The Health and Performance Characteristics of Current and Retired Jockeys in Ireland

Thesis submitted for the degree of Doctor of Philosophy

SarahJane Cullen (BSc)

Student Number: 54668791

School of Health and Human Performance

Dublin City University

Supervisor: Dr Giles Warrington

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ABSTRACT

Horse racing is a weight category sport and jockeys must chronically maintain a low body mass, necessary to attain the stipulated competition riding weights, whilst maintaining a sufficient level of physical conditioning in order to compete, possibly on a daily basis, in several races each day, over the protracted racing season. The purpose of this study was to further investigate the acute and chronic effects of the common weight loss practices used to rapidly reduce body mass in preparation for racing, building on the existing knowledge and subsequently attempting to improve the health, well-being and overall performance of jockeys throughout their racing career and beyond. **Methods:** The primary aim was achieved through the completion of 3 independent, though related studies. *Study One:* The effects of acute body mass loss in preparation for racing on cognitive function, balance and anaerobic performance were assessed in a group of jockeys in a simulated and competitive racing environment. *Study Two:* The potential long term health impact associated with the prolonged use of rapid weight loss strategies and an energy restricted lifestyle was established in a group of retired jockeys. *Study Three:* The physiological demands and energy requirements of training, racing and other daily activities were determined. **Results:** Study one showed that rapid reductions in body mass resulted in no significant impairments in cognitive function, balance or anaerobic performance however large individual variability in responses were apparent which is worrying in terms of the safety and welfare of all surrounding jockeys on the track. Study two suggests a life of chronic weight restriction and reliance on unhealthy weight making practices may have some long term health effects particularly in relation to gain in body mass since retirement, reduced resting metabolic rate and bone health. Study three suggests competitive horse racing requires both aerobic and anaerobic fitness and it further reports that the total estimated energy expenditure on a non-racing day is higher than that on a racing day and as a result the deleterious effects of living in a state of low energy availability may be further exacerbated. **Conclusion:** Results from this study suggest horse racing is a physically demanding sport and that making weight may result in many individual adverse responses both acutely and chronically. Ideally jockeys should be tracked longitudinally with information and support systems readily available to jockeys to encourage the adoption of healthier making weight strategies, assisting jockeys in enhancing their health, wellbeing and overall performance throughout their sporting career, and beyond.

DECLARATION

I hereby certify that this material, which I now submit for assessment on the programme of study leading to the award of PhD is entirely my own work, that I have exercised reasonable care to ensure that the work is original, and does not to the best of my knowledge breach any law of copyright, and has not been taken from the work of others save and to the extent that such work has been cited and acknowledged within the text of my work.

Signed: ______________________________

SarahJane Cullen

Student Number: 54668791

Date: ________________

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So to all....

"I can no other answer make, but, thanks, and thanks."

William Shakespeare

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GLOSSARY OF TERMS

Making Weight

The practice typically used by weight category athletes to attain the required competition weight.

To Ride Work

A task used in training in which the horse is pushed to a similar speed as is possible in racing. Training yards often have designated days in which they 'ride work' so jockeys typically only ride work a couple of times a week in training.

Weight/Claiming Allowance

Apprentice jockeys just starting out their career are granted a weight allowance to encourage trainers and owners to allocate rides to the more inexperienced jockeys. Apprentices may ride at a lower weight (up to 10lb/4.5 kg) than that actually allocated to the horse until a certain amount of winners are achieved. The claiming allowance is progressively reduced in accordance with the number of wins accumulated by an apprentice. It is then expected the apprentice has established a worthy reputation, no longer relying on the claiming incentive to secure rides in races.

Flat Racing

Flat races are started from the stalls, range from distances of 1 to 4 km and consist of a run in which no obstacles are present. The weight classifications for flat racing in Ireland range from 52.7 to 64 kg.

National Hunt Racing

National hunt races are started from a tape barrier and involve a number of fences or hurdles over which the horse must jump, covering distances of at least 3.2 km up to 7.2 km. The weight allocations for national hunt racing in Ireland range from 62 to 76 kg.

T Score

A standard score comparing a person's bone density with that of a healthy 30 year old of the same sex.

Z Score

A standard score comparing a person's bone density with that of an average person of the same age and sex.

Osteoporosis

Osteoporosis has been defined as "a progressive systemic skeletal disease characterized by low bone mass and micro architectural deterioration of bone tissue, with consequent increase in bone fragility and susceptibility of fracture" (Anonymous, 1993).

Osteopaenia

Osteopaenia is a precursor to osteoporosis.

Weight Cycling

Weight cycling can be defined as periods of weight loss interspersed by periods of subsequent weight gain.

LIST OF ABBREVIATIONS

ACE: Angiotensin converting enzyme

ADH: Antidiuretic Hormone

ANGII: Angiotensin II

ATP-PCr: Adenosine Triphosphate

AVP: Arginine Vasopressin

BA: Bone Area

BESS: Balance Error Scoring System

BMC: Bone Mineral Concentration

BMD: Bone Mineral Density

BMI: Body Mass Index

CP: Creatine Phosphate

DET: Detection (Simple Reaction Task)

DEXA: Dual-Energy X-ray Absorptiometry

DCU: Dublin City University

ECF: Extracellular Fluid

EDTA: Ethylenediaminetetraacetic Acid

EE: Energy Expenditure

EEE: Estimated Energy Expenditure

eGFR: Estimated Glomerular Filtration Rate

FI: Fatigue Index

FT4: Free T4

GFR: Glomerular Filtration Rate

HR: Heart Rate

HRI: Horse Racing Ireland

ICF: Intracellular Fluid

IDN: Identification (Choice Reaction Task)

MP: Mean Power

OBK: One Back (Attention/Working Memory Task)

OCL: One Card Learning (Attention/Visual Learning & Memory Task)

OGTT: Oral Glucose Tolerance Test

PBM: Peak Bone Mass

PP: Peak Power

pQCT: Peripheral Quantitative Computed Tomography

RACE: Racing Academy and Centre of Education

RAAS: Renin-Angiotensin Aldosterone System

REE: Resting Energy Expenditure

RER: Respiratory Exchange Ratio

RH: Relative Humidity

RMR: Resting Metabolic Rate

RPE: Rating of Perceived Exertion

RPM: Revolutions per Minute

RQ: Respiratory Quotient

RR: Respiratory Rate

SEBT: Star Excursion Balance Test

SNS: Sympathetic Nervous System

Usg: Urine Specific Gravity

VT: Ventilatory Threshold

WAnT: Wingate Anaerobic Test

WHO: World Health Organisation

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Chapter One: Introduction

1.1 Background Information & Justification

Horse racing is a weight category sport in which jockeys must chronically maintain a low body mass, necessary to attain the stipulated competition riding weights, whilst maintaining a sufficient level of physical conditioning in order to compete on a daily basis, in several races each day, over the protracted racing season which may last up to 10-12 months. The necessity to maintain this low body mass, which is considerably below normal living weight, render the use of strict and sometimes dangerous weight loss strategies necessary in order to maximise riding opportunities (Hill and O'Connor, 1998). Evidence suggests that the primary method used by jockeys to 'make weight' is dehydration by a number of different mechanisms, accompanied by severely restricted fluid and food (Dolan et al., 2011, Labadarios et al., 1993, Leydon and Wall, 2002, Moore et al., 2002). Such methods of weight reduction appear to result in jockeys living and competing in a dehydrated and energy deficient state (Dolan et al., 2011, Warrington et al., 2009). Research has shown jockeys to be a group with low energy availability (Dolan et al., 2011), poor bone health (Dolan et al., 2012a, Dolan et al., 2012b, Greene et al., 2013, Leydon and Wall, 2002, Waldron-Lynch et al., 2010, Warrington et al., 2009) and altered gonadal and reproductive hormone function (Dolan et al., 2012b), all of which indicate that jockeys may be susceptible to elements of the "Female Athlete Triad" (Nattiv et al., 2007).

Acute losses in body mass have been reported in other weight category sports to be detrimental to competitive performance (Franchini et al., 2012, Fogelholm, 1994, Wilmore, 2000) given the associated dehydration, depleted glycogen stores and reduced lean mass (Hall and Lane, 2001, Degoutte et al., 2006, Koral and Dosseville, 2009, Burge et al., 1993). However the effects of making weight on short duration anaerobic activities remain inconsistent and conflicting (Koral and Dosseville, 2009, Fogelholm, 1994). Moreover, cognitive performance and mood state may also be negatively influenced as a result of rapid body mass reductions (Choma et al., 1998, Hall and Lane, 2001, Landers et al., 2001, Koral and Dosseville, 2009). The precise effects of making weight on competitive performance are somewhat equivocal, as many factors including the time of body mass reduction, recovery time after weigh-in and the type of diet may affect responses to rapid body mass loss (Franchini et al., 2012). In horse racing, the detrimental effects of making weight may be further exacerbated for professional jockeys due to the length and intensity of the horse racing season, as well as the lack of opportunity to replenish energy or rehydrate before, during and after racing due to the requirement to weigh-in immediately before and after each race very often several times throughout a racing day. Many jockeys maintain a low body mass, almost daily, for the duration of their racing career with no defined off-season when diet and body mass can be normalised (Dolan et al., 2011). Other weight category sports such as boxing, wrestling and light weight rowing differ greatly such that a set number of competitions within a designated season occur as well as participants in these other weight category sports weighing in only prior to competition which may take place up to 24 hours before competition thereby providing the athlete with time to replenish energy and fluid stores depleted in making weight. Such opportunities are not afforded to jockeys (Warrington et al., 2009). While horse racing is regularly classified as an extremely dangerous and high risk sport (Hitchens et al., 2009b, Rueda et al., 2010), with no precise strategy for optimally managing and achieving the required body mass reduction, as a consequence many jockeys typically adopt strategies based on tradition which may place them at an increased risk of reduced physical and mental performance as well as compromising health and well-being (Dolan et al., 2012a, Dolan et al., 2013, Dolan et al., 2012b, Dolan et al., 2011, Greene et al., 2013, Labadarios et al., 1993, Leydon and Wall, 2002, Pruscino et al., 2005, Waldron-Lynch et al., 2010, Warrington et al., 2009, Wilson et al., 2013b).

Jockeys typically engage in weight making practices from as early as 15 or 16 years old and continue such practices through a racing career which may span over two decades (Tomkinson et al., 2012). The constant reliance on unhealthy weight making strategies may restrict the achievement of individual genetic potential for peak bone mass potentially producing deleterious musculoskeletal effects in later life (Greene et al., 2013). It has been suggested that increasing bone mass and strength during growth is the primary strategy for the prevention of osteoporosis (Bonjour et al., 2009, Hernandez et al., 2003). Large fluctuations in body mass early in life, be it during growth or young adulthood, have also been suggested to represent a risk factor for the development of obesity, type 2 diabetes and cardiovascular disease in later life (Dulloo, 2005). Back problems, arthritis, other joint complications and dental issues have been reported as the most common health issues experienced since retirement from a career in horse racing (Speed et al., 2001, Tomkinson et al., 2012). Excessive weight gain was also experienced amongst a small proportion of jockeys after retiring from racing (Speed et al., 2001). Limited information exists however investigating the long term health effects of a jockey in later life.

The commonly reported weight making practices prevalent amongst jockeys appear to be based on tradition rather than on sound scientific principles (Warrington et al., 2009). It is therefore imperative that in order to optimally support and prepare jockeys for a career in horse racing, sport specific nutritional and training guidelines need to be developed and in doing so reduce the reliance on such unhealthy weight making practices. Despite the international popularity of horse racing, the physiological demands of horse racing remain largely unknown causing great difficulties when prescribing specific nutrition and training programmes. There is a need to further understand the physiological demands of horse racing to allow the development of specific nutritional and training guidelines, information which appears to be of critical importance for jockeys, whose careers depend on making designated weights. Many strategies have been put in place to encourage best practice in recent years namely raising the stipulated competition weight standards, the availability of a dietician to all jockeys, providing an educational programme for apprentice jockeys (Waldron-Lynch et al., 2010) and most recently, in Ireland the implementation of a new individualised minimum weights structure for apprentice jockeys. Further research is required, which building on the present scientific base will allow the introduction of further positive advancements in this unique weight category sport to optimally equip and prepare jockeys for a career in horse racing while reducing the endemic reliance on such unhealthy weight making practices.

1.2 Purpose of the Research

Given the pressures associated with making weight, many jockeys typically find themselves in an energy deficient and dehydrated state on almost a daily basis for the duration of their riding career as a result of the repetitive use of strict and potentially dangerous weight loss strategies (Warrington et al., 2009, Dolan et al., 2011). In this context, the purpose of this study is outlined below:

Aim:

To build on existing knowledge and investigate the acute and chronic effects of 'making weight' in preparation for racing, subsequently attempting to improve the health, well-being and performance of jockeys throughout their racing career and beyond.

Objectives:

1. To examine the effect of acute body mass loss in preparation for racing on cognitive function and physical performance in a group of jockeys.
2. To evaluate the potential long term health impact associated with the prolonged use of rapid weight loss strategies and an energy restricted lifestyle in a group of retired jockeys.
3. To evaluate the physiological demands and energy requirements of jockeys during training, racing and other daily activities.

Hypothesis:

That the current weight restricted lifestyle of a jockey may not be conducive to optimal health, wellbeing and overall performance throughout their racing career and beyond.

As part of this research, three independent, though related studies were completed. The specific aims, objectives and hypotheses of each of these studies are outlined in the following section.

1.3 Research Aims and Objectives

1.3.1 Study One: The Acute Effects of Making Weight on Cognition and Performance in Jockeys

Aim

The aim of this study was to examine the effect of acute body mass loss in preparation for racing on cognitive function and physical performance in a group of jockeys in a simulated and competitive environment.

Objectives

1. To examine the impact of a 4 % reduction in body mass on cognitive function in a group of jockeys, as assessed through performance on a computerised cognitive test battery.

2. To examine the impact of a 4 % reduction in body mass on balance in a group of jockeys, as assessed through performance on a specific dynamic balance test.
3. To examine the impact of a 4 % reduction in body mass on anaerobic performance in a group of jockeys, as assessed through performance in a 30 second maximal test on a cycle ergometer.
4. To investigate the effect of 'making weight' on cognitive function in a group of jockeys prior to an actual race, as assessed through performance on a computerised cognitive test battery.

Hypothesis

1. That reducing body mass by 4% in 48 hours using typical weight loss practices would have a negative impact on cognitive function and physical performance in a group of jockeys.
2. That the use of acute weight loss strategies prior to an actual race would result in decrements in cognitive performance.

1.3.2 Study Two: The Long Term Health Implications of a Career in Horse Racing

Aim

The aim of this study was to evaluate the potential long term health impact associated with the prolonged use of rapid weight loss strategies and an energy restricted lifestyle in a group of retired jockeys.

Objectives

1. To evaluate the physiological and health characteristics of a group of retired jockeys.
2. To compare the physiological and health characteristics of a group of retired jockeys to existing data on current jockeys as well as age matched normative data.
3. To establish the long term health effects and potential risks factors associated with the lifestyle and demands of a jockey.

Hypothesis

That as a result of a career using unhealthy weight loss strategies, retired jockeys suffer from impaired physical health inclusive of excessive weight gain, poor bone health, reduced RMR and impaired kidney function compared to age matched individuals.

1.3.3 Study Three: The Physiological Demands of Horse Racing

Aim

The aim of this study was to evaluate the physiological demands and energy requirements of jockeys during training, racing and other daily activities.

Objectives

1. To establish a profile of the typical daily activities of jockeys.
2. To determine the physiological demands and energy requirements of a simulated race as assessed on a racehorse simulator.
3. To evaluate the physiological demands and energy requirements of the typical riding gaits (walk, trot, canter) undertaken throughout the day in training.
4. To determine the physiological demands and energy requirements of an actual race.
5. To estimate the typical daily energy expenditure of jockeys on a non-race and a race day.

Hypothesis

1. That the typical daily activities undertaken by a jockey have a high physiological demand.
2. That the estimated energy demands are greater on a non-race day when compared to a race day.

1.4 Delimitations

All studies were restricted to male jockeys as sample size would have been small since female jockeys are in the minority in Ireland but also to avoid hormonal variations which could have influenced the results. Each study had further restrictions with regards participants:

Study 1:

This study was restricted to apprentice male jockeys involved in thoroughbred horse racing and currently licensed by the Irish Turf Club.

Study 2:

This study was restricted to retired jockeys, flat or national hunt, of any age who previously held a licence by the Irish Turf Club. Participants must have been on the pension list to have been contacted ensuring participant held a racing licence for at least 8 years.

Study 3:

This study was restricted to trainee jockeys attending Racing Academy and Centre of Education (RACE) in addition to apprentice jockeys involved in thoroughbred horse racing and currently licensed by the Irish Turf Club

All subjects were excluded from the study if they had any injury or illness that may have affected their performance, as determined by the general health questionnaire (Appendix X) completed by each subject prior to testing.

1.5 Limitations

The specific limitations associated with each study are included in the individual study chapters (see Chapters 3 – 5).

1.6 Summary

The purpose of this study was to further investigate the acute and chronic effects of the common weight making strategies used to rapidly reduce body mass in preparation for racing, building on the existing knowledge and subsequently attempting to improve the health, well-being and overall performance of jockeys throughout their racing career and beyond. This document will begin with a review of the literature followed by three independent, though related studies as outlined above. A summary chapter will conclude this document inclusive of practical implications and future recommendations as a result of this research study.

Chapter Two: Review of Literature

Irish 2000 Guineas 2013

2.1 Horse Racing as a Weight Category Sport

2.1.1 Horse Racing in Ireland

Horse racing is one of the first known competitive sports, originating among the prehistoric nomadic tribesmen of Central Asia, who first domesticated the horse around 4500BC. For thousands of years, the sport of horse racing has developed and flourished and in the 18th century thoroughbred racing in the form recognised today was introduced. Today, horse racing, also known as "The Sport of Kings", has become a major professional sport in not only Ireland but in the UK, France, Germany, Australia, Asia, America, New Zealand, Canada, South America and South Africa, attracting followers from every age, nationality and walk of life.

Irish race horses compete in two main types of races, namely Flat and National Hunt. Flat races are started from the stalls, range from distances of 1 to 4 km and consist of a run in which no obstacles are present. Horses that race on the flat generally mature earlier and start racing as 2 – 3 years olds. In contrast, national hunt races are started from a tape barrier and involve a number of fences or hurdles over which the horse must jump, covering distances of at least 3.2 km up to 7.2 km. Furthermore, horses competing in national hunt races typically mature more slowly and do not begin racing until they are 4 – 5 year olds.

Professional jockeys in Ireland can be separated into the following categories: apprentice, conditional and professional. Apprentice and conditional jockeys are young professional flat and national hunt jockeys, respectively, who are given a weight allowance to compensate for their inexperience in race riding. With more experience and an increase in the numbers of winners ridden, this allowance is reduced. There are also trainee jockeys who are individuals who attend the 42 week residential programme in the Racing Academy and Centre of Education (RACE) in Kildare to acquire the skills, knowledge and attitudes necessary to ride and care for horses. Individuals entering this course must be at least 16 years of age and less than 57 kg (9 stone). Completion of the traineeship in RACE enables some participants to sign on as apprentice jockeys while others are employed as stable staff typically progressing to roles including groom, work rider, travelling head lad or assistant trainer.

Thoroughbred horse racing is one of Ireland's most popular sports and one in which this country can claim significant international success. The horse racing and breeding sector contributes nearly €1 billion annually to the Irish economy, employs in excess of 16,000 people and is responsible for annual exports worth €174 million (HRI, 2012). In Ireland in 2012, 350 race meetings (119 flat, 179 national hunt, 52 both) took place across the country's 26 race courses, comprising of 2,516 races in total (1084 flat; 1432 national hunt). In that same year, horse racing attracted 1.2 million race goers with an average of 3,500 people attending each race meeting (Figure 2.1). In 2012, 216 jockey licences were held including 107 flat licences (53 professional and 54 apprentices) and 109 national hunt licences, with approximately 40 of these jockeys holding a dual licence (HRI, 2012). Twenty three trainee jockeys graduated from the 2012/2013 programme in RACE.

Figure 2.1: Horse racing is not only a sport, but an industry, a hobby and a social outlet

2.1.2 The Jockey

2.1.2.1 Athlete

Paramount to the spectacle of horse racing is the central role played by jockeys, the individuals who push themselves and their steeds to the absolute limit on a race day. Very often overlooked and undervalued as a professional athlete, a jockey is no less an athlete than any other sports person in terms of fitness, strength, balance, flexibility, coordination and the desire to win (Gruender, 2007). This is emphasized with the execution of limited movements requiring great muscular strength and endurance as a jockey is perched over the saddle with only a small portion of the foot in contact with the stirrup (Perkins, 1996) for the duration of a race with distances varying from 1 km to 7.2 km often inclusive of large hurdles and obstacles. In contrast to athletes of other sports in which the responsibility lies only in individual performances, a jockey must coordinate a dual partnership controlling individual riding performance as well as the performance of the horse (Speed et al., 2001). Pfau et al., (2009) described how jockeys may directly influence the performance of the horse by adjusting individual riding style. In an account of the champion American racehorse, 'Seabiscuit', the unique challenge of racing is characterised as "to pilot a race horse is to ride a half-ton catapult. It is without question one of the most formidable feats in sport" (Hillenbrand, 2001). Horse racing is also one of the only major sports in which both men and women are perceived as equal, competing against each other and adhering to the same rules (Gruender, 2007).

Jockeys receive a retainer fee with the major stable in which they are based, in addition to a fee for each individual race they ride. In Ireland, jockeys receive, before tax, €130 per flat race and €150 per national hunt race after deductions to accident funds, valets etc. Jockeys additionally receive 6.5% of all prize money won. Success and financial security is achieved by only a small proportion of the jockeys. In 2012, 54% of all runners in flat races were ridden by the top 20 jockeys, while the top 20 national hunt jockeys rode 34% of all runners in national hunt races. In Ireland in 2012, the highest number of races ridden by one jockey on the flat was 572 races with 528 races being the highest number ridden by an individual national hunt jockey (HRI, 2012).

2.1.2.2 Challenges Faced by Jockeys

Being a jockey is not just a career or a sport; it's a way of life. Generally the glamorous side of racing is only seen, rarely are the risks, personal sacrifices, and hardship many jockeys endure spoken of (Gruender, 2007). Jockeys are typically presented as light, fit and strong individuals on the exterior however jockeys very often may be severely dehydrated and deficient in energy (Dolan et al., 2011, Dolan et al., 2008, Warrington et al., 2009), suffering from fatigue (Caulfield and Karageorghis, 2008), self-doubt and unrelenting stress (Gruender, 2007). The demanding lifestyle of a jockey encompasses many challenges through which jockeys must face, all of which are predominantly around the issue of 'making weight' or attainment of the required low body mass.

i. Weight Allocations

Based solely on demonstrated ability or "form" in previous races, all horses are allocated a designated weight to carry in a race with the better horses being allocated heavier weights. Such a handicapping system is an integral feature of horse racing, which in theory is designed to maximise the competitiveness of the sport providing every horse with an equal chance of winning. The weight classifications for racing in Ireland range from 52.7 to 64 kg and 62 to 76 kg for flat and national hunt races respectively. Jockeys must align their body mass with the stipulated weight of the mount that they are riding and this weight is inclusive of the saddle, clothing, riding boots and protective equipment required by the jockey. Additionally, the apprentice/conditional jockeys just starting out their career are granted a weight allowance referred to as a "claim" to encourage trainers and owners to allocate rides to the more inexperienced jockeys. Apprentices and conditionals may ride at a lower body mass than that allocated to the horse until a certain amount of winners are achieved. For example if a horse is allocated a weight of 55.5 kg (8st 10lb), a professional jockey would have to weigh in at this weight however an apprentice jockey who has just started out and has a claiming allowance of 4.5 kg (10lb) may weigh in at 51 kg (8st). Although a more inexperienced rider, an advantage may be provided to the horse given the reduced weight to be carried. The claiming allowance is progressively reduced in accordance with the number of wins accumulated by the apprentice. For instance, in flat racing, apprentice jockeys start off with a 4.5 kg (10lb) claim, after 3 wins the claim drops to 3.2 kg (7lb), after 20 wins to 2.3 kg (5lb), after 55 wins to 1.4 kg (3lb) and after 90 wins no claim is awarded. In national hunt, the claim starts off for conditionals at 3.2 kg (7lb), reducing to 2.3 kg (5lb) after 20 wins, 1.4 kg (3lb) after 40 wins and no claim after 50 wins. By this stage it is expected the new jockey has established a worthy reputation, no longer relying on the claiming incentive to secure rides in races.

Such weight allocations appear to be based on tradition and no longer suit the population size of today (Warrington et al., 2009). Secular increases in mass and stature are apparent within the Irish population (Whelton et al., 2007). Analysis of the records of the trainee jockeys entering RACE has revealed that since 1978 the mean body mass of apprentice jockeys has increased by 47%, rising from 37 kg to 54.5 kg in 2012. Yet the minimum weight allocation for flat jockeys has risen by just 10%, from 47.7 kg to 52.7 kg in the same time period. The potential pool of individuals deemed to naturally possess the physique characteristics to become a jockey appear to be reduced and there is increasing difficulty in achieving such a low body mass (Warrington et al., 2009). However with the strong desire to win to ensure continued work and success, jockeys appear to adopt extreme measures to achieve the necessary weight in order to meet the specific weight allocations (Dolan et al., 2011, Labadarios et al., 1993, Leydon and Wall, 2002, Moore et al., 2002).

ii. Making and Maintaining Weight for the Prolonged Season

It is vital that jockeys achieve and maintain a strict control of body mass in order to comply with the predetermined handicaps. Although there is not a specific body mass at which they must compete, the majority of jockeys strive to be the minimum weight possible to optimise their racing opportunities. A key challenge facing jockeys is the pressure of making weight and remaining at that weight for the duration of the season. The strict regulations in horse racing require jockeys to weigh in immediately before a race and again after the race if they are placed (if placed in the top 5 finishers). This differs greatly to other weight category sports, such as wrestling, boxing and rowing, in which weigh-in is only required prior to competition and, very often this weigh-in takes place up to 24 hours in advance (Walberg-Rankin, 2006). The athletes in such sports have time to replenish energy and fluid stores that were depleted during the process of making weight, an opportunity that is not afforded to jockeys. Many jockeys may also ride in more than one race during a race meeting and are therefore required to weigh in at many intervals and usually at different weights. Large variability exists on the specific weight targets that jockeys must comply with when riding several different horses. Continued monitoring of body mass throughout the day without any opportunity to replenish the depleted stores in between rides may occur under such circumstances especially if the last ride of the day requires the lightest weight. Typically the allocated weight for each horse is only announced before 10am on the morning preceding a race meeting further denying the jockey time to control and manipulate weight in a uniformly fashion thereby often necessitating the use of extreme acute weight loss methods. A detailed analysis of the weight loss strategies commonly adopted is included in the following section.

Moreover the need for strict weight management may be further exacerbated by the extended nature of the racing season which may last as long as 10 - 12 months per year. This is in direct contrast to many other weight category sports which typically have a distinct competitive phase of the seasons in which there may be a set number of competitions, thus allowing athletes to maintain less rigorous weight control during the off and pre-season phases of the annual training and competition cycle (Fogelholm, 1994). Horse racing however is conducted across the country all year round with a very heavy racing programme, providing limited respite from the need to maintain a strict control of body mass. Again the weight allocations to which jockeys must comply with can vary quite dramatically and meeting these specific weight targets in all races appears to place great demands on jockeys. As top jockey Richard Hughes quoted "It is a matter of pride that you ride at the weight your horse is supposed to run off. If you don't, you instantly penalise your own mount and also send out a signal to trainers that you cannot be relied upon" (Hughes and Mottershead, 2012).

