on the red cables were attached to the metal tab strip of the electrodes behind the knuckle of the middle finger and behind the second toe, as seen in Figure 3.9. The BODYSTAT®1500 unit was switched on. Gender, age, height and weight was keyed in. Waist and hip circumference and activity level were not keyed in as they did not influence the measurement. The apprentice remained in the supine position for approximately three minutes in order to allow for the body's fluid levels to stabilize before the measurement was performed. The *Enter* key was pressed to perform the measurement. The results were displayed on the LCD screen (%BF, lean body mass, TBW and impedance values) were recorded on the data sheet (Appendix A). The crocodile clips were disconnected from the electrodes. The test was repeated in exactly the same manner. If the %BF differed by more than one percent, the test was repeated for a third time and the mean of the two closest values was used.

3.7.4.1 *Equations used to calculate percent body fat from impedance*

The equation programmed into the BODYSTAT®1500 is not suitable for subjects younger than 18 years. Therefore, the BIA measurements of the apprentices who were younger than 18 years were downloaded onto the software provided with the BODYSTAT®1500 machine, The Bias Body Manager program. This program was used to apply another undisclosed regression equation to the BIA measurements of these apprentices. These measurements were recorded and used for data analysis.

To determine if equations other than that of the undisclosed equation of the BODYSTAT®1500 produced more accurate results, the impedance measurements were substituted into other age- and gender-appropriate equations (Table 3.5). The BODYSTAT®1500 machine however is not phase-sensitive, which means it measures impedance (Z) at a frequency of 50 KHz only, and does not measure resistance (R) and reactance (X) values separately. Although not recommended to be used interchangeably (Preedy, 2012), resistance values were substituted for Z values for the equations found in Table 3.5 using the same frequency as the BODYSTAT®1500. These values have been used interchangeably in a descriptive study by Meeuwsen, Horgan & Elia (2010a), where BODYSTAT®1500 impedance values were substituted into the equation by Sun *et al*. (2003), also given in Table 3.5. This study included 23 627 adults aged 18 to 99 years and aimed to determine the relationship between BMI and %BF. A strong correlation was seen between the %BF values given by the BODYSTAT®1500 and by substituting BODYSTAT®1500 impedance values into Sun *et al*. (2003) (r = 0.901).

All equations were only applied to the apprentices that fell into the recommended age group and compared to the mean value of the same group according to the reference method (DD).

Table 3.5: Equations used to calculate percent body fat from resistance

Author/s	**Recommended age range (years)**	**Equation**
Segal *et al.* (1988) [a]	17 – 62	$FFM = 0.0006636Ht^2 – 0.02117R_{50KHz} + 0.62854Wt – 0.1238A + 9.33285$
Gray *et al.* (1989)	19 – 74	$FFM = 0.00139Ht^2 – 0.0801 R_{50KHz} + 0.187Wt + 39.83$
Van Loan *et al.* (1990)	18 – 32	$FFM (kg) = 0.51Ht^2/R_{50KHz} + 0.33Wt + 1.69 + 3.66$
Deurenberg *et al*. (1991)	16 – 83	$FFM (kg) = 0.34Ht^2/ R_{50KHz} + 0.1534Ht + 0.273Wt - 0.127A + 4.56 - 12.44$
Lohman (1992)	18 – 29	$FFM (kg) = 0.485Ht^2/ R_{50KHz} + 0.338Wt + 5.32$
Houtkooper *et al.* (1992)	10 – 19	$FFM (kg) = 0.61Ht^2/ R_{50KHz} + 0.25Wt + 1.31$
Sun *et al*. (2003)	12 – 94	$FFM (kg) = 0.65Ht^2/R_{50KHz} + 0.26Wt + 0.02R_{50KHz} - 10.68$

Ht: Height (cm); R_{50KHz}: Resistance at a frequency of 50 KHz; FFM: Fat-free mass; Z_{50KHz}: Impedance at a frequency of 50 KHz.
[a] Equation recommended for males with a %BF less than 20% was used.

Percent body fat was determined by subtracting FFM from the apprentice's total weight to calculate fat mass (FM), and dividing by their total weight, as follows:

FM (kg) = Weight – FFM

%BF = FM/Weight x 100

Each of the methods (BMI, skinfolds and BIA), including each of the equations when both euhydrated and dehydrated, were then ranked in order of their agreement with DD (reference method). Due to the different age groups recommended for each equation, the %BF from each equation and from DD were compared as such. For example, since the BIA equation by Lohman (1992) was only used for apprentices 18 years and older, the DD results for the same apprentices were used to compare.

3.7.5 Deuterium dilution

Deuterium dilution was the reference method against which the accuracy of the BMI, skinfolds and BIA for predicting %BF were validated in this study. It has not previously been used in the jockey population. The technique has been validated against reference standards using 3-C and 4-C models in healthy subjects and is accepted as a reference method (Fuller *et al.*, 1992; Camarneiro, Júnior, Ciampo, Navarro, Antonucci & Monteiro, 2013). It is a costly method as it relies on the purchase of deuterium oxide, as well as expensive laboratory equipment and technical expertise, however the technique was used in this study as the local expertise, deuterium oxide and appropriate laboratory facilities were available.

The procedure followed was the SOP of the International Atomic Energy Agency (IAEA 2010)

3.7.5.1 *Preparation of the deuterium dose*

The preparation of the deuterium dose was done by the researcher who was trained in the techniques of deuterium dose preparation by laboratory technician Dr Helen Mulol, who has extensive experience in deuterium oxide and its applications due to its implementation in her doctoral study. The disposable wide mouth screw capped 60 ml plastic dosing bottles (EYDAM Thermo Scientific, Rochester), measuring cylinder (Glassco 50 ml) and 3 ml sterile Pasteur plastic pipette (EYDAM) used in this process were completely dry to avoid contamination by water. The doses were weighed to 0.001 g using a balance scale (BEL Mark 500) placed on a stable level surface. The scale was calibrated using a 200 g standard weight prior to use. The dosing bottle was placed on the weighing platform and the scale was tared. The deuterium oxide (SERCON Ltd UK Lot EB2039) was then poured into the dosing bottle using a measuring cylinder (Glassco 50 ml). The cylinder was not washed out between measuring the doses to avoid dilution of the deuterium. Excess solution was removed using a 3 ml dry sterile pipette until the deuterium solution added to the bottle weighed as close to 30.000 g as possible. During the process of weighing out the deuterium, the lid was replaced on the stock bottle of deuterium oxide to prevent loss by evaporation. The lid was tightly screwed on the dosing bottle which was labelled in indelible marking pen with the dose number. The date, dose number, batch number and exact weight of the deuterium solution, were recorded in a book. The deuterium samples were then stored upright at 4^{o}C in a refrigerator (LG GR389sQF) before use.

3.7.5.2 *Saliva collection*

The apprentices fasted overnight. Baseline saliva was collected immediately on arrival. Photographs of the data collection site can be seen in figures 3.10 and 3.11.

Figure 3.10: Photograph 1 of data collection site

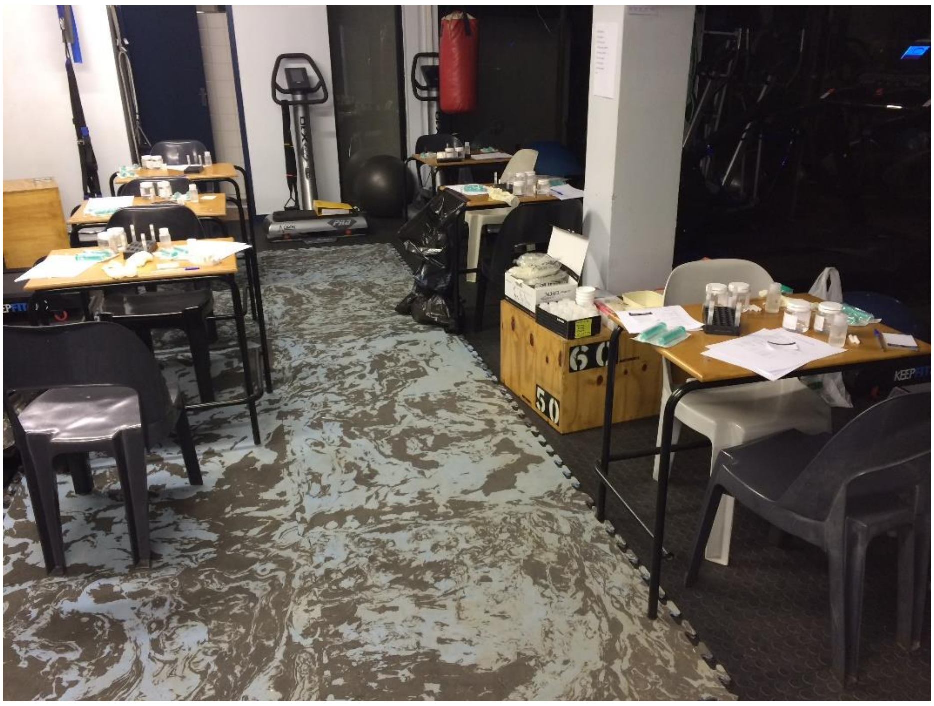


Figure 3.11: Photograph 2 of data collection site

The apprentices placed two dental cotton wool swabs (Henry Schein Dental Cotton Rolls) in their mouth which they sucked on until the swabs were wet with saliva. They were asked to move the swabs around their mouth and to keep their mouth closed during the process. The plunger was removed from a new 20 ml disposable syringe. The swabs were then transferred directly from the apprentice's mouth into a 20 ml syringe (Healthease Plus LUER SLIP). The plunger was replaced and the saliva from the swabs was syringed into a completely dry 4.5 ml cryovial (NUNC^{TM} CryoTube^{TM} Vials) labelled with the dose number of the deuterium that the apprentice consumed and whether the saliva sample was pre- or post-dosage. The cap was replaced on the cryovial and this process of collection was repeated until 4.5 ml of saliva had been collected. The cap was firmly replaced on the cryovial and the cryovial was placed in a separate zip lock bag. Each participant then drank the solution containing 30 g of deuterium oxide (SERCON Ltd UK Lot EB2039) from the dosing bottle (EYDAM Thermo Scientific, Rochester). Fifty ml of tap water was poured into the dosing bottle, the container lid was replaced and the bottle was inverted and then thoroughly shaken to ensure that any remaining deuterium was washed from the top and sides of the dosing bottle. The apprentice then drank this to ensure that no deuterium was remaining in the dosing bottle. A further 50 ml of tap water was placed in the dosing bottle and the procedure repeated. The time the deuterium dose was ingested was then noted in the apprentice's data collection sheet (Appendix A) and they were instructed not to eat or drink anything (including water and chewing gum) for the next four hours. They were also asked not to exercise or walk to prevent water from leaving the body via transdermal evaporation and rapid breathing as increased insensible water losses would increase the concentration of deuterium in the body and result in an overestimation of body fat. Most of the apprentices went back to sleep during this time. After four hours, the saliva was resampled using the technique described previously and the labelled post dose sample was placed together with the pre dose sample in one zip lock bag and labelled with the apprentice's dose number and the date. The saliva was kept at room temperature (20 to 28ºC) for a maximum of 6 hours before being frozen at –20ºC until analysis.

3.7.5.3 *Preparation of the calibration standards*

The calibration standard solution was prepared according to the IAEA SOP (International Atomic Energy Agency, 2010) by laboratory technician Dr Helen Mulol. The solution was to make a concentration of one gram of deuterium oxide per litre of water by weighing, as precisely as possible, one gram of deuterium oxide and diluting it with one litre of standard drinking water. A second litre of the standard drinking water was used as the zero standard. These solutions were placed in borosilicate bottles with polytetrafluoroethylene (PTFE) lined screw caps and kept in a cool, dark place separate from the deuterium oxide. To check the accuracy of the Fourier Transform Infrared Spectroscopy (FTIR) (FTIR IRPrestige-21 SHIMADZU) over a range of concentrations of deuterium, 100 ml standards were prepared according to the IAEA SOP. All standards were analysed in triplicate and a calibration curve was constructed.

3.7.5.4 *Measurement of the deuterium concentration in the saliva samples*

The deuterium content of the pre and post dose samples was measured by the researcher using the FTIR (FTIR IRPrestige-21 SHIMADZU) which was situated on a stable, level, independent surface in a well-ventilated, air conditioned, temperature (21ºC) and humidity controlled room at the Doris Duke Medical Research Institute (DDMRI). The machine was not exposed to vibration from any nearby instruments such as a centrifuge.

The saliva samples were thawed at room temperature and then centrifuged for 10 minutes at 1000 g (ALC PK 121 R multispeed refrigerated centrifuge). This was to remove condensation from the caps of the cryovials, to remove air bubbles and to ensure that any solid matter (remains of food or cotton wool used for sampling) settled at the bottom of the cryovial, leaving a clear liquid above which could be used for FTIR analysis.

The FTIR was prepared for measurement in accordance with the IAEA SOP. Before filling the cell, lint free tissue was used to clean the window of the cell. At least two millilitres of reference water was then syringed through the cell to remove all traces of the previous sample. Folded absorbent paper was then firmly pressed over the exit port of the cell to absorb excess sample and to prevent the entrance of air. The background standard (local drinking water) was then drawn up into a two ml disposable syringe and the cell was filled by attaching the syringe to the cell and firmly pressing the syringe plunger. Excess sample was removed from the outside of the cell using absorbent paper. The cell was held up to the light to check for air bubbles. More sample was syringed though the cell if there were air bubbles until all the air bubbles had been excluded. The cell was then placed in the FTIR and the absorbance measured at 2300-2900 cm^{-1}. On completion, the cell was removed from the FTIR and the syringe used for filling the cell was then used to remove the sample. This procedure was then repeated with the calibration standard to obtain the spectrum which was used to calibrate the software. The saliva samples were then analysed using the same technique. A pre-dose (background) saliva sample was run and then the post dose sample was analysed. The resulting FTIR spectrum was then compared to the calibration standard using the Medical Research Council software. A new one millilitre syringe was used for each sample to avoid cross contamination and the FTIR cell was flushed between samples to avoid any memory effect. The background and calibration standards were reanalysed in the middle and end of the batch to check the calibration of the FTIR. On completion of the batch of samples, the cell was thoroughly rinsed with drinking quality water before storing. During the entire process, care was taken to avoid evaporation by keeping the caps on the cryovials/bottles at all times and only removing them to access the sample/standard.

3.7.5.5 *Calculation of body composition*

Deuterium is a stable (non-radioactive) isotope of hydrogen, with the symbol ^2H. It is given orally as deuterium oxide (D_2O). V_D is the volume of distribution.

The dilution space of $^2H(V_D)$ is 4.1% higher than total body water (TBW) due to the exchange of hydrogen (H) with non-aqueous H in the body.

TBW (kg) = $V_D/1.041$

Where V_D (kg) = Dose D_2O (mg)/enrichment ^2H in saliva (mg/kg)

The hydration of FFM is assumed to be 73.2% in adults:

FFM (kg) = TBW (kg)/0.732

However, for males aged 15 to 16 years, the hydration of FFM is assumed to be 74.2%, and for males aged 17 to 20 years, 73.8% (Lohman, 1992).

Fat mass is calculated by the difference between body mass and fat-free mass:

FM (kg) = body mass (kg) – FFM (kg)

Results are often expressed as percent body weight.

%BF = FM (kg)/body mass (kg) x 100

The calculations were done by the researcher.

3.7.5.6 *Classification of percent body fat*

The lower limit of body fat (essential fat) for healthy active men of four to six percent was used to identify apprentices in the "essential" category (Friedl *et al.*, 1994).

The %BF-for-age percentiles established by Borrud *et al.* (2011) were used to classify the apprentices younger than 20 years, as indicated in table 3.6. For those aged 20 years and older, the healthy range of eight to 20 percent set out by Gallagher *et al.* (2000) was used to classify %BF, as indicated in table 3.7. There is no established minimum %BF for jockeys or apprentices.

Table 3.6: Percent body fat classification of apprentices younger than 20 years (Borrud *et al.*, 2011)

Age (years)	**Underfat (%)**	**Normal (%)**	**Overfat (%)**	**Obese (%)**
Percentile	**< 5th**	**5th ≤ %BF < 85th**	**85th ≤ %BF < 95th**	**≥ 95th**
16.00 – 16.49	<13.8	13.8 ≤ %BF < 31.2	31.2 ≤ %BF < 37.8	≥37.8
16.50 – 16.99	<13.7	13.7 ≤ %BF < 31.1	31.1 ≤ %BF < 37.6	≥37.6
17.00 – 17.49	<13.7	13.7 ≤ %BF < 31.1	31.1 ≤ %BF < 37.3	≥37.3
17.50 – 17.99	<13.7	13.7 ≤ %BF < 31.1	31.1 ≤ %BF < 37.2	≥37.2
18.00 – 18.49	<13.8	13.8 ≤ %BF < 31.1	31.1 ≤ %BF < 37.0	≥37.0
18.50 – 18.99	<13.8	13.8 ≤ %BF < 31.2	31.2 ≤ %BF < 37.0	≥37.0
19.00 – 19.49	<13.9	13.9 ≤ %BF < 31.3	31.3 ≤ %BF < 37.0	≥37.0
19.50 – 19.99	<13.8	13.8 ≤ %BF < 31.2	31.2 ≤ %BF < 36.9	≥36.9

Table 3.7: Percent body fat classification of apprentices 20 years and older (Gallagher *et al.*, 2000)

Classification	**%BF**
Underfat	< 8%
Normal	8 – 20 %
Overfat	> 20 %
Obese	> 30 %

3.7.6 Classification of fat mass index and fat-free mass index

The FMI and FFMI was initially proposed by VanItallie, Yang, Heymsfield, Funk & Boileau (1990) as a means of classifying various degrees of overweight and obesity, as well as chronic energy or protein deficit. These follow the same principle as the BMI with the advantage of taking body composition into account.

The FMI was calculated by dividing the FM by the height squared as follows:

FMI = FM (kg)/height (m)^2

The FFMI was calculated by dividing the FFM by the height squared as follows:

FFMI = FFM (kg)/height (m)^2

The FMI and FFMI of the apprentices younger than 18 years was classified according to the cut-off points given by Weber, Moore, Leonard & Zemel (2013) which corresponds to the classical BMI cut-off points set out by WHO (2007). These were generated from cross-sectional body-composition data measured by DXA from NHANES. The FMI and FFMI of those 18 years and older was classified according to the cut-off points given by Schutz, Kyle & Pichard (2002) which correspond to the classical BMI cut-off points set out by WHO (2014). These were based on values determined by SF-BIA and cross-validated by DXA. However, it must be noted that the cut-off points set out by Weber *et al.* (2013) also extend to 21 years of age with notably higher cut-off values for FMI and lower cut-off values for FFMI than that of Schutz *et al.* (2002). Tables 3.8 and 3.9 indicate the FMI and FFMI cut-off values used respectively. Upper limits of FFMI are not of interest because high levels of FFM, when euhydrated, are not associated with negative health effects (Kyle, Schutz, Dupertuis & Pichard, 2003).

Table 3.8: Fat mass index classification for males aged 16 years and older (Schutz *et al.*, 2002; Weber *et al.*, 2013) [a]

Age (years)	16.0–16.99	17.0–17.99	≥18
Underfat	<2.7	<2.7	<1.8
Normal	2.7 – 6.8	2.7 – 6.9	1.8 - 5.2
Overfat	>6.8	>6.9	> 5.2

[a] FMI given in kg/m^2.

Table 3.9: Fat-free mass index classification for males aged 16 years and older (Schutz *et al.*, 2002; Weber *et al.*, 2013) [a]

Age (years)	16.0–16.49	16.5-16.99	17.0–17.49	17.5-17.99	≥18
Under lean	<13.8	<14.1	<14.3	<14.4	<16.7
Normal	≥13.8	≥14.1	≥14.3	≥14.4	≥16.7

[a] FMI given in kg/m^2.

3.7.7 Lifestyle questionnaire

The advantages of using questionnaires are that they are relatively inexpensive and are quick to administer. They are also usually relatively simple to analyse if well-constructed. The disadvantages are that it is assumed that both the respondents and the researcher are able to interpret wording in a similar manner and share the same underlying assumptions about language (Bowling, 2014). Establishing trust between the respondent and the researcher administering the questionnaire may also present a challenge which could result in false reporting if this trust is not sufficiently established.

A number of studies have used lifestyle questionnaires to evaluate the weight-making techniques used by the jockeys (Cotugna *et al.*, 2011; Cullen, 2014; Dolan *et al.*, 2011; King & Mezey, 1987; Krog, 2015; Labadarios *et al.*, 1993; Leydon & Wall, 2002; Moore *et al.*, 2002b; O'Reilly *et al.*, 2017; Wilson *et al.*, 2014). The questionnaire (Appendix B) used in this study was adapted from the questionnaire used in a study involving the SAJA apprentices (Krog, 2015). It is a modified version of a lifestyle questionnaire which was previously designed and tested on professional jockeys (Dolan *et al.*, 2011). The questionnaire was validated for content validity by a qualified statistician (Dr Gill Hendry, hendryfam@telkomsa.net). Content validity refers to the extent to which the questionnaire's scale items are relevant to measuring what the questionnaire intended to measure.

The questionnaire contained of 50 open- and closed-ended (Likert scale) questions. Closed-ended questions were selected due to the small amount of time required to administer and the ease of coding and analysis. However, this possibly limited the depth and spontaneity of the answers and may have introduced bias by forcing the apprentices to choose pre-established responses (Meadows, 2003). To limit this, open-ended questions were also used. The questionnaire was interviewer-administered by Mrs Sarah Olds (sareolds@gmail.com), a registered social worker in private practise, who had previously administered the adapted questionnaire to the SAJA apprentices in the study by Krog (2015). Following the pilot study however, the questionnaire was further adapted by the researcher as certain questions proved to be irrelevant and difficult to understand. Certain words such as "hypnosis" and "fasting" had to be explained and/or translated into simpler terms. Additionally, the questionnaire asked whether the apprentices avoided eating meals with the family, which was an irrelevant question as the apprentices ate at the academy and not at home.

It was administered to each apprentice individually to ensure confidentiality and to encourage honest responses. Providing surety of confidentiality as much as possible was crucial, which is why a qualified social worker who had administered a similar questionnaire to the apprentices was used. The advantages of interviewer-administration as opposed to self-administration by the apprentices, were that it allowed for the interviewer to clarify misunderstandings and probe for additional information, and the recording of information was not dependent on the respondent's level of literacy. However, this was a more time-consuming process and could have also caused the apprentices to be more reluctant to answer truthfully due to reduced anonymity (Meadows, 2003). Where applicable, participants were instructed to select as many options as deemed personally relevant.

The questions surrounding diet, health and lifestyle issues collected information regarding the physical activities the apprentices were involved in and for what purpose, the specific chronic weight-making techniques used such as avoiding foods with a high carbohydrate content, specific acute weight-making techniques such as using the sauna, as well as feelings of hunger and thirst.

3.7.8 Eating Attitudes Test questionnaire

The Eating Attitudes Test 26 (EAT-26) questionnaire was used to assess the risk of abnormal eating behaviours as it has been utilised in several studies to assess the risk of jockeys developing eating disorders (Garner & Garfinkel, 1979; King & Mezey, 1987; Leydon & Wall, 2002; Caulfield & Karageorghis, 2008; Wilson *et al.*, 2015).

The EAT-26 questionnaire is a well-validated and frequently used tool in the general female and non-athletic population. It was initially validated in a descriptive study involving a sample of 160 female subjects with diagnosed AN and 140 female comparison subjects with a mean age of 21.5 years (Garner, Olmsted, Bohr & Garfinkel, 1982). It was again validated in a descriptive study involving a sample of 207 female college athletes (Doninger, Enders & Burnett, 2005). Pope, Gao, Bolter & Pritchard (2015) reviewed 50 studies which investigated eating disorders in athletic populations, aged 18 to 26 years, and assessed the validity and reliability of several commonly used psychometric measures including the EAT-26, Eating Disorder Inventory (EDI), Bulimia Test-Revised (BULIT-R), Questionnaire for Eating Disorder Diagnosis (QEDD) and the Eating Disorder Examination Questionnaire (EDE-Q). The review concluded that all measures have largely been validated in non-athletic female populations but scarcely validated in athletic populations. The Eat-26 questionnaire was however the most commonly used measure for athletes. To date, no studies have validated the EAT-26 questionnaire in the male athletic or jockey population.

The EAT-26 questionnaire (Appendix C) is a three-part psychometric instrument designed to identify abnormal eating patterns and concerns about weight. It is divided into three sections: Part A, where the respondent's current weight, lowest adult weight, highest adult weight and ideal weight are recorded; Part B, which comprises the 26-item test from which the score is derived; and Part C, which comprises of behavioural questions. The questions included are closed-ended using the Likert scale, with the exception of section A. Part B is the most significant section, where scores range from zero to 78. This section was scored according to the question responses using the system described in table 3.10. A score of 20 or more may indicate the presence of an eating disorder however it is not a diagnostic test, but merely a screening tool used to detect abnormal or disordered eating patterns which indicate a risk of eating disorders. Part A is used to interpret the respondent's BMI, which may indicate a risk of eating disorder if the respondent is underweight. Part C is interpreted in terms of the frequency of behaviours which may indicate a risk of eating disorders (Garner & Garfinkel, 1979). If the apprentice selected any of the responses checked (√) in table 3.11 it was advised that they seek an evaluation from a trained mental health professional.

Table 3.10: Scoring system for Part B of the EAT-26 questionnaire

	Always	**Usually**	**Often**	**Sometimes**	**Rarely**	**Never**
Score for questions 1 – 25	3	2	1	0	0	0
Score for question 26	0	0	0	1	2	3

Table 3.11: Scoring system for Part C of the EAT-26 questionnaire

In the past 6 months have you:	Never	Once a month or less	2 – 3 times a month	Once a week	2 – 6 times a week	Once a day or more
Gone on eating binges where you feel that you may not be able to stop?	□	□	√	√	√	√
Vomited to control your weight or shape?	□	√	√	√	√	√
Used laxatives, diet pills or diuretics to control your weight or shape?	□	√	√	√	√	√
Exercised more than 60 minutes a day to lose or control your weight?	□	□	□	□	□	√
Lost 9 kg (20 pounds) or more?		Yes √			No □	

The EAT-26 questionnaire was interviewer-administered, consecutively after the lifestyle questionnaire by the same registered social worker. The same advantages and disadvantages of using questionnaires therefore applies to the EAT-26 questionnaire.

3.8 METHODOLOGY

3.8.1 Preliminary training

Prior to the pilot study, in order to minimise errors during data collection, the researcher was trained on the use of the BODYSTAT®1500 by the senior technician at UKZN (Mrs Elsie Correia, correia@ukzn.ac.za) who had extensive experience in the use of the machine. Training on anthropometrical measurements was not done due to the extensive experience of the research team, as well as the prior ISAK training of the biokineticist and two dietitians. The research team for this study is summarised in Table 3.10.

Table 3.12: The research team

Title	Affiliation	Role in the study
Dr C Biggs (Dietitian, ISAK trained	Lecturer, Department of Dietetics and Human Nutrition, UKZN, Pietermaritzburg Campus.	Supervisor of the MSc dissertation. Assisted in planning and implementation of the study and data collection including urine and saliva samples and anthropometric measurements.
Ms M Read (MSc Diet, ISAK trained)	Private practice (Read & Biggs Consultant Dieticians, readmandy@gmail.com)	Assisted in planning the study and data collection including urine and saliva samples and anthropometric measurements.
Mrs K Krog (MSc Diet)	Dietitian at the SAJA (kathleenkrogsajeri@gmail.com)	Liaised between the academy and research team - obtained permission for the study to take place at the SAJA, facilitated the collection of consent, assent, and parent permission forms. Assisted with data collection – weight, height and BIA measurements. Designed the hydration protocol and ensured that it was followed and issued the rehydration supplements.
Mrs T Mason (MSc biokineticist, ISAK trained)	Biokineticist at the SAJA	Solely responsible for the measurement of the seven skinfold sites and assistance in urine sampling.
Mrs S Olds (social worker)	Registered social worker and in private practise.	Administration of the Lifestyle and EAT-26 questionnaires.
Ms E Illidge (Dietitian)	Principle investigator. Department of Dietetics and Human Nutrition, UKZN, Pietermaritzburg Campus. Part-time MSc student.	Assisted in the planning and implementation of the study. Assisted with the saliva collection and BIA measurements, and responsible for the interpretation of the results and writing up for publication.

3.8.2 Pilot Study

The pilot study was conducted at the SAJA on 11 June 2016. The purpose was to test the feasibility of the methodology, the flow of data collection, clarify any misunderstandings and to ensure that all members of the research team were competent in their roles. Five participants who were healthy, active males of similar age to the apprentices, but not jockeys, were included. The procedure as outlined in the methodology was followed. The flow of data collection proved to be successful.

Some difficulties were encountered with the lifestyle questionnaire as some questions were irrelevant or difficult to understand. The questionnaire was adapted as previously described. During the pilot study, the participants discussed the questions amongst each other which may have impacted their responses. At this stage, it was decided to include the social worker on the team to administer both questionnaires on a separate occasion to data collection to ensure that there would be no discussion amongst the apprentices and that sufficient time and thought would be put into their answers.

3.8.3 Data collection

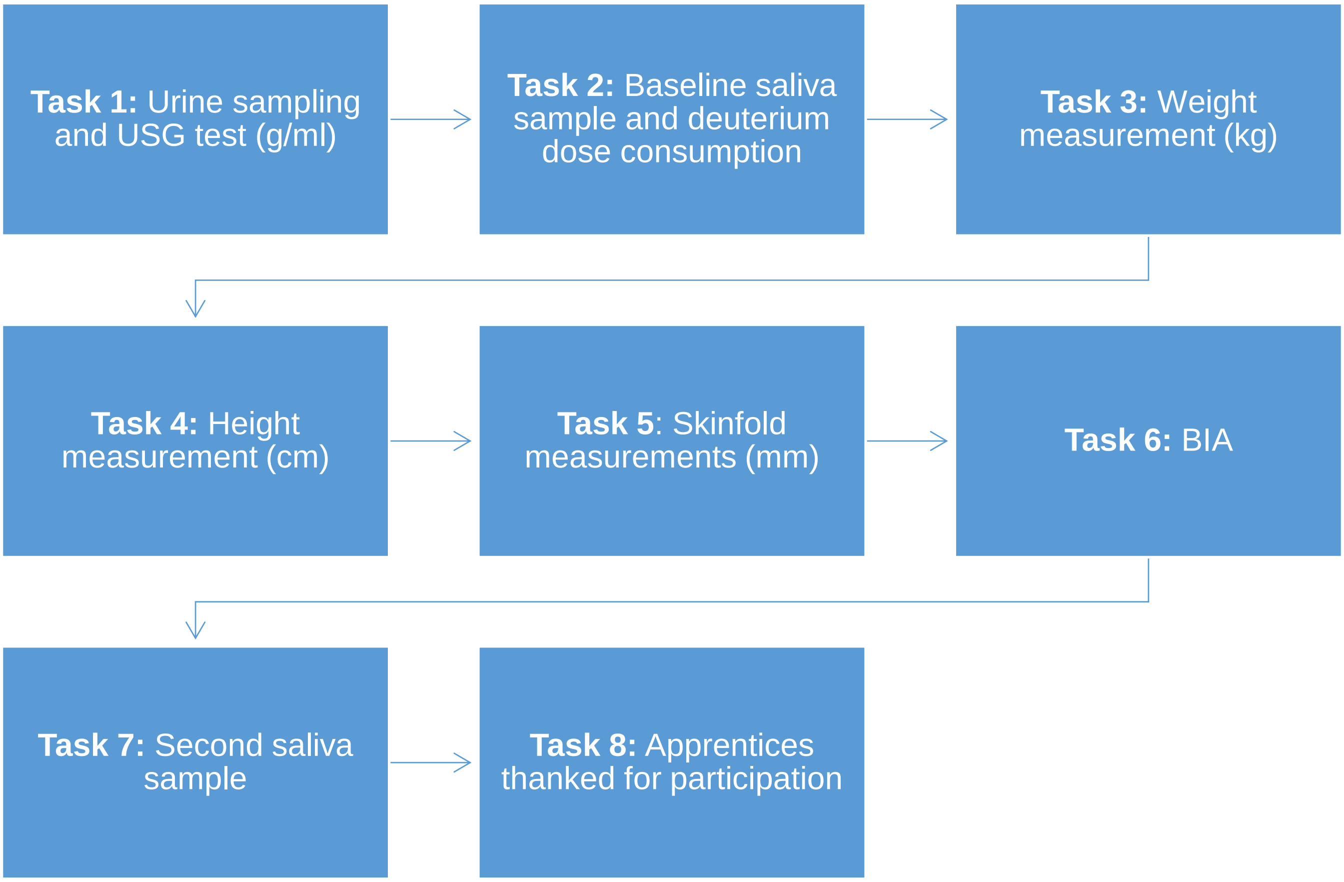
Prior to data collection, voluntary written informed consent was obtained from all participants 18 years and older (Appendix D1). Written informed consent was obtained from a parent or legal guardian of participants younger than 18 years (Appendix D2) as well as an assent form completed by those younger than 18 years (Appendix D3).

Data collection was scheduled on rest days (no work riding), which was usually a Sunday, and sometimes a Wednesday. Each apprentice was required to attend two sessions of data collection, one in a euhydrated state and the other in a dehydrated state. A wash-out period of at least a week between dehydrated and euhydrated sessions was ensured for each apprentice. The rehydration protocol (Appendix E) was followed for three days prior to the hydrated session. The SAJA dietitian issued each apprentice with a pack including two bottles of 500 ml Energade Lite, two cans of 330 ml diet cold drink (Coke Zero/ Lite), one 250 ml bottle of Future Life Smart Drink, one 30 g packet of Lays crisps and one 50 g Future Life Smart bar, to be consumed daily. The SAJA dietitian recorded the compliance of each apprentice to this protocol. The biokineticist measured the USG daily for the three days prior to euhydrated data collection to ensure the apprentices were euhydrated on the day of data collection.

No protocol was implemented prior to dehydrated measurements.

Data collection took place at 5 am following an overnight fast. The flow of data collection, following the euhydration protocol (if for euhydrated measurements) and an overnight fast, is illustrated in Figure 3.12. On arrival, the apprentices were asked if they had complied with the criteria regarding fasting overnight, which was a requirement for the techniques of both DD and BIA. They were then asked to supply a mid-stream urine sample for analysis of hydration status using a urine refractometer. The USG was immediately analysed to determine if they were in an appropriate state of hydration. If not another date for data collection was scheduled.

Figure 3.12: Diagram to show the flow of data collection on testing day



A baseline saliva sample was obtained. The apprentices were then weighed in minimal clothing (underwear), then their height was measured followed by their skinfold measurements and lastly the BIA. All measurements were repeated twice and were recorded on the data collection sheet (Appendix A). Once the measurements were complete, the apprentices returned to their dormitories to sleep after the researchers had confirmed that the apprentices knew the precise time that they needed to return to resample their saliva.

After four hours, their saliva was resampled and the apprentices attended breakfast in the academy dining hall. The labelled cryovials containing the pre- and post-dose saliva samples were placed into separate Ziploc bags and transported to DDMRI at stored in the freezer (-20 ºC) until analysis. On the first test occasion, the apprentices were thanked for their participation and a date was allocated for the second session. On the second occasion, the apprentices were thanked for their participation in the study and a method of conveying the results was established (email to the principle). The date for the questionnaires to be administered by the social worker was established and the apprentices were notified by the SAJA dietitian.

Both the lifestyle and EAT-26 questionnaires were administered consecutively and individually in an office at the SAJA by the social worker.

Once collection of saliva samples was complete, the samples were batch analysed using the FTIR. The FTIR results were recorded and double entered into the computer program Miscrosoft Office Excel 2013, along with the rest of the data for analysis.

3.8.4 Statistical analysis

The data was double entered by the researcher into the computer program Miscrosoft Office Excel 2013. The two data bases were compared to ensure that there were no input errors. The researcher checked the data for outliers and discrepancies. The cleaned database was then exported into Statistical Package for the Social Sciences (SPSS) version 24.0 and analysed by the statistician.

The statistical tests applied to each category of data are described in Table 3.11. Descriptive statistics, including means, standard deviations, range, frequencies and percentages (proportions) were used where data was normally distributed. Frequencies were represented in tables or graphs. All variables were tested for normality using the Shapiro-Wilk test (Shapiro & Wilk, 1965). Combined with the fact that some of the variables were shown to be non-normal and the sample size of 17 is considered small, it was decided to use the Wilcoxon signed ranks test (Wilcoxon, 1945), an equivalent non-parametric test for paired samples t-test, to compare two variables for a single group, being the %BF results of the field methods and DD. The Wilcoxon signed rank test reflects agreement, on average, between two measures at group level (Lombard, Steyn, Charlton & Senekal, 2015). A $p < 0.05$ indicated a significant difference. Correlations, such as Pearson or product-moment correlation, were not included as correlation studies the relationship between one variable and another, not the differences, and it is not recommended as a method for assessing the comparability between methods (Giavarina, 2015). Equations that showed no statistically significant difference from DD according to the Wilcoxon signed ranks test were further analysed using Bland-Altman plots to evaluate bias within the mean differences (Giavarina, 2015). The Binomial test was used to test whether a significant proportion of respondents selected one of a possible two responses. This was extended when data with more than two response options was split into two distinct groups. The Mann-Whitney test was used to test for association between two variables, being weight satisfaction and age, height, weight, BMI, %BF, FMI and FFMI. Chi-square goodness of fit test to test if any frequency response in the lifestyle questionnaire was selected significantly more often than others.

Table 3.13: Description of statistical tests used to analyse the data.

Data	Statistics test
Description of demographics and anthropometric characteristics of apprentices	Descriptive statistics including means, standard deviations and range, where applicable. Frequencies are represented in tables or graphs.
Comparison of %BF using BMI, skinfold and BIA equations in both euhydrated and dehydrated states to reference method.	Descriptive statistics including means and standard deviations, where applicable. Non-parametric Wilcoxon signed ranks test (equivalent to a paired t-test) to test for significant differences.
Evaluation of bias within mean differences between BMI, skinfold and BIA equations and reference method.	Bland-Altman plots to evaluate a bias within the mean differences.
Comparison of USG hydration measures on two occasions.	Non-parametric Wilcoxon signed ranks test (equivalent to a paired t-test) to test for significant differences.
Assessment of impact of hydration status on %BF scores for each method.	Non-parametric Wilcoxon signed ranks test (equivalent to a paired t-test) to test for significant differences between euhydrated and dehydrated measures.
Evaluation of apprentice participation in specific physical activities for specific reasons.	Binomial test to test if a significant proportion did an activity for a specific purpose.
Assessment of association between weight satisfaction and %BF (according to reference method), age, height, weight, BMI, FMI and FFMI.	Mann-Whitney test to test for association.

Evaluation of apprentice chronic weight-making (weight control) methods.	Descriptive statistics including frequencies and proportions (percentage) where applicable. Frequencies are represented in tables or graphs.
Evaluation of apprentice acute weight-making methods	Descriptive statistics including frequencies and proportions (percentage) where applicable. Frequencies are represented in tables or graphs.
Assessment of frequency of apprentice feelings of hunger and thirst	Chi-square goodness of fit test to test if any frequency response was selected significantly more often than others.
Assessment of apprentice risk of eating disorders according to EAT-26 questionnaire	Descriptive statistics including means and standard deviations, where applicable. Part A: Binomial test to test if a significant number were underweight. Part B: Binomial test to test if a significant proportion had a score above or below 20; descriptive statistics (percentage) to show proportion with a score of 20 or more. Part C: Binomial test to test if a significant proportion tick any of the behaviours that could indicate risk.

3.8.5 Reduction of bias

Bias is defined as any tendency which prevents unprejudiced consideration of a question and occurs in research when systematic error is introduced into sampling or testing by selecting or encouraging one outcome or answer over others (Pannucci & Wilkins, 2010).

For the purpose of this study, the reduction of bias is explained with regards to sampling, USG, anthropometry, BIA, DD and questionnaires.

3.8.5.1 *Sampling*

Total population sampling was used in this study. This is a type of purposive sampling technique where the entire population with a particular set of characteristics is examined (Lund Research, 2012). This type of sampling was chosen due to the small population size of jockey apprentices in KZN, since they must all train at the SAJA in order to obtain a license, as well as the unique characteristics of the population, in terms of physique and lifestyle habits.

This sampling technique reduces bias as it allows for wide coverage of the population of interest, reducing the risk of missing potential insights from members that are not included (Lund Research, 2012) .

3.8.5.2 *Urine specific gravity*

Urine specific gravity was measured to the nearest 0.001 g/ml using the same digital hand held pocket refractometer (ATAGO PAL-10S) for every apprentice. It was calibrated with tap water prior to every measurement. Each measurement was performed twice and an average of the two readings was recorded. If the two readings differed by more than 0.001 g/ml, a third reading was taken and an average of the two closest readings was used. All measurements were taken by the SAJA biokineticist, with extensive experience in USG measurement.

3.8.5.3 *Anthropometry*

Body weight was measured to the nearest 0.1 kg using a portable Seca 437 scale and height was measured to the nearest centimetre using a stadiometer in the SAJA gymnasium. The scale was calibrated prior to the study by SA Scales and was regularly checked during the study using a known 5 kg calibration weight (Avery) to minimise measurement errors. Skinfolds were measured using metal callipers (Lange) which were calibrated by Ross Calibration Services prior to data collection. All measurements were taken twice and the mean used in calculations. A third measurement was taken and the mean of the two closest readings recorded if the readings differed by more than 100 g, 0.2 cm, or 1 mm for weight, height and skinfold thickness respectively. Weight and height were taken by a registered dietician trained in taking anthropometric measurements. The skinfold measurements were taken by a biokineticist trained in the techniques of ISAK. This assisted with reduction of inter-observer error, however, bias between measurers is unavoidable. The same dietitian measured weight and height and the same biokineticist measured all of the skinfold measurements for each apprentice in order to control for inter-observer variability.

3.8.5.4 *Bioelectric impedance analysis*

The calibrator supplied with the BODYSTAT®1500 machine was used to independently verify that the unit remained in calibration prior to each day of data collection. The measurements were taken by the researcher following training by a senior technician at UKZN (Mrs Elsie Correia, correia@ukzn.ac.za) who had extensive experience in the use of the machine, in order to minimise errors during data collection.

3.8.5.5 *Deuterium dilution*

All deuterium doses were prepared to weigh as close to 30.000 g as possible using a balance scale (BEL Mark 500). The scale was calibrated using a 200 g standard weight prior to use. To ensure that no deuterium remained in the dosing bottle after drinking, the apprentice drank 100 ml tap water out of the dosing bottle in two separate doses. The samples were transferred to the DDMRI within a specified time and kept in the same freezer until analysis.

The FTIR was prepared for measurement in accordance with the IAEA SOP and was calibrated by laboratory technician Dr Helen Mulol, who has extensive experience in deuterium oxide and its applications due to its implementation in her doctoral study.

3.8.5.6 *Questionnaires*

Both the lifestyle and EAT-26 questionnaires were administered by a registered social worker with previous experience in administering a similar lifestyle questionnaire at the SAJA. Open- and closed-ended questions were included in both questionnaires. Closed-ended questions were selected due to the small amount of time required to administer and the ease of coding and analysis. However, this possibly limited the depth and spontaneity of the answers and may have introduced bias by forcing the apprentices to choose pre-established responses (Meadows, 2003). Where applicable, participants were instructed to select as many options as deemed personally relevant.

3.8.6 RELIABILITY

Reliability refers to the degree to which consistent results can be produced from repeated measurements (Hulley, Cummings, Browner, Grady & Newman, 2013). This was achieved by ensuring that all observers were competent in measurement, either by certification (ISAK for skinfold measurements, weight and height), previous experience and training (urinalysis, FTIR), or preliminary training (BODYSTAT®1500 machine); by calibrating measurement instruments such as the urine refractometer, weight scale, skinfold callipers, BODYSTAT®1500 machine and FTIR software; and by ensuring that the same field worker or researcher performed the same measurements. Standard operating procedures were followed for BIA and DD and ISAK procedures for skinfold measurement. The same measurement instruments were used throughout the study.

3.8.7 VALIDITY

Validity refers to the extent to which the results are accurate and the conclusions derived can be generalized (Hulley *et al.*, 2013). Content validity, which refers to whether the instruments measure the content they were intended to measure (Creswell, 2013), was ensured by using a validated reference method of measuring %BF, DD (Fuller *et al.*, 1992; Camarneiro *et al.*, 2013). Both questionnaires were validated for content validity by a qualified statistician, Dr Gill Hendry. The field methods assessed have also been validated in the general population, although none have been validated against a reference method in the jockey population. The skinfold equation by Durnin & Womersley (1974) has also been used in the professional jockey population before (O'Reilly *et al.*, 2017) and the BODYSTAT®1500 had been used in the SAJA apprentice population before (Krog, 2015). The lifestyle questionnaire used was adapted from a questionnaire that had been validated in the jockey population (Dolan *et al.*, 2011). The EAT-26 questionnaire has been well-validated and frequently used tool in the female and non-athletic population (Pope *et al.*, 2015) and has been utilised in several studies to assess the risk of jockeys developing eating disorders (Garner & Garfinkel, 1979; King & Mezey, 1987; Leydon & Wall, 2002; Caulfield & Karageorghis, 2008; Wilson *et al.*, 2015).

3.8.8 Ethical considerations

Permission to conduct the study at the SAJA was given by the principal, Mr Graham Bailey (Appendix F). Ethics approval was granted by the Biomedical Research Ethics Committee of the University of KwaZulu-Natal (BE212/16) in May 2016 (Appendix G) and approval of study amendment to compare hydrated and dehydrated results was granted in August 2016 (Appendix H).

Prior to data collection, the apprentices were informed in a group session by the SAJA dietitian of all aspects of the study, including the fact that participation was voluntary and that they were free to withdraw at any time during the study. Voluntary written informed consent was obtained from all participants 18 years and older prior to commencement of the study (Appendix H1). Written informed consent was obtained from a parent or legal guardian of participants younger than 18 years (Appendix H2) as well as an assent form completed by those younger than 18 years (Appendix H3). The benefits of participating in the study were indicated on the consent and assent forms, which included having an accurate measurement of %BF using a technique that is usually only available in advanced body composition research and that the research would assist the apprentice in achieving an optimal %BF by determining the most accurate available method of measuring %BF. It was also indicated of the consent and assent forms that there would be no possible risks to the apprentice for participating in the study.

The data base was password protected and can only be accessed by the researcher. The participants' files were stored in a secure locked cabinet and will be destroyed after a 5 year period.

The apprentices' identity was protected by the allocation of a study number which was used for all laboratory and data analysis.

Due to the delay between data collection from the apprentices and actual calculation of %BF, which was approximately 6 months, the apprentices did not receive feedback of their %BF results as they were no longer relevant. The apprentices were informed of their hydration results by the SAJA dietitian and action to promote better hydration practises were implemented accordingly.

CHAPTER 4: RESULTS

4.1 INTRODUCTION

This study measured the %BF of the jockey apprentices training at the SAJA. Percent body fat was obtained by using various regression equations in combination with BMI, skinfold measurements and BIA. These %BF values were compared to that of the DD technique (reference method) in both a dehydrated and euhydrated state to determine the impact of dehydration on the accuracy of each method.

A lifestyle questionnaire was used to determine the prevalence of use of weight-making and weight-control techniques. The prevalence of the risk of eating disorders was determined using the EAT-26 questionnaire.

4.2 RESPONSE RATE

The sample consisted of 17 of the 19 jockey apprentices who were training at the SAJA in Hillcrest during June to September 2016. One was unavailable to complete both the lifestyle and EAT-26 questionnaires due to riding commitments, therefore the sample for the questionnaires was 16 of 19 apprentices. Of those who did not take part, one obtained a professional licence and the other did not complete his apprenticeship, thus they were excluded. The response rate was 84% and therefore an adequate representation of the population.

4.3 SAMPLE DEMOGRAPHICS

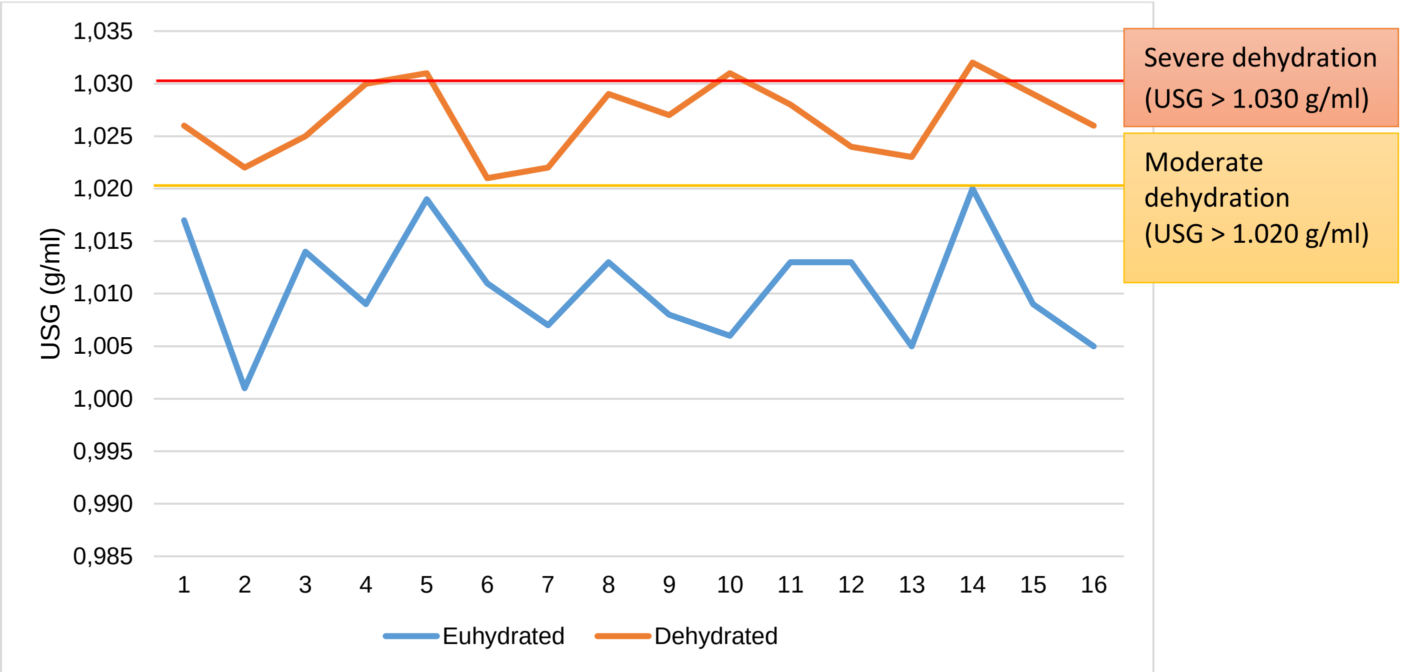
Almost half were white (47%, 8/17), followed by black (23%, 4/17), coloured (18%, 3/17) and Indian (12%, 2/17). The mean age was 18.8 years (SD± 1.7, range 16.1 - 23.1).

4.4 HYDRATION STATUS

Following the hydration protocol, the mean USG was 1.011 g/ml (SD± 0.005, range 1.001-1.020). The individual USG measurements when euhydrated are indicated in Figure 4.1.

The mean USG was significantly higher ($p < 0.001$) when dehydrated (1.027 g/ml, SD± 0.003, range 1.021-1.032). Nineteen percent (13/16) were severely dehydrated (Figure 4.1).

Figure 4.1: Line graph to show the urine specific gravity values of each apprentice when euhydrated (blue) and dehydrated (orange)



4.5 ANTHROPOMETRY

4.5.1 Height

The mean height was 1.62 m (SD± 0.06, range 1.52-1.72) which was significantly lower ($p < 0.001$) than the mean height of South African young adult males aged 15 to 24 years (1.69 m, range 1.68 - 1.69) according to the South African National Health and Nutrition Examination Survey of 2012 (Shisana *et al.*, 2014). Eighty-eight percent (15/17) fell below the average range.

For those 19 years or younger (10/17), 60% (6/10) were classified as moderately stunted (WHO 2007).

4.5.2 Weight

The mean weight when euhydrated was 50.4 kg (SD± 3.5, range 46.1 - 56.5), which was significantly higher ($p = 0.035$) than the mean weight when dehydrated (49.9 kg, SD± 3.3, range 44.5 - 55.5). In practical terms however the actual difference in weight was not very pronounced.