Every race is important for jockeys, carrying the constant hopes of the trainer, owners as well as their own financial awards and hopes of future riding opportunities. Jockey's careers and financial security depend on taking every ride possible and these are often accepted with only a day's notice. The need to relentlessly align body mass with the stipulated racing weights can necessitate the use of strict and potentially dangerous acute weight loss strategies amongst jockeys in an attempt to maximise riding opportunities (Hill and O'Connor, 1998, King and Mezey, 1987). Jockeys will often adopt extreme measures in order to reduce their body mass for a race creating a predicament in which making weight is a central aspect of being a jockey and very often documented as the most challenging aspect of life as a jockey (Dolan et al., 2011).

iii. Weight Management Practices

"Weight cycling" is defined as repeated episodes of weight loss and weight gain (Nitzke et al., 1992) and it is the practice that jockeys typically adopt in order to reach and compete at the various stipulated weight allocations (Warrington et al., 2009). Descriptive studies from New Zealand, Australia, South Africa, England and Ireland have provided information regarding the weight loss strategies currently utilised by the jockeys, suggesting a similar trend in all countries (Dolan et al., 2011, Hill and O'Connor, 1998, King and Mezey, 1987, Labadarios et al., 1993, Leydon and Wall, 2002, Moore et al., 2002). Severe energy restriction, and dehydration through a number of mechanisms including fluid restriction, saunas, the use of diuretics and laxatives, and exercising while wearing 'sweat suits' are typically reported as being the most common methods used (Dolan et al., 2011, Labadarios et al., 1993, Leydon and Wall, 2002, Moore et al., 2002).

Most recently, Dolan et al., (2011) in a survey of nutrition, health and lifestyle in professional jockeys cited the frequency of use of a number of acute weight loss strategies in which saunas (86%), exercising to sweat (81%) and restricted energy intake (71%) were the most commonly used methods of weight control. Furthermore, 56% of the smokers (38%) used smoking to control weight. Typical acute weight losses of 3.6 ± 2.4% of body mass were reported however reductions in body mass ranged up to 10.5% (Dolan et al., 2013). Most jockeys (86%) reported reducing body mass (if required) 24 – 48 hours before or on the designated race day, with no jockeys using a specific weight loss plan more than 4 days before racing (Dolan et al., 2011). Many negative side effects were reported to be experienced as a result of making weight, namely thirst (52%), dehydration (43%), hunger (38%), headaches (29%) and fatigue (25%) (Dolan et al., 2011).

The challenges of making weight seem to be an accepted culture of the sport (Dolan et al., 2011). Jockeys unfortunately appear to accept the negative physical effects associated with making weight as part of the sacrifice for a career as a jockey (Gruender, 2007). The acute weight loss methods currently used by jockeys appear to be based on tradition and passed on by peers rather than being founded on sound scientific principles (Warrington et al., 2009). The use of such acute weight making practices have been reported to increase the risk of dehydration (Sawka et al., 2007a) and energy deficiency (Alderman et al., 2004, Oppliger et al., 1996). Consequently, a large proportion of jockeys have been reported to be living and competing in a dehydrated and energy deficient state (Dolan et al., 2011, Warrington et al., 2009).

2.1.3 Injury Risk Associated with Horse Racing

Horse racing is classified as a high risk and dangerous sport (Hitchens et al., 2009a, Rueda et al., 2010). Hitchens et al., (2009) stated that working as a jockey was more dangerous than occupations such as a roofer, farmer or pilot and participants in sports such as skydiving, motorcycling and boxing. It is not in every sport that the athlete is followed by an ambulance. During a race a jockey perched 3 m above the ground, crouching over the miniature saddle on a thoroughbred race horse weighing up to 500 kg and capable of speeds in excess of 65 $km \cdot hr^{-1}$, the margins for error are tiny and the result of a misjudgement could be catastrophic for either the horse or rider or both (Balendra et al., 2008, Waller et al., 2000). Hillenbrand (2001), described horse racing as "…much like perching on the grille of a car while it speeds down a twisting, potholed freeway in traffic". Jockeys place themselves in this high risk environment on a daily basis to make a living and chase their dreams. Injuries, fractures, concussion and fatalities have been described as not merely possibilities in the sport but inevitable (Balendra et al., 2008). With the possibility of the horse being able to act autonomously and unpredictably, there are many causative factors which may lead to jockey's sustaining injuries from falling, to being hit or kicked or even bitten by the horse (Balendra et al., 2007). Such injuries can cost the jockey their livelihood and in extreme circumstances their life (Balendra et al., 2008).

Rueda et al., (2010) reviewed the fall and injury incidence rates of jockeys while racing in Ireland, France and Britain. In Ireland, the falls rate were estimated to be 1/250 rides and 1/20 rides for flat and national hunt racing respectively, with at least 1 in every 5 of these falls resulting in injury (Rueda et al., 2010). Soft tissue injuries (% of total injuries in Ireland: flat 57.6%; national hunt 55.2%), including muscle contusions, ligament sprains and muscle strains, have been reported to be the most common form of injury sustained during professional horse racing (McCrory et al., 2006). Fractures have also been reported as a common form of injury (Balendra et al., 2007) with a fracture occurring in 9.8% of the total falls in flat racing and in 3.4% in national hunt racing in Ireland (McCrory et al., 2006). Furthermore, fractures have been identified as the most common career-ending injuries suffered by jockeys along with neurological injury to the head and/or spine (Balendra et al., 2008). Concussion is a relatively common injury in jockeys in Ireland, with the concussion rate higher for flat racing (7.1% of total falls) compared to national hunt racing (2.1% of total falls) reflecting the high speed nature of flat racing and the likelihood of falls occurring when horses are bunched together and the jockeys sustain impacts from both the ground and other horses (McCrory et al., 2006). Despite always wearing helmets jockeys have been reported to have a higher concussion rate than reported in American football and boxing (Press et al., 1995).

The nature of the sport of horse racing render it high risk, however currently with no precise strategy for managing and achieving the required body mass reduction many jockeys may be placed at an increased risk due to a potential compromised physiological and cognitive function which may have a negative impact on health, safety and performance.

2.1.4 Physical Demands and Energy Requirements of Racing

Paramount to all jockeys is the need to chronically maintain a low body mass, necessary to attain the stipulated competition riding weights, whilst maintaining a sufficient level of physical conditioning in order to compete in several races each day. Despite this, the specific physical demands and energy requirements of racing, training and other daily activities remain to be determined. Horse racing is thought to be a physically demanding sport (Trowbridge et al., 1995) with an associated high total daily energy expenditure on a competitive race day (Dolan et al., 2008).

Jockeys have the task of guiding the horse over various distances, whilst keeping the horse balanced and at a controlled velocity, providing every opportunity for the horse to run to its full potential. Maintaining an optimal level of physical fitness would likely influence physical performance, the ability to recover from a ride and potentially reduce the likelihood of injury resulting from physiological fatigue. Lower anaerobic and aerobic fitness in jockeys have been associated with a greater risk of falls (Hitchens et al., 2011). Trowbridge et al., (1995) reported high peak heart rates (162-198 $beats \cdot min^{-1}$) and post-race blood lactate levels (3.5 to 15.0 $mmol \cdot L^{-1}$) which were measured in 7 male jockeys over 30 national hunt races indicating that national hunt racing requires jockeys to possess a high level of both aerobic and anaerobic fitness. A thorough analysis of the existing scientific literature revealed this to be the only study currently to investigate the physical demands of horse racing. The range in values seen within this study may be explained by the suggested variability amongst the energy demands dependent on individual riders and horses (Devienne and Guezennec, 2000). Wilson et al., (2013) estimated the energy requirements during a simulated 3.2 km race in a group of 9 national hunt jockeys on a manual mechanical race horse simulator. An estimated 43 kcal was provided as a guide for individuals on caloric expenditure during the competitive racing of such a distance. The additional energy demands associated with the physical exertion of restraining a horse plus the hormonal response in a competitive racing environment may not have been accounted for in this laboratory based protocol. Limited information exists relating to the physical demands and energy requirements of racing.

In other studies, the physiological demands of recreational horse riders (Westerling, 1983) and of riding in equestrian activities including dressage, show jumping and cross country (Devienne and Guezennec, 2000, Roberts et al., 2010) have been described. Devienne and

Guezennec (2000) evaluated the energy demands of riding at different gaits and reported that mean oxygen uptake of the rider increased as the riding pace progresses from a walk (0.70 ± 0.18 $L \cdot min^{-1}$) through to a trot (1.47 ± 0.28 $L \cdot min^{-1}$) and to canter (1.9 ± 0.3 $L \cdot min^{-1}$). Similarly, Westerling (1983) measured the oxygen uptake, pulmonary ventilation and heart rate during riding at a walk, trot and canter and found that more experienced riders used at least 60% of their maximal aerobic power in trot and canter (Westerling, 1983). In the cross country phase of eventing, Roberts et al., (2010) observed a high oxygen uptake and heart rate as individuals jumped over a series of obstacles whilst galloping (Roberts et al., 2010). Devienne and Guezennec (2000) concluded that performance in horse riding is influenced by aerobic capacity. In this particular study, participants completed the various trials on 4 different horses of varying dispositions including a lethargic horse requiring additional pushing, an easy horse and a nervous horse that had to be restrained. The variability in energy expenditure according to both the rider and horse was emphasized as a result. While these studies on equestrian and recreational horse riding progress the understanding of the demands and energy requirements of riding, limitations exist in that horse racing involves galloping at high velocities over distances typically ranging from 1-7 km, and in the case of national hunt racing jumping over hurdles or fences, thereby placing greater physiological demands on the horse and rider than typically seen in a trot or canter.

Dolan et al., (2008) reported the total daily estimated energy expenditure (EEE) on a competitive flat race day is relatively high. Total race day energy expenditure was estimated using the Sensewear Pro Armband (SWA, BodyMedia, Inc.) and reported as 3952 ± 577 $kcal \cdot day^{-1}$. A lower EEE has been reported on a non-racing working day in a group of national hunt jockeys by Wilson et al., (2013). Total daily EEE was 2689.40 $kcal \cdot day^{-1}$ when assessed using a heart rate monitor. With a dearth of sport specific information, a limited scientific base appears to exist to allow the development of precise nutritional and training guidelines for jockeys whose careers depend on maintaining a low body mass.

To date, the precise typical physical activity, training and lifestyle practices on a non-race day and race day remain to be determined, which limits the understanding of the apparent total daily energy expenditure as well as the appropriateness of preparation practices currently undertaken by jockeys. Greene et al., (2013) reported the average hours of training performed by apprentice jockeys each week was 24.6 ± 6.9 $hrs \cdot wk^{-1}$, an amount significantly greater to that of the controls (0.8 ± 0.1 $hrs{\cdot}wk^{-1}$). The precise activities of the jockeys were not alluded to within this study. It has been reported elsewhere that the main form of physical activity undertaken by jockeys is riding and racing horses, in many cases for several hours a day (Labadarios et al., 1993, Leydon and Wall, 2002). Leydon and Wall (2002) reported on the busy life jockeys have in New Zealand which typically includes 3 - 4 hours of track work being completed 5 or 6 days a week. This is usually followed by a trial or race meeting, with on average 1 trial and 2 - 4 race meetings occurring each week. At a trial meeting, anything from 2 - 22 horses may be ridden by a jockey over varying distances. In the race meeting, some jockeys may have only 1 ride, whereas others may have up to 8 in one race day meeting alone. This study also reported the low levels of alternative physical activity. Aside from normal work activities, only 22% of the jockeys participated in other forms of exercise, which included running, using an easy rider, tap and Irish dancing, gym work and roller blading. A number of jockeys believed exercise increased muscle mass resulting in weight gain, and for this reason exercise was restricted to work activities only (Leydon and Wall, 2002).

In contrast to the findings of Leydon and Wall (2002), data reported on South African jockeys found that aside from riding for 4 hours most mornings, extra exercise was recorded as being a predominant feature in the Jockey's lifestyle when observing their weight practices (Labadarios et al., 1993). The most popular forms of exercise were running, walking, swimming and squash 2 - 3 times per week for up to one and a half hours. When exercise is combined with the wearing of layers of heavy clothing and/or plastic suits, it was believed by a large proportion of the jockeys surveyed (82%) that exercise is very important in weight control. The results presented by Moore et al., (2002) highlighted that undertaking physical activity, other than riding on race day, was the most common weight management strategy. This conflicting evidence leaves a question over the typical daily activities and exercise that are undertaken by jockeys.

Further research is required in order to specifically quantify the physiological demands of jockeys during training and racing, so that sport-specific nutritional and training recommendations may be provided to assist them in making weight for competition. This would subsequently allow the introduction of tailored interventions of best practice strategies based on scientific principles which optimally equip and prepare jockeys for a career in horse racing while reducing the endemic reliance on such unhealthy weight making practices.

2.2 Physiological Implications of Making Weight

Having no precise strategy for achieving and maintaining the low body mass necessary for horse racing, acute and/or chronic energy restriction and dehydration through a variety of mechanisms are commonly reported amongst the most common 'making weight' strategies used by jockeys (Dolan et al., 2011, Labadarios et al., 1993, Leydon and Wall, 2002, Moore et al., 2002). Alone or in combination these weight making practices can have many adverse effects. An increase in the risk of dehydration (Sawka et al., 2007a) and in the longer term, chronic under-nutrition and energy deficiency (Alderman et al., 2004, Oppliger et al., 1996) are associated with such weight making practices. Extreme dehydration and its associated hyperthermia in an attempt to reach the stipulated competition weight has been implicated in the deaths of three American collegiate wrestlers (Remick et al., 1998). Excessive weight control and dehydration have also been suggested to be responsible for the deaths of two young jockeys in America. One individual was reported to have collapsed after a race due to severe dehydration (Scheinemann, 2005) while the other appeared to suffer a heart arrhythmia as a result of a potassium deficiency developed through constant weight control and energy restriction (Finley, 2000).

A large proportion of jockeys have been reported to be living and competing in a dehydrated and energy deficient state (Dolan et al., 2008, Warrington et al., 2009). Rarely throughout the course of a jockey's career are opportunities provided to normalise diet and body mass. The necessity to maintain a low body mass during each ride and typically over the course of a racing day in addition to this occurring almost daily for the duration of a jockey's career with no defined off season limits the opportunity to replenish energy or refuel. It is suggested this unique feature of horse racing may exacerbate the negative effects of making weight amongst professional jockeys (Dolan et al., 2011).

2.2.1 Dehydration

2.2.1.1 Important Role of Body Fluids for Physiological Functioning

i. Water as an Essential Nutrient

Water is an essential requirement for life and maintaining optimal hydration levels is important for the human body to function properly (Manz and Wentz, 2005). Water makes up a large proportion of body weight and is generally maintained within narrow limits. If water intake is reduced or losses are increased, acute or chronic body water deficits may result (Sawka et al., 2005). Without water, humans can survive only for days (Lunn and Foxen, 2008, Popkin et al., 2010). While humans can survive losses of up to 40% of total body weight in fat, carbohydrates and protein, a water loss of only 9% to 12% of body weight can be fatal (Wilmore et al., 2008).

ii. Distribution of Water in the Body

Varying somewhat with age, gender and body composition, water constitutes approximately 55 to 65% (~60%) of the human body mass (Verbalis, 2003). Lean tissue contains more water (~70%) than fat tissue (~20%) so a lower percentage of body water overall is generally seen with a higher percentage of body fat (Benelam and Wyness, 2010). Of the total body water, about two thirds is located in the intracellular fluid (ICF) and one third is in the extracellular fluid (ECF) which can be further divided into the plasma and the interstitial fluid (Sawka et al., 2005). The distribution of water in the body is represented schematically in Figure 2.2.

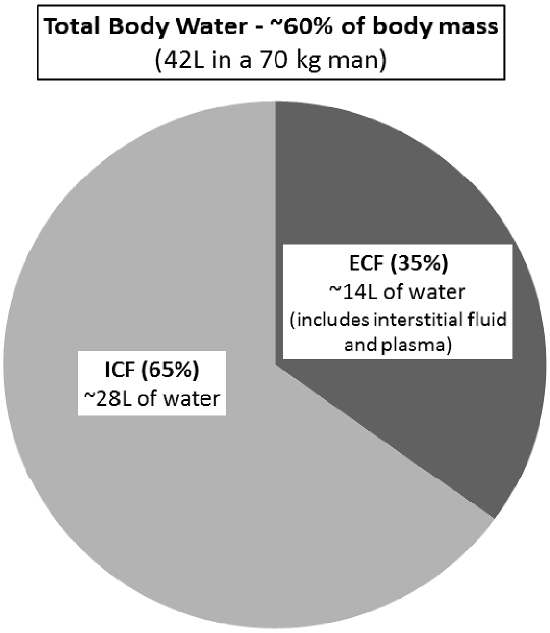


Figure 2.2: A representation of the compartments and the amounts that make up total body water in a typical 70 kg man (Benelam and Wyness, 2010)

The concentration of the solutes in the ICF and ECF differ considerably, with sodium being the predominant solute in the ECF and potassium in the ICF due to the membrane-bound Na^{+}/K^{+} pumps (Guyton and Hall, 1996). Since most biological membranes are highly permeable to water, water can move between the ICF and ECF. If the osmolality of both compartments remain the same, there is no osmotic gradient that pushes water in or out of the cells, keeping both ICF and ECF volumes constant. Osmotic pressure, a function of the concentrations of all the solutes in a fluid compartment, must always remain equivalent in the ICF and ECF. Water always diffuses across the membrane into a compartment with a higher solute concentration until a steady state is reached and the osmotic pressure on both sides of the cell membrane have become equalised (Thornton, 2010). Tightly controlled, variations in solute concentration will cause a water shift between both the ICF and ECF, in effect distributing the solute across both the extracellular and intracellular water (Verbalis, 2003).

iii. Functional Role of Body Fluids

Water performs several essential functions in the body (Benelam and Wyness, 2010, Jequier and Constant, 2010, Lunn and Foxen, 2008). Being a major component of all fluids in the body, water provides the basis for swallowing in addition to acting as a cushion to the joints and the nervous system and as a lubricant to the eyes (Benelam and Wyness, 2010, Lunn and Foxen, 2008). Water acts as a building material and provides a medium for almost all the chemical reactions that take place in the body to occur and it also has the important role of transporting nutrients to cells and removing waste from cells (Jequier and Constant, 2010). Critically, water has an essential role in the regulation of body temperature given its large capacity for the vaporisation of heat (Jequier and Constant, 2010). Evaporation of water from the skin surface through sweating is a very efficient way to lose heat and maintain normal body temperature during various challenges to homeostasis, particularly in hot climates and in periods of physical activity (Popkin et al., 2010). Evaporation has been reported to account for ~20% of heat loss at rest, rising significantly to 80% during exercise (Weller, 2005). Kleiner et al., (1999) stated that from energy production to joint lubrication to reproduction, there is no system in the body that does not depend on water.

2.2.1.2 Regulation of Fluid Balance

i. Daily Turnover of Body Fluids

Both fluid intake and fluid output are highly variable depending on the individual (Sawka et al., 2005). Water produced from metabolism is insufficient to fulfil the daily requirements and so the body relies on water ingested through food and fluid (Lunn and Foxen, 2008). While water may be lost from the body through the skin as sweat, in faeces and also through insensible water loss including evaporation of water from the lungs and skin, the largest part of overall water loss is normally in urine (Benelam and Wyness, 2010). Urine output however can vary greatly depending on the amount of fluid consumed or the amount of sweat produced (Jequier and Constant, 2010). While the typical daily turnover of water is represented schematically in Figure 2.3 (Guyton and Hall, 1996), water losses via the skin may vary considerably from 0.3 $L\cdot h^{-1}$ in sedentary conditions to 2 $L\cdot h^{-1}$ during activity in the heat (Popkin et al., 2010). The heavy reliance on weight making practices amongst jockeys including the restriction of fluids and the use of the sauna to induce sweating (Dolan et al., 2011) suggests the daily turnover in body fluids would differ greatly in the jockey population.

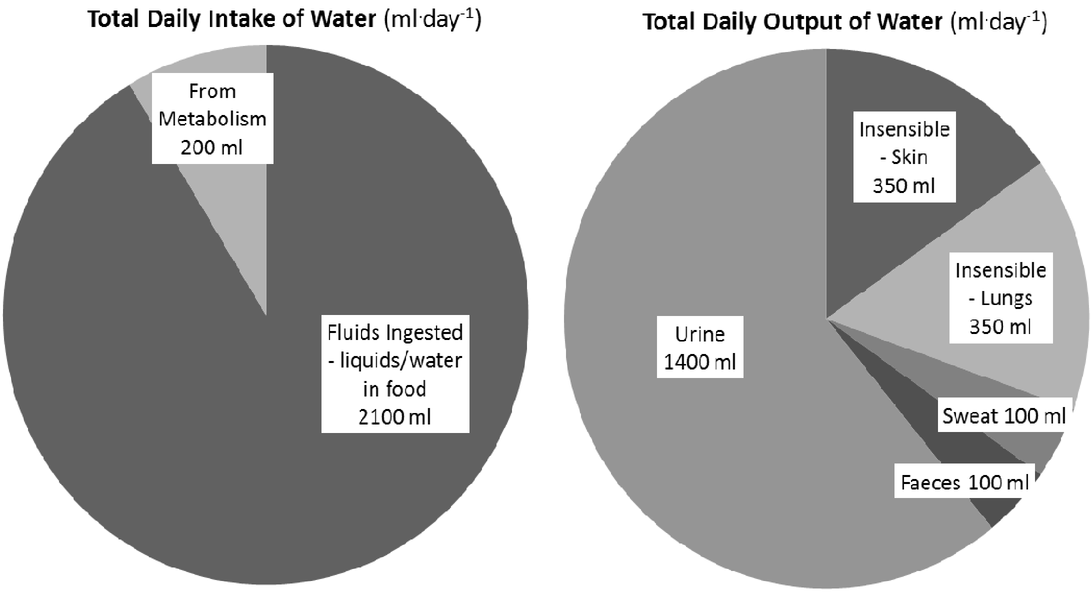


Figure 2.3: Typical Daily Turnover of Water (2300 $ml\cdot day^{-1}$) (adapted from (Guyton and Hall, 1996))

ii. Maintenance of Fluid Balance

The kidneys play a key role in regulating fluid balance in the body, maintaining a relatively constant kidney blood flow and glomerular filtration rate (GFR) primarily through efficient autoregulation as well as hormonal influences. Renal autoregulation involves feedback mechanisms inclusive of myogenic regulation, tubuloglomerular feedback and mesangial cell contraction which are all intrinsic to the kidney to regulate GFR. Such mechanisms cause either dilation or constriction in the afferent arteriole of the kidney in order to counteract blood pressure changes and maintain a steady GFR. Furthermore, homeostatic systems in the body ensure that plasma osmolality is maintained within a tight range (between 275 and 290

$mOsm \cdot kg^{-1}$), by regulating sensations of thirst and initiating the release of hormones necessary to ingest and conserve water and sodium within the body to correct any imbalances (Popkin et al., 2010), preserving homeostasis in both the ICF and ECF (Thornton, 2010, Verbalis, 2003). Essentially fluid balance in the body depends on two parameters namely thirst to influence water input and urine excretion that determines water output (Bouby and Fernandes, 2003). Feedback mechanisms are capable of sensing and reacting to very small changes in plasma osmolality (by 1 to 2%) (Lunn and Foxen, 2008). Typically a loss of 1% of body water is compensated within 24 hours (Jequier and Constant, 2010). A water deficit increases the plasma osmolality of the ECF which subsequently causes water to move out from the ICF to re-establish a state of equiosmolality. The cells shrink as a result and this is detected by brain sensors that control both thirst and the excretion of urine by sending a message to the kidneys to produce a smaller volume of more concentrated urine (Thornton, 2010).

The kidneys play a key role in regulating fluid balance from conserving water when body fluids are low due to restricted intake or excessive sweating to excreting excess water when fluid intakes are high (Guyton and Hall, 1996). The principal determinant of water excretion is the regulation of urinary flow by circulating levels of arginine vasopressin (AVP) (also known as antidiuretic hormone (ADH)) in plasma (Verbalis, 2003). Increased osmolarity of the body fluids, sensed by osmoreceptors in the hypothalamus, results in the secretion of AVP from the posterior pituitary gland. The renal response to AVP is an increase in the water permeability of the collecting duct through the insertion of water channels, aquaporin-2, into the apical membranes of the collecting tubule principle cells. A subsequent decrease in urine flow and increase in urine osmolality occur as water is reabsorbed (Antunes-Rodrigues, 2004). AVP, as depicted in Figure 2.4, is highly sensitive to small changes in osmolality (Robinson, 1985). The osmotic threshold for the release of AVP is lower than that for thirst. AVP release begins at a plasma osmolality of approximately 280 $mOsm \cdot kg^{-1}$ H_2O whereas plasma osmolality reaches about 290 $mOsm \cdot kg^{-1}$ H_2O before thirst is perceived (Bouby and Fernandes, 2003). Plasma osmolality changes of 1% or less are sufficient to cause significant increases in plasma AVP levels with proportional increases in urine concentration (Verbalis, 2003). The corresponding sensitivity of the kidney to small changes in plasma AVP levels is also apparent in Figure 2.4. Thornton (2010) also describes AVPs additional action of vasoconstriction to facilitate blood flow and increase blood pressure.

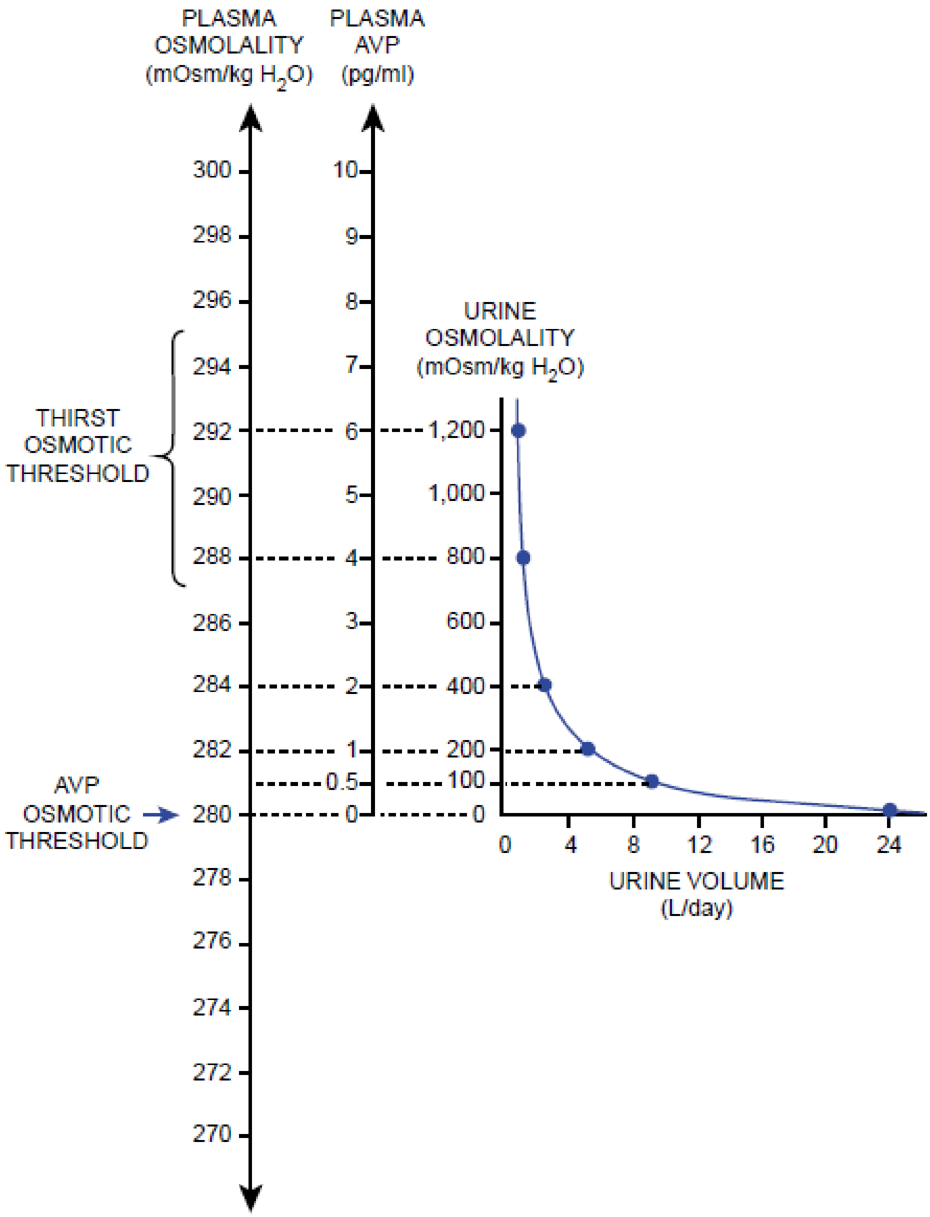


Figure 2.4: Physiological Relationships among Plasma Osmolality, Plasma AVP Concentration, Urine Osmolality and Urine Volume in man (Robinson, 1985)

The renin-angiotensin aldosterone system (RAAS) is also reported to play an integral role in the homeostatic control of arterial pressure, tissue perfusion and extracellular volume (Atlas, 2007). Baroreceptors in the juxtaglomerular apparatus of the kidney sense any apparent decrease in perfusion pressure which stimulates the secretion of the enzyme renin. This enzyme acts on the circulating angiotensinogen, released from the liver, forming angiotensin I. Angiotensin converting enzyme (ACE) in the lung converts this to angiotensin II (AngII)

(Thornton, 2010). Angiotensin II is regarded as the body's most powerful sodium-retaining hormone and its increased formation is often associated with low blood pressure and/or low ECF volume (Guyton and Hall, 1996). Atlas (2007) describes how AngII acts on the cardiovascular system (vasoconstriction, increases blood pressure), kidney (renal tubular sodium reabsorption, inhibition of further renin release), sympathetic nervous system as well as the adrenal cortex (stimulation of aldosterone synthesis). Aldosterone, secreted by the zona glomerulosa cells of the adrenal cortex, plays a major role in the regulation of the extracellular volume. Being a major regulator of sodium and potassium balance, it enhances the reabsorption of sodium and water in the distal tubules and collecting ducts and promotes potassium excretion (Thornton, 2010).