4.5.3 Body mass index

The mean BMI when euhydrated was 19.2 kg/m^2 (SD± 1.1, range 16.4 - 21.0), which was not significantly different from the BMI when dehydrated (19.0 kg/m^2, SD± 0.9, range 17.1 - 21.0). Only one (6%) was classified as moderately malnourished when measured euhydrated while the rest were classified as normal (Ralph *et al.*, 2000). For those 19 years or younger (10/16), all had a normal BMI for age.

4.6 ESTIMATION OF PERCENT BODY FAT

4.6.1 Body composition as determined by deuterium dilution

4.6.1.1 *Fat-free mass*

The mean FFM when euhydrated was 45.7 kg (SD± 3.5, range 40.1 – 53.4), which was significantly higher than when dehydrated (44.1 kg, SD± 3.5, range 38.1 – 50.4) ($p = 0.002$). Therefore the euhydrated FFM values were used to calculate the FFMI of 17.4 kg/m^2 (SD± 1.1, range 15.0 – 19.5). This was within the normal range[1].

There are different reference ranges for classifying the FFMI of those younger than 20 years and 18 years and older, namely those of Weber *et al.* (2013) and Schutz *et al.* (2002) respectively. The mean FFMI of those younger than 18 years (6/17) was 16.6 kg/m^2 (SD± 1.8, range 15.0 – 18.7), which was greater than the lower limit of normal for this age group (13.8 to 14.4 kg/m^2, depending on actual age) according to Weber *et al.* (2013) and none of the apprentices younger than 18 years were underlean. The mean FFMI of those 18 years and older (11/17) was 17.8 kg/m^2 (SD± 1.9, range 15.3 – 23.1), which was greater than the lower limit of normal for this age group (16.7 kg/m^2) according to Schutz *et al.* (2002). Eighteen percent (2/11) of those 18 years and older were classified as underlean. Overall, 18% (2/17) apprentices were classified as underlean according to their FFMI.

[1] Different lower limits were used for different age groups, for example the lower limit is 13.8 kg/m^2 for 16.0 - 16.49 years, whereas the lower limit for 18 years and older is 16.7 kg/m^2. High levels of FFM, when euhydrated, are not associated with negative health effects (Kyle *et al*., 2003), therefore no upper limit was used.

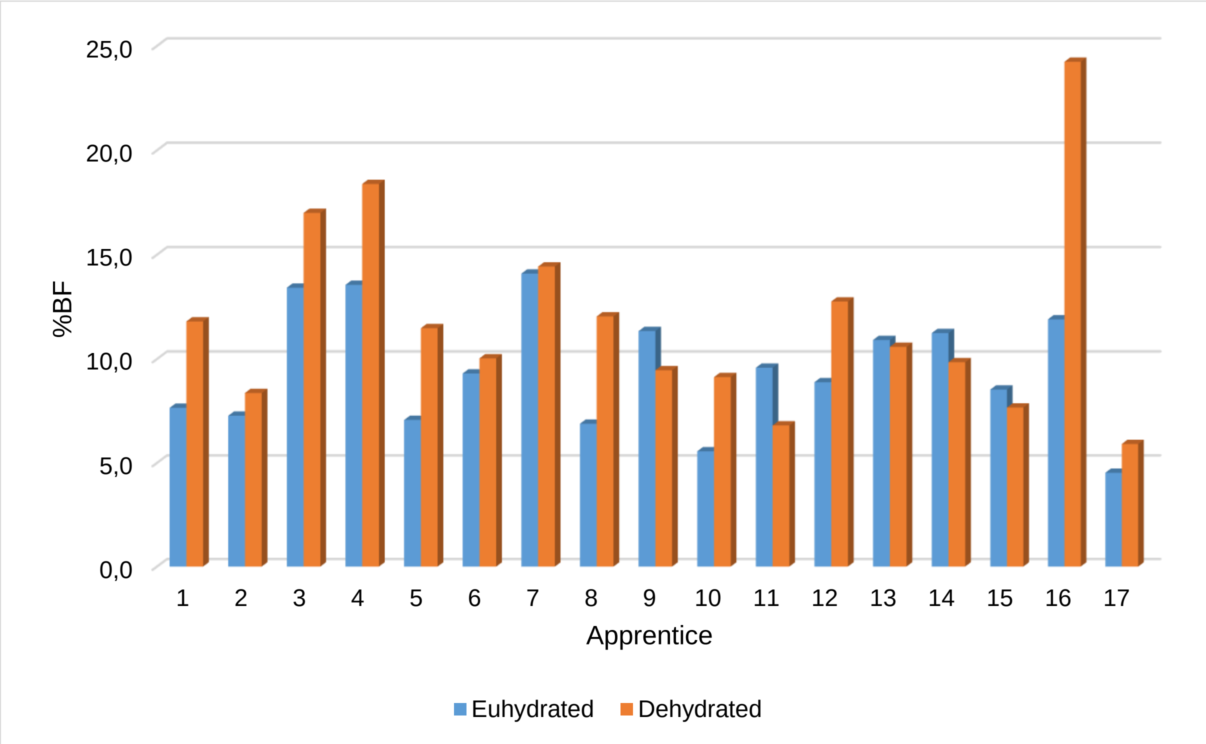
4.6.1.2 *Percent body fat and fat mass index*

The mean %BF of all the apprentices combined was 9.5 % (SD± 2.8, range 4.5 – 14.1), when euhydrated which was significantly lower than when dehydrated (11.8 %, SD± 4.6, range 5.9 – 24.2) ($p = 0.025$). Due to this difference, only the euhydrated DD (eDD) values were considered accurate and were therefore used as the reference standard for the other methods. The individual %BF according to DD when euhydrated and dehydrated are indicated in Figure 4.2. There was no significant correlation between %BF and BMI ($p = 0.793$).

Twelve percent (2/17) had a %BF within the "essential" fat range (3 - 6 %).

There are different reference ranges for classifying the %BF of those younger and older than 20 years namely those of Borrud *et al.* (2011) and Gallagher *et al.* (2000) respectively. The mean %BF of the apprentices who were younger than 20 years was 10.2 % (SD± 2.8, range 4.5 – 14.1), which was lower than the normal range (13.7 – 31.2 %) for this age group according to Borrud *et al.* (2011). Twelve of the 13 (92%) apprentices younger than 20 years, were underfat as their %BF fell below this normal range. The mean %BF of the apprentices 20 years and older was 7.3 % (SD± 1.2, range 5.6 – 11.9), which was also lower than the normal range (8.0 – 20.0 %) for this age group according to (Gallagher *et al.*, 2000). Three of the four (75%) apprentices 20 years and older were underfat, as their %BF fell below this normal range. Overall, 88% (15/17) of the apprentices were classified as underfat according to their %BF.

Figure 4.2: Column graph to show the percent body fat values of each apprentice according to deuterium dilution when euhydrated (blue) and dehydrated (orange).



The mean FM when euhydrated was 4.8 kg (SD± 1.4, range 2.2 – 7.2) which was significantly lower than when dehydrated (5.9 kg, SD± 2.4, range 2.9 – 13.3) ($p = 0.035$). Therefore the euhydrated FM values were used to calculate the FMI which was 1.8 kg/m^2 (SD± 0.6, range 0.8 – 2.7).

The classifications for FMI overlap between the ages of 18 and 21 years. Weber *et al.* (2013) recommends a minimum cut-off of 2.7 kg/m^2 for males aged 18 to 21 years, whereas Schutz *et al.* (2002) recommends a minimum cut-off of 1.8 kg/m^2 for males 18 to 72 years. Therefore, according to Weber *et al.* (2013), 89% (8/9) of the apprentices 18 to 21 years (9/17) were classified as underfat, whereas 56 % (5/9) of the apprentices from this age group were classified as underfat according to Schutz *et al.* (2002). This study uses the Weber *et al.* (2013) classification for those younger than 18 years, and the Schutz *et al.* (2002) classification for those 18 years and older.

The mean FMI for those younger than 18 years (6/17) was 1.8 kg/m^2 (SD± 0.7, range 0.8 – 2.7), which was lower than the normal range (2.7 – 6.8 kg/m^2) for this age group according to Weber *et al.* (2013) and 83% (5/6) were classified as underfat as their FMI fell below this range. The mean FMI for those 18 years and older (11/17) was 1.8 kg/m^2 (SD± 0.5, range 1.1 – 2.7), which was just within the normal range (1.8 – 5.2 kg/m^2) for this age group according to Schutz *et al.* (2002). Sixty-four percent (6/11) of those 18 years and older (11/17) were classified as underfat as their FMI fell below this normal range. Overall, 65% (11/17) were classified as underfat according to their FMI, which is less than that indicated by %BF according to Gallagher *et al.* (2000) and Borrud *et al.* (2011).

Therefore, different proportions of the apprentices were underfat depending on the classification as 88% were underfat according to %BF whereas 65% were underfat according to FMI.

4.6.2 Body Mass Index

The mean %BF as calculated by the BMI equation by Deurenberg *et al* (1991) was 11.2 % (SD± 1.5, range 9.1 – 13.9) euhydrated and 11.0 % (SD± 1.2, range 9.0 – 13.7) dehydrated. When euhydrated and dehydrated there were no significant differences relative to the reference method ($p = 0.062$ and $p = 0.076$ respectively). There were no significant differences between euhydrated and dehydrated %BF values determined by the BMI equation ($p = 0.083$).

4.6.3 Skinfold measurements

The results of the seven skinfold measurements are given in Table 4.1. Those not significantly impacted by dehydration are shaded in grey and include the biceps, subscapular, supra-iliac and the medial calf. The triceps, abdominal and frontal thigh sites all had significantly higher values when dehydrated.

Table 4.1: Measured mean values for seven skinfold measurements [a]

	Triceps	**Biceps**	**Subscapular**	**Supra-iliac**	**Abdominal**	**Medial calf**	**Frontal thigh**
Euhydrated	5.19 ± 1.48	3.46 ± 0.52	6.88 ± 1.08	5.44 ± 1.39	6.31 ± 1.42	5.18 ± 1.22	6.35 ± 1.49
Dehydrated	5.97 ± 2.14	3.66 ± 0.79	7.10 ± 1.25	5.24 ± 1.54	6.99 ± 2.36	4.96 ± 1.05	7.82 ± 2.16
P value [b]	0.046	0.172	0.510	0.076	0.049	0.230	0.013

[a] All values given in mm.
[b] A p value < 0.05 indicates a statistically significant difference.

4.6.3.1 *Euhydrated*

Of the 20 skinfold equation combinations, 15 (75%) were not significantly different to the reference method in the euhydrated state (Table 4.2). These are shaded in grey on Table 4.2. These were that of Sloan (1967); Durnin & Rahaman (1967); Forsyth & Sinning (1973); Durnin & Womersley (1974) and Withers *et al.* (1987) using either Siri (1961) or Brozek *et al.* (1963) to convert to %BF; Deurenberg *et al.* (1990) using two skinfolds with Siri (1961) or four skinfold measurements with either Siri (1961) or Brozek *et al.* (1963); as well as Slaughter *et al.* (1988)

4.6.3.2 *Dehydrated*

When dehydrated, 12 (60%) of the skinfold equation combinations were not significantly different to the reference method (Table 4.2). These were the same as when euhydrated with the exception of that of Withers *et al.* (1987) with either Siri (1961) or Brozek *et al.* (1963), and Deurenberg *et al.* (1990) using two with Brozek et al (1963). It would therefore be necessary to ensure euhydration prior to measurement when using these equations.

Table 4.2: The percent body fat results of the skinfold equations when euhydrated and dehydrated

		%BF (SD)									
		Euhydrated				**Dehydrated**				**Euhydrated vs dehydrated**	
		Indirect equations using BD and a conversion factor									
BD	**n**	**Siri (1961)**	**P value [a]**	**Brozek *et al.* (1963)**	**P value [a]**	**Siri (1961)**	**P value [a]**	**Brozek *et al.* (1963)**	**P value [a]**	**P value [b] Siri (1961)**	**P value [b] Brozek *et al.* (1963)**
Sloan (1967) [c]	11	10.4 ± 2.6	0.594	10.9 ± 2.4	0.182	12.2 ± 3.7	0.110	12.5 ± 3.4	0.075	0.017	0.017
Durnin & Rahaman (1967) [c]	17	10.7 ± 2.7	0.256	11.1 ± 2.5	0.093	11.1 ± 3.5	0.177	11.5 ± 3.3	0.124	0.115	0.115
Forth & Sinning (1973) [c]	6	7.3 ± 1.1	0.103	8.0 ± 1.1	0.227	6.6 ± 2.2	0.073	7.3 ± 2.0	0.147	0.025	0.023
Durnin & Womersley (1974) [c]	16	8.8 ± 1.7	0.266	9.3 ± 1.6	0.776	9.2 ± 2.6	0.717	9.7 ± 2.4	0.796	0.256	0.266
Lohman (1981) [c]	11	5.8 ± 0.5	0.004	6.6 ± 0.5	0.010	5.9 ± 0.9	0.007	6.7 ± 0.9	0.013	0.044	0.044
Withers *et al.* (1987) [c]	17	9.0 ± 1.2	0.332	9.6 ± 1.1	0.831	7.4 ± 1.5	0.011	8.1 ± 1.3	0.042	< 0.001	< 0.001
Deurenberg *et al.* (1990) two skinfolds (BD) [c]	16	10.4 ± 1.5	0.278	10.9 ± 1.4	0.098	11.2 ± 2.1	0.109	11.6 ± 2.0	0.030	0.063	0.063
Deurenberg *et al.* (1990) four skinfolds [c]	16	10.1 ± 1.1	0.796	10.6 ± 1.0	0.352	10.5 ± 1.7	0.501	10.9 ± 1.6	0.234	0.218	0.227

		%BF (SD)				
		Euhydrated		Dehydrated		Euhydrated vs dehydrated
		Direct equations to calculate %BF				P value **
Jackson & Pollock (1985)	11	3.9 ± 1.2	0.003	4.4 ± 1.7	0.004	0.002
Slaughter *et al.* (1988)	10	9.0 ± 1.8	0.445	9.7 ± 2.1	0.878	0.120
Peterson *et al.* (2003)	11	13.5 ± 1.5	0.003	14.0 ± 2.2	0.004	< 0.001
Evans *et al.* (2005)	11	6.5 ± 1.3	0.008	7.0 ± 1.6	0.018	0.002

BD: body density. %BF: percent body fat.
n varies due to different age groups recommended for different equations.
[a] $p < 0.05$ indicates significant difference from euhydrated DD, which means that the method is inaccurate.
[b] $p < 0.05$ indicates a significant difference between euhydrated and dehydrated values, which means that the equation is significantly influenced by hydration status.
[c] These equations were used to calculate BD, therefore Siri (1961) and Brozek *et al.* (1963) were used to translate the values into %BF.

4.6.4 Bioelectric impedance analysis

The %BF results in both the euhydrated and dehydrated states are presented in Table 4.3. Only two of the eight equations (25%) produced %BF values that were not significantly different from the reference method. These included Van Loan *et al.* (1990), when both euhydrated and dehydrated and Lohman (1992) when euhydrated only. For both these equations, the euhydrated and dehydrated values were not significantly different from each other ($p = 0.050$), although this was close to significance. Sixty-two percent (5/8) of the BIA equations were significantly impacted by dehydration.

<u>Table 4.3:</u> The percent body fat results of the bioelectrical impedance analysis equations when euhydrated and dehydrated

		Euhydrated		Dehydrated		
Equation	**n ***	**Mean %BF**	**P value [a]**	**Mean %BF**	**P value [a]**	**P value [b]**
BODYSTAT®1500	17	12.9 ± 4.1	0.003	14.1 ± 3.5	0.001	0.044
Segal *et al.* (1988)	16	12.0 ± 2.2	0.004	13.1 ± 2.0	0.001	0.004
Gray *et al.* (1989)	7	19.2 ± 5.3	0.018	22.0 ± 5.0	0.018	0.091
Van Loan *et al.* (1990)	11	9.1 ± 2.5	0.790	10.5 ± 2.3	0.447	0.050
Deurenberg *et al.* (1991)	17	11.6 ± 3.1	0.039	12.6 ± 2.7	0.003	0.025
Lohman (1992)	11	10.7 ± 2.3	0.131	12.0 ± 2.2	0.026	0.050
Houtkooper *et al.* (1992)	13	14.7 ± 4.2	0.001	16.7 ± 4.1	0.001	0.007
Sun *et al.* (2003)	17	11.6 ± 3.3	0.025	13.0 ± 2.9	0.001	0.010

[a] Compared to eDD
[b] Euhydrated versus dehydrated values.
n varies due to different age groups recommended for different equations.

4.6.5 Agreement of all methods with reference method

On the basis of Wilcoxon results, the equations that were not significantly different from the reference method on average were further analysed using the Bland-Altman plot, which enables analysis of the measurements across the full range.

Table 4.4 lists the BMI, skinfolds and BIA equations considered acceptable when compared to measures recorded using the reference method according to the Wilcoxon signed ranks test. They are listed in ascending order of mean difference from the reference method in both hydration states.

Table 4.4: Regression equations that were not significantly different on average from the reference method in ascending order of mean difference.

Method	Hydration status	Equation	Mean %BF	Mean difference from eDD	n*	ULOA	LLOA	RLOA	Trend line slope
Skinfold	Hydrated	Withers et al. (1987) (BD), Brozek et al. (1963) (%BF)	9.6 ± 1.1	-0.046	17	5.267	-5.359	10.626	1.233
Skinfold	Dehydrated	Slaughter *et al.* (1988) (%BF)	9.7 ± 2.1	-0.143	10	5.454	-5.740	11.194	0.504
Skinfold	Hydrated	Durnin & Womersley (1974) (BD), Brozek *et al.* (1963) (%BF)	9.3 ± 1.6	0.161	16	5.810	-5.488	11.299	0.893
Skinfold	Dehydrated	Durnin & Womersley (1974) (BD), Brozek *et. al* (1963) (%BF)	9.7 ± 2.4	-0.214	16	5.911	-6.339	12.250	0.315
BIA	Hydrated	Van Loan *et al.* (1990)	9.1 ± 2.5	0.319	11	5.373	-4.735	10.108	-0.004
Skinfold	Dehydrated	Durnin & Womersley (1974) (BD), Siri (1961) (%BF)	9.2 ± 2.6	0.336	16	6.648	-5.975	12.623	0.196
Skinfold	Hydrated	Deurenberg *et al.* (1990) four Skinfolds (BD), Siri (1961 (%BF)	10.1 ± 1.1	-0.484	16	5.013	-5.980	10.993	1.235
Skinfold	Hydrated	Withers et al. (1987) (BD), Siri (1961) (%BF)	9.0 ± 1.2	0.518	17	5.846	-4.811	10.657	1.159
Skinfold	Hydrated	Slaughter *et al.* (1988) (%BF)	9.0 ± 1.8	0.610	10	5.485	-4.266	9.752	0.634
Skinfold	Hydrated	Durnin & Womersley (1974) (BD), Siri (1961) (%BF)	8.8 ± 1.7	0.742	16	6.457	-4.972	11.429	0.794
Skinfold	Hydrated	Deurenberg *et al.* (1990) two Skinfolds (BD), Siri (1961) (%BF)	10.4 ± 1.5	-0.815	16	5.449	-7.079	12.529	1.064
Skinfold	Dehydrated	Deurenberg *et al.* (1990) four Skinfolds (BD), Siri (1961 (%BF)	10.5 ± 1.7	-0.848	16	4.903	-6.599	11.502	0.797

Method	Hydration status	Equation	Mean %BF	Mean difference from eDD	n*	ULOA	LLOA	RLOA	Trend line slope
Skinfold	Hydrated	Deurenberg *et al.* (1990) four Skinfolds (BD), Brozek *et al.* (1963) (%BF)	10.6 ± 1.0	-0.962	16	4.517	-6.441	10.958	1.305
Skinfold	Hydrated	Sloan (1967) (BD), Siri (1961) (%BF)	10.4 ± 2.6	-0.992	11	5.819	-7.804	13.624	-0.059
BIA	Dehydrated	Van Loan *et al.* (1990)	9.2 ± 2.6	-1.060	11	5.125	-7.246	12.371	0.131
Skinfold	Hydrated	Durnin & Rahaman (1967) (BD), Siri (1961) (%BF)	10.7 ± 2.7	-1.184	17	5.656	-8.024	13.681	0.103
BIA	Hydrated	Lohman (1992)	10.7 ± 2.3	-1.267	11	3.637	-6.172	9.809	0.073
Skinfold	Hydrated	Deurenberg *et al.* (1990) two Skinfolds (BD), Brozek *et al.* (1963) (%BF)	10.9 ± 1.4	-1.267	16	4.902	-7.437	12.339	1.166
Skinfold	Dehydrated	Deurenberg *et al.* (1990) four Skinfolds (BD), Brozek *et al.* (1963) (%BF)	10.9 ± 1.6	-1.298	16	4.379	-6.975	11.355	0.898
Skinfold	Hydrated	Sloan (1967) (BD), Brozek *et al.* (1963) (%BF)	10.9 ± 2.4	-1.445	11	5.102	-7.993	13.095	0.093
Skinfold	Dehydrated	Forth & Sinning (1973) (BD), Brozek *et al.* (1963) (%BF)	7.3 ± 2.0	1.455	6	6.675	-3.765	10.440	0.289
BMI	Dehydrated	Deurenberg *et al.* (1991)	11.0 ± 1.2	-1.464	17	4.932	-7.861	12.792	1.509
Skinfold	Dehydrated	Deurenberg *et al.* (1990) two Skinfolds (BD), Siri (1961) (%BF)	11.2 ± 2.1	-1.601	16	4.855	-8.056	12.911	0.501
Skinfold	Dehydrated	Durnin & Rahaman (1967) (BD), Siri (1961) (%BF)	11.1 ± 3.5	-1.610	17	6.208	-9.428	15.636	-0.350
Skinfold	Hydrated	Durnin & Rahaman (1967) (BD), Brozek *et al.* (1963) (%BF)	11.1 ± 2.5	-1.617	17	4.989	-8.223	13.212	0.235

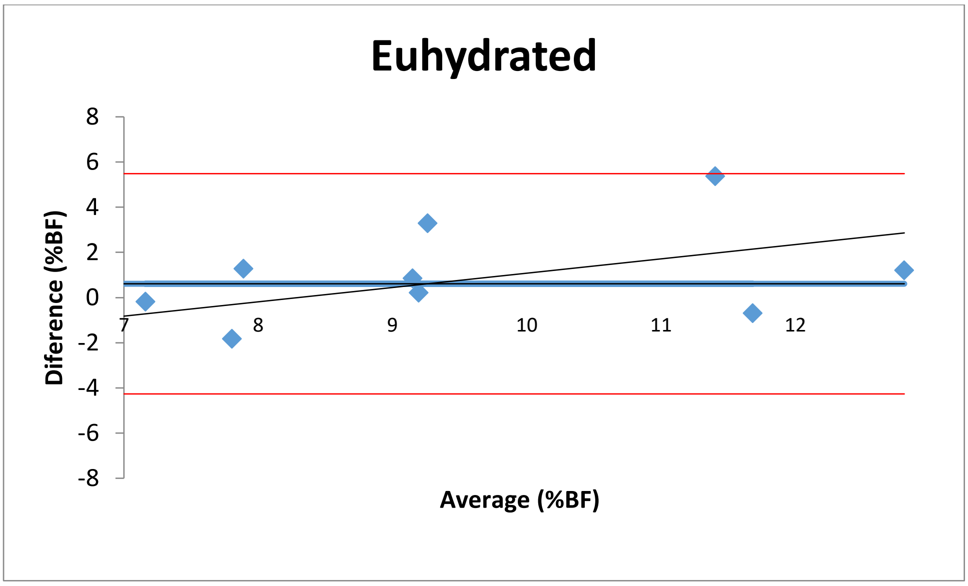
Method	Hydration status	Equation	Mean %BF	Mean difference from eDD	n*	ULOA	LLOA	RLOA	Trend line slope
BMI	Hydrated	Deurenberg *et al.* (1991)	11.2 ± 1.5	-1.702	17	4.583	-7.988	12.572	1.171
Skinfold	Dehydrated	Durnin & Rahaman (1967) (BD), Brozek *et al.* (1963) (%BF)	11.5 ± 3.3	-2.011	17	5.433	-9.454	14.887	-0.224
Skinfold	Dehydrated	Forth & Sinning (1973) (BD), Siri (1961) (%BF)	6.6 ± 2.2	2.125	6	7.475	-3.224	10.699	0.187
Skinfold	Hydrated	Forth & Sinning (1973) (BD), Brozek *et al.* (1963) (%BF)	8.0 ± 1.1	2.186	6	7.326	-2.953	10.278	1.051
Skinfold	Dehydrated	Sloan (1967) (BD), Siri (1961) (%BF)	12.2 ± 3.7	-2.772	11	7.373	-12.916	20.289	-1.165
Skinfold	Hydrated	Forth & Sinning (1973) (BD), Siri (1961) (%BF)	7.3 ± 1.1	2.918	6	8.038	-2.203	10.241	0.975
Skinfold	Dehydrated	Sloan (1967) (BD), Brozek *et al.* (1963) (%BF)	12.5 ± 3.4	-3.088	11	6.560	-12.736	19.296	-0.964

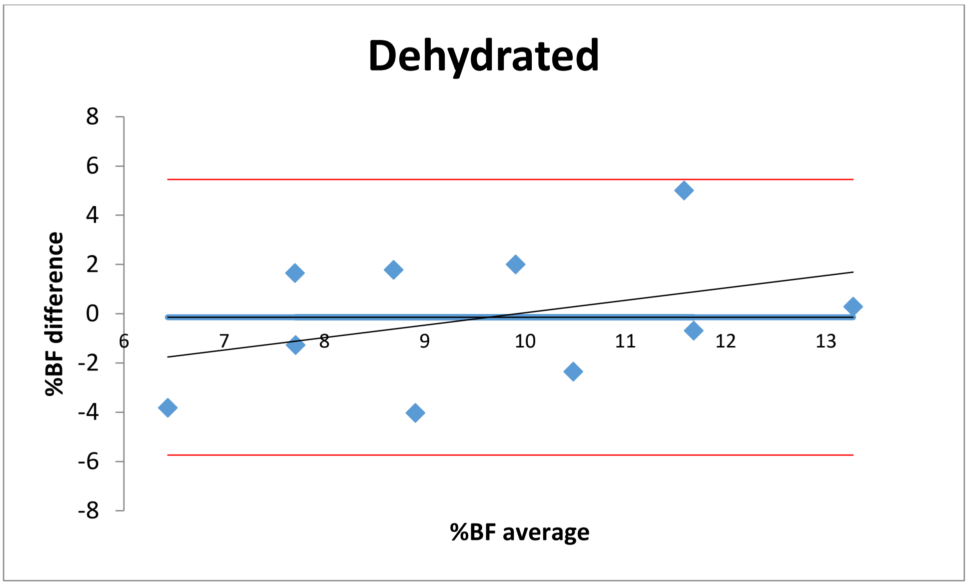
%BF: Percent body fat. eDD: %BF according to eDD (reference method). n*: Sample size. This varies due to different age groups recommended for different equations. ULOA: Upper limit of agreement within 95% CI. LLOA: Lower limit of agreement within 95% CI. RLOA: Range of limits of agreement (ULOA – LLOA). BD: body density. BIA: bioelectric impedance analysis. BMI: body mass index.