Overall, the most important effect of urine concentrating activity is achieving the desired result of returning the blood pressure and ECF volume towards normal (Guyton and Hall, 1996). Maintenance of body fluid homeostasis requires autonomic and endocrine responses and activation of specific behaviours. Alterations in blood volume or pressure lead to appropriate changes in both renal fluid and electrolyte excretion through neural and endocrine adaptive responses (Antunes-Rodrigues, 2004).

2.2.1.3 Fluid Deficit - Dehydration

Dehydration, or hypohydration, has been defined as the loss of fluid from the body (Brooks et al., 2005). It refers to the reduction of total body water below the mean basal value, a process resulting from uncompensated water loss via urine, sweat, faeces and respiratory vapour (Armstrong, 2007). Three types of dehydration may occur:

Isotonic Dehydration: This form of dehydration is commonly found in athletes competing in weight classification sports (Oppliger and Bartok, 2002b). Both water and sodium losses occur in equal amounts as is commonly seen as a result of a complete fast or vomiting (Jequier and Constant, 2010).

Hypertonic Dehydration: Insufficient water intake or large water loss resulting from vomiting or heavy sweating may cause this form of dehydration (Jequier and Constant, 2010). Such dehydration is often characterised by a loss of water in excess of salt with a serum osmolality greater than 300 $mOsm \cdot kg^{-1}$ as well as reductions in plasma volume (Oppliger and Bartok, 2002b).

Hypotonic Dehydration: A loss of salt in excess of water characterises hypotonic dehydration, revealing a lower than normal serum osmolality (Jequier and Constant, 2010). Diuretic use or restricted sodium intake may cause such dehydration (Oppliger and Bartok, 2002b).

The decrease in body water has been reported to provoke changes in cardiovascular, thermoregulatory, metabolic and central nervous function (Murray, 2007). Fluid loss has been described as coinciding with decreased plasma volume, reduced stroke volume and increased heart rate, decreased electrolytes (blood and muscle), reduced skin blood flow and a rise in core temperature (McArdle et al., 2010, Wilmore, 2000). Dehydration by 1% of body mass has been reported to result in reductions in the rate of sweating with an associated rise in rectal temperature of about 0.3°C and an increase in heart rate of 5 to 10 beats·min^{-1} (Morimoto, 1990). Dehydration resulting in body mass losses of 1 to 2% compromise physiological function and can have negative implications on performance specifically aerobic capacity, run time to exhaustion, total work performed and potentially anaerobic power and anaerobic capacity (Fogelholm, 1994, Oppliger et al., 1996, Wilmore, 2000). With dehydration levels greater than 3% of body mass, further disturbances in physiological function are apparent and there is an increased risk of the development of a heat illness (Casa et al., 2000). Such dehydration related injuries may include heat cramps, heat exhaustion, heat syncope and heat stroke (Brooks et al., 2005).

In addition to fluid restriction, many jockeys habitually self-induce dehydration through sauna exposure or excessive exercise in sweatsuits to rapidly reduce body mass in order to reach the stipulated racing weights (Dolan et al., 2011, Labadarios et al., 1993, Leydon and Wall, 2002, Moore et al., 2002). Dehydration due to thermal sweating causes both hypovolemia and hyperosmolality (Morimoto, 1990). The physiological responses to the high environmental temperatures within the sauna include cutaneous vasodilation to increase thermal conductance between the body core and the skin as well as an increase in evaporative heat loss (i.e. sweating) (Morimoto, 1990). Intense sweating leads to large water losses, generally larger than electrolyte losses due to the hypotonic nature of sweat compared with plasma or ECF (Sawka et al., 2005). This subsequently increases extracellular osmolarity, drawing water from the cells into the ECF. The loss of water from sweating concerns both the ICF and ECF, a situation characterising hypertonic dehydration (Jequier and Constant, 2010). Thornton

(2010) describes the physiology and consequences of dehydration which is represented in Figure 2.5.

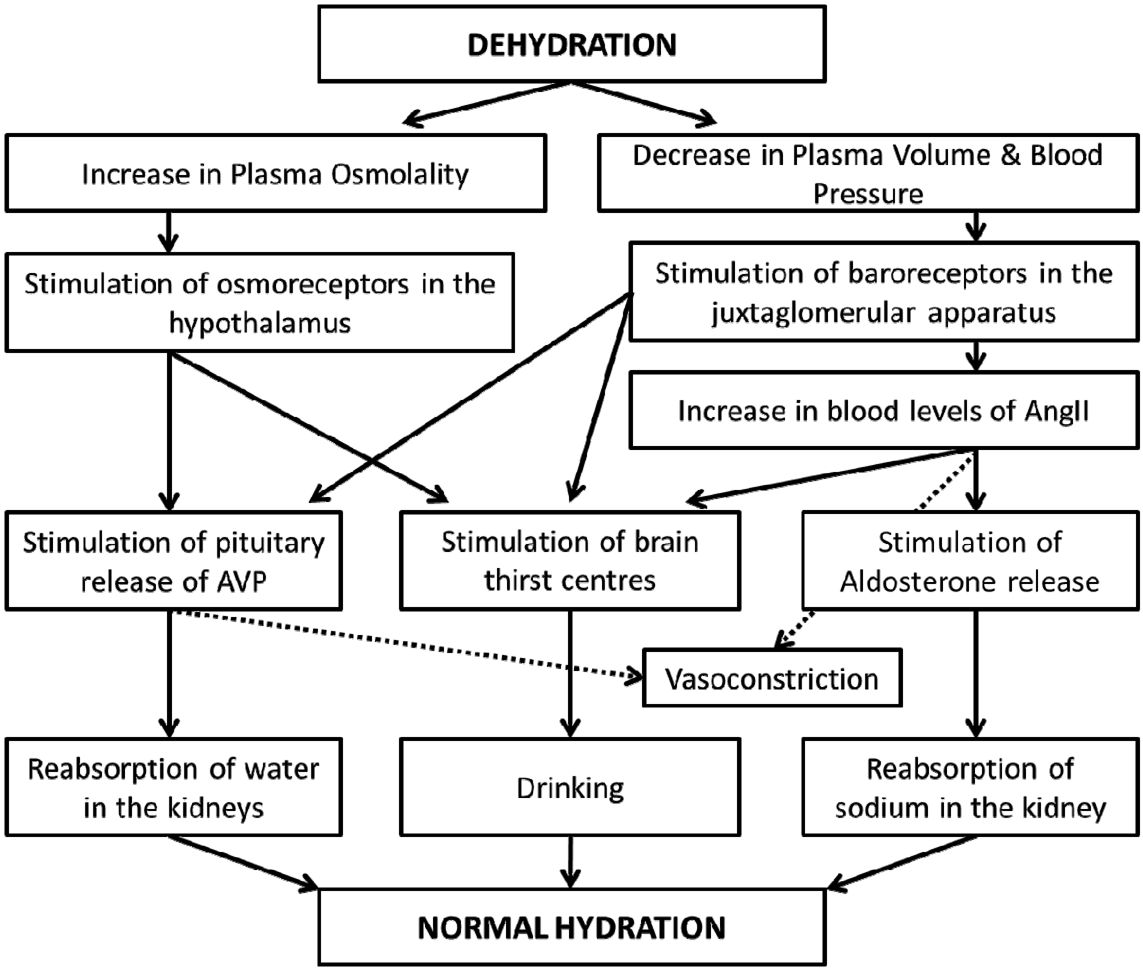


Figure 2.5: The Physiological Mechanisms Associated with Dehydration

(Adapted from Thornton (2010))

Furthermore, containing sodium and small amounts of many other electrolytes, heavy sweating is a route of solute loss (Benelam and Wyness, 2010). With an increased rate of sweating, limited time is available for the typical reabsorption of electrolytes (e.g. potassium, chloride, magnesium, calcium) that occurs in the uncoiled duct of the sweat gland (Wilmore et al., 2008). Given the many methods used by jockeys to 'make weight', all three forms of dehydration (isotonic, hypertonic, hypotonic) may be apparent in jockeys and so leading to the large proportion of jockeys reported to be living and competing in a dehydrated state (Warrington et al., 2009).

2.2.1.4 Prevalence of Dehydration amongst Jockeys

Warrington et al., (2009) reported jockeys appear to be habitually dehydrated in an attempt to 'make weight' for racing; a situation that may be further exacerbated on racing days. In a group of 27 professional jockeys, mean Usg values revealed moderate dehydration on a non-race day (Usg = 1.022 ± 0.005 and 1.021 ± 0.007 for flat and national hunt jockeys respectively). Further analysis of a number of flat jockeys (n = 11) revealed marked dehydration on a race day (Usg = 1.028 ± 0.005). Furthermore 54% of these jockeys were reported to be competing in a severely dehydrated state (Usg > 1.030). Blood samples taken on the day of the race for additional hydration assessment further substantiated these findings revealing a high serum osmolality of 320.4 ± 6.2 $mOsm \cdot kg^{-1}$ and serum sodium concentrations of 147.25 ± 1.75 $mmol \cdot L^{-1}$ at the start of the day. It is believed this apparent dehydration may be caused primarily by the weight making practices typically used by jockeys such as the use of saunas and fluid restrictions (Warrington et al., 2009). Such findings may have serious implications for the health and performance of jockeys given the high risk and competitive nature of the sport.

2.2.2 Energy Deficiency

2.2.2.1 Important Role of Nutrition for Physiological Functioning

Appropriate nutritional intake is required for several fundamental physiological processes namely cellular maintenance, thermoregulation, growth, reproduction, immunity and locomotion (Loucks et al., 2011). Consumption of sufficient additional energy is further required by athletes in order to meet various training demands, maintain health, and if young, for optimal growth and development (Loucks et al., 2011). Actual energy intake requirements depends on a variety of factors namely body composition, body mass, height, age, stage of growth and level of fitness. In athletes the intensity, frequency and duration of the exercise activity must also be taken into consideration (ADA, 2009).

2.2.2.2 Maintenance of Energy Homeostasis

Energy balance is defined as the state achieved when energy intake equals energy expenditure (Hill et al., 2013). Commonly reported in the literature, the concept of energy balance is based on the fundamental principle of thermodynamics such that energy can be transformed from one form to another but cannot be created or destroyed (Hall et al., 2012).

Humans take in energy through the consumption of food and drink, primarily in the form of macronutrients and micronutrients as well as a small proportion in the form of alcohol, and expend energy through RMR, the thermic effect of food, and physical activity. Any imbalance between energy intake and energy expended will lead to alterations in body mass and body composition (Hall et al., 2012). Changes in body mass are a function of energy balance; when energy intake exceeds energy expenditure the result is a gain in body mass as opposed to a loss in body mass when energy expenditure exceeds energy intake (Martin et al., 2007).

Precise mechanisms primarily controlled by the hypothalamus exist to balance energy intake and energy expenditure to minimise fluctuations in body mass on a daily basis (Harris, 2013) and to protect against adverse effects of negative energy balance (Fuqua and Togol, 2013). The hypothalamus links the sensing of nutrients to the control of metabolism and feeding behaviour by detecting ongoing systemic nutrients and adjusting the intake of food and peripheral metabolism accordingly (Benedini, 2009, Dietrich and Horvath, 2013). The supervision of fuel availability in the central nervous system is achieved directly by neurons using highly conserved intracellular fuel-sensing pathways that are capable of providing information on cellular fuel availability and indirectly by fuel sensing in peripheral cells translated to the brain neurons (Benedini, 2009). The hypothalamus elicits the appropriate behavioural and metabolic responses to counter balance any changes in the energy status (Benedini, 2009).

A complex interplay of endocrine signals that centrally influence appetite and satiety regulate the maintenance of energy homeostasis (Pasiakos et al., 2011). Leptin, an adipocyte hormone, is secreted by the hypothalamus in proportion to body fat mass and plays a central role in energy homeostasis predominantly by informing the central nervous system of any alterations in energy balance and the amount of fuel stored as fat (Guyenet and Schwartz, 2012). Morton et al., (2006) describes how leptin functions as a negative feedback regulator of adiposity in the brain, constraining fat mass by limiting energy intake and supporting energy expenditure. Reductions in leptin signalling promote an increase in food intake with an associated positive energy balance and fat accumulation. During periods of negative energy balance and loss of body fat, leptin is reduced while an increase in ghrelin (a potent orexigenic hormone secreted from the gastric mucosa) is apparent. Ghrelin typically stimulates feeding resulting in positive energy balance and the recovery of lost fat (Morton et al., 2006).

Energy deficits are partially offset by such neuroendocrine mechanisms regulating appetite and satiety (Fuqua and Togol, 2013). Following periods of energy restriction, reduced leptin concentrations function to signal lower satiety, increasing central drive to restore energy balance. In response to low energy availability and adiposity, ghrelin, is secreted to stimulate appetite. Decreases in leptin are characteristic of energy malnutrition (Haspolat et al., 2007) and such reductions are out of proportion to changes in fat mass in response to complete fasting (Chan and Mantzoros, 2005). It has been suggested the lower insulin concentrations resulting from glycogen depletion during energy restriction play a key role in the regulation of leptin (Pasiakos et al., 2011). Pasiakos et al., (2011) reported 2 days of severe energy restriction (<10% of estimated energy requirements) altered several endocrine regulators of appetite, such that concentrations of insulin and leptin were lower and ghrelin concentrations were higher during energy deficit compared to energy balance. Satiety was also reduced suggesting a possible physiological mechanism for overeating following acute periods of severe energy restriction (Pasiakos et al., 2011).

Leptin has been suggested to play an important role in the neuroendocrine adaptation to energy restriction and weight loss including alterations in hormone concentrations that could have a protective effect (Chan and Mantzoros, 2005, Friedman and Halaas, 1998, Friedman, 2002). Chan et al., (2005) postulate low leptin levels are important for signalling energy deficit to the hypothalamic-pituitary axes and might mediate various responses associated with energy restriction. According to Chan et al., (2005) these responses include a reduction in reproductive hormones to limit procreation, a decrease in thyroid hormones to conserve metabolism, an increase in stress hormones to mobilise needed energy stores and also a rise in growth hormone with a decrease in IGF-1 i.e. a state of reduced energy expenditure for growth-related processes while enabling growth hormone to increase use of alternative fuels through lipolysis (Chan and Mantzoros, 2005).

2.2.2.3 Negative Energy Balance – Low Energy Availability

Long term negative energy balance may have serious health implications (Fuqua and Togol, 2013). Defined as dietary energy intake minus the energy expended in exercise, energy availability refers to the amount of dietary energy remaining for other functions in the body after exercise (Nattiv et al., 2007). When energy availability is too low, physiological processes are suppressed reducing the amount of energy used for cellular maintenance, thermoregulation, growth and reproduction. While this compensation tends to restore energy balance and promote survival, it causes health impairments (Nattiv et al., 2007). Nattiv et al., (2007) suggest that energy balance can be restored while energy availability remains low as evidenced by the stable weight in amenorrheic athletes. Below an energy availability of 30 $kcal \cdot kg\ FFM^{-1} \cdot day^{-1}$, reproductive function (Loucks and Thuma, 2003) and bone formation (Ihle and Loucks, 2004) are impaired abruptly and promptly which also correspond to reductions in resting metabolic rate (Loucks et al., 2011).

The Female Athlete Triad refers to the interrelationships among energy availability, menstrual function and bone mineral density (BMD) which may have many clinical manifestations including eating disorders, functional hypothalamic amenorrhea and osteoporosis (Nattiv et al., 2007). While previously associated with female athletes, Barrack et al., (2013) suggest males may also experience the adverse metabolic, hormonal and physiological effects of low energy availability. While the expenditure of large amounts of energy during prolonged exercise training without adequate energy intake is emphasized as the possible cause of the apparent low energy availability in endurance athletes (Nattiv et al., 2007), chronic energy restriction to maintain body mass within the stringent weight limits may be the predominant contributor to such a phenomenon in jockeys (Dolan et al., 2011).

2.2.2.4 Prevalence of Energy Deficiency amongst Jockeys

While there appears to be a strong reliance on acute weight loss by jockeys for competition, the low energy intakes reported also suggest some degree of chronic energy restriction (Dolan et al., 2011, Leydon and Wall, 2002, Greene et al., 2013). Dolan et al., (2011) reported a mean daily intake of 1803 ± 564 $kcal \cdot day^{-1}$ for jockeys which appeared to be only 22% (1.2 times) above the estimated resting metabolic rate (RMR) (1492 ± 114 $kcal \cdot day^{-1}$), a value typically sufficient to only maintain the metabolic needs of men at rest (Manore and Thompson, 2006). An insufficient availability of energy (lower than 30 $kcal \cdot kg\ FFM^{-1} \cdot day^{-1}$) required for the sustainment of usual daily and metabolic processes was shown for the professional jockeys on a competitive race day (Dolan et al., 2011). Without equivalent information available on a non-race day, Dolan et al., (2011) proposed it was unlikely the energy deficiency estimated for race days is completely compensated for by an increased availability on non-race days due to the daily riding of track work and monitoring of body mass for subsequent race days (Dolan et al., 2011). Furthermore, Greene et al., (2013) previously reported a mean daily energy intake of 1796 ± 543 kcal·day^{-1} amongst apprentice jockeys using a 3 day (2 week days and 1 weekend day) food diary. Compared to controls, the jockeys consumed 47% ($p = 0.001$) less daily kilocalories despite the significantly greater number of hours training performed per week.

Carbohydrate intake amongst jockeys is also often reported as being significantly lower than the recommended daily intake (RDI) for athletic individuals (Dolan et al., 2011, Leydon and Wall, 2002). Both Leydon and Wall (2002) and Dolan et al., (2011) reported a similar carbohydrate intake of 3.4 g·kg^{-1} and 3.7 g·kg^{-1}, respectively, which fails to meet the recommended minimum athletic intake of 6 g·kg^{-1} of bodyweight (ADA, 2009). Jockeys also typically tend not to meet the RDI for a number of micronutrients in addition to consuming well below (0-2) the recommended five daily servings of fruit and vegetables (Dolan et al., 2011). The typical nutritional practices reported within the study by Dolan et al., (2011) would constitute a severe energy deficiency for the group of jockeys which may have serious health and performance implications for the jockeys both during their career and in the long term.

2.3 Effects of Making Weight on Performance

As seen in the previous section, the acute weight making practices used amongst jockeys may result in dehydration and a deficiency in energy. Such acute body mass losses have been reported in other weight category sports to be detrimental to competitive performance (Franchini et al., 2012, Fogelholm, 1994, Wilmore, 2000) given the associated dehydration, depleted glycogen stores and reduced lean mass (Hall and Lane, 2001, Degoutte et al., 2006, Koral and Dosseville, 2009, Burge et al., 1993). However the effects of making weight on short duration anaerobic activities remain inconsistent and conflicting (Koral and Dosseville, 2009, Fogelholm, 1994). Moreover, cognitive performance and mood may also be negatively influenced as a result of rapid body mass reductions (Choma et al., 1998, Hall and Lane, 2001, Landers et al., 2001, Koral and Dosseville, 2009). The precise effects of making weight on competitive performance are somewhat equivocal, as many factors including the time of body mass reduction, recovery time after weigh-in and the type of diet may affect responses to rapid body mass loss (Franchini et al., 2012).

Limited data currently exist on the effects of rapid reductions in body mass on the physical and cognitive performance of jockeys. Aerobic work capacity in a group of professional jockeys has been reported to be compromised as a result of the typical weight making practices used by jockeys to rapidly reduce body mass to attain the stipulated competition racing weights (Dolan et al., 2013). Through simulating typical race day preparatory practices, Dolan et al., (2013) reported a rapid reduction in body mass (-4%) in 48 hours resulted in decreased peak power output, as indicated by the power output reached at VO_2 peak during an incremental cycle ergometer test. A greater magnitude of submaximal cardiovascular strain was also experienced following this acute body mass reduction which incorporated both dehydration and an energy restriction (Dolan et al., 2013). In a separate study Wilson et al., (2013) reported that a 2% reduction in body mass, achieved by performing 45 minutes of exercise, significantly impaired simulated riding performance as assessed by maximum pushing frequency on a mechanical race horse simulator during the final 2 furlongs of a simulated 2 mile race. Chest and leg strength were also found to be reduced. Both of the above studies reported no significant impairment in cognitive performance (Wilson et al., 2013b, Dolan et al., 2013).

While the precise demands of horse racing have yet to be determined, it is believed to be a physically demanding sport (Trowbridge et al., 1995). Given the highly competitive and dangerous nature of horse racing, the need to be physically fit and mentally alert would appear to be of great importance to jockeys in order to ensure the horse runs to its full potential in the safest possible environment. For this reason, the effects of making weight on cognitive function, balance and anaerobic performance are further explored in the following section.

2.3.1 Making Weight and Cognitive Performance

The unpredictable and high risk nature of horse racing is perhaps best epitomised by a quote from top flat Irish jockey Johnny Murtagh "you can visualise what you think will happen in the race over and over beforehand and have your tactics worked out, but when those stalls open you have to be prepared for anything to happen and adapt to the situation" (HRI and GoRacing.ie). In a field where over 13 race horses may be moving in close proximity at velocities in excess of 65 $km \cdot hr^{-1}$, split second decisions, attention, concentration and memory efficiency can mean the difference between winning and losing as the jockey must monitor and take advantage of fleeting gaps and shifts in the field. Inevitably survival and success depend on how a jockey can adapt to any situation.

2.3.1.1 Cognitive Function

Cognition has been defined as "the symbolic (or conceptual) processing of information that is required for the central representation and organised expression of a response" (Lang, 1984). Cognitive function refers to those mental processes (attention, short-term/working memory, long-term memory, reasoning, the coordination of movement and the planning of tasks) essential for conducting the activities of daily living (Wesnes, 2002). Lezak et al., (2004) divided cognitive function into four major domains, all of which are inextricably bound to each other (Lezak et al., 2004). These include:

1. Receptive Functions – the ability to select, acquire, classify and integrate information
2. Memory and Learning – information storage and retrieval
3. Thinking – the mental organisation and reorganisation of information

4. Expressive Functions – the means through which information is communicated or acted upon.

Various tests of cognitive function in the form of both computerised tests and pen and paper tests have been designed to assess such mental processes. The conventional pen and paper tests often have poor psychometric properties for serial studies including a limited range of possible scores, floor and ceiling effects, learning effects and poor test-retest reliability (Collie et al., 2001). Using infinitely variable test paradigms, computerised testing may overcome such methodological limitations (Aubry et al., 2002). Computerised tests have been reported to have high test-retest reliability between test sessions (Collie et al., 2003, Straume-Naesheim et al., 2005) and increased sensitivity for cognitive function assessment over traditional methods with computerised tests of reaction time allowing the detection of very subtle cognitive changes (Makdissi et al., 2001). A reduction in practice effects is also apparent in computerised tests compared to the conventional pen and paper tests due to the randomisation of stimulus presentations creating many alternative and equivalent forms of the test (Collie et al., 2001).

2.3.1.2 Rapid Weight Loss and Cognitive Function

i. Dehydration

Several researchers have investigated the effects of dehydration on cognitive function, with findings consistently revealing a negative effect (Cian et al., 2001, Cullen et al., 2013, Smith et al., 2012, Tomporowski et al., 2007, Gopinathan et al., 1988). Despite this, the level of dehydration at which such impairments in cognitive performance are initially apparent remain unclear, in addition to understanding the exact behavioural functions that are most affected by dehydration (Adan, 2012, Grandjean and Grandjean, 2007, Lieberman, 2007, Secher and Ritz, 2012). Although it is commonly suggested that decrements in cognitive performance typically occur at a threshold level of a 2% fall in body mass or more (Cian et al., 2001, Cullen et al., 2013, Gopinathan et al., 1988, Tomporowski et al., 2007), dehydration levels of 1.5% have also been indicated to adversely affect cognitive performance (Smith et al., 2012). Lieberman et al., (2012) suggest the lowest level of dehydration that results in cognitive degradation has not been definitely established. Furthermore, previous studies have demonstrated that impairments in cognitive performance are proportional to the degree of dehydration (Gopinathan et al., 1988, Sharma et al., 1986). Table 2.1 summarises various studies assessing the association between cognitive performance and dehydration, the majority of which have been conducted on healthy individuals and military personnel rather than on athletic populations.

Table 2.1: Association between Cognitive Performance and Various Dehydration Methods

Reference	Dehydration Intensity (% Body Mass Loss)	Experimental Stress	Change in Cognitive Performance	Results
(Sharma et al., 1986)	1-3%	Exercise with Heat Exposure	Yes	*Working Memory* – Impaired at 2% dehydration *Psychomotor Performance* – Impaired at 2% dehydration
(Gopinathan et al., 1988)	1-4%	Exercise with Heat Exposure	Yes	*Visual Motor tracking* - Impaired at 2% or more dehydration *Short-Term Memory* - Impaired at 2% or more dehydration *Attention* - Impaired at 2% or more dehydration *Arithmetic Efficiency* – Ability impaired at 2% or more dehydration
(Cian et al., 2000)	2.8%	Exercise and Heat Exposure	Yes	*Perceived discrimination* - Impaired *Short-Term Memory* - Impaired
(Cian et al., 2001)	2.8%	Exercise and Heat Exposure	Yes	*Perceived discrimination* - Inhibiting effect on decision time *Psychomotor Skills* - Inhibited *Short-Term Memory* – Impaired
(Szinnai et al., 2005)	2.6%	Water Restriction	No	*No change in simple and choice reaction time, attention, working memory*
(Tomporowski et al., 2007)	3.7%	Exercise and Water Restriction	Yes	*Executive functioning* – Negative impact on mental tasks
(Patel et al., 2007)	2.5%	Exercise and Water Restriction	Yes	*Visual Memory* – Deteriorated

Reference	Dehydration Intensity (% Body Mass Loss)	Experimental Stress	Change in Cognitive Performance	Results
(Ganio et al., 2011)	1.6%	Exercise and Water Restriction	Yes	*Vigilance* - Increased errors *Working Memory* - Response latency slowed
(Cullen et al., 2013)	4.2%	Heat Exposure and Water Restriction	Yes	*Attention & Processing Speed* - Impaired
(Smith et al., 2012)	1.5%	Water Restriction	Yes	*Perception & Attention* – Increased errors

The earliest and most comprehensive studies investigating the effects of dehydration on cognitive function were conducted more than 20 years ago (Gopinathan et al., 1988, Sharma et al., 1986). Such studies employed a combination of heat and exercise to rapidly induce dehydration. Gopinathan et al., (1988) used step-up exercises in a heated room (45°C with 30% RH) to induce dehydration ranging from 1 - 4% in 1% increments in 11 healthy young males (aged 20-25 years). Impairments in visual motor tracking, short-term memory, attention and arithmetic ability were detected at 2% dehydration, deteriorating markedly with further levels of dehydration. All three administered tests detected consistent dose-related deterioration in cognitive performance indicating the methodology and results of this study to be particularly robust. Similarly, Sharma et al., (1986) assessed the effects of dehydration on cognitive performance in 8 young males (aged 21-24 years). Dehydration was induced through moderate exercise in three environments with varying temperature and humidity until ~1, 2 and 3% body mass loss occurred. Dehydration to 2 or 3% loss in body mass resulted in a significant decline in cognitive performance. Yet again, graded dose-related changes in cognitive performance were observed across all environmental parameters.

The impact of exercise on cognition has caused great controversy with cognitive performance varying as a result of exercise depending on when it is measured, the type of cognitive task selected, and the type of exercise performed (Coles and Tomporowski, 2008, Lambourne and Tomporowski, 2010, Tomporowski, 2003). Such studies suggest a possible interaction between dehydration and physical exertion and so leading to the assumption that exercise-induced dehydration causes disturbances to cognitive function to a lesser extent than dehydration caused by heat. Two separate studies performed by the same group investigated the effects of heat stress vs. exercise-induced dehydration on cognitive function (Cian et al., 2001, Cian et al., 2000). Subjects were dehydrated by controlled passive hyperthermia or exercised on a treadmill until a body mass reduction of 2.8% was reached. Both dehydrating conditions, heat stress and exercise, had a detrimental effect on cognitive performance (impaired perceived discrimination, short term memory, psychomotor skills, decision time) without any significant difference between the two dehydrating methods (Cian et al., 2001, Cian et al., 2000). Additionally, Cian et al., (2001) reported cognitive performance to be normalised 3.5 hours after dehydration induced through either passive exposure to heat or treadmill exercise, despite the continued level of hypohydration experienced. Cullen et al., (2013) also assessed the effects of passive dehydration on cognitive performance in twelve healthy young males (aged 18-23 years) who underwent heat exposure (40°C) until a 4% (mean 4.2%) reduction in body mass was achieved. Despite a variety of cognitive parameters being assessed both on a computerised test battery and pen and paper tests, cognitive impairments were only reported in the domains of attention and processing speed.

The high levels of heat used to induce dehydration in the aforementioned studies may in fact have interacted with dehydration to further exacerbate cognitive performance impairments (Lieberman, 2007). To avoid the confounding effects of heat exposure, many studies have used exercise-induced dehydration in conjunction with water restriction as a means of producing dehydration (Ganio et al., 2011, Patel et al., 2007, Tomporowski et al., 2007). Significant adverse effects on certain aspects of cognitive performance were reported with acute dehydration of 1.6% body mass loss following a 40 minute treadmill walk at $5.6 km \cdot hr^{-1}$, 5% grade in a 27.7°C environment (Ganio et al., 2011). Having induced dehydration to 3.7% body mass loss through cycling sub maximally for 120 minute ending with a test to exhaustion without fluid replacement, Tomporowski et al., (2007) reported only a greater negative affect on more effortful mental tasks than those performed repetitively and requiring less attention. Furthermore, Patel et al., (2007) observed only mild decreases in cognitive performance despite numerous neuropsychological parameters tested.

Methodological difficulties still remain in attempting to determine the effects of dehydration independent of the effects of other stressors (e.g. heat stress, exercise, fatigue). Few studies have assessed the effects of dehydration on cognitive performance induced solely by water deprivation. Szinnai et al., (2005) conducted a study to determine if slow progressive moderate dehydration induced by water deprivation effects cognitive performance in 16 healthy men and women (aged 20-34 years). Cognitive function remained unchanged and was concluded to be preserved during water deprivation up to a dehydration level of 2.6% of body mass over 28 hours. Interestingly, Smith et al., (2012) reported cognitive impairments as a result of mild dehydration (1.5% of body mass) induced through 12 hour fluid restriction. Error in the judgement of the distance to the target (perception and attention) increased in the 7 golfers tested.

Based on the existing scientific literature it is apparent from the majority of research that heat and exercise induced acute dehydration result in a significant impairment of specific aspects of cognitive function. Evidence suggests the tasks that require attention, immediate memory, and psychomotor skills, as well as assessment of the subjective state, are the aspects of cognitive function most negatively affected by dehydration (Adan, 2012). Simple reaction times and long-term memory appear to be unaffected, suggesting more demanding tasks might be more susceptible to dehydration (Cian et al., 2001, Cian et al., 2000). Despite these findings, a lack of consistency in evidence published to date is apparent. Such inconsistencies are largely due to the different methodologies adopted, primarily relating to the assessment of cognitive performance, the method used to induce dehydration (the nature and duration of the stressor), and the characteristics of the participants (Adan, 2012, Grandjean and Grandjean, 2007, Lieberman, 2007, Lieberman, 2010, Secher and Ritz, 2012, Lieberman, 2012). Not only are precise levels of dehydration difficult to achieve, very often when attempting to generate consistent levels of dehydration in humans the stressors used to induce dehydration may lead to misinterpretations of the actual effect of dehydration (Lieberman, 2007, Lieberman, 2010, Grandjean and Grandjean, 2007, Lieberman, 2012). Grandjean and Grandjean (2007) indicated many other physical factors that may affect cognitive function, namely length of the dehydration phase, the time of day that the neuropsychological assessment is conducted, circadian rhythm, quantity and quality of sleep, macronutrient and micronutrient composition of the diet, individual difference and practice effect. As a result of the methodological limitations that appear in the current published studies, difficulties arise when attempting to derive robust conclusions. Further research will require carefully controlled research to facilitate a greater understanding of the effects of dehydration on cognitive performance, particularly in athletic populations.

Potential Mechanisms

Several mechanisms have been proposed to potentially explain cognitive changes that may occur as a result of dehydration. Primarily, the systemic reduction in the fluid levels within the body associated with dehydration may have a negative effect on cognitive function (Wilson and Morley, 2003b). Dehydration decreases blood volume and increases plasma osmolarity leading to a change in brain volume (Dickson et al., 2005). Dehydration causes changes to the composition of the brain structure and also the function with an associated increase in ventricular volume (Dickson et al., 2005, Kempton et al., 2011). Dickson et al., (2005) found a correlation between the degree of dehydration and the change in ventricular volume and as such the volume of fluid in the brain and its surrounding structures. Maughan et al., (2003) reported that some areas of the brain receive reduced blood flow due to the changes in the blood brain barrier permeability typically associated with dehydration. Wilson and Morley (2003) review how dehydration may have both intracellular and extracellular effects in addition to leading to intravascular volume depletion. Intracellular effects may result in increased cytokine concentration, altered pharmacokinetics and increased anti-cholinergic burden, whereas extracellular effects may involve electrolyte imbalances, uremia from acute renal failure and contraction alkalosis. Depletion of the intravascular volume leads to cerebral hypoperfusion, cardiac ischemia and thromboembolic disorders. All such occurrences as a result of moderate to severe dehydration can result in disruptions to cognitive function (Wilson and Morley, 2003b).

Variations in the concentration of electrolytes in the body can also occur as a consequence of dehydration. Such changes may cause alterations in brain activity and the functioning of some of the neurotransmitter systems involved in cognitive processing (Lieberman, 2007, Wilson and Morley, 2003b). A compensatory rise in Nitric Oxide Synthase (NOS) activity occurs during periods of dehydration, which may interfere with cognitive function by altering learning and memory processing (Wilson and Morley, 2003b). Cerebral Arginine Vasopressin (AVP) is enhanced as a result of the activation of the renin-angiotensin system also negatively affecting memory. An increase in serum cortisol occurs as a result of dehydration impairing active learning, short-term memory and verbal memory (Wilson and Morley, 2003b). Wilson and Morley (2003) proposed various theories of both hormonal and cellular mediated responses to dehydration and their effects on cognitive function, suggesting alterations in either profile may result in cognitive dysfunction.

ii. Energy Restriction

Several studies have investigated the effects of food deprivation on cognitive performance, all of which vary in terms of the extent of food deprivation investigated. Hypoglycaemia, a typical consequence of fasting, causes decrements in cognitive function (Warren and Frier, 2005). Glucose is a major energy source for both the maintenance of brain metabolism and function. Warren and Frier (2005) suggest in general, complex tasks are more sensitive to hypoglycaemia than simple tasks. Reference to numerous case reports have been made within this review in relation to repetitive severe hypoglycaemia being linked with brain damage and cognitive deterioration (Warren and Frier, 2005).

Studies have examined all extremes of food restriction from relatively short periods such as missing individual meals (i.e. fasting) (Pollitt et al., 1981), dieting to lose weight (Green et al., 1994), to the other extreme of severe starving found in those with clinical disorders such as anorexia nervosa (Green et al., 1996). Evidence suggests food restriction of varying degrees is associated with impairments in cognitive function however the body of research concerning the effects of brief periods of food deprivation is less consistent to that relating to more severe degrees of deprivation.

Pollitt et al., (1981) reported fasting had an adverse effect on the accuracy of responses during a problem solving task in a group of children, however conversely improvements in short-term memory recall were also observed. Green et al., (1995) additionally reported a lack of effect of short-term fasting on sustained attention, attentional focus, simple reaction time or immediate memory. Various levels of food deprivation were used within this study ranging from missing just a single meal to 24 hours without food (Green et al., 1995). Similarly, Green et al., (1997) confirmed acute hypoglycaemia as a result of short-term food deprivation caused no significant impairments on simple reaction time, sustained attention, memory recognition or free recall. Improved recognition memory processing times were associated with such deprivation. Mean blood glucose levels in this study were recorded as 4.86 $mmol \cdot L^{-1}$; a level typical of those associated with overnight fasting (Green et al., 1997). In a review, Warren and Frier (2005) concluded cognitive function is impaired as a result of hypoglycaemia, however available data indicates such impairments occur at a blood glucose level of 2.6-3.0 $mmol \cdot L^{-1}$ in healthy subjects. Such results would suggest short-term fasting has minimal effect on cognitive function.

In contrast to the literature on brief periods of fasting, the effects of long-term, more severe food restriction (typically seen in dieters and restrained eaters) on cognitive function appears to be more consistent. Various cognitive decrements have been reported (Green et al., 1994, Brunstrom et al., 2005). Individuals who were dieting to lose weight displayed problems with short-term memory recall, impaired vigilance performance and poor reaction times (Green et al., 1994). Similarly, Brunstrom et al., (2005) reported slower reaction times and problem solving processing in a high restrained eating group of 8 to 11 year olds than in the low restrained eaters. Green et al., (1994) suggested the impaired cognitive performance associated with long-term food restriction could be resulting from the stressful effects of imposing and maintaining dietary restraint. Furthermore, cognitive impairments have been demonstrated to be a common feature of those with clinical eating disorders. Anorexics have been found to display poorer recall and reaction times than control subjects (Green et al., 1996). Green et al., (1996) interpreted these cognitive impairments as being the result of starvation-induced structural brain alterations and so having a strong possible link to a working memory deficit.

Extensive research has been conducted by the military to examine the effects of weight loss and caloric restriction on cognitive performance, the results of which appear to be consistent. Mays (1995) summarised such military studies and surprisingly reports that memory, attention and choice reaction time improved in the first 3 to 15 days of moderate under-consumption (consumption levels of 75 - 90% of requirements). A steady decline in performance is then seen following greater reductions in body mass after this period of time. Mays (1995) concluded that when food intake falls below 50% of daily requirements, significant negative effects on cognitive performance become apparent. Combining food restriction with additional stressors, specifically exercise and sleep deprivation, exacerbates the cognitive impairments seen within these military studies (Mays, 1995). More recently, Lieberman et al., (2005) investigated the effects of acute stressors including sleep loss, heat, dehydration and under-nutrition on cognitive function in 31 male U.S Army officers. Exposure to such a combination of severe stressors resulted in large decrements in cognitive performance involving reaction time, vigilance, learning, memory and reasoning.

2.3.1.3 *Weight Cutting and Cognitive Function in Weight Category Athletes*

Limited studies exist that examine the effects of a rapid reduction in body mass on cognitive performance in jockeys. Despite a lack of information about the procedures and measures within the study, Labadarios et al., (1993) assessed the ability of a cohort of 56 jockeys in South Africa to correctly perform certain tasks having reduced body mass by up to 6 kg in order to 'make weight' for racing. Statistical data was not provided within this study, however a decline in performance was reported in tasks including memory, recall and reaction times on race days compared to baseline measures (Labadarios et al., 1993). The lack of information provided with regards the study design adopted limits the interpretation and applicability of the results.

More recently Dolan et al., (2013) simulated race day preparation to investigate the effects of a rapid reduction in body mass on cognitive performance. A preliminary questionnaire was administered randomly to a group of jockeys (n = 24) in order to determine the exact protocol (extent of body mass loss and time allowed) to be used. Results from this questionnaire reported typical riding mass to be 3.6 ± 2.4% (2.2 ± 1.4 kg) below non-riding mass and participants were typically provided with 24 - 72 hours notification of the required weight standard (34 ± 13 hours). Following this questionnaire, 9 jockeys completed baseline cognitive measurements in a hydrated state. Participants were assigned a weight allocation of 4% below their individual baseline body mass to simulate the typical riding mass lost and advised to use their typical weight loss practices in order to achieve the assigned reduced body mass before returning 48 hours later. No change in any cognitive parameters measured (simple and choice reaction time, decision making, executive function and working memory) were reported when participants returned in a dehydrated state with an average reduced body mass of 3.6 ± 0.9%. However closer evaluation of the data revealed the results to be highly individual and variable.

Unpublished data from the Victorian Institute of Sport in collaboration with Victoria University for Racing Victoria tested 7 male jockeys (aged 17-42 years) on race days (pre- and post-race) and non-race days in mild conditions (9-20°C) (Pruscino et al., 2007). A reduction of 2% of body mass was reported with no apparent cognitive impairments within the group. Simple reaction time was significantly greater pre-race compared to post-race and non-race days. Pruscino et al., (2007) concluded that the slower pre-race reaction time scores may be caused by extraneous variables such as reduced attention or concentration span or increased anxiety prior to racing. In two individual case studies within the study group in which the jockeys each lost in excess of 4% body mass compared to the non-race day, simple reaction time was significantly reduced (Pruscino et al., 2007). Similar to Dolan et al., (2013), this study suggests a high degree of individual variability in the data reported.

In other weight category sports, research has been conducted on wrestlers who as athletes have many similarities to jockeys through not only engaging in similar weight cycles but also employing similar methods to achieve weight loss. Choma et al., (1998) examined the effects of cutting weight on cognitive function in 14 collegiate wrestlers during the competitive season. Rapid weight loss of a minimum of 5% of body mass (mean = 6.2%) prior to competition appears to cause an impairment of short-term memory however after rehydration (72 hours later) all measures returned to near baseline values suggesting the negative cognitive effects associated with rapid weight loss are reversible. A second study of wrestlers, by Landers et al., (2001), examined the effects of rapid weight loss on cognition in high school wrestlers. The subjects in this study lost a mean of 6.3% of their total body mass and again attention, visual motor, short-term memory and choice reaction time were assessed. Unlike the study by Choma et al., (1998), no impairments in cognitive performance were reported. While performance in the tests for attention and visual motor deteriorated from baseline measures, statistical significance was not reached. In comparison, improvements were seen in the performance of these tests in the control group. The authors concluded that while statistically insignificant, cognitive impairment did occur (Landers et al., 2001).

Choma et al., (1998) suggest the timed effort required by the cognitive tests may have stimulated the wrestlers to overcome the negative influences of the rapid weight loss and the circumstances surrounding the upcoming competitive event, anxiety and distraction for example, may have influenced cognitive function. Cognitive function was assessed in the collegiate wrestlers post weigh in when they were typically accustomed to replenishing themselves with food and fluids (Choma et al., 1998), while in the high school wrestlers testing took place at a time just before weigh in when no food or fluids would be expected to be consumed (Landers et al., 2001). As Choma et al., (1998) initially suggested, wrestlers may have been distracted and did not perform to their potential in the cognitive tests. This could possibly explain the difference in significant findings between the two aforementioned studies on wrestlers.

2.3.2 Making Weight and Physical Performance

During racing, while the horse's centre of gravity, located just behind its shoulders, remains unchanged, this is not the case for the jockey. Every stride results in a change in the jockey's centre of gravity in relation to the horse. To ensure the horse remains balanced, it is imperative that a jockey can maintain their own balance. An unbalanced horse may lose speed and direction. With only a small part of the foot in contact with the stirrup, jockeys must have total body control while perched over the saddle, squeezing as hard as possible from the knees to the heels, executing limited movements with great muscular effort required to keep still. An unbalanced jockey with a lack of muscular strength and endurance may be thrown about in the saddle, hindering the horse and causing it to lose balance (Perkins, 1996).

2.3.2.1 Balance

Balance refers to the ability to maintain the body's centre of mass within the limits of stability as defined by the base of support (Woollacott, 2007). Based on overall body position and/or neuromuscular response to a destabilising event, balance may be categorised as static or dynamic. In static balance, the body's centre of mass moves as the base of support remains stationary. Static balance necessitates the ability to maintain the centre of mass within the base of support or the limit of stability. In contrast however, the centre of mass and the base of support are moving in dynamic balance and the centre of mass is never kept within the base of support (Woollacott and Tang, 1997). To maintain balance within an environment, a systems model has been suggested, requiring a combination of components to function. These include the nervous system, muscles, joints, reflexes, skeletal system, gravity and inertia, sensory input (vision, vestibular, and proprioception), central processing time, and learned strategies (Shumway-Cook and Woollacott, 1995) (see figure 2.6). The central nervous system is responsible for maintaining balance by continuously monitoring the sensory inputs arising from the visual, vestibular and somatosensory systems and organising an adequate motor response through regulating the automatic and voluntary adjustments in motor output (Yim-Chiplis and Talbot, 2000). Muscle strength, learned strategies from past experience, and the size and stability of the base of support are among the factors that determine the strategies used by an individual if balance is disrupted to shift the centre of gravity back to a stable position (Guskiewicz and Perrin, 1996).

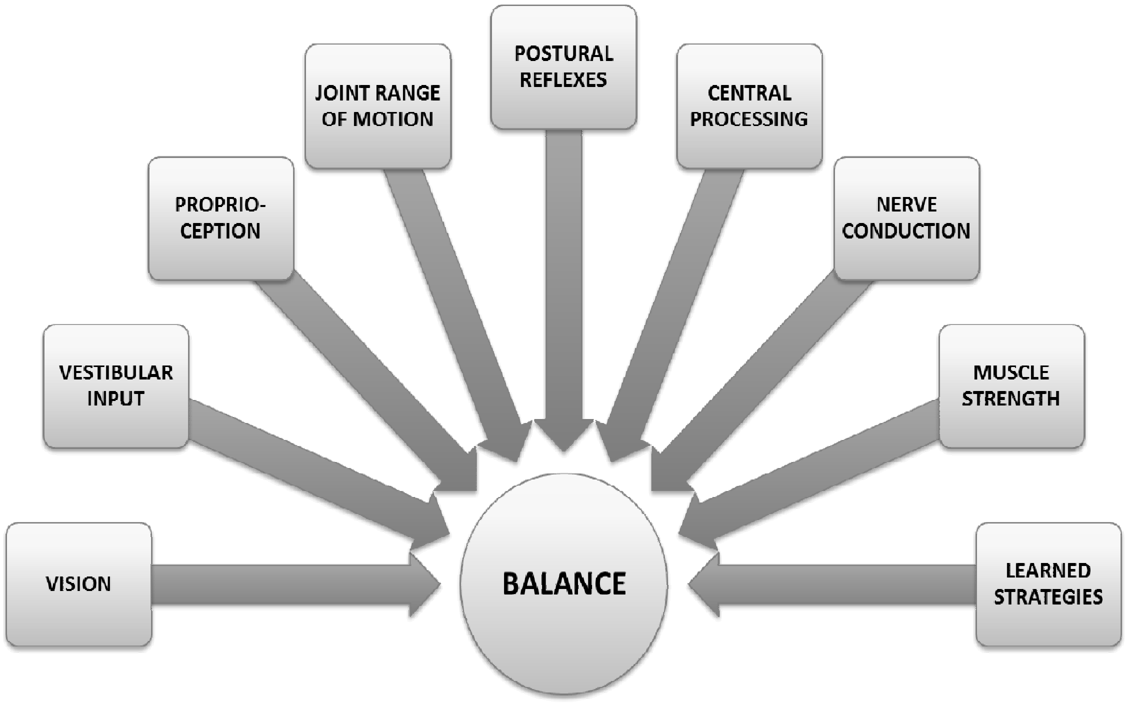


Figure 2.6: Systems model of balance control including the various components (Shumway-Cook and Woollacott, 1995)

2.3.2.2 Rapid Weight Loss and Balance

As previously indicated, sensory control involving the visual, vestibular and somatosensory systems in addition to the central neural control systems located in the spinal cord, brainstem, basal ganglia, cerebellum and cerebral cortex enable the use of muscular force to maintain the position of the body over its centre of support. Exercise and dehydration may lead to changes in one of these systems and result in impaired postural equilibrium (Cullen et al., 2013, Derave et al., 1998, Gauchard et al., 2002, McKinney et al., 2005). The current limited research investigating the effects of rapid weight loss on balance has focused primarily on weight reduction in terms of dehydration and the majority of findings remain equivocal (Table 2.2) (Derave et al., 1998, Eberman et al., 2005, Ely et al., 2013, McKinney et al., 2005, Patel et al., 2007, Gauchard et al., 2002, Cullen et al., 2013).

Table 2.2: Association between Balance and Rapid Weight Loss

Reference	Dehydration Intensity (% Body Mass Loss)	Experimental Stress	Change in Balance	Assessment Technique & Results
(Derave et al., 1998)	2.7%	Exercise and Fluid Restriction	Yes	*Postural Sway on Force Platform* Negative effect on postural stability
(Derave et al., 1998)	3%	Heat Exposure	No	*Postural Sway on Force Platform* No Change
(Gauchard et al., 2002)	Not reported	Exercise and Fluid Restriction	Yes	*Postural Sway on Force Platform* Increase in body sway after exercise especially when dehydrated
(Eberman et al., 2005)	3%	Exercise and Heat Exposure	No	*Biodex Balance System* No Change
(McKinney et al., 2005)	3%	Exercise and Heat Exposure	Yes	*BESS* Increase in total errors in balance test
(Patel et al., 2007)	2.5%	Exercise and Fluid Restriction	No	*BESS and Postural Sway on Force Platform* No Change
(Cullen et al., 2013)	4.2%	Heat Exposure and Water Restriction	Yes	*Y Balance Test* Reduced composite reach score achieved
(Ely et al., 2013)	4%	Exercise and Fluid Restriction	No	*Biodex Balance System* No Change

Two separate studies from the same laboratory examined the effects of active dehydration on dynamic balance in 10 healthy subjects (7 men and 3 women; age = 25.2 ± 4.7 years) and revealed conflicting results whilst using the same participants however a different assessment method of balance performance (Eberman et al., 2005, McKinney et al., 2005). In both studies, dehydration was induced by prolonged treadmill exercise (75 - 120 minutes) without fluid intake in a hot and humid environment (temperature 30°C; relative humidity 50%) until a mean body mass loss of 3% was achieved. The prolonged recovery period (44 ± 13.7 minutes) used in these studies was designed to allow the elimination of hyperthermia and fatigue as confounding factors. Core temperature was reported to have returned to baseline levels and such a recovery period was sufficient to decrease fatigue. A minimum of 20 minutes is suggested to allow balance to effectively recover after exertion (Susco et al., 2004). McKinney et al., (2005) found dehydration to adversely affect balance as measured by the Balance Error Scoring System (BESS), with a significant increase in errors reported in subjects that were dehydrated. Using a different method to assess balance, the Biodex Balance System, Eberman et al., (2005) demonstrated only a trend towards a reduction in balance in the dehydrated condition with no significant findings. The latter study suggests significant findings may have been limited by an insufficient sample size, sensitivity of the balance assessment method in addition to the severity of the dehydration level (Eberman et al., 2005).

Eliminating the potential confounding effects of exercise in the previous studies, Derave et al., (1998) assessed the effects of passive dehydration on static balance in 8 different young healthy males (aged 19-22 years). Having achieved a similar body mass loss of 3% following thermal dehydration through concurrent sauna exposure (temperature 85°C, relative humidity 50%), no significant effects on balance were reported. In contrast, passive dehydration equating to a greater reduction in body mass of 4% has been reported to negatively affect dynamic balance in 12 young healthy males (aged 18-23 years) (Cullen et al., 2013). A similar study design was used to Derave et al., (1998) with repeated sauna exposure (15 minutes sessions totalling ~90-120 minutes) to induce passive dehydration. Such sessions were interrupted with a cold shower and body mass and body temperature measurements. Dynamic balance as measured using the Y Balance Test was assessed 40 minutes after sauna exposure. Cullen et al., (2013) reported significant balance deficits indicated by a reduced composite reach score following sauna sessions for both the right ($p \leq 0.01$) and left ($p \leq 0.05$) leg.

At a similar dehydration level used in the study by Cullen et al., (2013), Ely et al., (2013) reported no alterations in dynamic balance by 4% dehydration achieved via exercise in the heat (3 hours at 50°C) without fluid ingestion. Dynamic balance, measured using a Biodex Balance System, was unaffected when assessed 90 minutes after dehydration was induced. A longer recovery period of 90 minutes was used to minimise the effect of the recent exercise which has previously been suggested to have influenced balance, resulting in confounding results through local muscle fatigue (Eberman et al., 2005). Eberman et al., (2005) believed the balance deficits reported in previous studies were influenced by fatigue and hyperthermia. Gauchard et al., (2002) reported impairments in balance immediately following exercise trials on a cycle ergometer for 45 minutes at an exercise intensity equivalent to 60% VO_2max with and without fluid ingestion. Fatigue induced through exercise was suggested to result in decrements in balance which were worse again in the dehydrated state (Gauchard et al., 2002).