The Bland-Altman plots indicate the differences between the %BF measured by the equation and that of the reference method for each apprentice on the Y axis, and the mean of these two values for each apprentice on the X axis. The mean of the differences is a measure of the bias and indicates whether the bias is positive or negative. The ULOA and LLOA are indicated by red lines. These indicate the range in which 95% of the values fall. The trend line gradient indicates if there is over- or underestimation in any specific range of the measurements.

Equations with a mean difference < 0.65 in either direction, RLOA less than 13 % and a trend line slope < 0.9 were considered the best. These were the Slaughter et al. (1988) skinfold equation and Durnin & Womersley (1974) skinfold equation with Brozek *et al.* (1963) in either hydration state, the Van Loan et al. (1990) BIA equation when euhydrated only, and the Durnin & Womersley (1974) skinfold equation with Siri (1961) when dehydrated only. The Bland-Altman plots for these equations are illustrated in figures 4.3 to 4.6.

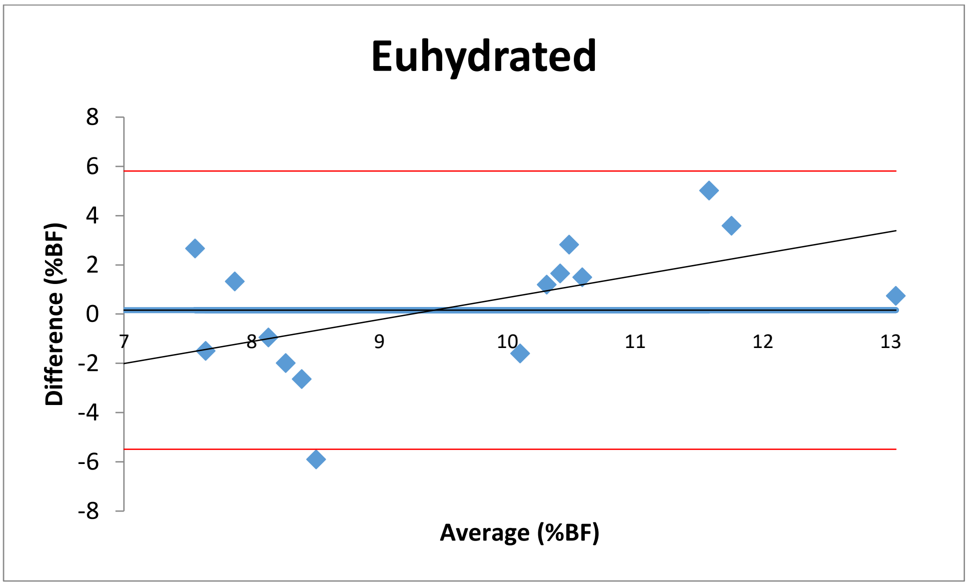
Figure 4.3: Bland-Altman plots for the Slaughter *et al.* (1988) skinfold equation when euhydrated and dehydrated

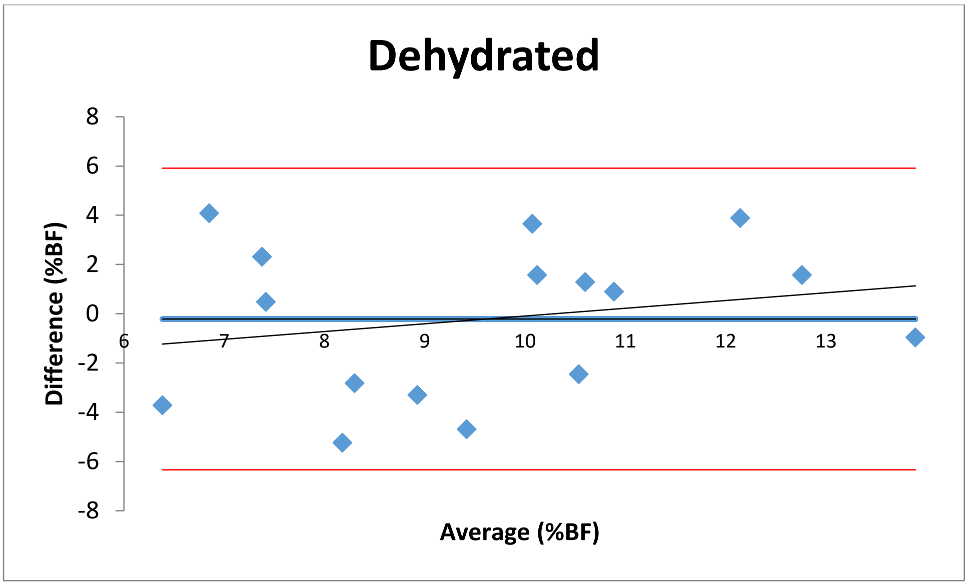




The Slaughter *et al.* (1988) skinfold equation overestimated %BF on average by 0.60997 % when euhydrated and underestimated by 0.14341 % when dehydrated compared to the reference method. The Bland-Altman plot indicates that there was a positive linear trend towards bias in both hydrated states. The equation overestimated %BF values less than and underestimated values greater than 9.25 % when euhydrated and overestimated %BF values less than and underestimated values greater than 9.5 % when dehydrated. This trend had narrower limits when euhydrated.

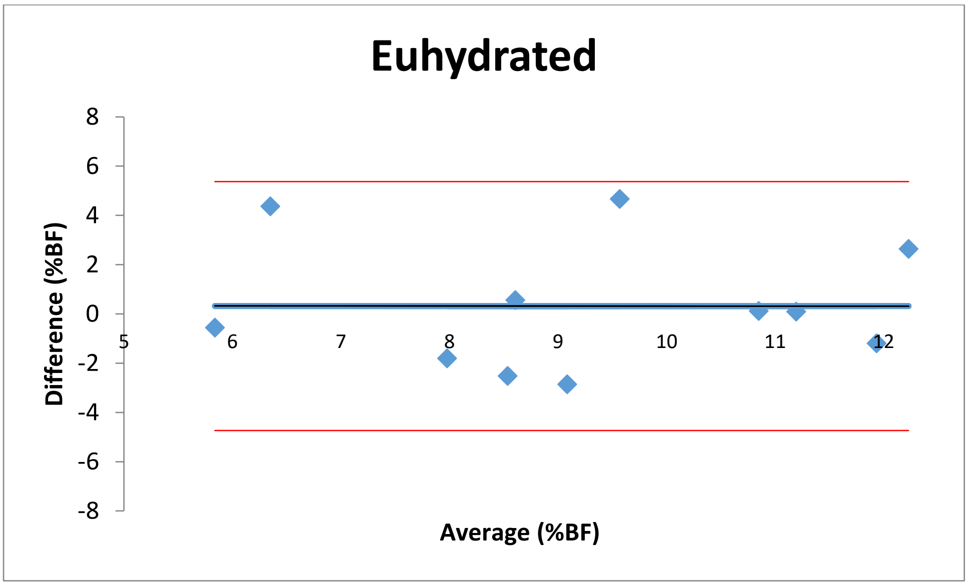
Figure 4.4: Bland-Altman plots for the Durnin & Womersley (1974) skinfold equation with Brozek *et al.* (1963) when euhydrated and dehydrated





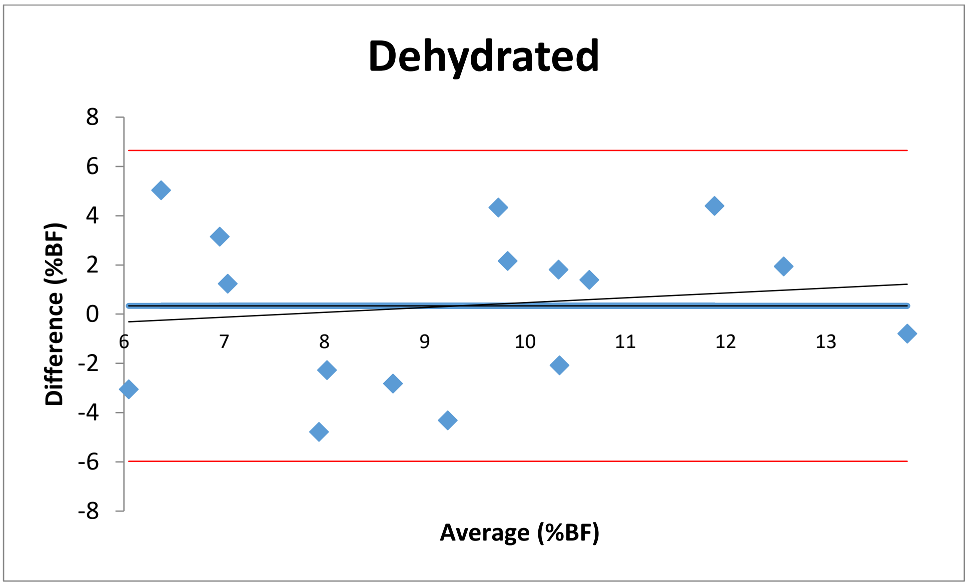
The Durnin & Womersley (1974) skinfold equation, with Brozek *et al.* (1963), overestimated %BF on average by 0.160957 % when euhydrated and underestimated by 0.21388 % when dehydrated compared to the reference method. The Bland-Altman plot indicates that there was also a positive linear trend towards bias in both hydration states where the equation overestimated %BF values less than and underestimated values greater than 9.5 %. This trend had narrower limits when dehydrated.

Figure 4.5: Bland-Altman plot for the Van Loan *et al.* (1990) bioelectrical impedance analysis equation when euhydrated



The Van Loan *et al.* (1990) BIA equation when euhydrated overestimated %BF on average by 0.318948 % compared to the reference method. It showed virtually no trend towards bias. However, it is necessary for the equation to meet the given criteria in both hydration states to be considered one of the best equations for the population.

Figure 4.6: Bland-Altman plot for the Durnin & Womersley (1974) skinfold equation using Siri (1961) when dehydrated



The Durnin & Womersley (1974) skinfold equation using Siri (1961) when dehydrated overestimated %BF on average by 0.336464 % compared to the reference method. The Bland-Altman plot indicates that there was a positive linear trend towards bias where the equation overestimated %BF values less than and underestimated values greater than 9.25 %, however the gradient of this trend was almost negligible.

4.7 BEHAVIOURS RELATED TO HYDRATION AND FOOD INTAKE

Of the 17 jockey apprentices, 16 completed the lifestyle questionnaire.

4.7.1 Weight satisfaction

Thirty seven percent (6/16) reported that they were not satisfied with their current weight. Of these 67 % (4/6) would like to weigh up to two kg less and 33 % (2/6) two to four kg less than their actual weight. Weight dissatisfaction was not significantly associated with age ($p = 0.515$), height ($p = 0.129$), weight ($p = 0.051$), BMI ($p = 0.663$), FMI ($p = 0.386$) or FFMI ($p = 0.057$). Those who were dissatisfied were heavier (52.3 kg, SD ± 3.0, range 49.2 – 56.5) than those who were satisfied (48.9 kg, SD ± 3.2, range 46.1 – 55.3) - this almost reached significance ($p = 0.051$). However those who were dissatisfied had a significantly lower %BF (7.7 %, SD± 2.5, range 4.5 - 11.2 %) than those who were satisfied (10.7 %, SD± 2.5, range 7.1 – 14.1 %) ($p = 0.039$).

4.7.2 Chronic weight-making methods

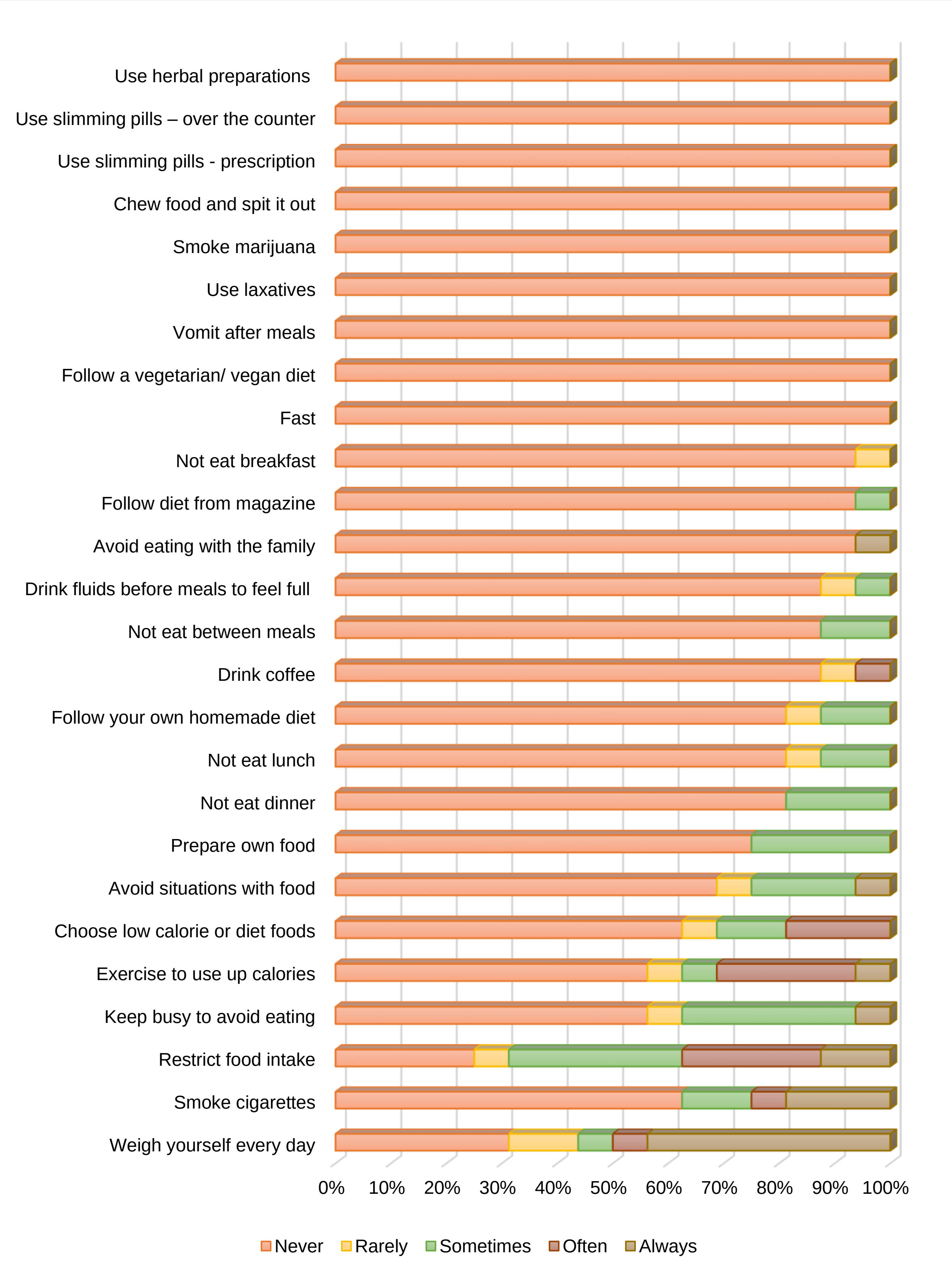
Restricting food intake was the most commonly reported method (75%), followed by daily weighing (69%), keeping busy to avoid eating (44%) and exercising to use up calories (44%). The chronic weight-making methods reported are summarised in Table 4.5.

Table 4.5: Self-reported chronic weight-making methods

Method	n	%	Method	n	%
Restrict food intake	12	75%	Drink fluids before meals to feel full	2	12%
Weigh yourself every day	11	69%	Not eat breakfast	1	6%
Keep busy to avoid eating	7	44%	Avoid eating with the family	1	6%
Exercise to use up calories	7	44%	Follow diet from magazine etc.	1	6%
Smoke cigarettes	6	37%	Fast	0	0%
Choose low calorie/ diet foods	6	37%	Follow a vegetarian/ vegan diet	0	0%
Avoid situations with food	5	31%	Vomit after meals	0	0%
Prepare own food	4	25%	Use laxatives (specify)	0	0%
Not eat lunch	3	19%	Smoke marijuana	0	0%
Not eat dinner	3	19%	Chew food and spit it out	0	0%
Follow your own homemade diet	3	19%	Use slimming pills - prescription	0	0%
Not eat between meals	2	12%	Use slimming pills – over the counter	0	0%
Drink coffee	2	12%	Use herbal preparations	0	0%

In terms of the frequency of which these methods were used, daily weighing was done most frequently, followed by smoking cigarettes, and restricting food intake. The proportion of responses to frequency of chronic weight-making methods used is illustrated in Figure 4.3.

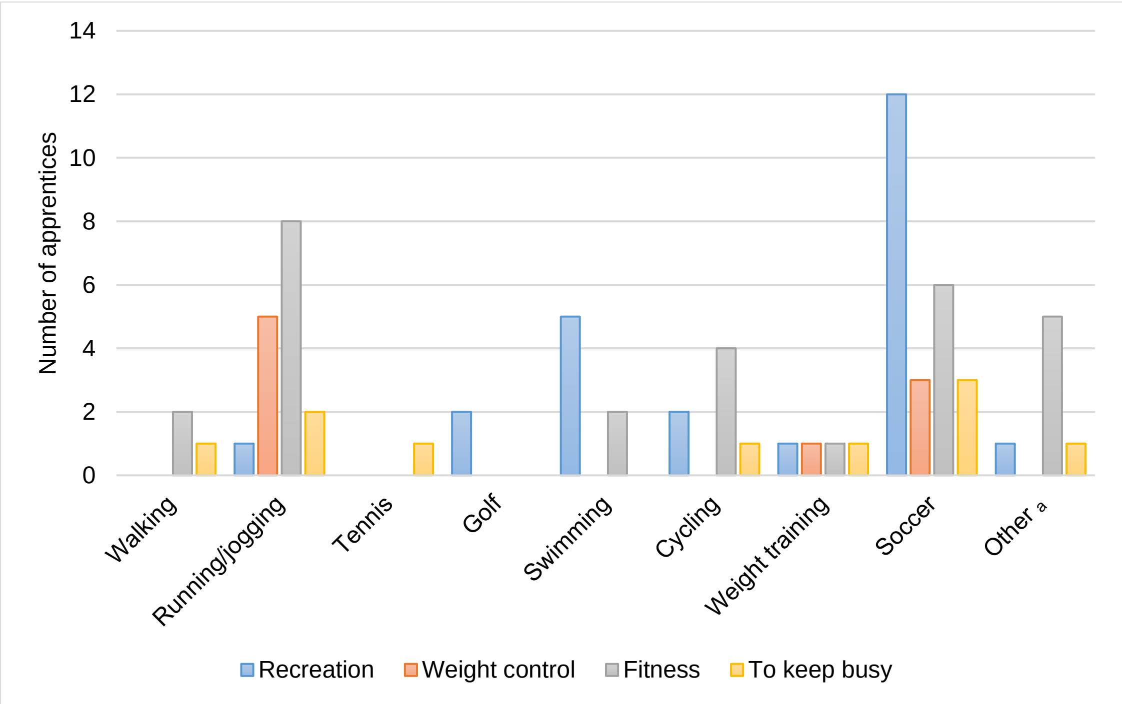
Figure 4.7: Bar graph to show the proportion of responses to questions regarding chronic weight-making methods



4.7.3 Sports and Exercise

The only physical activities used for weight control were running/jogging (37.5%, 6/16), soccer (18.8%, 3/16) and weight training (12.5%, 2/16) (Figure 4.2). The apprentices were relatively active in addition to horse riding. Many (88%, 14/16) indicated that they played soccer for recreational purposes ($p = 0.004$). The most popular reason for participating in any activity was for fitness, as indicated in Figure 4.4.

<u>Figure 4.8:</u> Column graph to illustrate the number of apprentices that participated in various sports and exercises



[a] The Equicizer™ is a mechanical horse that simulates riding to allow jockeys to improve overall fitness and practice riding skills (Equicizer TM, 2017).

4.7.4 Acute weight-making methods

A summary regarding acute weight-making methods is given in Table 4.6. None claimed to flip (purge after eating or drinking), or use diuretics or laxatives in order to make weight. The most common methods were taking hot baths (50%, 8/16) with or without Epsom salts (6%, 1/16) or Arnica (6%, 1/16), using the sauna (37.5%, 6/16) and wearing plastic to sweat during exercise (31%, 5/16). Hot baths were taken a few times every week by 19% (3/16), while 6.3% (1/16) reported once a week, 6.3% (1/16) reported one to three times a month and 19% (3/16) reported less than once a month. Nineteen percent (3/16) reported using the sauna once a week, 6.3% (1/16) reported one to three times a month and 12.5% (2/16) reported they used the sauna but less than once a month. Twelve and a half percent (2/16) reported that they wear plastic to sweat during exercise a few times a week, 12.5% (2/16) reported once a week and 6.3% (1/16) reported this less than once a month.

Table 4.6: Self-reported acute weight-making methods

Method	n	%
Hot baths, with:	8	50%
Water only	6	38%
Epsom salts	1	6%
Arnica oil	1	6%
Sauna	6	38%
Wear plastic to sweat while exercising	5	31%
Flipping	0	0%
Diuretics	0	0%
Laxatives	0	0%

4.7.5 Feelings of hunger and thirst

The proportion of responses to frequency of hunger and thirst were identical. Only 6.3% (1/16) never felt hungry or thirsty and 6.3 % (1/16) always felt hungry and thirsty. Twenty-five percent (4/16) reported that they often felt hungry and thirsty. Many (43.8%, 7/17) felt both hungry and thirsty "sometimes."

The apprentices felt that a mean amount of 7.4 cups (SD± 2.9 cups, range 4 – 15) daily, was a healthy amount of fluid to consume.

Ninety-four percent (15/16) thought that less than the adequate intake (AI) of 3300 ml and 3700 ml fluid for males 14 to 18 years and 19 to 30 years respectively (Popkin, D'anci & Rosenberg, 2010) was sufficient for good health.

4.8 RISK OF DEVELOPING EATING DISORDERS

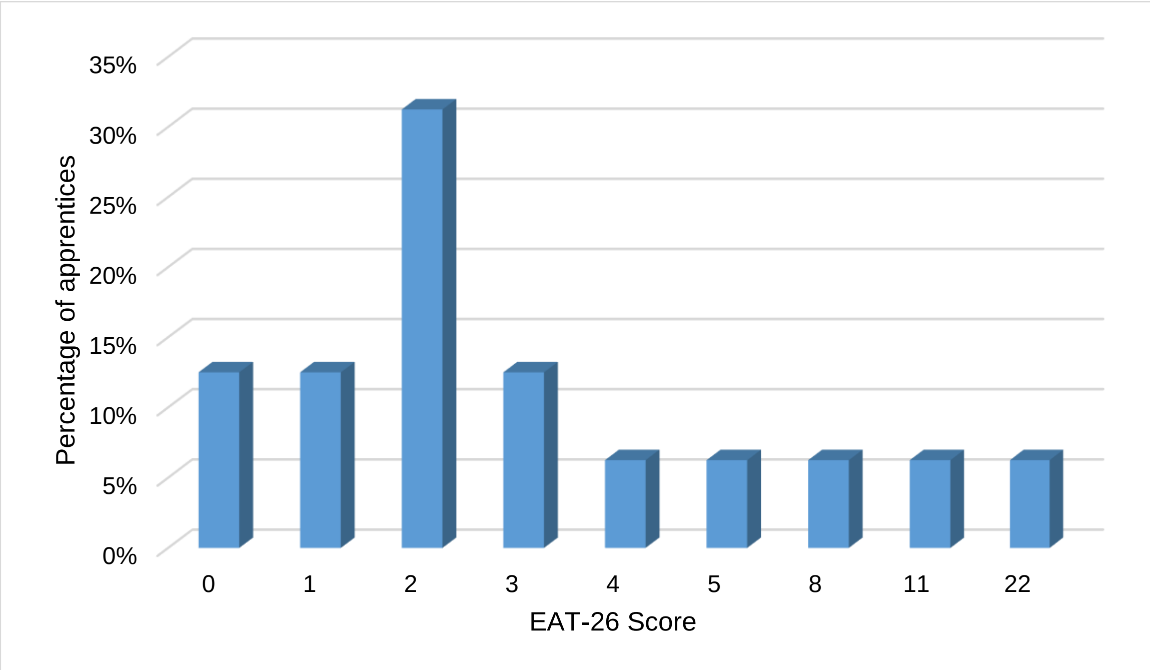
Of the 17 included in the study, 16 completed the EAT-26 questionnaire.

4.8.1 EAT-26 Part B: EAT-26 Test

The mean EAT-26 score was 4.9 (SD± 5.8, range 0 – 22). The proportions of the participants' scores is indicated in Figure 4.5.