Dehydration achieved through exercise in addition to fluid restriction has revealed contrasting results in the literature (Derave et al., 1998, Ely et al., 2013, Gauchard et al., 2002, Patel et al., 2007). Patel et al., (2007) reported the combination of both passive (fluid restriction) and active (exercise) dehydration revealed no significant impairment in balance despite 2 separate assessment methods being used: BESS and postural sway on force plates. The effects of dehydration on static and dynamic balance were investigated in 24 male recreational athletes (mean age 21.92 years) in which subjects were restricted from ingesting fluids from 15 hours prior to the trial and a 45 minute cycling task at 65-70% of maximum heart rate was performed achieving a mean negative body mass change of 2.5 ± 0.63% and a mean Usg of 1.025. A slight decrease in performance was however seen in the dehydrated condition in BESS leading the authors to suggest that a greater magnitude of dehydration might result in further deficits in balance. At a greater level of dehydration (2.7%), Derave et al., (1998) did report greater balance deficits (Derave et al., 1998). Derave et al., (1998) concluded that dehydrated participants were significantly more unstable than when tested in a euhydrated state. Eight male subjects performed a 2 hour cycle at a power output equivalent to 57 - 63% VO_2max on two separate occasions: once without any fluid and another time with a carbohydrate-electrolyte drink. Twenty minutes after the exercise, static balance was assessed using a Kistler force platform to measure postural sway while standing in normal position, feet side by side, and tandem position, feet heel to toe. Prolonged exercise without the ingestion of fluid resulting in a body mass loss of 2.7% appeared to have negative effects on static balance which may indicate negative implications for jockeys. Fluid intake was shown to affect postural stability after exercise, with subjects having increased stability in the fluid replacement trial when compared to the trial without fluid ingestion. In contrast to these findings, the previously discussed study by Ely et al., (2013) reported no significant impairments in dynamic balance despite a greater body mass loss of 4% apparent.

While there is a trend suggesting dehydration adversely affects balance, the current literature in the area is conflicting and therefore the effects of dehydration on balance remain disputed. The contrasting methodologies used within these studies involving the various methods used to induce dehydration, the dehydration level reached, recovery time allowed between the dehydration protocol and balance assessment and also the method used to evaluate balance may explain such contradictory findings.

Potential Mechanisms

Gauchard et al., (2002) proposed the theory that dehydration can result in body fatigue, reducing muscle efficiency and a subsequent reduction in the sensitivity of the muscle spindle, modifying the accuracy of proprioceptive information. As a result, the reduced proprioceptive sensitivity leads to a decrease in balance (Gauchard et al., 2002).

Lion et al., (2010) further suggest postural instability may be explained by dehydration-induced metabolic modifications of the vestibular fluid, since the vestibular level is the only level of postural control regulation in which liquid intervenes in the sensory transduction mechanisms. A change in endolymph volume and composition as a result of dehydration lowers the contribution of vestibular information on balance control (Lion et al., 2010).

A decrease in one or more component of the previously mentioned systems model of balance may lead to alterations of neurosensory postural organisation (Shumway-Cook and Woollacott, 1995).

2.3.2.3 Anaerobic Performance

An anaerobic activity refers to short duration single and/or repeated bouts of exercise primarily dependent on oxygen-independent metabolic pathways (Kraft et al., 2012). Two major energy sources are required for such activities including the adenosine triphosphate-phosphocreatine (ATP-PCr) system and anaerobic glycolysis. The ATP-PCr system lasts for 3 to 15 seconds during maximum effort while anaerobic glycolysis can then be sustained for the remainder of the all-out effort (Wilmore et al., 2008). High intensity anaerobic activities generally relate to maximal activities lasting less than 2 minutes however there is a noticeable aerobic contribution by this time (Judelson et al., 2007a). During such activities, peak power, anaerobic capacity and anaerobic endurance are generally assessed to measure the ability of the muscles to work using both the ATP-PCr and glycolytic energy systems (Zupan et al., 2009).

Many variations in assessment modes exist for anaerobic performance, all of which are dominated by anaerobic pathways but have inherent differences. Differences may exist in relation to the duration, active muscle volume, specific joint actions and skill requirements (Kraft et al., 2012). A 30 second or repeat 6 x 10 second maximal Wingate Anaerobic test (WAnT) on a cycle ergometer is commonly used for assessing anaerobic performance (Bar-Or, 1987, Fogelholm, 1994, Zupan et al., 2009). Kraft et al., (2012) provides an overview of the various tests for anaerobic performance including the body mass-dependent tests like the vertical jump, 50m/100m/200m/400m sprints and Margaria power tests (Kraft et al., 2012). Such body mass-dependent tests require the movement of one's own body mass which may lead to confounding results because of the innate changes in the force-to-mass relationship that occur in a dehydrated or energy restricted condition. It has been proposed that individuals should perform against consistent workloads in all testing trials and performance workloads should be based upon euhydrated subject characteristics (Judelson et al., 2007a).

2.3.2.4 Rapid Weight Loss and Anaerobic Performance

Rapid weight loss in many of the studies is discussed in terms of dehydration. Dehydration by as little as 2% of body mass has been shown to negatively affect aerobic performance (Sawka et al., 2007b, Cheuvront et al., 2003). However studies investigating the impact of dehydration on anaerobic performance have yielded equivocal findings reporting either no significant performance decrement (Cheuvront et al., 2006, Jacobs, 1980, Judelson et al., 2007b) or a significant impairment in performance (Cullen et al., 2013, Jones et al., 2008, Kraft et al., 2011, Yoshida et al., 2002). Yoshida et al., (2002) suggested that a critical level of water deficit leading to performance impairments does exist, a deficit which is greater for anaerobic performance (~-3.9%) compared to aerobic performance (~-2.4%). Table 2.3 includes a summary of the various studies.

Table 2.3: Association between Anaerobic Performance and Rapid Weight Loss

Reference	Dehydration Intensity (% Body Mass Loss)	Experimental Stress	Change in Performance	Assessment Technique & Results
(Jacobs, 1980)	2, 4 and 5%	Heat Exposure and Fluid Restriction	No	*30s WAnT*
(Webster et al., 1990)	4.9%	Exercise and Heat Exposure (previous night)	Yes	*40 s WAnT* Peak Power – decreased Anaerobic Capacity - decreased
(Yoshida et al., 2002)	0.7, 1.7, 2.5 and 3.9%	Exercise and Fluid Restriction	Yes	*10s Cycle Sprint* Anaerobic Capacity – decreased at 3.9%
(Cheuvront et al., 2006)	2.7%	Heat Exposure and Fluid Restriction	No	*15s WAnT*
(Jones et al., 2008)	3.1%	Exercise with Heat Exposure	Yes	*30s WAnT* Peak Power – decreased Anaerobic Capacity – decreased
(Kraft et al., 2011)	3%	Heat Exposure and Fluid Restriction	Yes	*6x15s Cycle Sprints (30s active recovery)* Anaerobic Capacity – decreased significantly
(Cullen et al., 2013)	4.2%	Heat Exposure and Fluid Restriction	Yes	*30s WAnT* Anaerobic Endurance - decreased

A combination of heat exposure and water restriction are commonly used to induce dehydration and rapid weight loss and subsequent impairments in anaerobic performance have been reported (Kraft et al., 2011, Cullen et al., 2013). Kraft et al., (2011) observed a significant reduction in mean power following water-bath heat exposure (39 °C, 120 mins) to 3% dehydration when compared to controls. Six cycle sprints, each lasting 15 seconds, were performed with 30 seconds of active recovery between each bout and decrements were apparent in sprint bout 5 and 6. Furthermore the difference in peak power during these bouts approached significance. Such results suggest a critical time duration may exist at which dehydration impairs anaerobic performance (Kraft et al., 2011). In a different study, participants (n = 12) completed intermittent sauna sessions (40 °C, ~123 mins) until a body mass loss of 4% (mean loss 4.2%) was achieved (Cullen et al., 2013). Fatigue index significantly increased during a 30 second WAnT and while decrements in peak power and mean power were apparent no statistical reduction was reported.

To further add to these findings, moderate dehydration indicated by a body mass reduction of 2.7% induced via passive heat exposure (45 °C, ~180 mins) has been demonstrated to have no effect on anaerobic performance (peak power and mean power) as assessed in active males (n = 8) during a single 15 second WAnT (Cheuvront et al., 2006). Similarly in a study by Jacobs et al., (1980), which employed a similar anaerobic performance assessment in the WAnT (30 seconds), no alterations in peak power or mean power were reported with moderate dehydration of various levels including body mass reductions of 2, 4 and 5% induced passively in a heat chamber (56 °C, ~120 mins) in 11 collegiate wrestlers tested. Thirty to 45 minutes of recovery from passive heat exposure was permitted in all the above passive dehydration through heat exposure tests before testing to minimise heat strain (Cheuvront et al., 2006, Cullen et al., 2013, Jacobs, 1980, Kraft et al., 2011). It is evident that varying protocols have been adopted in the above studies in terms of dehydration levels and testing modes with varying lengths leading to confounding results and making direct comparison problematical.

Exercise and heat exposure are commonly used as a means of reducing body mass within studies. Jones et al., (2008) suggest that active dehydration via treadmill exercise at 60% of age-predicted heart rate (45-90 minutes) in a hot, humid environment (33 °C) until 3% body mass loss (mean 3.1%) was reached has a negative effect on anaerobic muscular power, with decreases in the ability to generate upper and lower body anaerobic power reported. A 30 second Wingate test was performed 90 minutes after the heat stress trial and significant reductions were seen in lower body peak power (18.36%) and mean power (19.20%). No significant differences were reported for the fatigue index. Yoshida et al., (2002) analysed the dehydration level necessary to induce performance decrements in anaerobic exercise assessed during a 10 second maximal cycle sprint. Exercise in the form of a typical baseball practice session combined with fluid restriction was used to induce dehydration. Measurements were made 30 minutes after practice sessions to minimise the effects of high body temperatures and fatigue and exercise performance. No change was apparent in mean anaerobic power after dehydration by 2.5% of body mass, however significant reductions were reported in mean anaerobic power when body mass was reduced by 3.9%. Furthermore, Webster et al., (1990) reported a significant reduction in peak power (-21.5%) and mean power (-9.8%) during a 40 second WAnT following dehydration by 4.9% induced the previous evening via exercise in the heat.

The influence of caloric restriction alone on anaerobic performance is poorly documented. Caloric restriction has been reported to influence short duration (2-7 minutes) high intensity exercise (Maughan et al., 1997). Furthermore, after caloric restriction for 72 hours significant decreases in power output was reported during 8 x 15 second maximal arm ergometer sprints separated by 20 seconds of recovery (Rankin et al., 1996). In contrast, Kraft et al., (2012) suggest caloric restriction alone may be insufficient to influence shorter duration anaerobic performance. The influence of diet on power output has been assessed using the WAnT in two caloric restricted conditions revealing dietary composition is more important than actual caloric restriction (McMurray et al., 1991). Such results revealed that despite an overall negative calorie balance, consuming a high carbohydrate diet did not result in power output decrements. In contrast, performance was reduced when caloric restriction was combined with the consumption of a normal carbohydrate diet. From these results, it is difficult to quantify the extent to which caloric restriction affects performance given the influence that diet in addition to caloric restriction may have on anaerobic performance.

The influence of rapid body mass loss on anaerobic performance remains poorly understood due to the inconsistency in findings prevalent in previous studies. The vast differences seen within the various methodologies used provide difficulties when attempting to make comparisons between existing studies. Suggested differences may relate to variations in anaerobic performance measurement technique, the method of dehydration used (fluid restriction, sauna exposure, exercise induced and passive), the severity of dehydration, or other confounding variables (heat exposure, caloric restriction, training status and muscle group being tested) (Judelson et al., 2007a, Kraft et al., 2012). While many studies were often uncontrolled and caloric restriction was included as well as dehydration, results have generally been discussed in relation to dehydration. Despite these limitations, it is believed studies inducing dehydration at greater levels (3 - 5%) or those assessing anaerobic performance for bouts longer in duration (>30 seconds) generally show significant impairments in performance (Kraft et al., 2012).

Potential Mechanisms

Although several physiological mechanisms have been proposed to explain potential dehydration-induced performance impairments during prolonged endurance events (Cheuvront et al., 2003, Fogelholm, 1994), possible physiological causes which might explain the potential changes that occur in anaerobic performance remain less well explained. While such mechanisms remain unclear, some suggestions have been proposed (Judelson et al., 2007a).

Altered cardiovascular function may explain some of the many deleterious effects dehydration has on anaerobic performance. During strenuous exercise, dehydration has been shown to result in cardiac output reductions (Gonzalez-Alonso et al., 2008). Dehydration equivalent to a body mass reduction of 3.9% has been shown to result in elevated muscle lactate and carbohydrate oxidation in addition to a reduction in the blood flow to the active skeletal muscles during exercise (Gonzalez-Alonso et al., 1999). It has been suggested that reduced cardiovascular function cannot account for decrements in strength and power due to such activities primarily relying on stored intramuscular adenosine triphosphate (ATP) and creatine phosphate (CP) for energy (Judelson et al., 2007a). However, Fogelholm (1994) suggested cardiovascular changes might be more prevalent in explaining the reductions apparent in high intensity endurance performance. Reductions in blood flow leading to inadequate oxygen delivery and metabolic by-product removal from active muscles might have negative implications for longer anaerobic work (Yoshida et al., 2002).

The potential changes in carbohydrate metabolism post dehydration are commonly investigated and it is generally reported that no changes are apparent in intramuscular stores of ATP and CP (Montain et al., 1998) or circulating blood glucose concentrations (Bosco et al., 1974). It is believed however that the enhanced sympathetic nervous system (SNS) resulting from dehydration promotes muscle glycogen utilisation and prolonged dehydration procedures may lead to glycogen depletion consequently affecting anaerobic performance (Yoshida et al., 2002).

Reduced buffering capacity has been suggested to result from dehydration and so negatively influencing performance (Fogelholm, 1994). Rapid fluid and glycogen loss may affect the buffer systems of the blood and optimal cellular functioning requires maintenance of appropriate internal pH (Fogelholm, 1994). However Judelson et al., (2007) report that it is unlikely the acid-base balance represents a potential mechanism (Judelson et al., 2007a) given the evidence demonstrating that no changes exist in internal pH following dehydration (Montain et al., 1998).

A number of studies have suggested some element of the neuromuscular system is affected as a result of dehydration (Fogelholm, 1994, Judelson et al., 2007a, Yoshida et al., 2002, Jones et al., 2008). Whilst the precise mechanism remains unclear, Yoshida et al., (2002) has speculated that anaerobic power is impaired due to decreases in muscle contractibility. An altered electrolyte concentration (i.e. loss of potassium) typically accompanying a reduction in muscle water content as a result of dehydration generally leads to a disruption in the cell membrane electrochemical potential and inhibits the binding of calcium to troponin subsequently interfering with cross-bridge formation. This decreased muscle contractibility inevitably impairs anaerobic performance (Yoshida et al., 2002, Jones et al., 2008).

2.4 Effects of Making Weight on Health

Chronic energy restriction and dehydration practices, either through fluid restriction and/or fluid loss, are regularly reported as the common methods of managing and achieving the desired low body mass amongst jockeys (Dolan et al., 2011, Labadarios et al., 1993, Leydon and Wall, 2002, Moore et al., 2002). Such practices may have serious implications in terms of the health status of the individual jockeys. Several studies have revealed poor bone health amongst jockeys (Dolan et al., 2012a, Dolan et al., 2012b, Greene et al., 2013, Leydon and Wall, 2002, Waldron-Lynch et al., 2010, Warrington et al., 2009). Additionally research suggests metabolism and the renal function might also be affected by the lifestyle demands of a jockey (Steen et al., 1988, Zambraski, 1990). The following section further investigates how bone health, metabolism and kidney function might be adversely affected by utilising such weight making strategies.

2.4.1 Bone Health

Bone is a strong and resilient connective tissue which serves various structural and metabolic functions. Throughout life, bone has the ability to adapt its shape and size in response to mechanical loads (Brandi, 2009). During growth and development, modelling is the predominant process which is achieved by the independent occurrence of bone resorption on the endosteal surface of the bone and bone formation of new bone on the periosteal surface. Bone remodelling requires bone resorption and bone formation to occur in a coupled sequence at the same site and is the process by which bone is renewed to maintain bone strength and integrity and also mineral homeostasis (Clarke, 2008).

Osteoporosis has been defined as “a progressive systemic skeletal disease characterized by low bone mass and micro architectural deterioration of bone tissue, with consequent increase in bone fragility and susceptibility of fracture” (Anonymous, 1993). Osteopaenia is a precursor to osteoporosis. The World Health Organisation (WHO) (1994) proposed a diagnostic classification for BMD based on a T score, recognising three categories: normal (T score: -1 or higher), osteopenia (T score: -1 to -2.5) and osteoporosis (T score: -2.5 or lower). An imbalance between bone resorption and bone formation results in a loss of BMD which leads to the development of structural abnormalities that make the skeleton more fragile. Such a condition is highly prevalent amongst jockeys (Dolan et al., 2012a, Greene et al., 2013, Leydon and Wall, 2002, Warrington et al., 2009).

Many studies have reported low BMD and a high incidence of whole body, hip and lumbar spine osteopenia in professional jockeys (Dolan et al., 2012a, Leydon and Wall, 2002, Warrington et al., 2009). Warrington et al., (2009) reported 59% of flat and 40% of national hunt jockeys in Ireland showed osteopenia in one or more of the total body, hip or spine scans. Similar results were also observed in a group of New Zealand jockeys where 44% of jockeys assessed were classified as osteopenic (Leydon and Wall, 2002). Irish jockeys have also been reported to have a markedly lower BMD than would be expected for their age in addition to displaying lower bone mass than boxers at a number of sites (Dolan et al., 2012a). Unlike the previous studies which have typically used DEXA for the assessment of bone health, Greene et al., (2013) used the method of peripheral quantitative computed tomography (pQCT) and also displayed compromised musculoskeletal health in apprentice jockeys, specifically at the distal tibia and radius. Assessment of bone health using DEXA may have its limitations due to the two dimensional nature of imaging, and in comparison pQCT provides many advantages in terms of evaluating bone size, bone geometry and bone strength given its three-dimensional imaging nature. Specifically, pQCT evaluates volumetric BMD, provides transversal geometric bone characteristics and distinguishes between cortical and trabecular bone (Dowthwaite et al., 2009). Strength strain index (SSI) was specifically developed for the use of pQCT analysis and represents a surrogate marker of bone strength through the combination of a geometrical parameter of bone strength (section modulus) and a measure reflecting the properties of cortical bone (cortical volumetric BMD) (Rauch and Schonau, 2008). SSI essentially provides an estimate of the capacity of bone to resist bending forces. Using pQCT for the assessment of bone health provided Greene et al., (2013) with the ability to further profile the musculoskeletal health of jockeys and in doing so detail the site specific architectural changes apparent in the 25 apprentice jockeys (11 males and 14 females; age 20.1 ± 4.9 years) assessed. Compared with control participants, apprentice jockeys displayed bone health at risk at the distal tibia (less tibial cortical area and lower SSI at the distal, mid and proximal sites) and radius (lower SSI at the distal radius). In contrast, trabecular density at the distal radius and SSI at the proximal radius were greater in apprentice jockeys than controls (Greene et al., 2013).

Increased bone turnover is also prevalent in a substantial proportion of Irish jockeys compared to young healthy individuals (Dolan et al., 2012b, Waldron-Lynch et al., 2010). Waldron-Lynch et al., (2010) reported jockeys had high bone formation markers, high bone resorption markers and high bone turnover indices compared to healthy young men. In another study on Irish jockeys, bone resorptive activity was elevated resulting in a significantly negative uncoupling index between bone resorption and formation indicating an elevated loss of bone that appears to be associated with reduced bone mass (Dolan et al., 2012b).

Increased bone fragility has been reported to result from a decrease in BMD, thereby increasing fracture risk from an impact that might otherwise have left them unharmed (Brown and Josse, 2002). Recent research in a group of Irish jockeys presented mean incidence of reported racing-related fractures for flat and national hunt jockeys as 2.3 ± 2.9 and 4.5 ± 3.5 respectively (Warrington et al., 2009). Moreover, 78% of the participants had experienced a racing-related fracture at the time of the study. The authors concluded that the reported low BMD and high bone turnover prevalent amongst jockeys sampled was of growing concern and may have serious implications for the jockeys, especially in the context of the high risk nature of this sport and the frequent occurrence of falls (Warrington et al., 2009, Rueda et al., 2010, Hitchens et al., 2009a).

2.4.1.1 Risk Factors Affecting Bone Health in Jockeys

While genetics may predominantly determine baseline bone strength (~80%) (Matkovic and Ilich, 1993), it has been suggested that the exercise, nutritional and other lifestyle habits of jockeys may not be conducive to the development of optimal bone health (Warrington et al., 2009). Evidence has highlighted that childhood and adolescent years provide a 'window of opportunity' to maximise bone mass and strength (Greene and Naughton, 2006). Aspiring jockeys strive to attain an extremely low body mass at this imperative stage in their maturation to attract more rides and establish a reputation. Such jockeys are still experiencing growth and may be engaging in activities that prevent the achievement of optimal peak bone mass (PBM) since PMB has been reported to occur by the end of the second or early in the third decade of life (Baxter-Jones et al., 2011). Any factors that negatively influence the development of optimal PBM or promote loss of bone may increase the risk of developing a fracture in the future (Cashman, 2007). Increasing bone mass and strength during growth is the primary strategy for the prevention of osteoporosis (Bonjour et al., 2009). Hernandez et al., (2003) predicted a 10% increase in peak bone mass (PBM) would delay the onset of osteoporosis by 13 years. Greene et al., (2013) postulate the weight restricted nature of horse racing and the constant reliance on severe weight making strategies may adversely affect bone formation during growth, restricting the achievement of PBM and potentially producing deleterious musculoskeletal effects in later life. Despite apprentice jockeys being afforded the 'window of opportunity' to enhance musculoskeletal health, the emphasis on weight restriction at this early stage in life potentially presents an immediate and longer-term health risk for jockeys. This area warrants further investigation.

1. **Chronic Energy Restriction**

i. Low Energy Availability

Low energy availability appears to be the predominant factor impairing reproductive and skeletal health (Nattiv et al., 2007, Barrack et al., 2013, Ihle and Loucks, 2004). A deficiency in energy is associated with bone loss involving supressed bone formation and increased bone resorption (Souza et al., 2008). Low energy availability may result in a disturbed endocrine response, altering the actions of various energy regulating hormones (e.g. insulin, cortisol, growth hormone, IGF-1, T_3 and leptin) known to affect bone health (Haspolat et al., 2007, Misra et al., 2003, Souza et al., 2008, Nattiv et al., 2007). When prolonged activity is coupled with inadequate energy intake, endocrine changes appear to attenuate osteoblastic function and accelerate osteoclastic activity (Warren et al., 2002). Such disturbances may prevent the achievement of individual genetic potential for PBM amongst individuals (Ihle and Loucks, 2004).

The requirement to 'make weight' numerous times throughout the course of the extended racing season provide limited respite from the continuous need to maintain body mass within strict limits (Warrington et al., 2009). The pressures of the jockey lifestyle and rigid weight limits uniquely encourage unhealthy weight management practices including chronic energy restriction resulting in low energy availability (Dolan et al., 2011). Dolan et al., (2011) recently suggested jockeys may habitually operate with energy availability below the requirements to maintain usual metabolic function (30 $kcal \cdot kg\ FFM^{-1} \cdot day^{-1}$). Mean race day energy availability was reported as 0.8 ± 12 $kcal \cdot kg\ FFM^{-1} \cdot day^{-1}$ (Dolan et al., 2011). Below this recommended threshold for energy availability, it has been reported that bone turnover may be disrupted in favour of resorption, an effect which appears to occur in a dose-response fashion and if continued may cause irreversible reductions in BMD (Ihle and Loucks, 2004).

Dolan et al., (2012b) proposed that some jockeys may be susceptible to aspects of the Female Athlete Triad. Although typically associated with female athletes, results from previous studies in jockeys reveal a high incidence of low energy availability (Dolan et al., 2011) along with alterations in gonadal and reproductive hormone function and low bone mass (Dolan et al., 2012b) all of which are indicative of the Female Athlete Triad. Energy deficiency and low energy availability has been suggested as a possible contributor to the reported low BMD and high bone turnover in jockeys (Dolan et al., 2012b, Waldron-Lynch et al., 2010).

ii. Micronutrient Deficiencies

Calcium intake is a key modifiable environmental factor for normal skeletal development during growth and the maintenance of bone mass in later life (Zhu and Prince, 2012). Good sources of calcium include milk and dairy products as well as bony fish, legumes and certain nuts (Zhu and Prince, 2012). Playing a key role in skeletal mineralisation, calcium serves two main purposes in bone namely providing skeletal strength and also providing a dynamic store to maintain the intracellular and extracellular calcium pools (Peacock, 2010). In times of calcium imbalance, PTH is released to restore circulating calcium homeostasis primarily through an increase in osteoclast activity and the liberation of calcium from bone (Peacock, 2010). Inadequate calcium has been reported to negatively impact bone health (Bass et al., 2005). High calcium intakes however have been established to augment bone gain during growth, retard age-related bone loss and reduce osteoporotic fracture risk (Zhu and Prince, 2012).

Vitamin D is primarily sourced from exposure of the skin to direct sunlight (Holick, 2006) and plays an integral role in maintaining calcium homeostasis by acting on the intestinal cells to increase the absorption of dietary calcium and also on bone cells ability to mobilise the calcium stores when serum levels appear to be low (Heaney, 2007). A deficiency in vitamin D subsequently results in an inadequate absorption of dietary calcium required to sustain serum calcium levels. PTH secretion occurs to not only stimulate the kidneys to produce 25 hydroxyvitamin D (25(OH) D), the circulating form of Vitamin D necessary to enhance additional intestinal calcium absorption, but also increases osteoclastic activity with the consequential release of calcium into the circulation. As a result, vitamin D deficiency results in decreased BMD, higher bone turnover rate and is one of the predominant precipitating causes for both osteopaenia and osteoporosis (Holick, 2006, Lips and Van Schoor, 2011). Both calcium and vitamin D, particularly together, reduce excessive bone modelling by reducing the secretion of PTH (Heaney, 2007).

An insufficient intake of calcium is regularly reported amongst jockeys (Dolan et al., 2011, Leydon and Wall, 2002, Wilson et al., 2013a, Waldron-Lynch et al., 2010, Greene et al., 2013). Chronic calcium deficiency appears to result in the maintenance of circulating calcium concentration at the expense of bone mass (Greene et al., 2013). Waldron-Lynch et al., (2010) further suggest the reported high bone turnover in jockeys is a result of the low intake in calcium (541 ± 106 mg) combined with energy deficiency. Similar to calcium, inadequate vitamin D levels have been reported in jockeys (Dolan et al., 2011, Wilson et al., 2013a). Dolan et al., (2011) suggested the low 25(OH) D level of 43.9 ± 15.5 $nmol \cdot L^{-1}$ was unlikely to be a contributory factor to the reported differences in bone mass within the study. 25(OH) D was not shown to be significantly different to the control group, nor was it a predictor of any bone mass variable following subsequent analysis. An insufficient intake of calcium and vitamin D during growth could potentially compromise PBM and therefore predispose jockeys to an increased risk of osteoporotic fracture in later life.

Excessive sweating, a method typically used by jockeys to reduce body mass, results in the loss of calcium from the human body (Shirreffs and Maughan, 1997). When absorbed calcium from dietary intake is insufficient to offset the calcium lost during sweating, bone will release its calcium, reducing BMD. While sufficient calcium is thus required to offset the corresponding outputs, vitamin D is also important for the efficient absorption of calcium from the diet (Heaney, 2007). Inadequate calcium and vitamin D intakes may have further complications for jockeys in light of the severe and potentially dangerous weight making strategies.

2. Hormonal status

During times of low energy availability, several studies have shown the disruption of hormonal systems involved in growth and reproduction primarily due to the conservation of energy for more immediate and essential processes (DeSouza and Williams, 2005, Haspolat et al., 2007, Loucks and Thuma, 2003, Misra et al., 2003). Alterations in sex hormones and growth hormones may have many effects on bone metabolism (Bonjour et al., 2009, Souza et al., 2008, Misra et al., 2003).