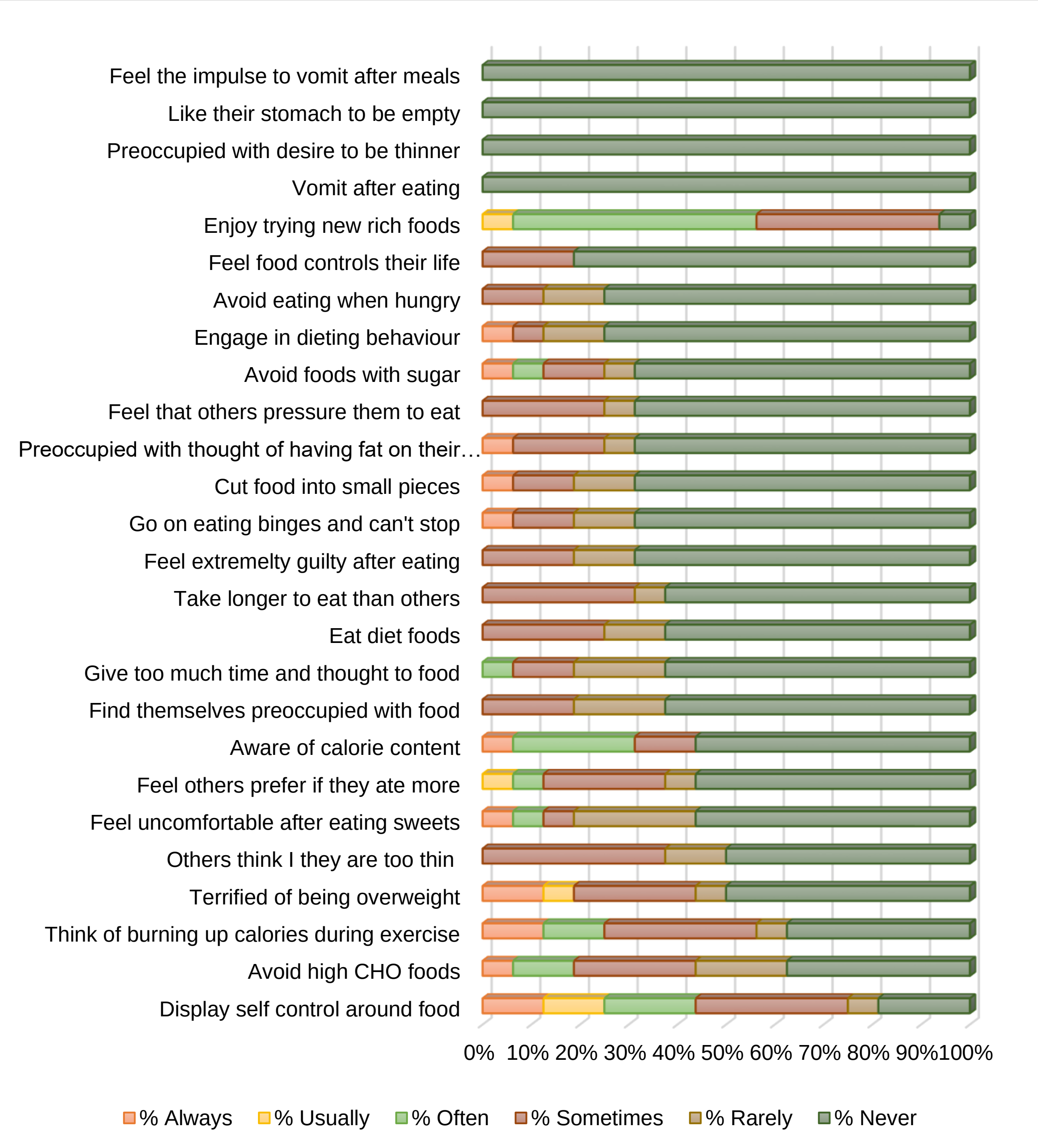
Only one (6.3%) scored greater than 20, indicating the risk of an eating disorder. The majority (94%, 15/16) therefore were not at risk.

Figure 4.9: Column graph to show the score percentage of the apprentices



The proportions of responses to each of the questions included in the EAT-26 test are illustrated in Figure 4.6. Note that the question regarding enjoying trying new rich foods was scored differently to the rest of the questions, as increased frequency equated to a lower score, for example "never" increased the total score by five while "always" did not increase the total score. Displaying self-control around food was most frequently reported, followed by avoiding foods with a high carbohydrate content. None reported that they felt the impulse to vomit after meals, liked their stomach to be empty, and were preoccupied with the desire to be thinner or to vomit after meals. The latter agrees with the results of the lifestyle questionnaire.

Figure 4.10: Bar graph to show the apprentices responses to Part B of the EAT-26 questionnaire



4.8.2 EAT-26 Part C: Behavioural questions

Only one (6.3%) reported that they engaged in behaviours that indicate risk. This apprentice reported that he goes on eating binges once a week where he feels he may not be able to stop. This agrees with part B as it was the same participant that scored higher than 20.

4.9 SUMMARY

The response rate was 84% and therefore an adequate representation of the population.

The mean USG when dehydrated was close to severe dehydration (1.027 g/ml, SD± 0.003, range 1.021 - 1.032) and 24% (4/17) were classified as severely dehydrated.

For those 19 years or younger, 60% (6/10) were classified as moderately stunted (WHO 2007) which indicates either chronic malnutrition or as a result of genetics, however these apprentices all had a normal BMI for age. Only one apprentice (6%), who was older than 19 years, was classified as moderately malnourished (BMI 16.0 - 16.9 kg/m^2) when measured euhydrated, and mildly malnourished (BMI 17.0 - 18.5 kg/m^2) when dehydrated (Ralph *et al.*, 2000).

The mean %BF using DD was 9.5 % (SD± 2.8, range 4.5 – 14.1), when euhydrated which was significantly lower than when dehydrated (11.8 %, SD± 4.6, range 5.9 – 24.2) ($p = 0.025$). There was no significant correlation between %BF and BMI.

According to the classifications of Gallagher *et al.* (2000) and Borrud *et al.* (2011), 88% (15/17) were underfat according to their %BF. Twelve percent (2/17) were underfat as their %BF fell into the "essential" (3 - 6 %) range, meaning that these apprentices did not have sufficient fat stores to protect FFM (Friedl *et al.*, 1994). According to their FMI, 65% (15/17) were classified as underfat. Eighteen percent (2/17) were classified as underlean according to their FFMI.

Although %BF, as calculated by the BMI equation by Deurenberg *et al.* (1991), in both hydration states was not significantly different from the reference method, the difference between a %BF of 11.2% and 9.5% is considerable and they were ranked 29th and 32nd overall for accuracy. This degree of overestimation could lead to excessive reduction of body fat which is dangerous to the apprentices' health.

The skinfold equation by Slaughter *et al.* (1988) was the most accurate method to determine the %BF in the dehydrated state and was not affected by dehydration. It is a simple and practical method involving only two skinfolds (triceps and medial calf). However it was only age-appropriate for 59 % (10/17) of the apprentices. It can therefore be recommended for apprentices 18 years and younger. This was followed by the seven skinfold equation by Withers *et al.* (1987) using Brozek *et al.* (1963) when euhydrated, however it was significantly affected by dehydration to the extent where it was not accurate in the dehydrated state, therefore it is not appropriate for the apprentices. The Durnin & Womersley (1974) equation for BD, using Brozek *et al.* (1963) to translate to %BF was ranked third and sixth when dehydrated and euhydrated respectively. It was not significantly affected by dehydration and was age-appropriate for 94 % (16/17) of the apprentices making it most appropriate for the apprentices older than 18 years.

The equation by Van Loan *et al.* (1990) was the only BIA equation that did not differ from the reference method in both hydration states and was also not significantly impacted by dehydration.

Thirty-seven percent (6/16) reported weight dissatisfaction, but this was not associated with age, height, BMI, FMI or FFMI. Weight dissatisfaction was however associated with a significantly lower %BF according to the reference method and a close to significantly higher body weight.

Restricting food intake, daily weighing, keeping busy and exercising were the most commonly reported chronic weight-making methods. The only physical activities reported to be used for weight control were running/jogging, soccer and weight training, although most physical activities were used for fitness as opposed to weight control.

The most frequently reported acute weight-making method reported was the use of hot baths with or without Epsom salts or Arnica oil, followed by the use of saunas and sweat suits.

Ninety-four percent reported that they feel both hungry and thirsty at least sometimes and of these 25% reported that they often feel both hungry and thirsty. The majority (94%, 15/16) thought that less than the AI of daily fluid is sufficient for good health.

The mean EAT-26 score was 4.87 (SD± 5.84, range 0 – 22). Only one (6%) could be classified as at risk of eating disorders. The same apprentice was the only one who reported engaging in behaviours that indicate risk, which was going on eating binges once a week where he feels he may not be able to stop.

CHAPTER 5: DISCUSSION

5.1 INTRODUCTION

This chapter will discuss the findings of this study with regards to hydration status, anthropometry, FFM, %BF, FMI, the accuracy of methods to estimate %BF, the prevalence of weight-making and weight control techniques and the risk of eating disorders.

5.2 HYDRATION STATUS

When not following any protocol for data collection, all participants were dehydrated according to their USG (Casa *et al.*, 2000) of which 81% were moderately dehydrated while 19% were severely dehydrated. An upon-waking USG value less 1.020 g/ml has been used to indicate a state of euhydration according to Casa, Clarkson & Roberts (2005). Therefore, a USG greater than 1.020 g/ml, upon waking, can be considered an indication of chronic dehydration if no intervention was taken to ensure dehydration. The dehydrated USG was measured on a non-race day with no "light" rides pending, therefore there was no reason to dehydrate acutely and acute dehydration does not occur while sleeping. This result was unexpected as the apprentices were at acceptable handicapping weights and did not need to dehydrate to make weight. Since this data was collected, education regarding proper hydration practises and monthly USG assessments have taken place, which has decreased the prevalence of dehydration among the apprentices (Mrs K Krog 2017, personal communication, 27 November).

The USG results of the present study were extremely concerning as the mean USG on a non-race day was similar to or greater than that of apprentice and professional jockeys on race days. The mean USG (1.027 g/ml) was greater than that reported by other studies on jockeys, although only one had investigated this in apprentices. Cullen *et al.* (2015) measured the USG of ten male jockey apprentices on two separate race days at their "normal" weight[2] and at their "light" weight.[3] At their "normal" weight, the apprentices mean USG was 1.017 g/ml (euhydrated) which was considerably lower than that of this study. At their "light" weight, their mean USG was significantly higher (1.026 g/ml) although this was still lower than the SAJA apprentices on a non-race day. This suggests that chronic

[2] This implied that the handicaps were similar to that of their current weight therefore acute weight-making methods were not necessitated.

[3] This implied that the handicaps were set closer to the minimum weight range.

dehydration is more prevalent and severe among the apprentices at the SAJA than that of other apprentices.

Most studies on professional jockeys have reported a non-race day USG of between 1.021 to 1.022 g/ml which was just within the range of dehydration. Dolan, McGoldrick, Mac Manus, O'Gorman, Moyna & Warrington (2007) measured the USG of 11 male professional jump and flat jockeys on both a non-race and race day. The mean USG was 1.022 g/ml on a non-race day and 1.028 g/ml on a race day, which was similar to that of the present study on a non-race day. On typical race days however, Benardot *et al.* (2008) reported a considerably lower mean USG of 1.021 g/ml in 47 male American flat jockeys which was similar to what Warrington *et al.* (2009) found in 27 flat and jump jockeys on a non-race day (mean USG 1.022 g/ml). Dolan *et al.* (2013) measured the USG of five jump and four flat professional jockeys before and after reducing their body mass by 4 % of their baseline measure mimicking the acute weight-making methods they typically would use before racing. The mean USG was 1.019 g/ml (hydrated) prior to 4% weight loss and 1.028 g/ml (moderately dehydrated) after 4% weight loss.

Acute and chronic dehydration can have negative consequences for both jockeys and apprentices. In terms of physical performance, Wilson *et al.* (2013b) reported a significant increase in heart rate and rate of perceived exertion, and a significant reduction in chest and leg strength and pushing frequency in eight male professional jump and flat jockeys after a 2% induced acute weight loss despite the USG only being borderline dehydrated (mean urine osmolality 514 mOsmols/kg which is equivalent to 1.020 g/ml).[4] Dolan *et al.* (2013) reported a significantly reduced peak work capacity as a result of acute dehydration (4% weight loss over 48 hours) in professional jockeys with a mean USG of 1.028 g/ml when compared with age-, gender-, and BMI-matched euhydrated controls, who were not jockeys. Acute weight-loss by dehydration therefore impairs the physical performance of professional jockeys, which has negative implications on their chance of winning, as well as their risk of falling.

In terms of cognitive function, a significant impact by dehydration has not been reported in jockeys. The study by Dolan *et al.* (2013) reported no significant impact on cognitive function, in terms of motor response, decision making, executive function, and working memory. Cullen *et al.* (2015) conducted two experimental trials involving 12 and ten flat jockey

[4] Cut-off for moderate dehydration is 700 mOsmols/kg (Kenefick *et al.*, 2012).

apprentices in a simulated (USG 1.032 g/ml) and competitive race environment (USG 1.026 g/ml) respectively and reported no significant impact on simple reaction time [5] and memory as a result of acute moderate and severe dehydration.

In general, chronic dehydration has been associated with impaired renal function (García-Trabanino *et al.*, 2015). In the descriptive study by Labadarios *et al.* (1993), five percent (5/93) of the South African flat jockeys reported renal complaints, which included kidney stones and haematuria post-race meeting. Wilson *et al.* (2013a) measured the markers of kidney and liver function in 19 flat and 18 jump male elite professional jockeys in England and reported no abnormalities. Cullen, Donohoe, McGoldrick, McCaffrey, Davenport, Byrne, Donaghy, Tormey, Smith & Warrington (2016) claimed that four percent (1/28) of the retired Irish flat jockeys reported the loss of a kidney after retiring. However, these statistics were lower than the prevalence of chronic kidney disease in the general population of South Africa (14%) (Stanifer, Jing, Tolan, Helmke, Mukerjee, Naicker & Patel, 2014), England (6%) (Barron, 2014) and Ireland (11%) (Stack, Casserly, Cronin, Chernenko, Cullen, Hannigan, Saran, Johnson, Browne & Ferguson, 2014) implying that the prevalence in the aforementioned jockey studies is not a concern as it was relatively low.

Therefore, although there is limited evidence to indicate reduced cognitive function and renal dysfunction as a result of acute and chronic dehydration in jockeys, it can negatively impact racing performance by reducing peak work capacity, increasing heart rate and rate of perceived exertion and reducing chest and leg strength and pushing frequency. Accurately measuring %BF and optimising body composition may help to reduce the need for deleterious weight-making methods which involve dehydration and therefore protect the health and performance of the jockeys.

5.3 ANTHROPOMETRY

5.3.1 Height

The stunting experienced by 60% of those under 19 years may have been the result of either chronic malnutrition during childhood or genetics.

[5] The time required for a subject to initiate a prearranged response to a defined stimulus, which is used as an indicator of cognitive function (Merriam-Webster, 2017).

According to Jinabhai, Reddy, Taylor, Monyeki, Kamabaran, Omardien & Sullivan (2007), the prevalence of stunting amongst 2398 black male teenagers, aged 13.0–17.9 years, in South Africa was 22%, based on the data of the South African Youth Risk Behaviour Survey (YRBS) of 2002. These figures were higher than those in the SANHANES-1 report for 2012 which was 15.2% amongst South African children aged ten to 14 years (Shisana *et al.*, 2014). Of the six apprentices who were classified as stunted, three (50%) came from lower income groups, which could indicate chronic malnutrition as a result of poor food security as stunting is associated with a poor socio-economic background. Stunting as a result of chronic malnutrition further exacerbates the negative implications for the apprentices as it is significantly correlated with poor BMD and BMC (Martins, Toledo Florêncio, Grillo, Do Carmo P Franco, Martins, Clemente, Santos, Vieira & Sawaya, 2011), which could increase the risk of fractures from falls.

5.3.2 Body mass index

The hypothesis that the mean BMI of the apprentices would be close to the minimum cut-off range for normal BMI with a high prevalence of underweight, can be rejected.

The euhydrated mean BMI (19.2 kg/m^2) was normal, with only one being underweight. Table 5.1 compares the anthropometry with that of other jockey studies. The mean BMI therefore was comparable to that of most apprentice studies which ranged from 18.8 (Krog, 2015) to 20.5 kg/m^2 (Moore *et al.*, 2002a; Leydon & Wall, 2002; Silk *et al.*, 2015) except for the higher BMI (22.7 kg/m^2) reported by Cullen *et al.* (2015). Neither Moore *et al.* (2002b) nor Leydon & Wall (2002) differentiated the mean BMI between the male and female apprentices.

The mean BMI of professional jockeys was slightly higher than that of the apprentices - this ranged from 19.4 to 20.7 (Labadarios *et al.*, 1993; Moore *et al.*, 2002a; Leydon & Wall, 2002; Warrington *et al.*, 2009; Dolan *et al.*, 2009; Cotugna *et al.*, 2011; Dolan *et al.*, 2012a; Wilson *et al.*, 2012b; Wilson *et al.*, 2013a; Dolan *et al.*, 2013; O'Reilly *et al.*, 2017; Jackson *et al.*, 2017) except for Dolan *et al.* (2012b) who reported a mean BMI of 21.4 kg/m^2.

Theoretically, as the mean BMI was above the lower limit of the normal range (18.5 kg/m^2) there was scope for some to reduce weight. The BMI however must be interpreted in conjunction with their %BF and FFM as their %BF is the component that needs to be reduced and a high BMI could be a result of a high FFM.

Table 5.1: Anthropometry of jockeys [a]

Study	Sample	Country	Age (years)	Weight (kg)	Height (m)	BMI (kg/m²)
Present study	17 (apprentice)	South Africa	18.8 ± 1.7	50.5 ± 3.5	1.62 ± 0.06	19.2 ± 1.1
			Studies involving apprentices			
Moore *et al.* (2002a)	20 (11 male, 9 female) [b]	Australia	19.1 ± 0.6	49.7 ± 0.6 [c]	1.59 ± 0.02 [c]	19.9 ± 0.5
Leydon & Wall (2002)	11 (2 male, 9 female) [b]	New Zealand	20.5 ± 3.8	52.8 ± 2.4	1.62 ± 0.04	20.1 ± 1.5
Cullen *et al.* (2015)	12	Republic of Ireland	23.0 ± 3.0	61.8 ± 5.6	1.65 ± 0.02	22.7 ± 1.2
Silk *et al.* (2015)	17	Australia	22.3 ± 5 [d] 19.3 ± 1.8 [e]	52.7 ± 36 [d] 52.6 ± 3.3 [e]	1.66 ± 0.04 [d] 1.67 ± 0.04 [e]	19.4 ± 1.7 [d] 19.1 ± 1.3 [e]
Krog (2015)	21	South Africa	18.0 ± 1.4	47.7 ± 3.5	1.58 ± 0.07	18.8 ± 1.1

Study	Sample	Country	Age (years)	Weight (kg)	Height (m)	BMI (kg/m^2)
Studies involving professional jockeys						
Labadarios *et al.* (1993)	93	South Africa	28.8 [f]	52.9 [f]	1.61 [f]	20 [f]
Moore *et al.* (2002a)	96 (80 male, 16 female) [b]	Australia	30.5 ± 0.9	53.0 ± 0.3 [c]	1.61 ± 0.07 [c]	20.2 ± 0.2
Leydon & Wall (2002)	9 (4 male, 5 female) [b]	New Zealand	28.7 ± 5.0	51.3 ± 3.7	1.59 ± 0.05	20.4 ± 1.6
Warrington *et al.* (2009)	17	Republic of Ireland	26.7 ± 7.6	53.1 ± 4.1	1.60 ± 0.10	19.9 ± 1.3
Dolan *et al.* (2009)	16	Republic of Ireland	24.1 ± 8.6	53.4 ± 4.9	1.65 ± 0.06	19.6 ± 2.1
Cotugna *et al.* (2011)	20 [g]	USA	35 [f]	51.0 ± 1.5 [c]	1.60 ± 0.05 [c]	20.0 ± 1.0
Dolan *et al.* (2012a)	14	Republic of Ireland	25.9 ± 3.26	54.6 ± 3.6	1.65 ± 0.06	20.2 ± 1.6
Dolan *et al.* (2012b)	20 [h]	Republic of Ireland	25.9 ± 3.26	61.1 ± 5.4	1.7 ± 0.07	21.4 ± 1.8
Wilson *et al.* (2012b)	9 (protocols 1-3) [i] 6 (protocol 4)	Great Britain	24.0 ± 3.1 (protocols 1-3) 26.0 ± 3.7 (protocol 4)	63.2 ± 4.7 (protocols 1-3) 65.9 ± 3.1 (protocol 4)	1.72 ± 0.05 (protocols 1-3) 1.75 ± 0.04 (protocol 4)	n/r

Study	Sample	Country	Age (years)	Weight (kg)	Height (m)	BMI (kg/m^2)
Wilson *et al.* (2013a)	19	England	27.0 ± 5.0	56.1 ± 2.9	1.67 ± 0.05	20.3 ± 1.4
Dolan *et al.* (2013)	9 [j]	Republic of Ireland	24.0 ± 7.0	58.2 ± 5.3	1.68 ± 0.05	20.7 ± 1.7
O'Reilly *et al.* (2017)	20	Hong Kong	29.3 ± 7.8	53.8 ± 3.3	1.62 ± 0.06	19.4 ± 1.4
Jackson *et al.* (2017)	79	England	18.5 ± 1.9	52.9 ± 2.9	1.67 ± 0.06	19.0 ± 1.4

BMI: n/r: not reported. %BF: percent body fat. DD: deuterium dilution. DXA: dual X-ray absorptiometry.
[a] Male flat jockeys, unless otherwise specified.
[b] Male and female jockeys included. Results did not specify means of each sex.
[c] Self-reported.
[d] Supplement group (n = 8). This study involved six-month vitamin D supplementation.
[e] Placebo group (n = 9).
[f] No standard deviation (SD) data given.
[g] Not specified whether jump or flat jockeys.
[h] Not specified whether male or female, jump or flat.
[I] Professional jump jockeys included only. This study involved four protocols used to assess the energy expenditure in elite jockeys during a simulated race riding and a working day.
[j] Four flat and five jump jockeys included.

5.4 BODY COMPOSITION

5.4.1 Fat-free mass

The hypothesis that the mean FFM of the apprentices would be normal was accepted.

The mean FFMI (17.4 kg/m^2) was within the normal ranges, even when the cut-offs for each age group were taken into consideration. Table 5.2 summarises the FFMI, %BF and FMI reported by studies on jockeys. No studies have reported the FFMI of apprentices. The mean age (18.5 years) of the professional jockeys from the study by Jackson *et al.* (2017) was similar to the present study (18.8 years) and is therefore comparable as FFMI is affected by age (Bahadori *et al.*, 2006; Weber *et al.*, 2013). The present study reports a considerably higher mean FFMI than that of Jackson *et al.* (2017) (15.3 kg/m^2). Since the minimum cut-off values of a normal FFMI for males 18 years and older is 16.7 kg/m^2, the jockeys in the study by Jackson *et al.* (2017) were underlean while those in the present study were normal. Older jockeys had a higher FFMI as reported by Dolan *et al.* (2012a) (18.2 kg/m^2) and Dolan *et al.* (2012b) (18.3 kg/m^2). This is not surprising as FFMI is reported to increase with age during early adulthood in males and females (Bahadori *et al.*, 2006; Weber *et al.*, 2013).

Twelve percent (2/17) of the apprentices in the present study were underlean overall. One was also classified as underweight according to his BMI, although his %BF was normal. The other had a BMI close to the minimum acceptable value and his %BF was normal. It is recommended that these two increase their FFM through strength training and diet to avoid the negative consequences of an inadequate FFM.

Adequate FFM is important in horse racing as higher levels are associated with better postural balance (Alonso *et al.*, 2012) which could assist the jockey to remain stable and maintain control while riding and reduce the risk of falls. Adequate FFM is also associated with higher BMD in athletes and non-athletes (Gjesdal, Halse, Eide, Brun & Tell, 2008; Dolan *et al.*, 2012a), which is also important to prevent fractures as a result of a fall. Maintaining FFM is also essential to sustained weight loss as it is positively correlated with RMR (Cunningham, 1991).

Table 5.2: Body composition of jockeys [a]

Study	Sample	Country	Age (years)	Method used	%BF	FMI (kg/m^2)	FFMI (kg/m^2)
Present study	17 (apprentice)	South Africa	18.8 ± 1.7	DD	9.5 ± 2.8	1.8 ± 0.6	17.4 ± 1.1
Studies involving apprentices using reference methods							
Leydon & Wall (2002)	2	New Zealand	20.5 ± 3.8	DXA	12.3 [b]	n/r	n/r
Studies involving apprentices using BIA							
Krog (2015)	21	South Africa	18.0 ± 1.4	BIA (BODYSTAT® 1500 MDD)	12.2 ± 2.5	n/r	n/r
Studies involving professional jockeys using reference methods							
Leydon & Wall (2002)	4	New Zealand	28.7 ± 5.0	DXA	10.7 [b]	n/r	n/r
Warrington *et al.* (2009)	17 (professional)	Republic of Ireland	26.7+7.6	DXA	9.0 ± 2.5	n/r	n/r
Dolan *et al.* (2009)	16 (professional)	Republic of Ireland	24.1 ± 8.6	DXA	8.3 ± 2.5	n/r	n/r
Dolan *et al.* (2012a)	14 (professional)	Republic of Ireland	25.9 ± 3.3	DXA	8.3 ± 2.9	1.6 ± 0.6	18.2 ± 1.3
Dolan *et al.* (2012b)	20 (professional) [c]	Republic of Ireland	25.9 ± 3.3	DXA	11.4 ± 5.6	2.4 ± 1.4	18.3 ± 1.5

Study	Sample	Country	Age (years)	Method used	%BF	FMI (kg/m^2)	FFMI (kg/m^2)
Wilson *et al.* (2012b)	9 (protocols 1-3) 6 (protocol 4) [d]	Great Britain	24 ± 3.1 (protocols 1-3) 26 ± 3.7 (protocol 4)	DXA	11.3 ± 2.2 (protocols 1-3) 11.7 ± 2.8 (protocol 4)	n/r	n/r
Wilson *et al.* (2013a)	19 (professional)	England	27 ± 5	DXA	13.0 ± 3.0	n/r	n/r
Jackson *et al.* (2017)	79	England	18.5 ± 1.9	DXA	14.6 ± 2.3	2.7 ± 0.5	15.3 ± 1.1
Studies involving professional jockeys using skinfold measurements							
Warrington *et al.* (2009)	17 (professional)	Republic of Ireland	26.7+7.6	Skinfolds [e]	7.9 ± 1.7	n/r	n/r
Dolan *et al.* (2009)	16 (professional)	Republic of Ireland	24.1 ± 8.6	Skinfolds [e]	7.8 ± 1.3	n/r	n/r
Dolan *et al.* (2013)	9 (professional) [f]	Republic of Ireland	24.0 ± 7.0	Skinfolds [e]	9.0 ± 1.4	n/r	n/r
O'Reilly *et al.* (2017)	20 (professional)	Hong Kong	29.3 ± 7.8	Skinfolds [g]	5.8 ± 2.6	n/r	n/r

%BF: percent body fat. DD: deuterium dilution. DXA: dual X-ray absorptiometry. n/r: not reported. BIA: bioelectric impedance analysis.
[a] All male flat jockeys unless otherwise specified.
[b] No standard deviation (SD) data given.
[c] Both flat and jump jockeys included. Ratio of jump and flat not specified. Ratio of professional to apprentice also not specified.
[d] Professional jump jockeys included only. This study involved four protocols used to assess the energy expenditure in elite jockeys during a simulated race riding and a working day.
[e] Withers *et al.* (1987) 7-skinfold equation for BD, and Siri (1956) equation to translate to %BF was used.
[f] Four flat and five jump jockeys included.
[g] Durnin & Womersley (1974) for BD, and Siri (1956) equation to translate to %BF was used.

5.4.2 Percent body fat and fat mass index

5.4.2.1 *Percent body fat*

The hypothesis that the %BF of the apprentices would be high relative to professional jockeys was rejected.

The present study was the only study in South Africa to use a gold standard reference method to measure the %BF of apprentices.

The mean %BF (9.5 %) was much lower than that of other apprentices as reported by Leydon & Wall (2002) using DEXA (12.3%) and Krog (2015) using BIA (BODYSTAT®1500 MDD) (12.2%) (Table 5.2). The mean %BF fell within the lower range (8.3 to 14.6 %) of professional jockeys (Leydon & Wall (2002); Warrington *et al.*, 2009; Dolan *et al.*, 2009; Dolan *et al.*, 2012a; Dolan *et al.*, 2012b; Wilson *et al.*, 2012b; Wilson *et al.*, 2013a; Jackson *et al.*, 2017) (Table 5.2). Labadarios *et al.* (1993) reported a mean %BF of 11.0 % for South African professional jockeys using skinfold measurements, with an undisclosed equation involving four unknown skinfold sites. The apprentices at the SAJA were already making a concerted effort to attain a lower %BF in line with the professional jockeys.

Although the jockeys in the study by Warrington *et al.* (2009), were measured on a non-race day, the mean USG (1.022 g/ml) indicated moderate dehydration. The %BF results of Warrington *et al.* (2009) (7.9 %) were similar to that of the present study when %BF was calculated using the Withers *et al.* (1987) equation with the Siri (1961) equation and the apprentices were dehydrated (7.4 %). The %BF results of study by Dolan *et al.* (2009) (7.8 %) were also similar to that of the present study when the Withers *et al.* (1987) equation with the Siri (1961) equation when the apprentices were dehydrated, although Dolan *et al.* (2009) did not test hydration status. When compared to DXA, Dolan *et al.* (2009) found that skinfolds significantly underestimated %BF. Dolan *et al.* (2013) ensured euhydration prior to skinfold measurement and reported similar %BF results (9.0 %) to that of present study when the Withers *et al.* (1987) equation with the Siri (1961) equation when the apprentices were euhydrated (9.0 %). It can de deduced that the %BF results in these studies were underestimated by skinfolds. The Durnin & Womersley (1974) skinfold equation, together with the Siri (1961) equation, was used in a study involving male professional flat jockeys in Hong Kong by O'Reilly *et al.* (2017). The %BF results of this study (5.8 %) were notably lower than that of the present study when the Durnin & Womersley (1974) equation was used with Siri (1961) when euhydrated (8.8 %) or dehydrated (9.2 %). This result is surprising as a number of studies have indicated that %BF for a given BMI is significantly greater in Asian populations when compared to white and black populations (Wang, Thornton, Russell, Burastero, Heymsfield & Pierson, 1994; Deurenberg, Yap & Van Staveren, 1998; Deurenberg, Deurenberg-Yap & Guricci, 2002; Gallagher *et al.*, 2000).

The lower limit of body fat (essential fat) in healthy active men is four to six percent or ~2.5 kg according to Friedl *et al.* (1994). Although Friedl *et al.* (1994) only described the essential %BF range for adult men (18 years and older), the occurrence of such a low %BF in an apprentice younger than 18 years can be considered more severe as the lower limit of normal %BF for children is higher than that of adults (Borrud *et al.*, 2011). There is no known lower limit for children and adolescents. Despite a normal BMI, a few (12%) fell within this essential fat range, and therefore had insufficient fat stores and should be prevented from reducing their weight further. They can be encouraged to gain weight as essential fat has a number of important functions. Fat tissue secretes adipokines which are involved in bone physiology regulation (Gomez-Ambrosi, Rodriguez, Catalan & Frühbeck, 2008) therefore insufficient fat stores may compromise bone health and increase the risk of fractures. Fat tissue also has a mechanical protective effect as layers of subcutaneous adipose tissue cushion the limbs and internal organs from physical trauma such as falls and blows (Norgan, 1997b). Warrington *et al.* (2009) suggested that the combination of low BMD, dehydration and low %BF was associated with the high incidence of fractures seen in professional male jockeys. Low levels of essential fat therefore could have a detrimental impact on the jockey/apprentice's career.

It is important to have a small amount of storage fat, over and above the essential fat, to avoid the risk of compromising FFM when there is an energy deficit as once the essential fat level has been reached, muscle is catabolised for energy (Friedl *et al.* (1994). Therefore rather than using the essential fat ranges, the normal ranges of %BF as recommended by Borrud *et al.* (2011) and Gallagher *et al.* (2000) were used in the present study.

According to these recommendations of Borrud *et al.* (2011) and Gallagher *et al.* (2000), 88% (15/17) were underfat. The mean %BF of the apprentices who were younger than 20 years was 10.2 %, which was lower than the lower limit for normal %BF (13.7 %) for this age group according to Borrud *et al.* (2011). The mean %BF of the apprentices 20 years and older was 7.3 %, which was also lower than the lower limit of normal %BF (8 %) for this age group according to Gallagher *et al.* (2000). Four of the apprentices (24%) had the potential to reduce their %BF to the lower limit of normal for their respective age group.

Each individual apprentice needs to be carefully assessed therefore taking into consideration his body composition and handicapping demands before deciding what %BF would be appropriate for them. It is not recommended that all of the apprentices reduce their FM as this presents a high risk of compromising FFM. These results are not in agreement with the BMI results which indicate scope for further reduction of weight (mean 19.2 kg/m^2). This further emphasises the need to measure body composition as opposed to weight and BMI.

5.4.2.2 *Fat mass index*

According to FMI, 65 % (11/17) of the apprentices were underfat, as opposed to 88 % when using %BF. The mean FMI for those younger than 18 years (1.8 kg/m^2) is low according to Weber *et al.* (2013) and the mean FMI for those 18 years and older (1.8 kg/m^2) was just within the normal range according to Schutz *et al.* (2002). Five of the apprentices (29%), had the potential to reduce their FMI to the lower limit of normal for their respective age groups. Only one of these apprentices also had a %BF that showed scope for reduction. It can be noted that there are large gaps between the lower limit of normal %BF for the under 20 year age group (13.7 %) (Borrud *et al.*, 2011), and the 20 years and older age group (8 %) (Gallagher *et al.*, 2000). The same can be said for the lower limit of normal FMI for the under 18 year age group (2.7 kg/m^2) (Weber *et al.*, 2013), and 18 years and older age group (1.8 kg/m^2) (Schutz *et al.*, 2002). Therefore, both the %BF and FMI should be considered before the decision to reduce FM is made. It can be recommended that whichever classification indicates scope for loss of FM be used as both classifications allow for an amount of storage fat to prevent muscle catabolism.

5.5 ACCURACY OF METHODS TO ESTIMATE PERCENT BODY FAT

5.5.1 Body mass index

The hypothesis that using BMI to calculate %BF would not provide accurate %BF results and would be significantly impacted by dehydration was rejected.

Although the %BF values calculated from the Deurenberg *et al.* (1991) BMI equation were not significantly different to the reference method according to the Wilcoxon signed ranks test, and were not significantly affected by dehydration, the Bland-Altman analysis showed that there was unacceptable bias. This degree of overestimation could lead to excessive reduction of body fat which is dangerous to the apprentices' health. A weak relationship between BMI and %BF has been found in athletes and non-athletes with a BMI less than 25 kg/m^2 (Nevill *et al.*, 2006; Meeuwsen *et al.*, 2010a; Kupusinac, Stokić, Sukić, Rankov & Katić, 2017). Calculating %BF from BMI is therefore not recommended for the apprentice population.

5.5.2 Skinfold measurements

The hypotheses that regression equations using skinfolds would underestimate %BF in both the euhydrated and dehydrated states, and that dehydration would significantly impact all of the skinfold measurements and %BF values, was rejected.

Only 20% (4/20) of the skinfold equation combinations significantly underestimated %BF and 30% (6/20) of the skinfold equation combinations were significantly influenced by dehydration, as the euhydrated and dehydrated %BF values were significantly different according to the Wilcoxon signed ranks test.

The Slaughter *et al.* (1988) skinfold equation and the Durnin & Womersley (1974) skinfold equation using Brozek *et al.* (1963) were the only equations that showed acceptable levels of bias according to the Bland-Altman analysis in both hydration states. These equations showed a positive linear trend towards bias in both hydration states, therefore %BF values on either extreme of 9.5% should also be approached with caution.

This Durnin & Womersley (1974) skinfold equation using Brozek *et al.* (1963) is indicated for males 17 years and older therefore it was age-appropriate for 94% of the apprentices. This equation can therefore be considered suitable for apprentices 17 years and older. This equation has been used in another study involving jockeys by O'Reilly *et al.* (2017).

The Slaughter *et al.* (1988) skinfold equation was only age-appropriate for 59% of the apprentices as it is not recommended for males older than 18 years. Therefore it should only be recommended as the most suitable equation for the apprentices 18 years and younger. Rodriguez *et al.* (2005) supports this as they reported that the Slaughter *et al.* (1988) equation was the most accurate equation for measuring %BF in adolescent males aged 13 to 17.9

years, when compared to 14 other skinfold equations including that of Durnin & Womersley (1974) and Deurenberg *et al.* (1990).

Due to the simplicity of the Slaughter *et al.* (1988) skinfold equation, as it does not require a second equation to convert BD into %BF, it is recommended that this equation be used for apprentices 18 years and younger while the Durnin & Womersley (1974) skinfold equation using Brozek *et al.* (1963) should be used for apprentices older than 18 years.

Including an increased number of skinfold sites into %BF equations does not necessarily increase the accuracy of the calculation. There have been advocated equations using two, three or four skinfold sites. Table 5.3 summarizes the specific skinfold sites included in each equation.

Table 5.3: Skinfold sites included by skinfold equations used

Equation	Triceps	Biceps	Supra-iliac	Subscapular	Abdominal	Calf	Thigh	Total
Sloan (1967)				√			√	2
Durnin & Rahaman (1967)	√	√	√	√				4
Forsyth & Sinning (1973)				√	√			2
Durnin & Womersley (1974)	√	√	√	√				4
Lohman (1981)	√			√	√			3
Jackson & Pollock (1985)	√		√		√		√	4
Withers *et al.* (1987)	√	√	√	√	√	√	√	7
Slaughter *et al.* (1988)	√					√		2
Deurenberg *et al.* (1990) (2 skinfold)	√	√						2
Deurenberg *et al.* (1990) (4 skinfold)	√	√	√	√				4
Peterson *et al.* (2003)	√		√	√			√	4
Evans *et al.* (2005)	√				√		√	3

5.5.2.1 Two skinfold sites

The two-skinfold equations by Sloan (1967), Forsyth & Sinning (1973), Slaughter *et al.* (1988) and Deurenberg *et al.* (1990) were used in the present study.

The use of fewer skin fold sites to accurately predict %BF would have a number of advantages including ease of measurement, practicality and less time spent measuring. The most accurate equation in the present study was the two skinfold site by Slaughter *et al.*

(1988). As early as 1967, Sloan (1967) reported that BD measured by UWW had the highest correlation with a regression equation using the two skinfolds (frontal thigh and subscapular) in males aged 18 to 26 years, after considering five other sites (abdominal, supra-iliac, chest, triceps and buttock). Forsyth & Sinning (1973) advocated the use of two skinfold sites (abdominal and triceps) to calculated the %BF of male athletes aged 19 to 22 years. Mueller & Stallones (1981) concluded from a principle components analysis that the medial calf and one other trunk site, such as the supra-iliac, lateral chest wall or subscapular were sufficiently accurate to measure %BF for males and females aged seven to 80 years. Slaughter *et al.* (1988) also demonstrated that just two skinfolds (triceps and either subscapular or calf) were satisfactory in predicting %BF when compare to nine skinfolds (triceps, biceps, subscapular, mid-axilla, supra-iliac, anterior supra-iliac, abdominal, mid-thigh and medial calf) in children aged eight to 18 years. Deurenberg *et al.* (1990) advocated the use of the triceps and biceps sites in a two skinfold equation as they found that the correlation coefficient of the sum these two skinfolds and body density was comparable to that of four skinfolds (triceps, biceps, subscapular and supra-iliac) in children aged seven to 20 years. However, it can be noted that in the present study the two-skinfold equation by Deurenberg *et al.* (1990) was significantly impacted by dehydration while the four-skinfold equation was not. This presents a possible disadvantage to using fewer skinfold sites.

5.5.2.2 Three skinfold sites

The three-skinfold equations by Lohman (1981) and Evans *et al.* (2005) were used in the present study, both of which were inaccurate in either hydration state.

The use of three skinfold sites was advocated by Jackson & Pollock (1978) who reported a close correlation (r = 0.98) between %BF calculated using the sum of three (chest, abdominal and thigh) and seven skinfolds (chest, mid-axillary, triceps, subscapular, abdominal, supra-iliac and thigh) in male athletes and non-athletes aged 18 to 61 years. This equation was not used in the present study as the chest skinfolds were not routinely measured at the SAJA. Similarly, Evans *et al.* (2005) concluded that a prediction equation using three sites (triceps, abdominal and thigh) produced a similar accuracy to that of same seven skinfold sites in male athletes aged 18 to 26 years. However, in the present study, the results of the Evans *et al.* (2005) equation were the least accurate overall and were significantly affected by dehydration. The three-skinfold equation by Lohman (1981) (triceps, abdominal and subscapular sites) also proved to be inaccurate.

Therefore, the use of three skinfold sites was less accurate, less practical and more time-consuming than using two sites.

5.5.2.3 Four skinfold sites

The four-skinfold equations by Durnin & Rahaman (1967), Durnin & Womersley (1974), Jackson & Pollock (1985), Deurenberg *et al.* (1990) and Peterson *et al.* (2003) were used in the present study, none of which were significantly impacted by dehydration. However, only that of Durnin & Rahaman (1967), Durnin & Womersley (1974) and Deurenberg *et al.* (1990) were accurate in either hydration state.

The Durnin & Womersley (1974) equation, which involves the biceps, triceps, subscapular and supra-iliac sites, was ranked third most accurate in combination with the Brozek *et al.* (1963) equation and was not significantly affected by dehydration. The authors recommended this equation for male athletes and non-athletes ages 16 to 72 years.

It is of interest to note that the equation that was currently used to calculate %BF from skinfolds at the SAJA, which was retrieved from (Topend Sports Network, 2015) and attributed to Jackson & Pollock (1985), was the least accurate overall. This equation includes the abdominal, triceps, thigh and supra-iliac sites. It resulted in significant under-estimation of the %BF, with a mean %BF of 3.8 % and 2.6 % when euhydrated and dehydrated respectively.

5.5.2.4 Multiple skinfold sites

Stewart & Hannan (2000) demonstrated contrarily to the previous studies that more skinfolds increased the accuracy of calculation of %BF as the SEE for regression equations decreased as the number of skinfold sites used increased in male athletes with a mean age of 28.1 years. The sites included the abdominal, chest, thigh, supra-iliac, forearm and medial calf sites and the SEE decreased as the number of sites were added to the regression equation in this order. Stewart & Hannan (2000) proposed an alternative regression equation for male athletes using all six skinfold sites. This equation was not used in the present study as the chest and forearm skinfolds are not routinely measured at the SAJA.

The equation by Withers *et al.* (1987), using seven skinfold sites (triceps, biceps, subscapular, supra-iliac, abdominal, medial calf and thigh) was the second most accurate but only in the euhydrated state. It is suggested that this is because this equation includes all of the sites that were significantly impacted by dehydration (tricep, abdominal and frontal thigh). This equation has been used in a number of studies involving jockeys (Warrington *et al.*, 2009; Dolan *et al.*, 2009; Dolan *et al.*, 2013) (Table 5.2).

Therefore, an increased number of skinfold sites does not necessarily increase the accuracy of %BF calculation. Additional sites may introduce error into the equation as some sites are more susceptible to be influenced by dehydration than others, which was suggested by the effect of dehydration in the present study. Fewer skinfolds are more practical, less time-consuming and less invasive. Therefore, it is difficult to specify which equation might be more suitable, in terms of sites, variables and constant values used, without validating in a specific population.

Using skinfold measurements to accurately determine %BF would be a cheap, quick and practical method of measuring %BF at the SAJA, particularly those equations which were not impacted by dehydration, such as that of Slaughter *et al.* (1988) and Durnin & Womersley (1974).

5.5.3 Bioelectrical impedance analysis

The hypothesis that BIA would be most comparable to DD (reference method) can be rejected. However, it was significantly affected by dehydration, as hypothesised. The Van Loan *et al.* (1990) BIA equation can however be considered relatively comparable to the reference method.

Seventy-five percent of the BIA equations produced %BF values that differed significantly from the reference method according to the Wilcoxon signed ranks test in both hydration states, including the undisclosed equation of the BODYSTAT®1500, with regression equations applied to the apprentices younger than 18 years using the product software. Applying the equations by Van Loan *et al.* (1990) in either hydration state and Lohman (1992) when euhydrated only to the impedance values given by the BODYSTAT®1500 machine produced %BF results that were not significantly different to the reference method according to the Wilcoxon signed ranks test. However, only the Van Loan *et al.* (1990) BIA equation when euhydrated was considered to have an acceptable level of bias according to the Bland-Altman analysis. There was virtually no trend towards bias therefore, %BF on either extreme of 9.5% could be verified using these BIA equations. From a practical perspective however, most people using a BIA will simply use the equation given by the machine. Therefore this is not a very suitable method.

5.5.4 Recommended method for measuring the percent body fat of apprentices

Given the results of the present study, it is recommended that the SAJA continues to utilize the skinfold method for measuring %BF. However, the currently used equation is not suitable for this population. Although raw skinfold thickness measurements, and the sum thereof, may be used to assess and monitor body fatness, which is an indicator of nutritional status in both athletes and non-athletes (Wells & Fewtrell, 2006), these cannot be validated without deriving population-specific regression equations for %BF. Therefore, validated regression equations are recommended. The study aimed to determine the actual %BF of the apprentices in order to assess scope for reduction of body fat and not to monitor the change.

The Slaughter *et al.* (1988) skinfold equation can be recommended for the apprentices who are 18 years and younger due to its acceptable level of bias in both hydration states. The Durnin and Womersley (1974) equation for BD, using Brozek *et al.* (1963) to translate to %BF is recommended for apprentices older than 18 years as it also had an acceptable level of bias in either hydration state. Percent body fat values measured on either extreme of 9.5 % should be approached with caution when using these equations due to the positive linear trend towards bias.

It is still essential that the correct techniques (ISAK) are strictly adhered to, the callipers such as Lange or Harpenden used have been validated for accuracy, and that inter-observer variability is controlled by ensuring that the same observer takes all of the measurements at each assessment.

Should an ISAK-trained individual not be available for measurement, or should %BF values be on either extreme of 9.5%, BIA may be used by substituting the impedance value given by the BODYSTAT®1500 machine into the equation by Van Loan *et al.* (1990) after ensuring euhydration as it had an acceptable level of bias and a neutral trend.

The BMI equation for measuring %BF is not recommended as the level of bias was found to be unacceptably large and BMI and %BF are known to have a weak relationship in athletes and non-athletes with a BMI less than 25 kg/m^2 (Nevill *et al.*, 2006; Meeuwsen *et al.*, 2010a; Kupusinac *et al.*, 2017). It also showed a positive linear bias on either extreme of 10.25%.

5.6 WEIGHT-MAKING BEHAVIOURS

5.6.1 Weight satisfaction

The hypothesis that weight dissatisfaction would be significantly associated with a higher weight and BMI was rejected, however weight dissatisfaction was significantly associated with a lower %BF.

Approximately one third (37%) were dissatisfied with their current weight which was less than that reported by Krog (2015) (57%) and Moore *et al.* (2002b) (52%). These included both apprentices whose %BF was within the essential fat range, and the remainder who were all underfat. Interestingly, those dissatisfied with their body weight had a higher body weight but a lower %BF than those satisfied. This reinforces the need for a practical, cheap and accurate measurement of body composition analysis to individualise weight loss in terms of %BF. Therefore, should these apprentices reduce their weight to what they consider to be ideal, they would compromise their FFM. An apprentice who is unsatisfied with his weight but has a %BF less than the recommended range should be reassured and counselled, and ideally not be prescribed a diet or exercise regime that will increase FFM further.

5.6.2 Chronic weight-making methods

The hypothesis that the prevalence of chronic and acute weight-making behaviours of the apprentices studied would be similar to that of the previous study on apprentices at the SAJA (Krog, 2015) and implicate necessary intervention was accepted.

Restricting food intake was the most commonly reported method (75%), followed by daily weighing (69%), keeping busy to avoid eating (44%) and exercising to use up calories (44%). It should also be noted that smoking cigarettes was relatively common (37%), which presents other potential health concerns, including negative effects on immunity (Sopori, 2002) and BMD (Ward & Klesges, 2001). The results of the present study were similar to other studies involving jockey apprentices (Moore *et al.*, 2002b; Leydon & Wall, 2002; Krog, 2015) (Table 5.3). In keeping with the study conducted by Krog (2015), none reported using laxatives or induced vomiting to lose weight. The apprentices may be under less pressure to maintain a lower weight than the professional jockeys, as they have not developed to their full adult size, and may therefore be less inclined to adopt more “extreme” methods such as the use of laxatives and induced vomiting. This result however may be due to false reporting. Although confidentiality and anonymity was assured, the apprentices may have been afraid or uncertain of the consequences of admitting to these habits.

Table 5.4: Chronic weight-making methods used by jockeys [a]

	Sample size	Mean age (years)	Country	Excessive exercise	Food restriction	Smoking cigarettes	Laxatives	Induced vomiting
Present study	16	18.8 ± 1.7	South Africa	n/r	75%	37%	0%	0%
				Apprentice studies				
Moore *et al.* (2002) [b]	116	29.6 ± 0.9	Australia	76%	75% [c]	48%	26%	10%
Leydon & Wall (2002) [d]	9	20.5 ± 3.8	New Zealand	33%	67%	50% [e]	0%	n/r
Krog (2015)	21	18.0 ± 1.4	South Africa	24%	67%	24%	0%	0%
				Professional jockey studies				
King & Mezey (1987) [f]	10	22.9 ± 4.4	England	100%	90%	n/r	60%	10%
Labadarios *et al.* (1993)	93	27.8 [g]	South Africa	n/r	77%	75%	27%	n/r
Moore *et al.* (2002) [b]	116	29.6 ± 0.9	Australia	76%	75% [c]	48%	26%	10%

	Sample size	Mean age (years)	Country	Excessive exercise	Food restriction	Smoking cigarettes	Laxatives	Induced vomiting
Leydon & Wall (2002) [h]	9	28.7 ± 5	New Zealand	11%	67%	50% [e]	0%	n/r
Dolan *et al.* (2011)	21	27.3 ± 6.8 [i]	Ireland	38%	71%	24%	5%	14%
Cotugna *et al.* (2011) [j]	20	35 [f]	America	40%	35%	30%	n/r	10%
Cullen (2014)	33	n/a [k]	Ireland	97%	100%	73%	61%	6%
Wilson *et al.* (2013b)	8	n/r	England	n/r	62%	n/r	n/r	n/r
O'Reilly *et al.* (2017)	20	29.3 ± 7.8	Hong Kong	16%	20%	25%	n/r	4%

[a] Male flat jockeys unless otherwise specified.
[b] Apprentices (n = 20) and professionals (n = 96) included (91 male and 25 females) as results were not differentiated.
[c] Skipped meals.
[d] Two males and seven females included.
[e] Professionals and apprentices (n = 20) included as results for smoking were not differentiated.
[f] Not specified whether jump or flat jockeys.
[g] No SD given.
[h] Four males and five females included.
[i] A total of 27 flat and jump jockeys were included. Only 21 completed the questionnaire.
[j] 19 males and one female included. Results were not differentiated
[k] The study involved retired jockeys (mean age 63 ± 10 years) who reported on methods used during their career. Of the 37 participants included, only 33 completed the questionnaire.

The consequences of food restriction includes poor BMD as a result of low EA. This is particularly important when considering the mean age of the apprentices (18.8 years) as peak BMD for males typically occurs before the age of 20 years (Cvijetić Avdagić *et al.*, 2009; Berger *et al.*, 2010). Krog (2015) reported a low mean calculated EA of 113.28 kJ/kg FFM in the SAJA apprentices over two training days and one rest day. Training with an EA less than 125 kJ/kg FFM, with or without disordered eating, has previously been shown to negatively impact physiological function and bone health in male athletes (Sundgot-Borgen *et al.*, 2013). Leydon & Wall (2002) reported that 44% of the flat jockeys were osteopenic. This was related to a restricted food intake as 58% of the males consumed less than 60% of the recommended daily intake (RDI) of calcium according to their seven-day weighed food records. Warrington *et al.* (2009) found that 53% of flat jockeys were osteopenic and 12% had osteoporosis, which was suggested to be a result of the exercise, nutritional and other lifestyle habits of the jockeys. This is of concern due to the high risk of injuries and fractures from falling in horse racing (Waldron-Lynch *et al.*, 2010; Rueda *et al.*, 2010).

Restriction of energy and fluid intake is also associated with impaired mood profiles in jockeys. Caulfield & Karageorghis (2008) reported significantly increased depression, anger, fatigue, confusion and tension and significantly decreased vigour when 41 professional male flat and jump jockeys (mean age 30.9 years) were at their lightest weight compared to a relaxed weight. The descriptive study by Wilson *et al.* (2013a) also demonstrated high levels of depression, anger and fatigue as well as low vigour according to the Brunel Mood Scale (BRUMS) as a result of food and fluid restriction in 19 flat (mean age 27 years) and 17 jump (mean age 25 years) jockeys. This may have negative implications for their physical performance in the sport, as well as their personal lives.