Dolan et al., (2012) suggest the elevated rate of bone loss and reduced bone mass in professional jockeys is associated with disrupted hormonal activity that possibly occurred in response to the chronic weight cycling habitually experienced by jockeys (Dolan et al., 2012b). Jockeys exhibited an altered hormonal profile when compared to age, gender and BMI matched controls. Compared with controls, sex hormone binding globulin (SHBG) levels were significantly higher in jockeys (41.21 ± 9.77 vs. 28.24 ± 9.98 $nmol \cdot L^{-1}$; $p \leq 0.01$) and a lower percentage of bioavailable testosterone (48.89 ± 7.38 vs. 59.18 ± 6.74 $nmol \cdot L^{-1}$; $p \leq 0.01$) was present. Elevated SHBG has previously been correlated with increased bone remodelling markers, low bone mass and an increased risk of fracture (Legrand et al., 2001, Lormeau et al., 2004). Additionally a trend toward lower IGF-1 was also identified in the jockey group ($p = 0.07$). IGF-1, a pleiotropic growth hormone, is commonly reported to be involved in bone regulation (Nindl et al., 2008), involved in the complex coupling process of bone remodelling (Ueland, 2004). SHBG and IGF-1 appeared to be the primary endocrine determinants of bone mass in the cohort of Irish jockeys. Such abnormalities appeared to be associated with an increased rate of bone turnover and lower bone mass in jockeys (Dolan et al., 2012b).

3. Physical Activity

Physical activity and its associated mechanical loading are widely accepted as a major determinant of BMD (Tenforde and Fredericson, 2011, Greene and Naughton, 2006). Despite remaining unclear which force actually dominates the response of bone to its mechanical environment (Kohrt et al., 2009), both muscular (Robling, 2009) and gravitational forces (Judex and Carlson, 2009) are acknowledged as the primary sources of mechanical loading on bone. The "mechanostat" theory proposed that the skeletal system will adjust and adapt in accordance with its physical environment. Bone strain from mechanical loading is sensed by the osteocyte cells which initiate remodelling to modify bone structure accordingly (Bass et al., 2005).

Weight bearing activities are commonly reported to react more favourably with BMD, creating a greater osteogenic stimulus (Greene et al., 2012, Greene et al., 2005, Morel et al., 2001). Morel et al., (2001) suggested that variations in BMD among different sporting events are site specific and related to the strain and loading placed on the bone during participation in that particular activity. Such physical activity appears to also have long-term beneficial skeletal effects (Andreoli et al., 2012).

To optimise bone health, exercise including mechanical loading strains of a high rate and magnitude, distributed in a varied and unusual manner have been recommended (Bailley and Brooke-Wavell, 2008). Bone adaptation typically occurs in response to changes in mechanical stressors which must be above or below precise threshold levels to illicit an adaptive response (Frost, 1987). Site specific habitual loading of bone increases this threshold such that subsequent stimuli must exceed this threshold for remodelling to occur. In horse riding, jockeys must maintain a strong hold on the reins to adequately control the speed and direction of their mount. It has been speculated that the muscular forces experienced by jockeys during riding may have positively influenced bone strength at the forearm of jockeys (Greene et al., 2013). However, it is highly likely the physiological loading threshold necessary to illicit an adaptive response at the distal tibia is increased in jockeys given the habitual loading gained from daily ambulation and physical activity (Greene et al., 2013). As the "mechanostat" theory states, the skeletal system will adjust and adapt in accordance with its physical environment, so enabling it to cope with the typical voluntary muscle loads placed on it (Bass et al., 2005). Greene et al., (2013) hypothesized that the compromised bone health reported in apprentice jockeys at the distal tibia may be due to insufficient loading at the distal tibia to elicit positive site specific bone responses. The loading nature of horse riding remains largely unknown, however it has also been suggested elsewhere that horse riding may not provide a significant osteogenic stimulus (Alfredson et al., 1998, Cullen et al., 2009). Similarities to cycling have previously been elucidated to in work conducted by our research group (Cullen et al., 2009). In a study on cyclists, it was reported that the non-weight bearing nature of the activity coupled with the reasonably fixed body position adopted provokes a repetitive muscular strain pattern of moderately low magnitude and regular or even distribution (Nichols et al., 2003). Nichols et al., (2003) proposed a rather poor osteogenic stimulus was provided by cycling as a result of both biomechanics of the sport as well as its lack of impact. Furthermore, the conflicting evidence regarding the additional exercise jockeys partake in, away from the horse, leaves a doubt as to whether sufficient impact loading is attained elsewhere (Dolan et al., 2011, Labadarios et al., 1993, Leydon and Wall, 2002).

Participation in high impact sports has also been suggested to convey a protective effect on bone mass, potentially overcoming the negative osteogenic effects associated with weight cycling (Prouteau et al., 2006). Prouteau et al., (2006) demonstrated a bone resorptive state in a group of elite judoists who were actively reducing body mass for competition. Between competitions when weight regain was coupled with the high impact nature of judo, the protective effect of the high impact activity appeared to be demonstrated given the overall osteogenic balance favouring bone formation and a high bone mass in comparison to controls. With limited information available on the loading nature associated with horse racing (Cullen et al., 2009), the protective effect of high impact activity appears not to be afforded to jockeys (Dolan et al., 2012a). Dolan et al., (2013) reported a low bone mass in both jockey groups (flat and national hunt) and high bone mass in the boxer group when compared to an age, gender and BMI matched control group. While the degree of high intensity mechanical loading associated with boxing may have accounted for these findings, it was suggested the repeated exposure to low levels of energy availability and the chronic nature of weight cycling associated with jockeys may have actually affected the development of lean and bone mass in the jockey groups.

4. Smoking

Smoking has been reported to have a negative impact on BMD and is associated with an increased risk of fracture (Yoon et al., 2012). Wong et al., (2007) reported how each decade of smoking is associated with a 0.015 $g \cdot cm^{-2}$ reduction in BMD and fracture risk is increased by 10 - 30%. A population-based cohort study with over 40 years of prospectively collected data on smoking revealed a consistently lower BMD (4 - 15.3%) amongst male smoker's at all skeletal sites regardless of when in their life they smoked (Kiel et al., 1996). However the effect of smoking during early adulthood on BMD was of a lesser magnitude (4 - 8% lower) (Kiel et al.,

1996) and it has been suggested the deleterious effects of smoking on bone health may potentially be reversible (Wong et al., 2007, Yoon et al., 2012).

The possible mechanisms by which smoking affects bone mass remain poorly understood. Yoon et al., (2012) proposed many potential mechanisms including alterations in calciotropic hormone metabolism and intestinal calcium absorption, dysregulations in the production and metabolism of sex hormones in addition to alterations in adrenal hormone metabolism. Typically a reduction in bone formation and augmentation in bone resorption appear to be the primary consequence of smoking (Yoon et al., 2012).

Dolan et al., (2011) reported 57% of jockeys in Ireland were past or current smokers, a figure that is higher than the general Irish population (48%). Almost a quarter (24%) of these jockeys and a substantial proportion of the current smokers (56%) employed smoking as a method of weight control (Dolan et al., 2011). Such information is in accordance with the previous high incidence of smoking reported amongst jockeys in South Africa and New Zealand. Labadarios et al., (1993) reported that 75% of the jockeys smoked and 58% of these did so specifically as a means to aid weight control. Leydon and Wall (2002) reported 50% of the jockeys smoked, of which 50% smoked in order to manage weight. Interestingly, it was also noted that of the jockeys tested by Leydon and Wall (2002) who were osteopenic, 38% smoked. This high incidence of smoking may be a potential risk factor affecting bone health in jockeys.

5. Alcohol

The effects of alcohol consumption on bone are predominantly linked to the amount consumed. The unavailability of exact universal definitions for low, moderate and severe drinking levels cause difficulties when interpreting data (Venkat et al., 2009). While a low to moderate intake of alcohol may actually increase BMD (Tucker et al., 2009, Venkat et al., 2009), heavy alcohol consumption is reported to have many negative effects (Turner, 2000). Tucker et al., (2009) reported an intake of two glasses of alcohol per day increased BMD in men while more than 2 glasses of liquor was associated with lower hip and spine BMD in men. Maurel et al., (2012) further report various microarchitectural changes that occur as a result of high intakes of alcohol including decreased cortical thickness, decreased trabecular thickness and volume. Binge drinking, a common occurrence today, is also believed to negatively affect bone health (Maurel et al., 2012).

Lower overall bone remodelling may explain the increased BMD observed following low alcohol consumption (one glass per day). Decreased resorption with no apparent change in bone formation has been suggested to contribute to the positive osteogenic effects seen with low intakes of alcohol (Maurel et al., 2012). Maurel et al. (2012) also report the decrease in bone mass and strength following heavy alcohol consumption is primarily due to an imbalance in bone remodelling, with a predominant decrease in bone formation. The proposed reduction in bone formation is primarily due to an inhibition of osteoblastic proliferation and activity (Turner, 2000). The impaired microarchitecture and BMD associated with binge drinking is also suggested to be the result of alterations in bone remodelling (increased resorption and decreased formation) (Maurel et al., 2012). The reoccurring impaired bone formation and occasional enhanced bone resorption that results from the ingestion of alcohol is thought to result via various mechanisms directly involving changes in the number and activity of the osteoblasts and osteoclasts as well as an increase in osteocyte apoptosis and indirectly including reductions in fat mass and lean mass, leptin levels, IGF-1 concentration and the associated effect on GH, cell differentiation ability, Vitamin D and PTH, testosterone levels, ion concentrations in addition to increased calcitonin levels (Maurel et al., 2012).

High alcohol consumption has been reported amongst jockeys. Energy from alcohol was considered high relative to the low energy intake reported amongst jockeys (Dolan et al., 2011, Leydon and Wall, 2002). Dolan et al., (2011) and Leydon and Wall (2002) reported alcohol intake to represent 5% and 6%, respectively, of the total energy intake. Dolan et al., (2011) further reported 6% of the jockeys exceeded the current recommended weekly intake of 210 g of alcohol while Leydon and Wall (2002) reported 25% consumed excessive alcohol. Furthermore, 3 (75%) of the 4 jockeys who drank alcohol greater than the current recommendations and additionally had a bone scan were classified as osteopenic (Leydon and Wall, 2002). The high alcohol consumption relative to total energy intake is likely a key contributor to the poor bone health prevalent in jockeys.

2.4.2 Resting Metabolic Rate

Body mass changes are dependent on energy balance such that weight gain occurs when energy intake exceeds energy expenditure and weight loss occurs when energy expenditure exceeds energy intake. Energy can be expended through resting metabolic rate (RMR), the thermic effect of food and physical activity. RMR is the energy expended to maintain vital body functions (Volp et al., 2011) and is the predominant component of daily energy expenditure, accountable for approximately 60-75% of the total daily energy expenditure (Gravante et al., 2001).

2.4.2.1 Risk Factors Affecting RMR in Jockeys

Resting metabolic rate may be affected by many individual factors including genetics, ethnicity, body size, fat free mass (FFM), fat mass (FM), age, gender, smoking habits, physical activity, diet and hormones (Volp et al., 2011, Johnstone et al., 2005, Arciero et al., 1993). FFM is commonly reported as the most significant contributor to variations in RMR (Johnstone et al., 2005). The precise effects of repetitive rapid weight loss remain inconclusive.

Extensive debate has occurred over the effects of caloric restriction on RMR due to the associated changes occurring in body mass and body composition. Speakman and Mitchell (2011) reviewed the many studies debating that when adjustments for body mass are made no difference in RMR was apparent between calorie restrictive and ad libitum animals and also that a reduction in RMR exists even after adjustment for body mass differences. While Speakman and Mitchell (2011) were unable to draw any specific conclusions, it is generally believed that RMR exhibits metabolic adaptations following caloric restriction. Martin et al., (2007) indicated RMR was 91 $kcal \cdot day^{-1}$ less in a group of dieters following 6 months on a 25% calorie restriction than that observed in control participants even after differences in FFM were taken into consideration. Elliot et al., (1989) reported metabolic adaptations of RMR after a protein-sparing modified fast of approximately 300 $kcal \cdot day^{-1}$ in obese females. RMR remained depressed for 2 months after the weight reduction despite caloric consumption being increased to a level that allowed weight stabilisation. Weyer et al., (2000) reported after 2 years on an energy restricted diet, RMR was significantly lower than predicted for age, sex and body composition and RMR further remained lower than predicted after weight recovery although body composition was no longer significantly different from that of the control subjects.

Conflicting evidence exists relating to the effects of weight cycling on RMR. Melby et al., (1990) determined the effect of multiple cycles of weight loss and regain on RMR in a group of weight cycling wrestlers (n = 12) with a minimum of 3 previous seasons of weight cycling compared with physically active, non-cycling control subjects (n = 13). RMR was measured before, during and after a 6 month wrestling season. A significantly higher ($p \leq 0.05$) baseline RMR was initially exhibited in wrestlers compared with the control subjects (1973.8 ± 64.4 $kcal \cdot day^{-1}$ and 1776.0 ± 59.8 $kcal \cdot day^{-1}$ respectively). RMR was reduced ($p \leq 0.05$) during the season when wrestlers had lost weight for competition however the RMR was not significantly lower than that of the control subjects who maintained weight (1644.8 ± 62.7 $kcal \cdot day^{-1}$ and 1768.9 ± 69.2 $kcal \cdot day^{-1}$ respectively). RMR then returned to preseason values at the end of the weight cycling season following the final weight regain and was actually higher than that of the non-cycling controls (2030.7 ± 90.6 $kcal \cdot day^{-1}$ and 1762.6 ± 42.4 $kcal \cdot day^{-1}$ respectively). McCargar et al., (1992) reported no differences in metabolism between a group of wrestlers classified as weight cyclers and non-cyclers at any of the 3 time points assessed throughout a wrestling season. Contrary to these findings, Steen et al., (1988) reported a 14% difference in RMR between 27 adolescent wrestlers classed as either cyclers or non-cyclers, showing that weight cycling in wrestlers appeared to be related to a lowering in RMR. Age, height, body mass, surface area and body fat did not differ between the two groups.

RMR has only previously been estimated within a cohort of jockeys using the equation developed by Mifflin-st Jeor (Mifflin et al., 1990) derived from a sample of normal weight, overweight, obese and very obese individuals. Estimated RMR in the group was reported as 1479 ± 124 $kcal \cdot day^{-1}$ (Flat: 1393 ± 47 $kcal \cdot day^{-1}$; National Hunt: 1614 ± 71 $kcal \cdot day^{-1}$) (Dolan et al., 2011). While various equations based on height, body mass, body composition, gender and age are commonly used to predict RMR, large individual variations may still exist. Gravante et al., (2001) suggest the variation in RMR among individuals with the same physical characteristics may be largely genetically determined with processes such as sympathetic nervous system (SNS) activity, thyroid hormone activity and Na^{+}-K^{+} pump activity all in response to training can potentially influence RMR and therefore contribute to the individual variation. For this reason, the estimated RMR within this group of jockeys may only be used as a guideline.

The current conflicting evidence regarding the implications of caloric restriction and weight cycling on RMR limits the understanding of what RMR is to be expected amongst jockeys. A large proportion of jockeys (71%) employ energy restriction as a predominant method to control weight (Dolan et al., 2011). In that same study 81% of the jockeys exercised and a further 38% were current smokers (Dolan et al., 2011). While the chronic metabolic effects of smoking have not been fully elucidated, it is believed smoking leads to an increase in RMR (Chiolero et al., 2008). Several studies indicate that RMR is significantly higher in physically active individuals than those who are inactive (Speakman and Selman, 2003, Gravante et al., 2001). While an elevation in RMR as a long term effect of training may be attributed to increases in FFM (Speakman and Selman, 2003), Gravante et al., (2001) reported RMR can remain elevated as a result of training despite adjusting for differences in FFM in a group of sports women and sedentary women. This suggests various mechanisms independent of changes in body composition and increases in FFM may stimulate RMR. While these mechanisms remain predominantly unknown, the increase in RMR may be attributed to hyperactivity of the SNS, raising levels of norepinephrine or to an increase in protein turnover (Gravante et al., 2001). It could be suggested the positive effects physical activity elicits on RMR may actually overcome the potential negative effects of caloric restriction and weight cycling on RMR within this unique population of jockeys however further investigations are required.

2.4.3 Kidney Function

As previously mentioned, the kidneys play a central role in the regulation of fluid homeostasis, specifically conserving water when body fluids are low due to restricted intake or excessive sweating and excreting excess water when fluid intakes are high (Guyton and Hall, 1996). A multiple-loop feedback system primarily involving the hypothalamus and the kidneys regulates water homeostasis. The reported effects of chronic dehydration and poor fluid intake on kidney function remain limited (Armstrong, 2012).

2.4.3.1 Risk Factors Affecting Kidney Function in Jockeys

Few studies have documented the effects of chronic dehydration and low water intake on kidney function. Manz and Wentz (2005) outlined the kidneys undergo alterations in both structure and function as a result of dehydration. AVP, as previously described, is secreted during a state of dehydration in order to regulate water excretion from the kidneys. Chronic low dehydration and high levels of AVP induce morphological and functional changes in the kidney to enable greater urine concentrating activity, namely the insertion of the aquaporin-2 water channels into the apical membranes of the collecting tubule principle cells to induce water reabsorption and an increase in the expression and activity of solute transporters in the kidney (Bouby and Fernandes, 2003). A sustained increase in AVP has been shown to be accompanied by a rise in renal plasma flow and GFR. Bouby and Fernandes (2003) emphasize the large additional workload for the kidney when an increase in GFR as small as 20% is seen given the normal GFR is approximately 150 $L \cdot day^{-1}$ and 95-99.5% of the water and 99% of the sodium are reabsorbed. Such changes were suggested as potential risk factors in several renal disorders, such as chronic renal failure, diabetic nephropathy and hypertension. During severe dehydration however, kidney perfusion and GFR both decrease (Bouby and Fernandes, 2003).

Further changes are apparent as a result of restoring fluid homeostasis in a state of dehydration and such changes in the normal functioning of the kidney may have many further negative effects. While the RAAS plays a predominant role in maintaining circulatory homeostasis via the actions of both AngII and Aldosterone restoring renal perfusion by increasing blood pressure and volume, Atlas et al., (2007) suggest continued or inappropriate activation of the system may actually contribute to the pathophysiology of diseases including hypertension and heart failure.

One study in the literature evaluated the association between fluid intake and chronic kidney disease (Stippoli et al., 2011). Stippoli et al., (2011) administered 2 surveys to a group of individuals >50 years of age at 5 year intervals with 3654 and 3508 individuals participating in each. The results concluded that subjects who consumed more than 3.2 L of fluid daily had a lower risk of developing chronic kidney disease, with an associated reduction of 30-50% in the prevalence of chronic kidney disease defined as Cockcroft-Gault eGFR <50 $ml \cdot min^{-1} \cdot 1.73\ m^{-2}$ compared with an intake of 1.7 $L \cdot day^{-1}$.

Exercise completed in conjunction with hypohydration, sodium deprivation and/or heat stress may present a significant stress to the kidneys (Zambraski, 1990). In a review on renal function, fluid homeostasis and exercise, Zambraski (1990) emphasized how renal vasoconstriction and antinatriuretic responses are typically increased in magnitude when dehydration and/or heat stress are combined with exercise. This may have significant implications in light of the prevalence of chronic dehydration amongst jockeys.

The negative consequences of dehydration on renal function are elaborated upon above. Despite the constant state of dehydration in jockeys, given the daily reliance on severe dehydrating procedures to achieve and maintain the required low body mass (Warrington et al., 2009), the kidneys appear not to be compromised in jockeys (Wilson et al., 2013a). No kidney malfunctions were detected in a group of flat and national hunt jockeys and eGFR (Estimated GFR) (using the Chronic Kidney Disease Epidemiology Collaboration Formula – CKD-EPI) were all within normal reference ranges reading as 112.6 ± 11.3 $ml \cdot min^{-1} \cdot 1.73\ m^{-2}$ and 116.8 ± 14.3 $ml \cdot min^{-1} \cdot 1.73\ m^{-2}$ for flat and national hunt jockeys respectively. Wilson et al., (2013a) believed that the unique nature of a jockey's lifestyle deemed no control group appropriate for these athletes and the most relevant comparison was that of a clinical norm. Furthermore, there was no significant difference in eGFR between the two groups of jockeys despite the suggested need for flat jockeys to utilise more drastic weight making strategies to attain the lower stipulated weight limits (Wilson et al., 2013a). It remains unknown though if any long-term negative consequences exist in relation to the functioning of the kidney amongst the individuals who both live and compete in a dehydrated state almost daily for the duration of their racing career.

2.5 Long Term Health Implications of Making Weight

The ultimate question that very often emerges in the current literature surrounding the health and performance of jockeys relates to the long term consequences of a career in horse racing. Due to the lack of longitudinal data, the long term health effects associated with a jockey's lifestyle remain unknown and very often the longer-term health risk for jockeys is speculated, particularly in relation to stature, bone development and fracture risk in later life (Dolan et al., 2011, Greene et al., 2013, Warrington et al., 2009, Wilson et al., 2013a). With ageing, many inherent physiological changes will occur. Various physiological changes that are characteristic of ageing are discussed initially in this section, followed by the long term health impact of prolonged energy deficits and weight cycling on health.

2.5.1 Physiological Aspects of Ageing

Ageing is often characterised by the progressive loss of physiological integrity which inevitably leads to the impaired functional ability of each organ and system in the body (Farley et al., 2006). Many theories have been proposed in an attempt to explain the physiological changes associated with ageing, all of which generally agree that the ageing process results from unrepaired cellular damage that accumulates over time (Farley et al., 2006). Lifestyle, environment and family history all play a role in ageing. Ageing may have various adverse effects on many of the health issues previously discussed in this review of literature, in particular relation to body composition, bone health, RMR and kidney function.

2.5.1.1 Body Composition

During adulthood, an initial increasing phase followed by a decreasing trend characterise the physiological variation of body mass. Physiological changes of body composition with age concern both the FM and the FFM however the onset, rate and intensity of the physiological variations remain inconclusive (Buffa et al., 2011). Vermeulen et al., (2002) suggest FFM decreased by 20 - 40% in individuals between the ages of 25 and 75 years and FM doubles. Jackson et al., (2012) report that FM increases with ageing and levels off at ~70 years while FFM increases slightly between 20 and 47 years of age, steadily decreasing at a non-linear rate with ageing. There is no general consensus of the mean magnitude and rate of loss of FFM with ageing, however reductions in FFM by 15% can be seen between the third and eight decade of life (Buffa et al., 2011). Sarcopenia, the progressive and irreversible reduction of muscle mass and strength due to the reduction of motor neurones and atrophy of muscle fibres, is the predominant contributor to the apparent reduction in FFM with ageing (Buffa et al., 2011). The initial rise in FM with age is attributed to the reduction of overall energy expenditure and any decreases in advanced age are due to loss of subcutaneous fat (Buffa et al., 2011). The extent and nature of such changes are influenced by various factors namely genetics, hormonal, metabolic and lifestyle factors including nutrition and physical activity (Vermeulen, 2002).

2.5.1.2 Bone Health

Ageing and osteoporosis are closely linked. A review by Khosla et al., (2010) revealed men lose BMD at a rate of ~1% per year from PBM with ageing and 1 in 5 men over the age of 50 years will suffer an osteoporotic fracture during their lifetime. Changes in the ageing male skeleton involve trabecular thinning in comparison to the reduced trabecular connectivity seen in women after menopause (Watts et al., 2012). Elevated osteoblast and osteocyte apoptosis and an insufficient number of osteoblasts characterise the age-related skeletal fragility such that the amount of bone resorbed by the osteoclasts is not fully restored with bone deposited by the limited osteoblasts and the resulting imbalances lead to microarchitectural deterioration (Almeida, 2012). Reductions in bioavailable testosterone along with increases in serum PTH levels, vitamin D insufficiency and decreases in IGF-1 levels appear to play a central role in mediating age-related bone loss in men (Khosla et al., 2008). In men, trabecular bone loss begins early in life with the associated alterations in IGF-1 whereas cortical bone loss occurs later in life (85% occurs after 50 years of age) as a result of the reductions in physical activity and the bioavailability of both sex hormones (Ebeling, 2008).

2.5.1.3 Resting Metabolic Rate

Decreases of 13 - 20% in RMR have been suggested with advancing age in men (typically between the ages of 30 and 80 years) of which appears to be dependent on the associated loss of FFM (Wilson and Morley, 2003a). Many studies however suggest the decline in RMR with advancing age could not totally be explained by changes in body composition. Krems et al., (2005) compared RMR of young (20-35 years) and older (>60 years) men and women revealing that even after adjusting for FFM, FM and smoking history, RMR was lower in older individuals compared to the younger individuals. Furthermore Frisard et al., (2007) compared young (20-34 years), older (60-74 years) and very old (>90 years) individuals and reported a lower RMR in old and very old individuals after adjusting for FFM, FM and gender. Absolute RMR values were reported as 1587 ± 50 $kcal \cdot day^{-1}$, 1465 ± 37 $kcal \cdot day^{-1}$ and 1165 ± 20 $kcal \cdot day^{-1}$ for the young, old and very old individuals respectively. It has been suggested the reduction in RMR with age is greater than what can be explained by FFM and FM and may be due in part to slowed organ metabolic rates (St-Onge and Gallagher, 2010).

2.5.1.4 Kidney Function

Progressive structural and functional deterioration of the kidney is associated with ageing (Weinstein and Anderson, 2010, Abdelhafiz et al., 2010, Musso and Oreopoulos, 2011). Progressive reductions in GFR and renal blood flow are commonly exhibited with ageing and the fall in GFR is primarily attributed to reductions in glomerular capillary plasma flow rate. GFR is typically maintained at ~140 $ml \cdot min^{-1} \cdot 1.73\ m^{-2}$ until the fourth decade and declines by ~8 $ml \cdot min^{-1} \cdot 1.73\ m^{-2}$ per decade after (Weinstein and Anderson, 2010). Such physiological changes may be mediated by alterations in the activity and responsiveness to vasoactive stimuli with ageing such that responses to vasoconstrictor stimuli are enhanced and impaired to vasodilatory responses (Weinstein and Anderson, 2010). These physiological alterations in addition to the vascular and renal structural changes reduce the functioning of the kidney and they occur at varying stages of ageing depending on predisposing genetic factors and other lifestyle factors with associated exposure to cardiovascular risk factors such as hypertension and diabetes (Abdelhafiz et al., 2010, Musso and Oreopoulos, 2011, Weinstein and Anderson, 2010). The decline in renal function is however slow, particularly in the absence of any associated progressive cardiovascular disease and appears to be of no major clinical significance (Abdelhafiz et al., 2010).

2.5.2 Long Term Health Consequences of a Career in Horse Racing

A thorough review of the international scientific literature revealed, only 2 studies in which the health of retired jockeys was investigated (Speed et al., 2001, Tomkinson et al., 2012). Tomkinson et al., (2012) evaluated the long term consequences of multiple falls and the impact of musculoskeletal injuries in retired jockeys. A questionnaire completed by 120 retired jockeys based in the UK revealed a higher prevalence of pain amongst the sample of retired jockeys than the general population, with the lower back most commonly reported as the predominant area for pain. While 90% of the respondents had experienced a musculoskeletal injury during their career of racing, 80% believed the current pain experienced was a result of the many injuries sustained.

Speed et al., (2001) also reported a significant proportion of retired jockeys frequently experience a range of health issues. Amongst the 72 questionnaires (28% of the potential 260 retired jockeys surveyed) completed by a group of retired jockeys (age 52.1 ± 12.4 years; range 27 to 79 years) in Australia, back problems (42%), arthritis (41%), other joint problems (41%) and dental problems (17%) were reported as the most common health issues experienced since retiring. The jockeys surveyed had racing careers lasting 19.8 years (range 4 to 45 years) and more than 50% stated weight problems or injury as the reason for retirement. The struggle with weight for many of the retired jockeys appears to have continued into retirement with 13% experiencing excessive weight gain after retiring from racing.