5.6.2.1 Sports and exercise

Although exercising to use up calories was a popular method of weight control, the most popular reason reported for engaging in any physical activity besides horse riding was for fitness. The most popular activities were soccer and running or jogging. Soccer, running and weight training were the only physical activities used for weight control. From the body composition results of this study, increased weight training should not be recommended as it may increase FFM. The present study did not assess the prevalence of excessive exercise.

5.6.3 Acute weight-making methods

The only methods reported for rapidly losing weight were taking hot baths with or without Epsom salts (most common method) or Arnica, using the sauna and wearing plastic to sweat during exercise. These results were similar to that of Krog (2015), indicating that the behaviour of the SAJA apprentices has not changed but much lower than reported 25 years ago in professional jockeys in South Africa. This can be attributed to the change in race rules as medications such as laxatives and diuretics are no longer allowed, and that the apprentices may have not yet adopted these practises.

In comparison to other studies involving apprentice and professional jockeys, the general use of acute weight-making methods was less prevalent in the present study with the exception of taking hot baths (Table 5.4). None in the present study claimed to flip[6] or use diuretics or laxatives in order to make weight, whereas the average prevalence in other jockey studies was 8%, 40% and 26% respectively. The prevalence of these specific habits among apprentices was not differentiated out in the studies by Moore *et al.* (2002b) and Leydon & Wall (2002). This indicates that these habits have not yet been adopted by the apprentices. This could also be due to less pressure to make handicaps as well as false reporting.

[6] purge after eating or drinking

Table 5.5: Acute weight-making methods used by jockeys [a]

	Sample size	Country	Saunas	Sweat suits	Diuretics	Laxatives	Fluid restriction	Hot/salt baths	Induced vomiting
Present study	17	South Africa	38%	31%	0%	0%	n/r	50%	0%
				Apprentice studies					
Moore *et al.* (2002) [b]	116	Australia	68%	n/r	39%	26%	95% [c]	n/r	10%
Leydon & Wall (2002) [d]	9	New Zealand	67%	n/r	0%	0%	56%	22%	n/r
Krog (2015)	21	South Africa	43%	29%	0%	0%	n/r	n/r	0%
				Professional jockey studies					
King & Mezey (1987) [e]	10	England	100%	80%	70%	60%	n/r	n/r	10%
Labadarios *et al.* (1993)	93	South Africa	70%	48%	70%	27%	77%	27%	n/r
Moore *et al.* (2002) [b]	116	Australia	68%	n/r	39%	26%	90% [c]	n/r	10%
Leydon & Wall (2002) [f]	9	New Zealand	44%	n/r	33%	0%	56%	33%	n/r
Dolan *et al.* (2011)	21	Ireland	86%	43%	5%	5%	n/r	n/r	14%

	Sample size	Country	Saunas	Sweat suits	Diuretics	Laxatives	Fluid restriction	Hot/salt baths	Induced vomiting
Cotugna *et al.* (2011) [g]	20	America	60%	n/r	n/r	n/r	5%	n/r	10%
Cullen (2014) [h]	33	Ireland	73%	n/r	61%	61%	91%	79%	6%
Wilson *et al.* (2014)	8	England	75%	100%	n/r	n/r	62%	37%	n/r
O'Reilly *et al.* (2017)	20	Hong Kong	26%	20%	n/r	n/r	20%	n/r	4%

[a] All male flat jockeys unless otherwise specified.
[b] Apprentices (n = 20) and professionals (n = 96) included (91 male and 25 female) as results were not differentiated, with the exception of fluid restriction.
[c] Eat or drink less or nil pre-race meeting.
[d] Two males and seven females included.
[e] Not specified whether jump or flat.
[f] Four males and five females included.
[g] 19 males and one female included. Results were not differentiated.
[h] The study involved retired jockeys (mean age 63 ± 10 years) who reported on methods used during their career. Of the 37 participants included, only 33 completed the questionnaire.

The prevalence of chronic and acute weight-making methods was considerably lower in the present study when compared to that of studies involving professional jockeys, particularly regarding acute weight-making methods as well as the use of laxatives and forced vomiting to control weight.

The reported acute weight-making behaviours such as the use of saunas, sweat suits and hot baths as well as the reports of feelings of thirst which suggest fluid restriction, may explain the findings of chronic dehydration in the apprentices.

5.6.4 Feelings of hunger and thirst

The majority (94%) felt both hungry and thirsty at least “sometimes,” which included those that reported feeling both hungry and thirsty “often” and “always.” Only 6% reported that they never feel hungry or thirsty. This reflects a disturbing level of discomfort in terms of hunger and thirst. Krog (2015) indicated that 80% reported thirst as a short-term negative effect of weight control methods.

Dolan *et al.* (2011) found that hunger (38%) and thirst (52%) were the most frequently reported short-term negative effects among professional jockeys. It was suggested by Warrington *et al.* (2009) that habituation to dehydration may have led to an impairment of the thirst mechanism in professional jockeys, although further investigation into this phenomenon is required. This may indicate that the apprentices have not yet undergone the extent of habituation to cause this impairment. The same may apply to feelings of hunger, wherein the apprentices have not yet adapted to energy deficiency as the professionals have.

5.7 RISK OF DEVELOPING EATING DISORDERS.

The hypothesis that there would be a high risk of developing eating disorders such as AN and BN was rejected.

The mean EAT-26 score was considerably lower than 20, indicating a low risk with only one being considered at risk, which was surprising considering their preoccupation with body weight. The prevalence of risk of chronic eating disorders was lower in apprentices than in professional jockeys (Table 5.5).

This apprentice was dissatisfied with his body weight, and although his BMI was above the sample mean, his %BF (8.89 %) was bordering the lower limit of the normal range for his age group (8%). This supports the need to accurately measure %BF in order for such apprentices to be aware that it is dangerous to reduce weight if their %BF is borderline or below normal. Although the EAT-26 questionnaire is a screening as opposed to a diagnostic tool, it is the recommendation of Garner & Garfinkel (1979) that this apprentice should be referred for professional assessment.

The prevalence of abnormal eating behaviour was lower when compared to other jockey studies (King & Mezey, 1987; Leydon & Wall, 2002; Caulfield & Karageorghis, 2008; Wilson *et al.*, 2015) as reflected by a lower mean score, including that of a group of male and female apprentices (Table 5.5). Female jockeys were reported to have a significantly lower mean EAT-26 score than that of male jockeys in the study by Leydon & Wall (2002), which makes the mean score of the present study more surprising. The mean age in the present study was lower than that of the other jockey studies, which may account for a lower EAT-26 score as the apprentices may not have developed to their full adult size yet making it easier to attain a low weight.

Table 5.6: The EAT-26 scores of jockeys [a]

	Sample size	Mean age (years)	Mean EAT score	% >20 [b]
Present study	16	18.8 ± 1.7	4.9 ± 5.8	6.3%
		Apprentice studies		
Leydon & Wall (2002) [c]	9	20.5 ± 3.8	13.2 ± 9.9	22%
		Professional jockey studies		
King & Mezey (1987) [d]	10	22.9 ± 4.4	14.9 [e]	n/r
Leydon & Wall (2002) [f]	20	28.7 ± 5	13.5 ± 9.3	20%
Caulfield & Karageorghis (2008) [g]	41	30.9 ± 7.0	8.6 ± 9.1 (lightest weight) 6.8 ± 8.1 (optimal) 6.2 ± 7.8 (relaxed)	20% (lightest)
Wilson *et al.* (2015)	14	32.0 ± 6.0	14.8 ± 9.6 (prior to study intervention)	28.6%

n/r: not reported.
[a] All male flat jockeys unless otherwise specified.
[b] A score of greater than 20 indicates the possibility of an eating disorder.
[c] Two males and nine females were included.
[d] Not specified whether jump or flat jockeys.
[e] No SD given.
[f] Four males and five females included.
[g] Both jump and flat jockeys involved but ratio was not specified.

The low score however may be a result of underreporting, because of the shame associated with the stereotype that eating disorders afflicts only female and male homosexuals (Murray, 2017). Underreporting of symptoms of eating disorders is not uncommon in athletes due to poor credibility of efforts to ensure confidentiality (Joy *et al.*, 2016). However, a strong effort to ensure confidentiality was made in the present study by having both the EAT-26 and lifestyle questionnaires administered by a registered social worker with no affiliations to the SAJA who had experience doing similar questionnaires with the apprentices. The questionnaires were administered to each apprentice separately in a private location.

No eating disorders were diagnosed in the studies described in Table 5.5, despite the high prevalence of disordered eating. The typically used diagnostic criteria for eating disorders (DSM-IV) is known to present a gender bias as it indicates that amenorrhoea is a specification for AN (Strother *et al.*, 2012; Mitchison *et al.*, 2017). The revised diagnostic classification, Diagnostic and Statistical Manual of Mental Disorders, 5th edition (DSM-V), which allows more eating disorders in males to be identified by a specific diagnosis (Raevuori, Keski-Rahkonen & Hoek, 2014), was only published in 2013. Therefore it is possible that eating disorders in these jockey samples were undiagnosed.

5.8 CONCLUSION

As indicated by USG, the apprentices are chronically moderately dehydrated which may have long term health implications although chronic dehydration could not be associated with negative consequences such as renal dysfunction in jockeys.

Stunting was reported in 60% of those under 19 years, of which three (50%) came from lower income groups, which could indicate chronic malnutrition as a result of poor food security. Stunting as a result of chronic malnutrition presents negative implications for the jockeys as it is significantly correlated with poor BMD and BMC (Martins *et al.*, 2011), which could increase the risk of fractures from falls.

Only twelve percent (2/17) fell into the “essential” fat range, and 88% and 65 % were underfat according to their %BF and FMI respectively and therefore had insufficient fat stores to protect their FFM. Most of the apprentices had a %BF that was close to the lower limit of the normal range, although some did indicate some scope to reduce either their %BF or FMI to the lower limit of normal for their age group. Therefore it is not recommended that all of the apprentices reduce their FM as this presents a high risk of compromising FFM. Recommendations for reducing FM should be individualised.

Calculating %BF from BMI using the Deurenberg *et al.* (1991c) equation is not recommended for the apprentice population as it showed an unacceptable level of bias and a weak relationship between BMI and %BF has been reported in athletes and non-athletes with a BMI less than 25 kg/m^2 (Nevill *et al.*, 2006; Meeuwsen *et al.*, 2010a; Kupusinac *et al.*, 2017).

Given the results of the present study, it is recommended that the SAJA continues to utilize the skinfold method for measuring %BF. However, the currently used equation is not suitable for this population.

The Slaughter *et al.* (1988) skinfold equation can be used for the apprentices that are 18 years or younger. The Durnin and Womersley (1974) equation for BD, using Brozek *et al.* (1963) to translate to %BF is therefore recommended for those apprentices older than 18 years. Caution should be taken when approaching %BF values on either extreme of 9.5% given by these equations due to the positive linear trend towards bias.

An increased number of skinfold sites does not necessarily increase the accuracy of %BF calculation from skinfold equations as the three most accurate equations involved the use of two, four and seven sites respectively with varying site locations. The use of a population-specific equation is more important.

The use of the undisclosed equation from the BODYSTAT®1500 machine was not accurate in either hydration state. Although an acceptable level of bias was found when substituting the resistance values into the BIA equation by Van Loan *et al.* (1990), from a practical perspective, most people using a BIA will simply use the equation given by the machine. Therefore this is not a very suitable method. However, this method may be used to verify results from the skinfold equations on either extreme of 9.5%

Weight dissatisfaction was associated with a significantly lower %BF meaning that the higher body weight of those dissatisfied was not due to excess fat mass, which reinforces the need to accurately measure %BF. An apprentice who is unsatisfied with his weight but has a %BF less than the recommended range should be reassured and counselled, and ideally not be prescribed a diet or exercise regime that will increase FFM further.

Food restriction was the most popular chronic weight-making method, which can negatively impact bone health and therefore increase the risk of fracture from falling.

Acute weight-making techniques reported explain the findings of chronic dehydration. Some acute weight-making methods that are used by professional jockeys, such as the use of diuretics, laxatives and induced vomiting, have not yet been adopted by the apprentices.

The prevalence of weight-making techniques in the present study was similar to that of other studies involving apprentices but lower than that of professional jockeys. This indicates that these habits have not yet been adopted by the apprentices. Acute dehydration is associated with poor performance when racing.

There was a disturbing level of discomfort in terms of both hunger and thirst as the majority felt both hungry and thirsty as least sometimes and very few reported that they never felt hungry or thirsty.

Only one apprentice was at risk for an eating disorder and overall the risk was low according to the mean EAT-26 and lower than that of other jockey studies.

CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS

6.1 INTRODUCTION

This study aimed to assess the accuracy of methods (BMI, skinfolds and BIA) of accurately determining the %BF of the male jockey apprentices training at the SAJA, the weight-making behaviours adopted and the risk of eating disorders. The specific objectives were:

i. To determine the hydration status prior to intervention of the male apprentice jockeys at the SAJA by urinalysis.
ii. To accurately determine the mean %BF of the apprentices using the reference method DD.
iii. To classify the height-for-age, BMI, %BF, FMI and FFMI of the apprentices.
iv. To validate the accuracy of three methods of body composition analysis (BMI, skinfolds and BIA) in measuring %BF to the reference method DD, in male apprentice jockeys at the SAJA when euhydrated and dehydrated.
v. To investigate the association between weight satisfaction of the apprentices and their %BF, age, height, weight, BMI, fat mass index (FMI) and fat-free mass index (FFMI).
vi. To investigate the use of various weight-making techniques of the apprentices using a lifestyle questionnaire.

To investigate the apprentices' risk of developing eating disorders such as anorexia nervosa (AN) and bulimia nervosa (BN) using the EAT-26 questionnaire.

6.2 CONCLUSION

The study sample consisted of jockey apprentices training at the SAJA during 2016, most of whom were Caucasian teenagers.

The apprentices were chronically moderately dehydrated due to the perceived need to reduce weight to meet handicapping requirements. It is important to address this by regular hydration assessment and education on how to ensure proper hydration as dehydration could negatively impact racing performance, renal function and BMD particularly in conjunction with a low %BF.

The mean BMI, although within the normal range, was above the lower limit with only one being classified as underweight. Although two apprentices were classified as underlean, the mean FFMI was normal, which would assist them to remain stable and maintain control while riding reducing the risk of falls and help prevent a low BMD as well as to sustain weight loss. The mean %BF (10.2 %) for those under 20 year and those over 20 years (7.3 %) was below the minimum range of normal, and although lower than that of other apprentices, it was comparable to that of professional jockeys. The majority were classified as being underfat, with two falling within the essential fat range compromising both their health and FFM. For some apprentices, there is some scope to reduce either their %BF or FMI to the minimum normal level for their age group. Recommendations to reduce weight therefore in this population should be individualised and based on %BF and FMI established by accurate methods of body composition.

Both the BMI and BIA as measured in this study were not as appropriate as the skinfold measurements regression equations. The Slaughter *et al.* (1988) skinfold equation is recommended for apprentices that are 18 years or younger and the Durnin & Womersley (1974) skinfold equation with Brozek *et al.* (1963) is recommended for those older than 18 years. Caution should be taken when approaching %BF values on either extreme of 9.5% given by these equations due to the positive linear trend towards bias. An increased number of skinfold sites does not necessarily increase the accuracy of %BF calculation from skinfold equations as the most accurate equations involved the use of two skinfold sites.

Should an ISAK-trained individual not be available to measure skinfolds, or the skinfold equations produce %BF values on either extreme of 9.5 %, BIA could be used by substituting the impedance value given by the BODYSTAT®1500 machine into the equation by Van Loan *et al.* (1990) which was reasonably accurate when both euhydrated and dehydrated and had a neutral trend towards bias.

Weight dissatisfaction was associated with a higher body weight but a significantly lower %BF, which reinforces the need to accurately measure %BF and to individualise recommendations regarding weight loss according to body composition and not actual weight or BMI.

Chronic weight-making techniques included restricting food intake, daily weighing, keeping busy to avoid eating, exercising to use up calories and smoking cigarettes. Food restriction was the most popular, which can negatively impact bone health and therefore increase the risk of fracture from falling. Acute weight-making techniques included taking hot baths, with or without Epsom salts or Arnica oil, using the sauna and wearing plastic to sweat while exercising with hot baths were most popular. Extreme methods, such as vomiting, were not used by the apprentices. There was a disturbing level of discomfort in terms of both hunger and thirst as the majority felt both hungry and thirsty at least sometimes and very few reported that they never felt hungry or thirsty.

The risk of eating disorders was low as reflected by a low EAT-26 score with only one apprentice at risk. This was surprising considering that the results of the lifestyle questionnaire indicated a high prevalence of food restriction as well as other habits associated with disordered eating such as skipping meals and avoiding situations with food.

Therefore, the use of the skinfold method with the equations by Slaughter *et al.* (1988) for those 18 years and younger and Durnin & Womersley (1974) for BD, with the Brozek *et al.* (1963) equation to translate to %BF, for those older than 18 years, is recommended for this population. Some of the deleterious weight-making methods used by professionals have not yet been adopted by the apprentices, although they are chronically dehydrated and there was a disturbing level of discomfort in terms of hunger and thirst. The risk of eating disorders was low.

6.3 STUDY LIMITATIONS

- The sample size was small as the total population of apprentice jockeys in South Africa was small, however the high response rate allowed for a good representation of the population.

- The BODYSTAT®1500, does not measure separate values for resistance and reactance. This limited the number of BIA equations that could be applied to the data. Other machines, which measure resistance and reactance separately, could have also been more accurate.
- The questionnaires involved subjective self-reported data. These should be approached with caution as participants might have misinterpreted questions or tried to impress the social worker and thus the data could be aligned with socially accepted norms and sporting rules, rather than the truth.

6.4 RECOMMENDATIONS FOR NUTRITION PRACTISE

6.4.1 Prescriptions of weight-loss diets and exercise regimes for the jockey apprentices at the SAJA be individualised based on body composition (%BF and FFMI), instead of weight and BMI.

6.4.2 Continued use of the skinfold method by an ISAK-trained individual is recommended, however with the Slaughter *et al.* (1988) equation for those 18 years and younger and the Durnin & Womersley (1974) equation for BD, with that of Brozek *et al.* (1963) to translate to %BF, for those older than 18 years.

6.4.3 Regular education regarding the risks of deleterious weight-making methods, especially those involving energy restriction and dehydration, be conducted at the SAJA by the faculty and medical team (clinic sister, dietitian, biokineticist).

6.4.4 Regular monitoring of hydration status according to USG should also be done and the apprentices should be encouraged to remain euhydrated, especially on non-race days.

6.5 IMPLICATIONS FOR FURTHER RESEARCH

6.5.1 To investigate the bone health of the apprentices according to their BMD and BMC using DXA, since a number the apprentices in the present study indicated a high prevalence of stunting, a low %BF, as well as the use of weight-making methods that involved energy restriction and dehydration. A low %BF, combined with energy restriction and dehydration, has been shown to reduce BMD and increase the prevalence of osteopenia and fractures in studies in other jockey studies.

6.5.2 To investigate the effects of implementing an initiative to encourage better hydration practices (drinking more fluids and avoiding dehydration practises) as the apprentices were reported to be chronically dehydrated which could have detrimental effects on their long-term health and their career.

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Appendix A: Data Collection Sheet

General

1. ID (dose number): ______
2. Name: ___________________________

3. Urine osmolality: _______ Euhydrated (<1.020) □ / Euhydrated (>1.020) □
4. Weight: 1. ______ 2. ______ Average: ______

5. Time of dose taken: ___:___ 100ml water taken: □ + 4 hours: ___:___
6. Dose weight (g): _______

7. Date of birth (dd/mm/yyyy): ___/___/______ Age: _____ years

8. Height: 1. ______ 2. ______ Average: ______

BIA (Body Stat 1500)

Body fat: 1. _____% 2. _____% Average: _____%

1. _____kg 2. _____kg Average: _____kg

9. Lean mass: 1. _____% 2. _____% Average: _____%

1. _____kg 2. _____kg Average: _____kg

10. Body water: 1. _____% 2. _____% Average: _____%

1. _____kg 2. _____kg Average: _____kg

11. Tricep skin-fold

	Bicep	Tricep	Subscapular	Supra-iliac	Abdominal	Thigh	Calf
1							
2							
Average							

12. Time of post-dose saliva sample: ___:___

13. ^{2}H enrichment in saliva (mg/kg): _________

14. ^{2}H pool space (V_D, kg)

    = Dose (mg)/^{2}H concentration (mg/kg): _________

Appendix B: Lifestyle Questionnaire

Please note that there are 4 pages in this questionnaire and you are required to complete all pages.

1. ID (not to be filled in by respondents): _____

2. Apart from riding, what other exercise do you participate in regularly and for what reason? If you don't do an activity leave it blank. (You may tick more than one option per activity).

Activity	Recreation	Weight control	Fitness	To keep busy	Other –please specify
2.1 Walking					
2.2 Running/jogging					
2.3 Tennis					
2.4 Golf					
2.5 Swimming					
2.6 Cycling					
2.7 Weight training					
2.8 Soccer					
2.9 Other –please specify: ______________________					

3. Weight:

3.1 Are you happy with your current weight?

Yes	
No	

3.2 If no to q3.1, how much would you like to weigh? ______ kg

4. Please indicate how often you currently use the following **for the purpose of controlling your weight**.

For example, if you are drinking three cups of coffee <u>every</u> day for the sole purpose of controlling your weight, you will answer "always" for Q4.15. If however you are drinking the coffee for pleasure and this is not related to weight control then you would reply never.

Ways to control weight…	**Never**	**Rarely**	**Sometimes**	**Often**	**Always**
4.1 Not eat between meals					
4.2 Not eat breakfast					
4.3 Not eat lunch					
4.4 Not eat dinner					
4.5 Avoid eating with the family – when/if staying at home					
4.6 Avoid situations where there will be food					
4.7 Keep busy to avoid eating					
4.8 Restrict food intake					
4.9 Fast					
4.10 Choose low calorie/ diet foods					
4.11 Follow your own homemade diet					
4.12 Follow a diet from a magazine/ website/ book/ newspaper					
4.13 Follow a vegetarian/ vegan diet					
4.14 Prepare your own food eg. 2 minute noodles					
4.15 Drink coffee					
4.16 Drink fluids before meals to feel full					
4.17 Weigh yourself every day					
4.18 Exercise to use up calories					
4.19 Vomit after meals					
4.20 Use laxatives (specify) ____________________					
4.21 Smoke cigarettes					

Ways to control weight…	Never	Rarely	Sometimes	Often	Always
4.22 Smoke marijuana					
4.23 Chew food and spit it out					
4.24 Use slimming pills – prescription (specify)					
4.25 Use slimming pills – over the counter (specify)					
4.26 Use herbal preparations (specify)					
4.27 Other methods (please specify)					

5. The following is a list of behaviours used by people to control their body weight or to lose weight over a very short period of time. Please indicate how often you <u>currently</u> use the following to lose weight during training or for a race?

Behaviour	Daily	A few times a	Once a week	1-3 times a month	Less than once a month	Never
5.1 Sauna						
5.2 Rub downs						
5.3 Wearing plastic to sweat while exercising						
5.4 Flipping						
5.5 Diuretics (specify)						
5.7 Laxatives (specify)						
5.8 Other (specify) ____________________ ____________________						

6. Please indicate how often you feel the following:

	Never	Rarely	Sometimes	Often	Always
6.1 Hungry					
6.2 Thirsty					

7. How many cups of fluid do you think you need to drink per day in order to be healthy?

_______ cups/day

Thank you for completing this questionnaire

Appendix C: EAT-26 Questionnaire

Eating Attitudes Test (EAT-26)©

Instructions: This is a screening measure to help you determine whether you might have an eating disorder that needs professional attention. This screening measure is not designed to make a diagnosis of an eating disorder or take the place of a professional consultation. Please fill out the below form as accurately, honestly and completely as possible. There are no right or wrong answers. All of your responses are confidential.

Part A: Complete the following questions:

1) Birth Date	Month:		Day:	Year:	2) Gender:	Male	Female
3) Height	Feet :		Inches:			☐	☐
4) Current Weight (lbs.):			5) Highest Weight (excluding pregnancy):				
6) Lowest Adult Weight:			7: Ideal Weight:				

	Part B: Check a response for each of the following statements:	Always	Usually	Often	Some times	Rarely	Never
1.	Am terrified about being overweight.	☐	☐	☐	☐	☐	☐
2.	Avoid eating when I am hungry.	☐	☐	☐	☐	☐	☐
3.	Find myself preoccupied with food.	☐	☐	☐	☐	☐	☐
4.	Have gone on eating binges where I feel that I may not be able to stop.	☐	☐	☐	☐	☐	☐
5.	Cut my food into small pieces.	☐	☐	☐	☐	☐	☐
6.	Aware of the calorie content of foods that I eat.	☐	☐	☐	☐	☐	☐
7.	Particularly avoid food with a high carbohydrate content (i.e. bread, rice, potatoes, etc.)	☐	☐	☐	☐	☐	☐
8.	Feel that others would prefer if I ate more.	☐	☐	☐	☐	☐	☐
9.	Vomit after I have eaten.	☐	☐	☐	☐	☐	☐
10.	Feel extremely guilty after eating.	☐	☐	☐	☐	☐	☐
11.	Am preoccupied with a desire to be thinner.	☐	☐	☐	☐	☐	☐
12.	Think about burning up calories when I exercise.	☐	☐	☐	☐	☐	☐
13.	Other people think that I am too thin.	☐	☐	☐	☐	☐	☐
14.	Am preoccupied with the thought of having fat on my body.	☐	☐	☐	☐	☐	☐
15.	Take longer than others to eat my meals.	☐	☐	☐	☐	☐	☐
16.	Avoid foods with sugar in them.	☐	☐	☐	☐	☐	☐
17.	Eat diet foods.	☐	☐	☐	☐	☐	☐
18.	Feel that food controls my life.	☐	☐	☐	☐	☐	☐
19.	Display self-control around food.	☐	☐	☐	☐	☐	☐
20.	Feel that others pressure me to eat.	☐	☐	☐	☐	☐	☐
21.	Give too much time and thought to food.	☐	☐	☐	☐	☐	☐
22.	Feel uncomfortable after eating sweets.	☐	☐	☐	☐	☐	☐
23.	Engage in dieting behavior.	☐	☐	☐	☐	☐	☐
24.	Like my stomach to be empty.	☐	☐	☐	☐	☐	☐
25.	Have the impulse to vomit after meals.	☐	☐	☐	☐	☐	☐
26.	Enjoy trying new rich foods.	☐	☐	☐	☐	☐	☐

	Part C: Behavioral Questions: In the past 6 months have you:	Never	Once a month or less	2-3 times a month	Once a week	2-6 times a week	Once a day or more
A	Gone on eating binges where you feel that you may not be able to stop? *	☐	☐	☐	☐	☐	☐
B	Ever made yourself sick (vomited) to control your weight or shape?	☐	☐	☐	☐	☐	☐
C	Ever used laxatives, diet pills or diuretics (water pills) to control your weight or shape?	☐	☐	☐	☐	☐	☐
D	Exercised more than 60 minutes a day to lose or to control your weight?	☐	☐	☐	☐	☐	☐
E	Lost 20 pounds or more in the past 6 months	Yes	☐	No	☐		

* Defined as eating much more than most people would under the same circumstances and feeling that eating is out of control

Appendix D1: Information sheet and consent Form

Study title: Comparing the methods of accurately determining the percent body fat in male jockey apprentices at the South African Jockey Academy (SAJA) and the impact of hydration status on the accuracy of these methods

We are inviting all apprentices training at SAJA to participate in the study.