Limited research exists relating to the long term health implications. For this reason we must seek guidance from other weight category sports and individuals within the general population in which weight cycling is prevalent.

2.5.3 Long Term Health Consequences of a Career in Weight Category Sports

Few studies have investigated the long term health effects associated with chronic weight cycling in athletic populations. Most recently, Marquet et al., (2013) identified the long-term changes in BMI in 136 retired French athletes (age 40.4 ± 6.9 years) who had previously participated in major International competitions in weight class sports including boxers, wrestlers, rowers and judokas and had experienced frequent periods of weight cycling over their career. Telephone interviews identified body mass and height of each individual at both 18 years of age and at the current age at the time of the study (22 years post-career) in order to determine the BMI changes. Marquet et al., (2013) concluded repetitive weight loss and regain during an athletic career does not induce a noticeable body mass gain following retirement from sports competition. Between the age of 18 and 50 years, the athletes BMI increased by 3.2 $kg \cdot m^{-2}$ compared to the 4.2 $kg \cdot m^{-2}$ increase apparent in the general population. It was further suggested the lack of weight gain was potentially due to the high level of physical activity (mean 4.8 ± 4.3 hours weekly) typically still practiced after retirement by the athletes in the study. The risks associated with cessation of physical activity in former elite athletes have previously been reported such that sedentary older athletes had significantly higher mean values in body mass, BMI, body fat percentage, total cholesterol, LDL and triglycerides than that of the active older athletes and sedentary older non-athletes (Dey et al., 2002).

Similar results were also reported in a study on former male wrestlers in comparison with other athletes (Nitzke et al., 1992). Survey questionnaires were completed by 60 ex-wrestlers (competed between 1950 and 1988) and 104 non-wrestlers with results indicating no significant differences in body mass gained after graduation (4.6 kg and 3.6 kg for wrestlers and non-wrestlers respectively) in addition to no differences between the groups in current exercise practices, incidence of chronic disease, prevalence of obesity and current dieting rates. In contrast, Saarni et al., (2006) reported the repeated cycles of weight loss and regain, prevalent in weight category athletes, appear to enhance subsequent weight gain and may predispose such individuals to obesity. In this study, 370 men engaged in weight category sports (including boxers, weight lifters and wrestlers), 1468 other male elite athletes and 838 male controls with no athletic background completed questionnaires at 3 separate time points in 1985, 1995 and 2001 (depending on survival). All athletic participants had represented Finland in major International sports competitions between 1920 and 1965. The weight gain post career in elite athletes who experienced weight cycling was higher than that observed in non-dieting athletes. Specifically, the estimated increase in body mass from 20 years of age to its maximum value was 5.2 BMI units (at age 58.7 years). In contrast, corresponding figures were 4.2 BMI units at age 58.5 years and 3.3 BMI units at 62.5 years for the controls and other athletes respectively. Furthermore, the weight cyclers had a higher proportion of subjects classified as obese at all the time points compared to the other athletes in addition to the controls in 1985 and 1995. Unlike the study by Marquet et al., (2013), the retired weight cycling athletes were reported to have a lower physical activity level than the other athletes which may explain some of the discrepancies within the results. Furthermore, the participants in the study by Marquet et al., (2013) competed from 1978 to 2003 so the specific time period of testing could explain the variability in results due to the specific sport constraints in that time period.

The current findings in this area remain limited and are typically based on self-report questionnaires and surveys. Such studies were predominantly based on weight category athletes however a further insight into the long term effects of weight cycling in addition to chronic dehydration and energy restriction may be gained from the general population.

2.5.4 Long Term Health Implications of Weight Cycling

Dulloo (2005) suggest that large fluctuations in body mass early in life, be it during growth or young adulthood, represent a risk factor for the development of insulin-related complications in later years, specifically obesity, type 2 diabetes and cardiovascular disease. Suggestions explaining the negative consequences of such perturbations in body mass in early life centre upon the permanent alterations in the structures and functions of certain tissues and in the resetting of major neuroendocrine systems resulting from food deprivation occurring during critical periods of growth and development (Young, 2002, Hales and Barker, 2001). Montani et al., (2006) suggest the potential mechanisms by which weight cycling may contribute to cardiovascular disease include total body and visceral fat accumulation, alterations in adipose tissue fatty acid composition, insulin resistance, hypertension and dyslipidaemia. Furthermore, higher than normal values of blood pressure, heart rate, sympathetic activity, glomerular filtration rate, blood glucose and lipids typically associated with rapid weight gain following a period of food restriction may put an additional load on the cardiovascular system over time (Montani et al., 2006). Sea et al., (2000) further offers the possible explanation that the change in lipid metabolism as a result of weight cycling over time may increase the risk of coronary heart disease.

Difficulties arise when attempting to directly apply these findings to jockeys. Thein-Nissenbaum (2013) however reviewed the long term consequences of the Female Athlete Triad revealing all of the components of the syndrome – energy availability, menstrual function and bone density – appear to have a negative long-term effect on bone. Women who were diagnosed with the Female Athlete Triad syndrome as adolescents and young adults in the 1990s are now suffering from low BMD at 30 and 40 years of age (Thein-Nissenbaum, 2013). Despite a small number of female riders, the vast majority of jockeys are male and a similar negative effect may be apparent in all jockeys. The long-term health effects of chronic weight restriction have not been studied within this unique population and for this reason the impact of the lifestyle demands of a jockey on health in later life warrant further investigation.

2.6 Summary

This review of literature demonstrates that with no precise strategy for managing or achieving the stipulated low body mass required for racing, chronic energy deficiency and dehydration are a consequence of consistently utilising such severe weight making practices. Individually or combined, a lifestyle of energy deficiency and dehydration may have serious acute and chronic adverse implications on the health and performance of jockeys during their career and long into retirement. Further investigation into the acute and chronic impacts of making weight on the health and performance of jockeys are required to further understand the precise adverse effects such lifestyle demands may have throughout the life span of a jockey. While some information may be applied from the findings of studies in other weight category sports, the unique nature of horse racing in terms of the duration and intensity of the racing season make comparisons problematical. In particular due to the nature of the sport jockeys, unlike other weight category athletes are not afforded the opportunity to replenish food and fluid stores prior to racing due to the stringent weigh in procedures make horse racing a unique sport with regards its weight making practices. Such methods of making weight appear to be based on tradition rather than on sound scientific principles (Warrington et al., 2009). Without knowing the specific physiological demands of a jockey during racing, training and other daily activities difficulties arise when attempting to provide precise nutritional and training guidelines for such individuals whose careers depend on competing at a designated low body mass while remaining in peak physical condition. The development of such guidelines are essential in order to progress on from such traditional methods of making weight and to inevitably help jockeys 'make weight' in a safe and controlled manner for the health, safety and welfare of all involved in the horse racing industry. In this context this research study will further investigate the acute impacts of making weight on performance parameters including cognitive function, balance and anaerobic performance, the long term implications of the lifestyle demands of a jockey and it will conclude with the evaluation of the physiological demands and energy requirements of jockeys during racing, training and other daily activities. This research study will consist of 3 individual studies which will be outlined in detail in the following chapters.

Chapter Three: The Acute Effects of Making Weight on Cognition and Performance in Jockeys

Irish 1000 Guineas 2013

3.1 Abstract

With no precise strategy for managing and achieving the required low body mass for racing, many jockeys may be placed at an increased risk of compromised physiological and cognitive function which may have many adverse effects on health, safety and performance when racing. The purpose of this study was to examine the effects of acute weight loss in preparation for racing on cognitive function, balance and high intensity anaerobic performance in a group of jockeys. **Methods:** Twelve male apprentice jockeys (Group 1:age 19 ± 2yr; height 1.72 ± 6.3 m; body mass 59.8 ± 4.7 kg; BMI 20.3 ± 1.4 $kg^{.}m^{-2}$) completed a battery of tests assessing cognitive function, balance and anaerobic performance on two occasions. Following baseline testing, where subjects were assessed in a euhydrated state, each participant was required to reduce their body mass by 4% of their baseline measure using weight loss methods typically adopted in preparation for racing, returning 48 hours later for repeat-testing in a dehydrated state. Twelve age and gender matched male participants acted as a control group (Controls: age 20.5 ± 2yr; height 1.78 ± 7.3 m; body mass 81.1 ± 10.8 kg; BMI 25.6 ± 2.6 $kg^{.}m^{-2}$), completing both of the trials in DCU in a euhydrated state 48 hours apart having maintained typical dietary and physical activity habits between trials. A further 10 jockeys (Group 2: age 23 ± 3yr; height 1.65 ± 2.1 m; body mass 61.8 ± 5.6 kg; BMI 22.7 ± 1.3 $kg^{.}m^{-2}$) completed a battery of computerised tests assessing cognitive performance at a race course immediately prior to actual racing on two separate occasions, at a normal body mass and at a light body mass having attempted to 'make weight'. Body mass and hydration status were assessed in all testing sessions. **Results:** A significant decrease in mean body mass of 4.1 ± 0.2% ($p \leq 0.001$) and increase in Usg from 1.016 ± 0.002 to 1.032 ± 0.003 ($p \leq 0.001$) was reported in the jockey group in the simulated weight loss trial, while the control group showed no significant change in body mass or hydration status between trials. No significant change in cognitive function, balance or anaerobic performance was reported in the simulated testing environment however noticeable individual differences exist within the results. Large individual variation were apparent in the results obtained for the cognitive function tests within the group of jockeys (Group 2) tested at the race course who were assessed after a body mass change of 5.7 ± 1.9% ($p \leq 0.001$) and an increased Usg from 1.018 ± 0.003 to 1.026 ± 0.003 ($p \leq 0.001$). **Conclusion:** Results from this study indicate that a rapid loss in body mass through the typical methods employed for racing in association with a significant increase in Usg resulted in no significant impairments in mean cognitive function, balance or anaerobic performance within the 2 experimental groups. The individual variability in results observed however, especially within the less experienced apprentice jockeys in Group 1 who were less

familiar with undergoing rapid reductions in body mass, is worrying in terms of the safety and welfare of all surrounding jockeys on the track. Further research is required to investigate the extent to which some jockeys may now be habituated to such a level of dehydration and reduction in body mass in order to encourage best practices in preparation for competition ensuring the optimisation of health, safety and performance of all jockeys on the racing track.

3.2 Introduction

Horse racing is commonly classified as a high risk and dangerous sport given the high incidence of falls and fractures reported (Hitchens et al., 2009a, Rueda et al., 2010). During a race, the combination of a number of factors including: the high velocities attained by the horse (~60 $km \cdot h^{-1}$); the positioning of the jockey; the close proximity of the horses to each other; the unpredictable nature of the horse (Waller et al., 2000, Rueda et al., 2010); the tactical elements employed by many jockeys which require split second decision making (Balendra et al., 2008) and the physiological attributes of jockeys (i.e. lower anaerobic and aerobic fitness and high muscular strength and power) (Hitchens et al., 2011) may contribute to the numerous falls and accidents reported in this high risk sport. Any slight misjudgement, error, imbalances or fatigue could be catastrophic for both the horse and individual jockey in addition to the surrounding jockeys on the race track (Balendra et al., 2008).

Due to the severe weight restrictions placed on jockeys, the need to achieve a constant low body mass render the use of strict and sometimes dangerous weight loss strategies amongst many jockeys necessary in order to maximise riding opportunities (Hill and O'Connor, 1998). Jockeys have been reported to typically reduce body mass acutely within 24-48 hours of or on the race day itself, with no specific weight loss strategy for more than 4 days before the race day (Dolan et al., 2011). Typical losses have been reported as 3.6 ± 2.4% of body mass however reductions in body mass of up to 10.5% have been reported (Dolan et al., 2013). A strong reliance on acute body mass loss for competition is apparent, primarily achieved through dehydration by a number of different mechanisms including heat exposure and exercise in sweat suits, accompanied by severely restricted fluid and food intake (Dolan et al., 2011, Hill and O'Connor, 1998, Leydon and Wall, 2002, Moore et al., 2002). Some degree of chronic energy restriction has also been suggested given the low energy intakes (Dolan et al., 2011). Such methods of weight reduction appear to result in jockeys living and competing in a dehydrated and energy deficient state (Dolan et al., 2011, Warrington et al., 2009).

Dehydration, induced acutely through heat exposure or exercise, has been reported to result in a significant impairment of specific aspects of cognitive function (Cian et al., 2001, Gopinathan et al., 1988, Tomporowski et al., 2007). Despite these findings, a lack of consistency in the evidence published to date is apparent primarily due to methodological differences in study design, thereby making direct comparisons problematical (Grandjean and

Grandjean, 2007, Lieberman, 2010, Lieberman, 2007, Lieberman, 2012). Exposure to a combination of acute stressors including sleep loss, heat, dehydration and under nutrition in the military have been reported to result in large decrements in cognitive performance (Lieberman et al., 2005) however difficulties exist when extrapolating such results to jockeys. Inconclusive and contradictory evidence exists in relation to decrements in balance (Derave et al., 1998, Ely et al., 2013, Cullen et al., 2013) and high intensity anaerobic performance (Cullen et al., 2013, Jacobs, 1980, Jones et al., 2008) as a result of dehydration and caloric restriction.

Similar acute weight loss methods are also common in other weight category sports including wrestling, boxing and judo and have been reported to negatively affect physical and cognitive capacities in combat sports (Franchini et al., 2012). The inability to replenish the depleted food and fluid stores before, during and after racing, and over such long and intense seasons of horse racing may exacerbate unfavourable health and performance effects for jockeys. Previous research from our research group have reported physiological impairments in terms of aerobic work capacity as a result of rapid reductions in body mass in jockeys, however no cognitive function decrement was apparent in the same group (Dolan et al., 2013). Inconclusive evidence exists relating to cognitive performance decrements in jockeys within the literature (Labadarios et al., 1993, Pruscino et al., 2007).

The nature of the sport of horse racing render it high risk, however currently with no precise strategy for managing and achieving the required body mass reduction, many jockeys may be placed at an increased risk due to a compromised physiological and cognitive function which may have a negative impact on health, safety and performance. In such a highly competitive and dangerous sport, being physically fit and mentally alert are imperative to these athletes whose careers depend on the ability to 'make weight' in order to compete. For this reason, the effects of making weight on cognitive function, balance and anaerobic performance were further investigated in a group of apprentice jockeys.

3.2.1 Aim and Objectives

The aim of this study was to examine the effect of acute body mass loss in preparation for racing on cognitive function and physical performance in a group of jockeys in a simulated and competitive environment.

Objective One:

To examine the impact of a 4% reduction in body mass on cognitive function in a group of jockeys, as assessed through performance on a computerised cognitive test battery.

Objective Two:

To examine the impact of a 4% reduction in body mass on balance in a group of jockeys, as assessed through performance on a specific dynamic balance test.

Objective Three:

To examine the impact of a 4% reduction in body mass on anaerobic performance in a group of jockeys, as assessed through performance in a 30 second maximal test on a cycle ergometer.

Objective Four:

To investigate the effect of 'making weight' on cognitive function in a group of jockeys prior to an actual race, as assessed through performance on a computerised cognitive test battery.

Hypotheses

1. That reducing body mass by 4% in 48 hours using typical weight loss practices would have a negative impact on cognitive function and physical performance in a group of jockeys.
2. That the use of acute weight loss strategies prior to an actual race would result in decrements in cognitive performance.

3.3 Methods

3.3.1 Study Design Overview

The following research study consisted of two parts: Part A was completed in both RACE and DCU while Part B was completed during an actual race meeting at various race courses around Ireland. Ethical approval for the study was granted by Dublin City University Research Ethics Committee.

Part A: Simulated Environment

Twenty four male participants were recruited to take part in this study (12 jockeys and 12 age and gender matched controls). The experimental group (Group 1: jockeys) and the control group were required to report to RACE and DCU respectively for three separate trials: 1) Habituation trial 2) Baseline trial and 3) Experimental trial (see figure 3.1). The habituation trial allowed participants to practice all testing procedures to minimise and eliminate all learning effects. Trials two and three were conducted 48 hours apart and consisted of a battery of tests assessing cognitive function, balance and anaerobic performance which were completed in a standardised order as well as hydration status (Usg) and body mass assessment. Group 1 were required to undergo the previously reported acute weight loss patterns typically used in preparation for racing as reported by Dolan et al., (2013), reducing their body mass by 4% of their baseline measure in the 48 hours between trials through the typical weight loss methods employed for racing. A record of any methods used to actively reduce body mass was required by each participant in Group 1. The control group were instructed to maintain usual dietary and physical activity habits between test trials, returning for repeat testing at the same body mass as before and again in a euhydrated state. Wherever possible, the timing of the testing was standardised and all testing was performed in a quiet room in a temperate environment.

A similar protocol was performed to that previously utilised in another research project within the same laboratory (Dolan et al., 2013). This current study was however chosen to allow further investigation into the effects of rapid reductions in body mass on cognitive function using a more sensitive computerised test battery as well as assessing other performance parameters inclusive of balance and anaerobic performance that have not been previously investigated.

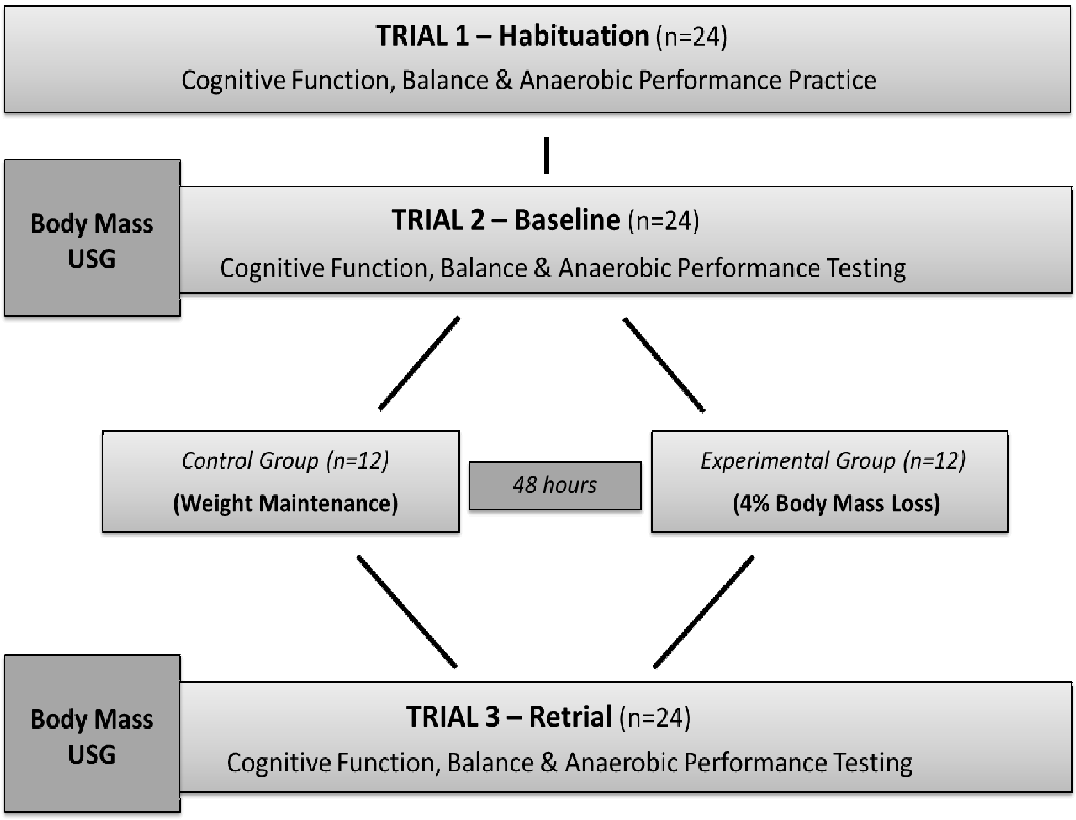


Figure 3.1: Schematic Representation of the Experimental Design in RACE and DCU

Part B: Competitive Racing Environment

A further 10 male jockeys (Group 2) were recruited to undergo a battery of computerised tests assessing cognitive performance immediately prior to actual racing on two separate race days: 1) when racing at a comfortable body mass in which no acute weight loss practices were utilised (participants attended the race meeting without attempting to employ any previously reported weight loss method (Dolan et al., 2011, Labadarios et al., 1993, Leydon and Wall, 2002, Moore et al., 2002)) 2) when racing at a body mass in which rapid weight loss strategies were employed (see figure 3.2). Rapid weight loss strategies included any method typically used by jockeys in preparation for racing. These trials occurred no more than 3 weeks apart and were completed in a random order. Hydration status (Usg) and body mass were assessed on both occasions.

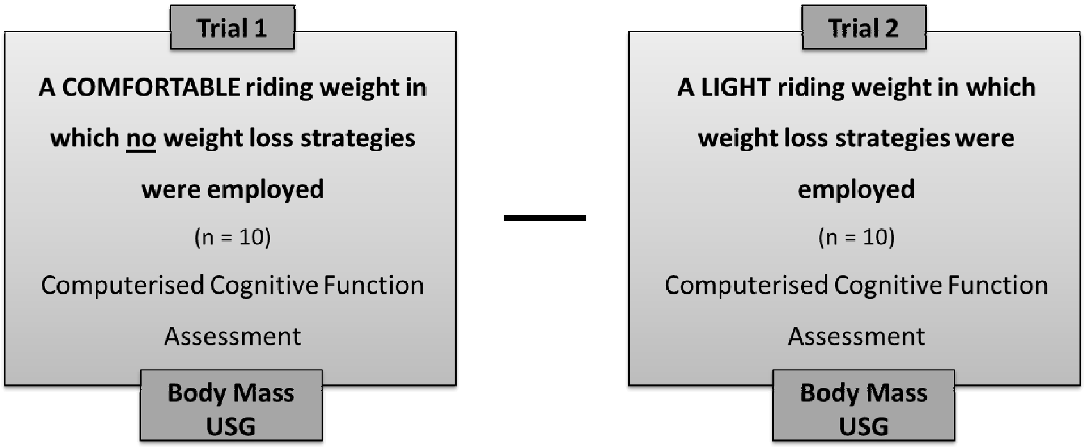


Figure 3.2: Schematic Representation of the Experimental Design in a Competitive Racing Environment

3.3.2 Participants

Twelve male apprentice jockeys (Group 1) (representing 32% of all male licenced apprentice jockeys at the time of testing) between eighteen and thirty years of age were recruited for Part A of the study via email and advertisements at Irish racecourses. Inclusion criteria for these participants included male apprentice/conditional jockeys currently receiving 'rides' at the races and the exclusion criteria included female jockeys, trainee or professional jockeys and those not regularly racing. Twelve physically active individuals, all age and gender matched, were recruited for the control group via email advertisement within DCU. An additional 10 male apprentice (Group 2) (representing 26% of all male licenced apprentice jockeys at the time of testing) volunteered to participate in Part B involving race day testing. These subjects were recruited via advertisement at Irish racecourses and word of mouth. Inclusion and exclusion criteria were the same as above. All participants received detailed information on the study *(Plain Language Statement, Appendix A1)* and prior to participation in this study each participant provided medical history *(General Health Questionnaire, Appendix C)* and written informed consent *(Informed Consent Form, Appendix B1)*. Any participant who was absolutely contraindicated from exercise participation due to an inhibiting medical condition or injury was excluded from the study. All participants were requested to abstain from alcohol and from any unusual and strenuous activity for 24 hours prior to the collection of baseline data.

3.3.3 Procedures

3.3.3.1 Anthropometric Assessment:

On all occasions, body mass (kg) was assessed in minimal clothing and reported to the nearest 0.1 kg using a portable digital scales (Seca 877, Germany). Standing height (m) was measured to the nearest 0.1 cm using a portable stadiometer (Seca, Leicester Height Measure). Body mass index (BMI; $kg \cdot m^{-2}$) was calculated by dividing the weight in kilograms by the square of the height in metres.

3.3.3.2 Hydration Assessment: Urine Specific Gravity (Usg)

Hydration status was assessed through measurement of Usg using a handheld refractometer (TS400, Leica Microsystems, Germany) which has been suggested as a practical and reliable means of hydration status evaluation (Oppliger et al., 2005, Armstrong, 2005). This method compares the density of a urine sample to that of distilled water. A few drops of a urine specimen were placed on the display of the refractometer and it was pointed towards a light source which passed through the specimen. Usg exceeding 1.000 was seen for any fluid denser than water. A value of 1.020 was accepted as the threshold of euhydration with values greater being indicative of a dehydrated state (Oppliger and Bartok, 2002a, Casa et al., 2000, Sawka et al., 2007a).

3.3.3.3 Variables Assessed: Cognitive Function, Balance and Anaerobic Performance

Three variables were assessed in the same order for each participant and for each trial: cognitive function, balance and anaerobic performance. This was to eliminate any potential affect exercise has been reported to have on cognitive function (Coles and Tomporowski, 2008, Lambourne and Tomporowski, 2010, Tomporowski, 2003).

1. **Cognitive Function**

Cognitive function was assessed using the CogState Sport (CogState Sport, CogState Ltd, Melbourne, Victoria, Australia) computerized battery of tests. The CogState Sport programme was selected for the purposes of the study due to the sensitivity previously reported to very mild cognitive changes (Makdissi et al., 2001), as well as reported high test-retest reliability between test sessions and the resistance to performance manipulation (Collie et al., 2003).

Furthermore, CogSport is the current recognised neuropsychological test battery used within horse racing in Ireland for the detection and assessment of concussion, with all jockeys having baseline cognitive function testing prior to receiving a riding licence and then again every 2 years.

The CogState Sport assessment typically takes 15 minutes to complete and consists of four individual tasks, each measuring a specific area of cognition (Table 3.1) with speed and accuracy used as the direct benchmarks of cognitive performance. Playing cards were used as the stimulus in this battery of tests and based on a simple question asked at the beginning of each task, the participant had to respond as quickly and accurately as possible to the individual card with either a “yes” or a “no”, the **d** key on the keyboard indicating ‘no’ and the **k** key indicating ‘yes’. Once the participant responded, visual feedback was given with an error sound if the incorrect response was given. The sequence of the card appearing and the participant responding was termed a ‘trial’ and each of the 4 tasks consisted of at least 30 trials.

Prior to each task, the test administrator read full instructions to the participant from the test supervisor script with further instructions appearing on the screen in front of the participant. A practice trial (consisting of up to 20 trials) was performed before each task for additional familiarisation, minimising any practice effects (Straume-Naesheim et al., 2005).

Table 3.1: Description of the CogState Sport tests and the cognitive domain assessed

TASK	DESCRIPTION	COGNITIVE DOMAIN ASSESSED
Detection (DET)	*"Has the card turned over?"* As soon as a card flipped over so it was face up, the subject was required to press the "Yes" key. The card went to the back of the pack and the subject pressed the "Yes" key as soon as the next card flipped over and so on.	Simple Reaction Time, Psychomotor Processing Speed & Simple Attention
Identification (IDN)	*"Is the card red?"* As soon as a card flipped over so it was face up, the subject had to decide whether the card was red or not. If it was red, the "Yes" key was pressed, if it was not red the "No" key was pressed.	Choice Reaction Time, Vigilance, Attention & Concentration
One Card Learning (OCL)	*"Have you seen this card before in the task?"* Each time a card was revealed, the subject was required to decide whether that card had been shown before in that task & responded by pressing the "Yes" or "No" key.	Attention/Visual Learning & Memory
One Back (OBK)	*"Is the previous card the same?"* The subject was required to decide as each card was presented whether it was identical to the one just before it. If the face up card was identical to the one presented immediately before it, the subject pressed the "Yes" key, if it was not the same, the subject pressed the "No" key.	Attention & Working Memory

Reports were generated from the test data immediately once the participant responses were received by the CogState's database via the internet. Integrity checks were generated from the raw data and both anticipatory responses (reaction times <100ms) and abnormally slow responses (reaction times >3500ms) were recorded as errors and excluded from the analyses. Results were reported in terms of both reaction time (ms) and accuracy (%) for each task.