Methods under investigation include both the current technique of measuring the skinfolds at seven sites as well as bioelectrical impedance analysis (BIA). The results will be compared to the gold standard research technique (deuterium dilution) to determine whether these methods accurately estimate body fat percent. Measurements will be taken on two separate occasions in both dehydrated and well-hydrated states in order to determine the impact of hydration status on the accuracy of measurements. Proper hydration will be achieved by following a drinking schedule prior to measurement.

Benefits to you:

- You will have an accurate measurement of your body fat percent using a technique that is usually only available in advanced body composition research.
- This research will determine the most accurate available method of measuring body fat percent which will assist you in achieving an optimal body fat percent.

(Emma Illidge) an MSc Dietetics student of the University of KwaZulu Natal (UKZN), along with my supervisor Dr Chara Biggs (Programme of Dietetics and Human Nutrition, UKZN), Kathleen Krog (SAJA dietitian) and Tarryn Sneyd (biokineticist), will be conducting the study. We are affiliated with the Programme of Dietetics and Human Nutrition of the College of Agricultural, Earth and Environmental Science at UKZN.

If you agree to participate you will be asked to do the following:

- To attend measurement sessions on 2 separate occasions
- To follow a drinking schedule prior to one of these measurement sessions in order to achieve good hydration.
- Not to eat or drink for at least 1 hour prior to the measurements being taken on both occasions

- To produce a urine sample on arrival. This will tell us whether you are properly hydrated or dehydrated so that we can determine the impact of dehydration on the accuracy of our measurements.
- To be weighed wearing shorts only.
- To collect your saliva by sucking on cotton wool swabs. When wet the swabs will then be put into a syringe and the saliva squeezed out into a test tube.
- To drink a tasteless solution containing 30 g of deuterium oxide. This is the special marker which is safe and has been used extensively in other studies.
- To not eat or drink or be physically active for 4 hours after drinking the deuterium solution to make sure the tests are very accurate.
- To have your height, skinfold thickness and BIA measured during this four hour period.
- At the end of 4 hours you will be asked to give another saliva sample and the testing will be over.
- To answer a questionnaire regarding weight and weight-making techniques on a separate occasion.

<u>Possible risks/discomforts participating in this trial</u>

None of these techniques are painful, uncomfortable or unsafe. There is no risk to you taking part in the study.

<u>Important information</u>

- You must be 18 years or older to consent to participating in this study. Otherwise, informed consent must be obtained from a parent or legal guardian and you must complete an assent form.
- Participation is voluntary - you do not have to be part of the study and you will not be disadvantaged if you do not participate.
- You may choose to withdraw from the study at any time and you will not incur any penalty.
- When the study is over you will be given the results personally via SMS or via email when they become available. The results of the study will also be published and presented at meetings but your name will not be used so no one will know who you are.

- Participation in the study will require two mornings (for measurements - approximately 5 hours each) and one afternoon (for the questionnaire - approximately 1 hour) of your time.
- The study will take place at the SAJA.
- Written recordings of results will be made using a preliminary form for each participant. No audio or video recordings will be made.

  The results of this study will be published in a scientific journal and may be presented at a congress. In signing this form, you are consenting to having the information you provide published. As you will have been allocated an identification number your name will not be used and you will remain anonymous and your information confidential.
- Every effort will be made to keep personal information confidential. However absolute confidentiality cannot be guaranteed. Personal information may be disclosed but only if required by law.
- Organizations that may inspect and/or copy your research records for quality assurance and data analysis include groups such as the Research Ethics Committee and Data Safety Monitoring Committee (where appropriate).
- The raw data collection sheets will be locked in a secured cabinet in the study supervisor's office and the electronic copy on a password protected memory stick which will also be locked away. The data will be kept secure for five years following the completion of the study and then disposed of by shredding.

Thank you for your interest in this study. If you have any questions about the study and/or testing procedures please do not hesitate to contact me Miss Emma Illidge 071 354 1001 or the study supervisor Dr Chara Biggs 081 4877950.

In the event of any problems or concerns, you may contact the UKZN Biomedical Research Ethics Committee, contact details as follows:

BIOMEDICAL RESEARCH ETHICS ADMINISTRATION

Research Office, Westville Campus

Govan Mbeki Building

Private Bag X 54001
Durban
4000

KwaZulu-Natal, SOUTH AFRICA

Tel: 27 31 2604769 - Fax: 27 31 2604609

Email: BREC@ukzn.ac.za

Consent

I, the undersigned ____

Full names, Surname and ID number

hereby confirm that I understand the contents of this document and the nature of the research project, and I consent to participating in the research project.

I confirm that I am 18 years or older.

I understand that I am at liberty to withdraw from the project at any time, should I so desire.

SIGNATURE OF PARTICIPANT: DATE: ________________

SIGNATURE OF WITNESS: DATE: ________________

Appendix D2: Information sheet and consent form for Parent/legal guardian

(If the participant is younger than 18 years)

Study title: Comparing the methods of accurately determining the percent body fat in male jockey apprentices at the South African Jockey Academy (SAJA) and the impact of hydration status on the accuracy of these methods

We are inviting all apprentices training at SAJA to participate in the study.

Methods under investigation include both the current technique of measuring the skinfolds at seven sites as well as bioelectrical impedance analysis (BIA). The results will be compared to the gold standard research technique (deuterium dilution) to determine whether these methods accurately estimate body fat percent. Measurements will be taken on two separate occasions in both dehydrated and well-hydrated states in order to determine the impact of hydration status on the accuracy of measurements. Proper hydration will be achieved by following a drinking schedule prior to measurement.

Benefits to the participants:

- He will have an accurate measurement of your body fat percent using a technique that is usually only available in advanced body composition research.
- This research will determine the most accurate available method of measuring body fat percent which will assist him in achieving an optimal body fat percent.

(Emma Illidge) an MSc Dietetics student of the University of KwaZulu Natal (UKZN), along with my supervisor Dr Chara Biggs (Programme of Dietetics and Human Nutrition, UKZN), Kathleen Krog (SAJA dietitian) and Tarryn Sneyd (biokineticist), will be conducting the study. We are affiliated with the Programme of Dietetics and Human Nutrition of the College of Agricultural, Earth and Environmental Science at UKZN.

If he agrees to participate he will be asked to do the following:

- To attend measurement sessions on 2 separate occasions
- To follow a drinking schedule prior to one of these measurement sessions in order to achieve good hydration.
- Not to eat or drink for at least 1 hour prior to the measurements being taken on both occasions
- To produce a urine sample on arrival. This will tell us whether you are properly hydrated or dehydrated so that we can determine the impact of dehydration on the accuracy of our measurements.
- To be weighed wearing shorts only.
- To collect your saliva by sucking on cotton wool swabs. When wet the swabs will then be put into a syringe and the saliva squeezed out into a test tube.
- To drink a tasteless solution containing 30 g of deuterium oxide. This is the special marker which is safe and has been used extensively in other studies.
- To not eat or drink or be physically active for 4 hours after drinking the deuterium solution to make sure the tests are very accurate.
- To have your height, skinfold thickness and BIA measured during this four hour period.
- At the end of 4 hours you will be asked to give another saliva sample and the testing will be over.
- To answer a questionnaire regarding weight and weight-making techniques on a separate occasion.

Possible risks/discomforts participating in this trial

None of these techniques are painful, uncomfortable or unsafe. There is no risk to the participant taking part in the study.

Important information

- Participation is voluntary – the athlete does not have to be part of the study and will not be disadvantaged if he does not participate.
- The participant may choose to withdraw from the study at any time and will not incur any penalty.

- When the study is over he will be given the results personally via SMS or via email when they become available. The results of the study will also be published and presented at meetings but participant names will not be used and full anonymity is ensured.
- Participation in the study will require two mornings (for measurements - approximately 5 hours each) and one afternoon (for the questionnaire - approximately 1 hour) of your time.
- The study will take place at the SAJA.
- Written recordings of results will be made using a preliminary form for each participant. No audio or video recordings will be made.

  The results of this study will be published in a scientific journal and may be presented at a congress. In signing this form, you are consenting to having the information provided published. As participants will have been allocated an identification number names will not be used and anonymity and confidentiality is ensured.
- Every effort will be made to keep personal information confidential. However absolute confidentiality cannot be guaranteed. Personal information may be disclosed but only if required by law.
- Organizations that may inspect and/or copy research records for quality assurance and data analysis include groups such as the Research Ethics Committee and Data Safety Monitoring Committee (where appropriate).
- The raw data collection sheets will be locked in a secured cabinet in the study supervisor's office and the electronic copy on a password protected memory stick which will also be locked away. The data will be kept secure for five years following the completion of the study and then disposed of by shredding.

If you have any questions about the study and/or testing procedures please do not hesitate to contact me Miss Emma Illidge 071 354 1001 or the study supervisor Dr Chara Biggs 081 4877950.

In the event of any problems or concerns, you may contact the UKZN Biomedical Research Ethics Committee, contact details as follows:

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Durban
4000

KwaZulu-Natal, SOUTH AFRICA

Tel: 27 31 2604769 - Fax: 27 31 2604609

Email: BREC@ukzn.ac.za

Consent of parent/legal guardian

I, the undersigned ____

Full names, Surname and ID number

hereby confirm that I understand the contents of this document and the nature of the research project, and I consent to my child/dependent participating in the research project.

I understand that he is at liberty to withdraw from the project at any time, should he so desire.

SIGNATURE OF PARENT/ LEGAL GUARDIAN: DATE: _________________

SIGNATURE OF WITNESS: DATE: _________________

Appendix D3: Information sheet and assent form for participants younger than 18 years

Study title: Comparing the methods of accurately determining the percent body fat in male jockey apprentices at the South African Jockey Academy (SAJA) and the impact of hydration status on the accuracy of these methods

We are inviting all apprentices training at SAJA to participate in the study.

Methods under investigation include both the current technique of measuring the skinfolds at seven sites as well as bioelectrical impedance analysis (BIA). The results will be compared to the gold standard research technique (deuterium dilution) to determine whether these methods accurately estimate body fat percent. Measurements will be taken on two separate occasions in both dehydrated and well-hydrated states in order to determine the impact of hydration status on the accuracy of measurements. Proper hydration will be achieved by following a drinking schedule prior to measurement.

Benefits to you:

- You will have an accurate measurement of your body fat percent using a technique that is usually only available in advanced body composition research.
- This research will determine the most accurate available method of measuring body fat percent which will assist you in achieving an optimal body fat percent.

(Emma Illidge) an MSc Dietetics student of the University of KwaZulu Natal (UKZN), along with my supervisor Dr Chara Biggs (Programme of Dietetics and Human Nutrition, UKZN), Kathleen Krog (SAJA dietitian) and Tarryn Sneyd (biokineticist), will be conducting the study. We are affiliated with the Programme of Dietetics and Human Nutrition of the College of Agricultural, Earth and Environmental Science at UKZN.

If you agree to participate you will be asked to do the following:

- To attend measurement sessions on 2 separate occasions
- To follow a drinking schedule prior to one of these measurement sessions in order to achieve good hydration.
- Not to eat or drink for at least 1 hour prior to the measurements being taken on both occasions

- To produce a urine sample on arrival. This will tell us whether you are properly hydrated or dehydrated so that we can determine the impact of dehydration on the accuracy of our measurements.
- To be weighed wearing shorts only.
- To collect your saliva by sucking on cotton wool swabs. When wet the swabs will then be put into a syringe and the saliva squeezed out into a test tube.
- To drink a tasteless solution containing 30 g of deuterium oxide. This is the special marker which is safe and has been used extensively in other studies.
- To not eat or drink or be physically active for 4 hours after drinking the deuterium solution to make sure the tests are very accurate.
- To have your height, skinfold thickness and BIA measured during this four hour period.
- At the end of 4 hours you will be asked to give another saliva sample and the testing will be over.
- To answer a questionnaire regarding weight and weight-making techniques on a separate occasion.

<u>Possible risks/discomforts participating in this trial</u>

None of these techniques are painful, uncomfortable or unsafe. There is no risk to you taking part in the study.

<u>Important information</u>

- Participation is voluntary - you do not have to be part of the study and you will not be disadvantaged if you do not participate.
- You may choose to withdraw from the study at any time and you will not incur any penalty.
- When the study is over you will be given the results personally via SMS or via email when they become available. The results of the study will also be published and presented at meetings but your name will not be used so no one will know who you are.
- Participation in the study will require two mornings (for measurements - approximately 5 hours each) and one afternoon (for the questionnaire - approximately 1 hour) of your time.

- The study will take place at the SAJA.
- Written recordings of results will be made using a preliminary form for each participant. No audio or video recordings will be made.

  The results of this study will be published in a scientific journal and may be presented at a congress. In signing this form, you are consenting to having the information you provide published. As you will have been allocated an identification number your name will not be used and you will remain anonymous and your information confidential.
- Every effort will be made to keep personal information confidential. However absolute confidentiality cannot be guaranteed. Personal information may be disclosed but only if required by law.
- Organizations that may inspect and/or copy your research records for quality assurance and data analysis include groups such as the Research Ethics Committee and Data Safety Monitoring Committee (where appropriate).
- The raw data collection sheets will be locked in a secured cabinet in the study supervisor's office and the electronic copy on a password protected memory stick which will also be locked away. The data will be kept secure for five years following the completion of the study and then disposed of by shredding.

Thank you for your interest in this study. If you have any questions about the study and/or testing procedures please do not hesitate to contact me Miss Emma Illidge 071 354 1001 or the study supervisor Dr Chara Biggs 081 4877950.

In the event of any problems or concerns, you may contact the UKZN Biomedical Research Ethics Committee, contact details as follows:

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Tel: 27 31 2604769 - Fax: 27 31 2604609

Email: BREC@ukzn.ac.za

Assent

I, the undersigned ____

Full names, Surname and ID number

hereby confirm that I understand the contents of this document and the nature of the research project, and I assent to participating in the research project. Consent has been given by my parent or legal guardian.

I understand that I am at liberty to withdraw from the project at any time, should I so desire.

SIGNATURE OF PARTICIPANT: DATE: ________________

SIGNATURE OF WITNESS: DATE: ________________

Please note that a consent form from a parent or legal guardian must also be completed in order to participate in the study.

Appendix E: Hydration protocol for apprentices at the SAJA (July 2016)

Each apprentice taking part in this weeks' research study will receive the following drinks and Protein Bar for each day of the study:

2 x Energade Lite   2x 500ml

2 x Diet cold drink 2x 330ml

1 x Future Life Smart Drink 250ml

1 x 30g pkt Lays crisps

1 x Future Life Smart bar

Please take these in the recommended way.

Please also drink and eat normally

Please fill in the form below every day.

THERE WILL BE A R50 PRIZE FOR EACH APPRENTICE WHO COMPLETES THE FORM CORRECTLY AND IS PROERLY HYDRATED ON SUNDAY!

Remember

1 mug = 250ml (1cup)

½ mug = 125ml (1/2 cup)

¾ mug = 200ml (3/4 cup)

Fluid and Food Consumed Day 1 Thursday				
Supper Thursday night				
protein	Ate full portion	Ate small portion		
carb	Ate full portion	Ate small portion		
veggies	Ate full portion	Ate small portion		
Tea/coffee	½ cup	¾ cup	1 cup	sip
water	½ cup	¾ cup	1 cup	sip
Before bed				
tea /coffee	½ cup	¾ cup	1 cup	sip
water	½ cup	¾ cup	1 cup	sip
diet cold drink	1	330	½ tin	¼ tin
30gm pkt crisps	1			
Fluid and Food Consumed Day 2 **Friday**				
Fluid before track				
water	½ cup	¾ cup	1 cup	sip
Energade	½ bottle	500ml	1 bottle	sip
Future life drink	½ bottle	250ml	1 bottle	sip
coffee	½ cup	¾ cup	1 cup	sip
Future Life bar	1			
Fluid after track				
water	½ cup	¾ cup	1 cup	sip
Energade	½ bottle	500	1 bottle	sip
Future life drink	½ bottle	250ml	1 bottle	sip
coffee	½ cup	¾ cup	1 cup	sip
Future life bar	1			

<u>Day 2</u> **<u>Friday</u>** **<u>Breakfast</u>**				
cereal				
milk	½ cup	¾ cup	1 cup	sip
toast				
eggs/fish				
coffee / tea	½ cup	¾ cup	1 cup	sip
Milk	½ cup	¾ cup	1 cup	sip
water	½ cup	¾ cup	1 cup	sip
<u>Mid-morning</u>				
Future life bar	1			
water	½ cup	¾ cup	1 cup	sip
Energade Lite	½ bottle	500	1 bottle	sip
diet cold drink	½ can	330ml	1 can	sip
Fruit				
<u>Lunch Friday</u>				
Protein				
Carb				
Salad				
Soup				
Fruit				
tea /coffee	½ cup	¾ cup	1 cup	sip
water	½ cup	¾ cup	1 cup	sip
Yogurt	½ cup	¾ cup	1 cup	
<u>Mid afternoon</u>				
Future life bar	1			
water	½ cup	¾ cup	1 cup	sip
Energade Lite	½ bottle	500	1 bottle	sip
diet cold drink	½ can	330	1 can	sip
Popcorn + salt				
Fruit				

Supper				
Protein				
Carb				
Veggies				
water	½ cup	¾ cup	1 cup	sip
tea/coffee	½ cup	¾ cup	1 cup	sip
milk	½ cup	¾ cup	1 cup	sip
Before bed				
tea /coffee	½ cup	¾ cup	1 cup	sip
water	½ cup	¾ cup	1 cup	sip
diet cold drink	½ can	330 ml	1 can	sip
30gm pkt crisps				

Fluid and Food Consumed **Day 3** **Saturday**				
Fluid before track				
water	½ cup	¾ cup	1 cup	sip
Energade	½ bottle	500ml	1 bottle	sip
Future life drink	½ bottle	250 ml	1 bottle	sip
coffee	½ cup	¾ cup	1 cup	sip
Future Life bar	1			
Fluid after track				
water	½ cup	¾ cup	1 cup	sip
Energade	½ bottle	500 ml	1 bottle	sip
Future life drink	½ bottle	250ml	1 bottle	sip
coffee	½ cup	¾ cup	1 cup	sip
Future life bar	1			
Saturday **Breakfast**				
cereal				
milk	½ cup	¾ cup	1 cup	sip
toast				
eggs/fish				
coffee / tea	½ cup	¾ cup	1 cup	sip
Milk	½ cup	¾ cup	1 cup	sip
water	½ cup	¾ cup	1 cup	sip
Mid-morning				
Future life bar	1			
water	½ cup	¾ cup	1 cup	sip
Energade Lite	½ cup	500ml	1 bottle	sip
diet cold drink	½ can	330ml	1 can	sip
Fruit				

Lunch Saturday				
Protein				
Carb				
Salad				
Soup				
Fruit				
tea /coffee	½ cup	¾ cup	1 cup	sip
water	½ cup	¾ cup	1 cup	sip
Yogurt	½ cup	¾ cup	1 cup	
Mid afternoon				
Future life bar	1			
water	½ cup	¾ cup	1 cup	sip
Energade Lite	½ bottle	500 ml	1 bottle	sip
diet cold drink	½ can	330ml	1 can	sip
Popcorn + salt				
Fruit				
Supper Saturday				
Protein				
Carb				
Veggies				
water	½ cup	¾ cup	1cup	sip
Tea /coffee	½ cup	¾ cup	1 cup	sip
milk	½ cup	¾ cup	1 cup	sip
Before bed				
tea /coffee	½ cup	¾ cup	1 cup	sip
water	½ cup	¾ cup	1cup	sip
diet cold drink	½ can	330ml	1 cup	sip
30gm pkt crisps				

Appendix F: Permission letter from the principle of the South African Jockey Academy

South African Jockey Academy

THE ACADEMY OF CHOICE FOR JOCKEY TRAINING

The South African Jockey Academy

15 JB Mcintosh Drive
Summerveld 3624
Private Bag X1008
Hillcrest 3650
KwaZulu Natal
Tel: +27 31 769 1103/86
Fax: +27 31 769 1034

Sect. 21 No: 2002/007593/08
PBO Reg No: 18/11/13/3060
NPO No: 059-904
VAT No: 4270198957
E-mail: pa@theacademy.co.za
Admissions: marketing@theacademy.co.za
www.saja.co.za

GATEKEEPER/ PERMISSION-GIVER LETTER

Re: University of KwaZulu-Natal

METHODS OF BODY COMPOSITION ANALYSIS OF MALE JOCKEY APPRENTICES OF THE SAJA

Investigators

Ms. EMMA ILLIDGE, under the supervision of Chara Biggs, UKZN Dietetic Department.
Mrs. KATHLEEN KROG and Ms. TARRYN SNEYD, SAJERI.

Permission to measure the body composition of the Apprentice Jockeys resident at the Academy, 2016, with three methods in order to determine the accuracy and reliability of the 7 skinfold method and BIA as methods of body composition analysis for male apprentice jockeys when compared to the gold standard, being deuterium dilution, as well as to compare the body composition of male jockey apprentices with that of male athletes of the same age group.

As the Principal at the South African Jockey Academy, I give my permission to the researchers to measure the body composition of the Apprentice Jockeys resident at the Academy with the three different methods of body analysis and to compare the results to age-matched athletes.

Name of permission-giver: Mr. Graham Bailey

Signature of permission-giver ______________________

Date: 08 / 02 / 2016

ISASA

Appendix G: Approval letter from the Biomedical Research Ethics Committee

UNIVERSITY OF KWAZULU-NATAL™
INYUVESI YAKWAZULU-NATALI

06 May 2016

Ms E Illidge (211504611)
Discipline of Dietetics and Human nutrition
SAEES
emma.illidge@gmail.com

Protocol: Comparing methods of accurately determining the percent body fat in male jockey apprentices at the South African Jockey Academy (SAJA) and whether their levels of body fat are similar to those of other athletes.
Degree: MSc
***BREC reference* number:** BE212/16

The Biomedical Research Ethics Committee has considered and noted your application received on 14 March 2016.

The study was provisionally approved pending appropriate responses to queries raised. Your response received on 02 May 2016 to queries raised on 02 April 2016 have been noted and approved by a sub-committee of the Biomedical Research Ethics Committee. The conditions have now been met and the study is given **full ethics approval.**

This approval is valid for one year from **06 May 2016.** To ensure uninterrupted approval of this study beyond the approval expiry date, an application for recertification must be submitted to BREC on the appropriate BREC form 2-3 months before the expiry date.

Any amendments to this study, unless urgently required to ensure safety of participants, must be approved by BREC prior to implementation.

Your acceptance of this approval denotes your compliance with South African National Research Ethics Guidelines (2015), South African National Good Clinical Practice Guidelines (2006) (if applicable) and with UKZN BREC ethics requirements as contained in the UKZN BREC Terms of Reference and Standard Operating Procedures, all available at http://research.ukzn.ac.za/Research-Ethics/Biomedical-Research-Ethics.aspx.

BREC is registered with the South African National Health Research Ethics Council (REC-290408-009). BREC has US Office for Human Research Protections (OHRP) Federal-wide Assurance (FWA 678).

The sub-committee's decision will be **RATIFIED** by a full Committee at its meeting taking place on **14 June 2016.**

We wish you well with this study. We would appreciate receiving copies of all publications arising out of this study.

Yours sincerely

Professor J Tsoka-Gwegweni
Chair: Biomedical Research Ethics Committee

cc supervisor: biggsc@ukzn.ac.za
cc postgraduate: manjoom@ukzn.ac.za

Biomedical Research Ethics Committee
Professor J Tsoka-Gwegweni (Chair)
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Website: http://research.ukzn.ac.za/Research-Ethics/Biomedical-Research-Ethics.aspx

Appendix H: Approval of amendments letter from Biomedical Research Ethics Committee

UNIVERSITY OF
KWAZULU-NATAL
INYUVESI
YAKWAZULU-NATALI

RESEARCH OFFICE
BIOMEDICAL RESEARCH ETHICS ADMINISTRATION
Westville Campus
Govan Mbeki Building
Private Bag X 54001
Durban
4000
KwaZulu-Natal, SOUTH AFRICA
Tel: 27 31 2604769 - Fax: 27 31 260-4609
Email: BREC@ukzn.ac.za
Website: http://research.ukzn.ac.za/ResearchEthics/BiomedicalResearchEthics.aspx

19 August 2016

Ms E Illidge (211504611)
Discipline of Dietetics and Human nutrition
SAEES
emma.illidge@gmail.com

Protocol: Comparing methods of accurately determining the percent body fat in male jockey apprentices at the South African Jockey Academy (SAJA) and whether their levels of body fat are similar to those of other athletes.
Degree: MSc
BREC reference number: BE212/16

New Study Title: **Comparing methods of accurately determining the percent body fat in male jockey apprentices at the South African Jockey Academy (SAJA) and the impact of hydration status on the accuracy of these methods.**

We wish to advise you that your correspondence dated 27 July 2016 requesting approval of Amendments on the above study has been **noted and approved** by a sub-committee of the Biomedical Research Ethics Committee.

The following have been noted and approved:

- Change of Title (see new study title above).
- Request to measure the participants on two different occasions - the first in a dehydrated state, and the second following a hydration protocol that will ensure that they are in a euhydrated state.
- Replace the SCOFF with the EAT questionnaire.

This approval will be ratified at a BREC meeting to be held on 13 September 2016.

Yours sincerely

Mrs A Marimuthu
Senior Admin Officer: Biomedical Research Ethics Committee