2. Balance

The Y balance test was used to assess balance and it required the use of strength, flexibility and proprioception. An instrumented version of the Star Excursion Balance Test (SEBT), the Y balance test has been developed to enhance the repeatability of measurement and to standardize performance of the test. The test aims to disorientate the equilibrium of participants to near maximal and then return to a state of normal equilibrium (Kinzey and Armstrong, 1998). In order to do this, participants were required to maintain a single leg stance whilst reaching as far as possible with the opposite leg, in a number of random movement trajectories (Pliskey et al., 2009). The Y test utilizes the anterior, posteromedial and posterolateral (figure 3.3) components of the SEBT test and proves to be a superior test given the excellent intrarater and interrater reliability (Pliskey et al., 2009).

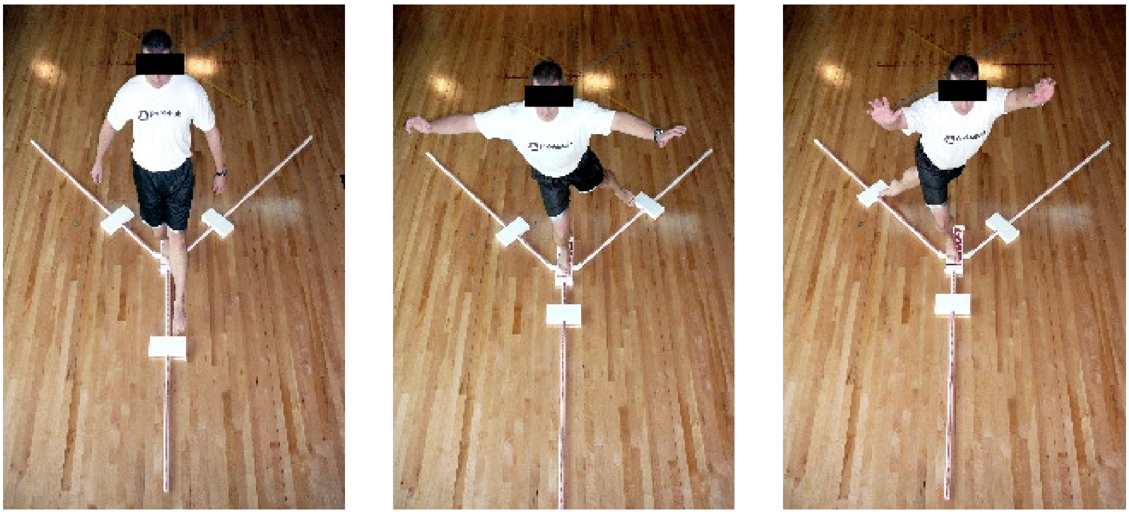


Figure 3.3: Performance of the Y Balance Test for the Right Leg: Anterior, Posterolateral and Posteromedial Reach

Prior to testing, the right limb length of the participant was measured in cm from the most inferior aspect of the anterior superior iliac spine to the most distal portion of the medial malleolus. Barefoot and sustaining a single legged stance, participants reached with the contra lateral leg in the anterior, posteromedial and posterolateral directions, and pushed the reach indicator. Each participant completed 6 practice trials on both legs in the 3 reach directions preceding 3 test trials in order to eliminate any learning effects (Pliskey et al., 2009). The specific testing order used was right anterior, left anterior, right posteromedial, left posteromedial, right posterolateral, and left posterolateral. The test was discarded and repeated if subjects lost the single leg stance, kicked the reach indicator, used the reach indicator for support to maintain stance or failed to return to the starting position. Reach distance was measured by reading the measuring tape at the edge of the reach indicator. The greatest successful reach for each direction was used for analysis. The total (composite) reach distance compared to limb length was calculated as follows and then used for analysis:

$$\text{Composite Score} = \frac{(\text{Anterior} + \text{Posteromedial} + \text{Posterolateral})}{(3 \times \text{Limb Length})} \times 100$$

3. Anaerobic Performance

The Wingate Anaerobic Test (WAnT) was used to evaluate anaerobic performance. WAnT has been established as an effective tool in measuring both muscular power and anaerobic capacity (Zupan et al., 2009) and it is considered the most commonly used laboratory test of anaerobic muscle performance (Bar-Or, 1987). WAnT was completed on a Monark ergometer (Monark, Ergomedic 894E, Peak Bike), requiring each participant to cycle at maximal velocity for 30 seconds using a standardised resistance set as 7.5% of the individual's body mass (see figure 3.4). Participants were required to perform against the same set resistance in both trials which was determined as 7.5% of the baseline body mass. This eliminated any discrepancies in results typically seen as a consequence of using testing methods such as the vertical jump test or sprinting that involve an individual moving one's own body mass that varies between tests (Judelson et al., 2007a). Participants stood beside the bike initially to determine seat height was at hip level while standing and adjustments to the ergometer were made accordingly to ensure an optimal riding position was obtained. Participants cycled for 5 minutes to warm up and were subsequently required to maintain a cadence of 70 RPM for a 10 second countdown. Rapid adjustment of the flywheel tension was then performed by the test supervisor such that the required tension was achieved at the start of the 30 second test. Verbal encouragement was provided to ensure participants pedalled as quickly and as forcefully as possible while remaining seated throughout the 30 second period.

Figure 3.4: Cycle Ergometer used for the Assessment of Anaerobic Performance

Three indices of performance were obtained from the WAnT and used for analysis: a) Peak Power output relative to body mass ($PP \cdot kg^{-1}$), the highest power output achieved relative to body weight; b) Anaerobic Capacity relative to body mass ($MP \cdot kg^{-1}$), the mean power output over the entire duration of the test relative to body mass and c) Fatigue Index (FI), the difference between the highest power output and the lowest power output, usually expressed as a percentage and providing an index of anaerobic endurance (Zupan et al., 2009).

3.3.3.4 Habituation Trial:

Familiarisation with the various methods of assessment took place in a separate session whereby participants completed each of the cognitive function, balance and aerobic performance tests to minimise any possible learning effects. As previously mentioned, CogSport is the recognised neuropsychological test battery currently used within Irish horse racing for the assessment of cognitive function in relation to concussion so all jockeys within this study were familiar with this method of assessment. Practice effects have been reported to be reduced due to the randomisation of stimulus presentations creating many alternative and equivalent forms of the test (Collie et al., 2001). Furthermore each specific cognitive function test was also preceded by a brief practice trial to minimise any practice effects at the time of testing (Straume-Naesheim et al., 2005). Completion of the 30 second WAnT within this trial ensured all participants were familiar with the protocol and had experienced such a high intensity test. The Y balance test was practiced in this particular trial and as suggested previously 6 practice trials on each leg in each of the 3 reach directions preceded the 3 official testing trials in order to eliminate any learning effects (Pliskey et al., 2009).

3.3.4 Statistical Analysis

Data was analysed using SigmaPlot version 12.0. Descriptive statistics were found for each dependent variable for each task. Normality of data distribution was determined using the Shapiro Wilks test. A 2x2 repeated measures ANOVA was performed on the group means in Part A to assess if between-group and within-group differences were present. A pairwise comparison identified the location of the significant difference if present. Pearson product-moment correlations examined the relationships between speed and accuracy in the cognitive function tasks. Pre-post within-group differences were further assessed only in those individuals in Part A Group 1 who were not used to regularly acutely reducing body mass ($n = 8$) using a paired sample *t* test or Wilcoxon signed ranks test depending on data distribution. Significance was accepted at the level of $p \leq 0.05$.

3.4 Results

3.4.1 Part A: Simulated Environment

3.4.1.1 Subject Characteristics

Descriptive data for all subjects in Part A are presented in Table 3.2, with groups being age and gender matched.

Table 3.2: Subject Characteristics at Baseline (Group 1 and Controls)

	Jockeys (n = 12)	Controls (n = 12)
Age (years)	19 ± 2	20 ± 2
Height (m)	1.72 ± 6.3	1.78 ± 7.3$^{♦}$
Body Mass (kg)	59.8 ± 4.7	81.1 ± 10.8$^{\Omega}$
BMI ($kg{\cdot}m^{-2}$)	20.3 ± 1.4	25.6 ± 2.6$^{\Omega}$

Data presented as mean ± SD; $^{♦}p \leq 0.05$ between groups, $^{♦♦}p \leq 0.01$ between groups, $^{\Omega}p \leq 0.001$ between groups

3.4.1.2 Body Mass

Anthropometric data for all subjects are presented in Table 3.3. Mean body mass of the jockeys was significantly reduced by 2.5 ± 0.3 kg between the trials, equating to a mean loss of 4.1 ± 0.2%. The control group maintained body mass between the trials.

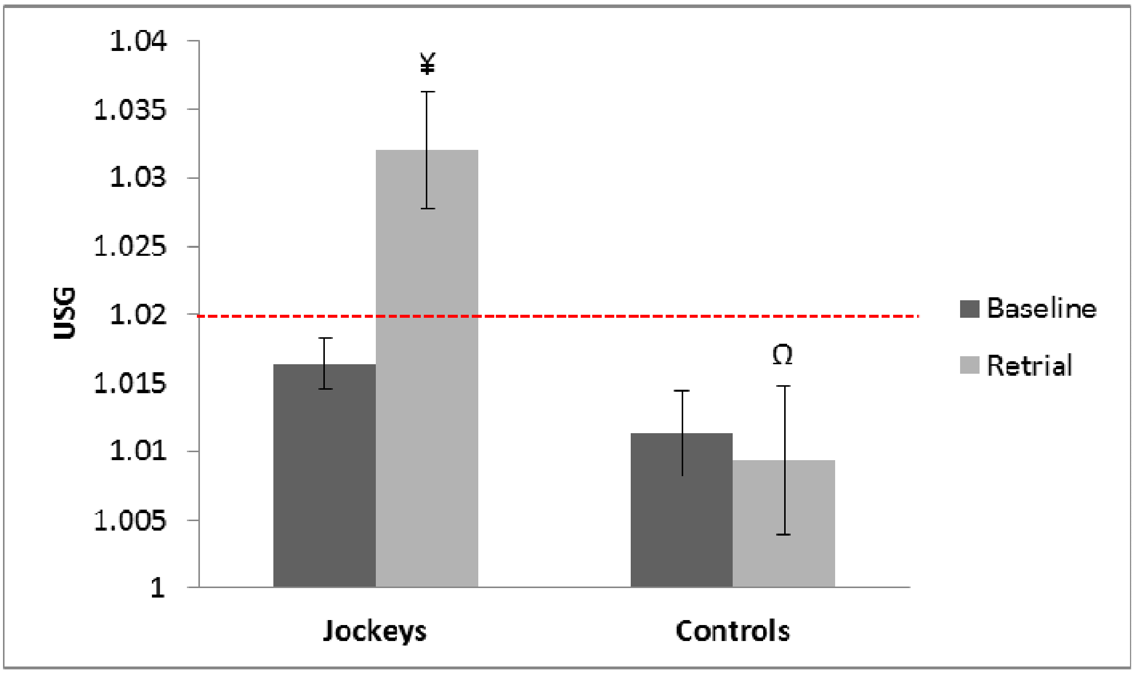
Table 3.3: Body Mass Changes

	Jockeys		Controls	
	Baseline	*Retrial*	*Baseline*	*Retrial*
Body Mass (kg)	59.8 ± 4.7	57.3 ± 4.4$^{¥}$	81.1 ± 10.8$^{\Omega}$	81 ± 10.8$^{\Omega}$

Data presented as mean ± SD; $^{*}p \leq 0.05$ between trials, $^{**}p \leq 0.01$ between trials, $^{¥}p \leq 0.001$ between trials, $^{♦}p \leq 0.05$ between groups, $^{♦♦}p \leq 0.01$ between groups, $^{\Omega}p \leq 0.001$ between groups

3.4.1.3 Hydration Status

As seen in figure 3.5, both groups attended the baseline trial in a euhydrated state, with no significant differences in hydration status between the groups. The reduction in body mass resulted in a significant increase in Usg in the jockey group, rising from 1.016 ± 0.002 to 1.032 ± 0.003 ($p \leq 0.001$). Significant (Usg: 1.021 – 1.030) to serious (Usg: >1.030) dehydration as previously classified by Casa et al., (2000) was demonstrated by all jockeys (range from 1.028 to 1.037) when they returned to complete the tasks in the reduced body mass condition. A state of euhydration was maintained by the control group between both test trials.



*$p \leq 0.05$ between trials, **$p \leq 0.01$ between trials, ¥$p \leq 0.001$ between trials, ♦$p \leq 0.05$ between groups, ♦♦$p \leq 0.01$ between groups, Ω$p \leq 0.001$ between groups

Figure 3.5: Hydration Status as measured by Usg in the trials

3.4.1.4 Individual Jockey Information in Group 1

Table 3.4 provides further information relating to the acute body mass reduction in the individual jockeys. Experience levels varied amongst the 12 apprentice/conditional jockeys recruited. Of the 12 jockeys, 6 of the individuals were only newly licenced jockeys and had only been attempting to 'make weight' for races in recent months, 4 jockeys had been apprentices for many years and were familiar with rapidly losing weight when necessary and 2 of the jockeys while having lost weight many times in the past, they had not undergone rapid body mass loss for a period of time. Severe diet restriction and running with extra layers were amongst the common methods used by the individuals to lose the designated body mass.

Table 3.4: Individual Information on Jockey Group 1 in Relation to Body Mass Reduction

Subject ID	Body Mass Lost (%)	Usg Following Loss	Wasting Experience	Methods Used to Lose Weight
J1	3.9	1.029	Regularly Undergo Rapid Weight Loss	Restricted food and fluid Running on treadmill wearing extra clothing
J2	4.3	1.032	New Conditional	Restricted food and fluid No eating at all on day of testing Running
J3	3.8	1.028	Regularly Undergo Rapid Weight Loss	Restricted food and fluid Power Walked
J4	4.1	1.037	Regularly Undergo Rapid Weight Loss	Restricted Diet Hot Baths
J5	4.3	1.033	Regularly Undergo Rapid Weight Loss	Restricted food and fluid Ran outdoors with bin liners on
J6	4.3	1.029	New Apprentice	Restricted food and fluid Played football wearing extra clothing
J7	4.1	1.028	Has not wasted in a while	Restricted Diet Running wearing extra clothing
J8	4.2	1.033	Has not wasted in a while	Restricted food and fluid Running wearing extra clothing
J9	4	1.031	New Conditional	Restricted Diet Running wearing extra clothing
J10	4.4	1.035	New Apprentice	Restricted food and fluid No eating at all on day of test Running wearing extra clothing
J11	3.8	1.036	New Apprentice	Restricted food and fluid
J12	3.9	1.033	New Apprentice	Restricted food and fluid No eating at all on day of test Running

3.4.1.5 Variables Assessed: Cognitive Function, Balance and Anaerobic Performance

1. **Cognitive Function**

Following analysis of cognitive performance on the computer tasks for all subjects, no significant differences were found in any of the domains assessed following the rapid reduction in body mass (Table 3.5).

Table 3.5: Mean Reaction Times and Accuracy Scores in CogSport Cognitive Function Tasks in a Simulated Testing Environment

	Jockeys		Controls	
	Baseline	*Retrial*	*Baseline*	*Retrial*
DET – Simple Reaction Task				
Speed (ms)	359.8 ± 56.3	350.3 ± 68.4	304.5 ± 38.3$^{\Omega}$	309.2 ± 50
Accuracy (%)	94.9 ± 5.3	97.9 ± 3.5	99.1 ± 1.5	98.6 ± 2.2
IDN – Choice Reaction Task				
Speed (ms)	518.7 ± 96.2	524.3 ± 88.7	479.7 ± 62.8	484.3 ± 51.8
Accuracy (%)	94 ± 5.2	95.3 ± 5.3	97 ± 2.7	94 ± 4.4
OCL – Attention / Visual Learning & Memory Task				
Speed (ms)	892.6 ± 188.9	831.2 ± 163.8	874 ± 136	929.1 ± 181.5
Accuracy (%)	67.1 ± 6.7	70.5 ± 6.2	76.2 ± 8.5$^{♦♦}$	75.8 ± 8.5
OBK – Attention / Working Memory Task				
Speed (ms)	683.4 ± 124.2	663.3 ± 127.6	600.3 ± 63.5	611.6 ± 78.2
Accuracy (%)	89.4 ± 7.4	91.1 ± 7.1	94 ± 3	95.1 ± 3.5

Data presented as mean ± SD; *p ≤ 0.05 between trials, **p ≤ 0.01 between trials, $^{¥}$p ≤ 0.001 between trials, $^{♦}$p ≤ 0.05 between groups, $^{♦♦}$p ≤ 0.01 between groups, $^{\Omega}$p ≤ 0.001 between groups

Analysis of Individual Cognitive Responses of Jockeys in Group 1

Individual differences in cognitive performance between the trials were further analysed within the jockey group revealing all individuals had reduced performance in some element of the cognitive function tasks. Five of the jockeys (subjects 1, 4, 7, 11 and 12) demonstrated impaired cognitive performance in at least 3 of the 4 tasks performed. Subjects 11 and 12, both newly licenced jockeys, had the poorest performance overall, having slower reaction times in DET (-14.2% and -15.5% from baseline respectively), IDN (-17.0% and -9.7% respectively) and OBK (-12% and -4.8% respectively) tasks in addition to also having reduced accuracy in the OCL (-20.6% and -4.5% respectively) and OBK (-8.3% and -8.0% respectively) tasks in the retrial. Whilst demonstrating a quicker reaction time in all 4 tasks completed after the reduction in body mass, subject 1 also appeared to have more errors in each task with the percentage decrease in accuracy from baseline being 2.2%, 3.2%, 4.6% and 3.1% for the DET, IDN, OCL and OBK tasks respectively.

Pearson correlations reveal no significant relationship between speed and accuracy in the various tasks. Figures 3.6, 3.7, 3.8 and 3.9 represent individual performances in each of the tasks DET, IDN, OCL and OBK and a highly individual response is identified with the more difficult tasks resulting in longer times to respond and more errors being made overall in the trials.

In Figure 3.6, it can be seen that while subjects 2, 11 and 12 (all new jockeys) demonstrated improvements in accuracy of 90% to 100%, 94.7% to 100% and 86% to 92.1%, respectively, following the acute body mass loss, slower reaction times in this simple processing speed task were detected. Decrements in reaction time from of 3.1%, 14.2% and 15.5% from baseline were found for subjects 2, 11 and 12 respectively. Subject 8 exhibited a faster reaction time of 2.5% from baseline however accuracy was impaired by 5.4%. Similarly subject 1 also showed a more inaccurate performance in the retrial (-2.2%) however subject 1 also demonstrated the quickest mean response over all in the task with a reaction time of 257 ms in both trials. The longest times to respond in the retrial were detected in 3 newly licenced jockeys with a time of 403 ms for subject 10, 484 ms for subject 11 and 448 ms for subject 12.

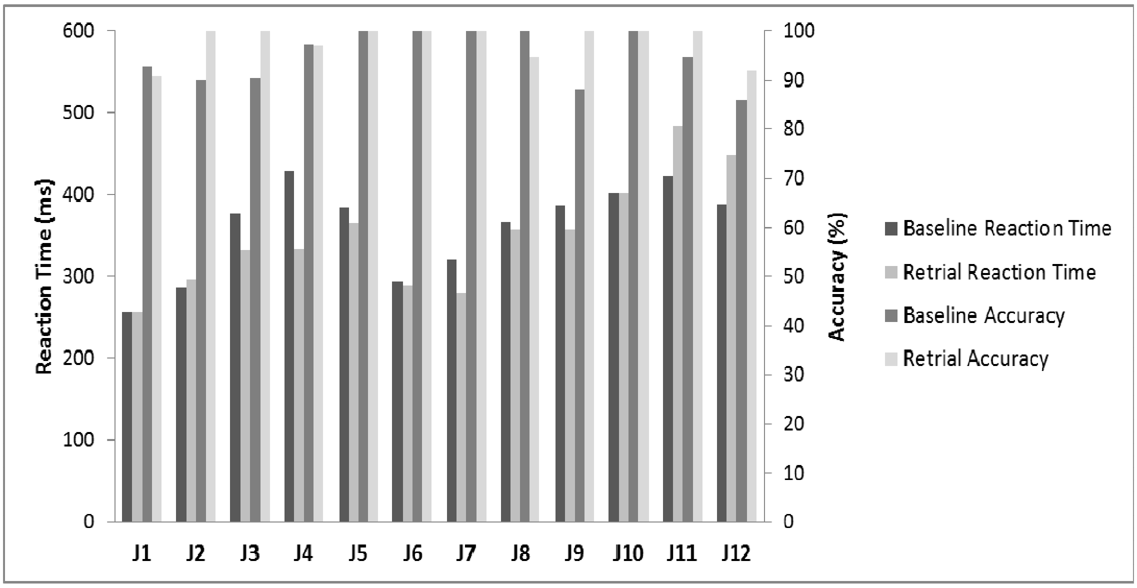


Figure 3.6: Individual Responses in CogSport Detection Task for Simple Reaction Time

The choice reaction time task revealed wide ranging individual impairments in performance (figure 3.7). Subjects 3 and 6 not only had a slower response time by -15.8% and -4.1%, respectively, in the retrial, but also demonstrated larger errors with accuracy scores reduced by 8% and 3.2%. Subjects 4, 9, 11 and 12 all had diminished reaction times in the retrial with mean time to respond increasing from 513 ms to 647 ms (26.1%), 425 ms to 476 ms (12%), 528 ms to 618 ms (17%) and 621 ms to 681 ms (9.7%) for each subject respectively. Subject 7 showed a reduction in accuracy from 100% to 93.7% following the reduction in body mass as did subject 1 with accuracy reducing from 96.8% to 93.7%. Four participants revealed no impairments in this decision making task in the retrial.

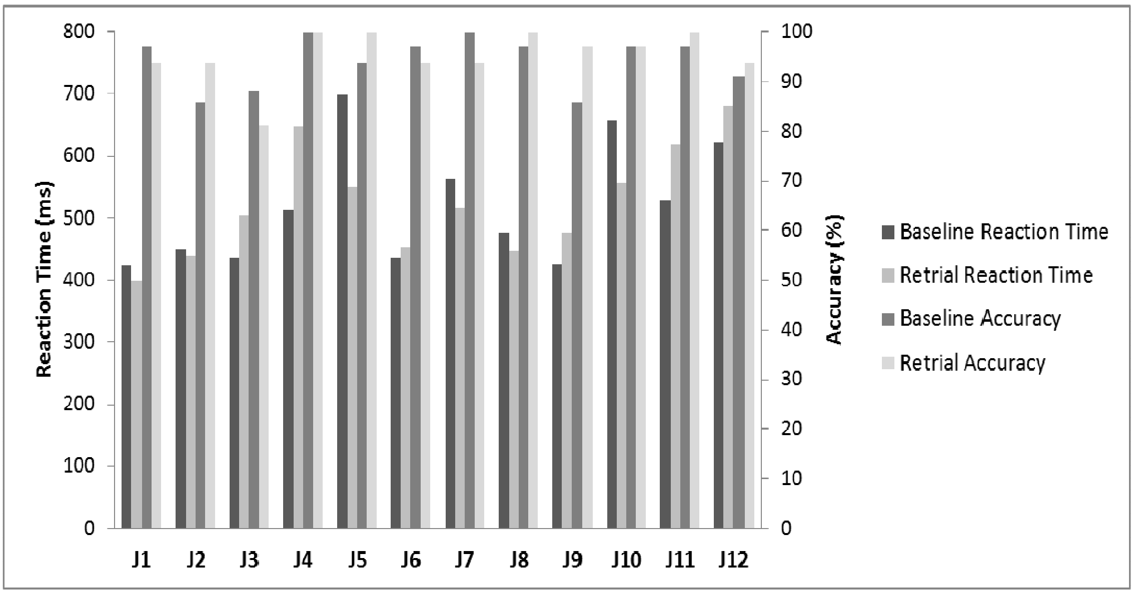


Figure 3.7: Individual Responses in CogSport Identification Task for Choice Reaction Time

No subject achieved 100% accuracy in this task of attention and visual learning and memory in either baseline or the retrial (figure 3.8). Subjects 1, 3, 11 and 12 demonstrated a reduction in accuracy of 4.6%, 2.4%, 20.6% and 4.5%, respectively, from baseline. Subjects 3, 4 and 8 all showed poorer reaction times following the body mass reduction with response times showing great variability: 751 ms to 789 ms, 1017 to 1067 ms and 805 to 817 ms for subjects 3, 4, 8 respectively.

The statistical analysis conducted on the 8 individuals (subjects 2, 6, 7, 8, 9, 10, 11, 12) who were not using weight loss methods on a regular basis, revealed a significant improvement ($p \leq 0.05$) in mean reaction time (914.8 ± 183.5 ms to 818.6 ± 140.2 ms) in this task with a corresponding increase in accuracy.

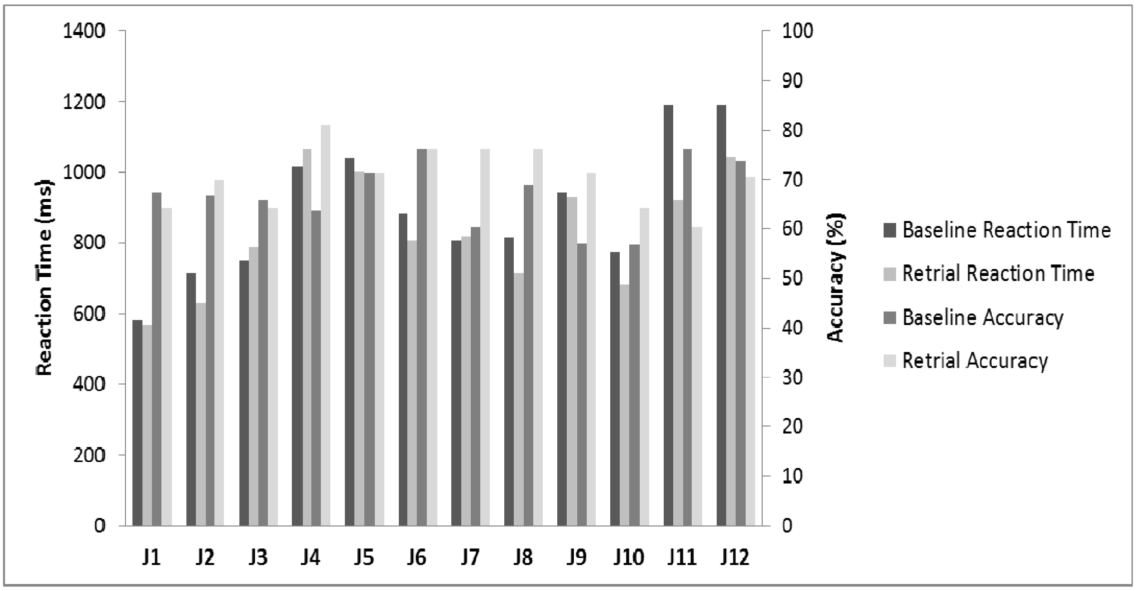


Figure 3.8: Individual Responses in CogSport One Card Learning Task for Attention, Visual Learning and Memory

Subjects 11 and 12 showed impairments in both speed and accuracy in this task of attention and working memory (figure 3.9). The reaction time of subject 11 in the baseline trial was 725 ms and it slowed by 12% to a time of 812 ms in the retrial, and accuracy also decreased from 93.9% to 86.1% (-8.3%) between the trials. Similarly subject 12 demonstrated a longer mean time to respond of 4.8% and a poorer performance in accuracy by 8% in the retrial. Subjects 1, 5 and 7 also showed a reduction in accuracy, while subject 8 took longer to respond to this task in the retrial whilst maintaining accuracy.

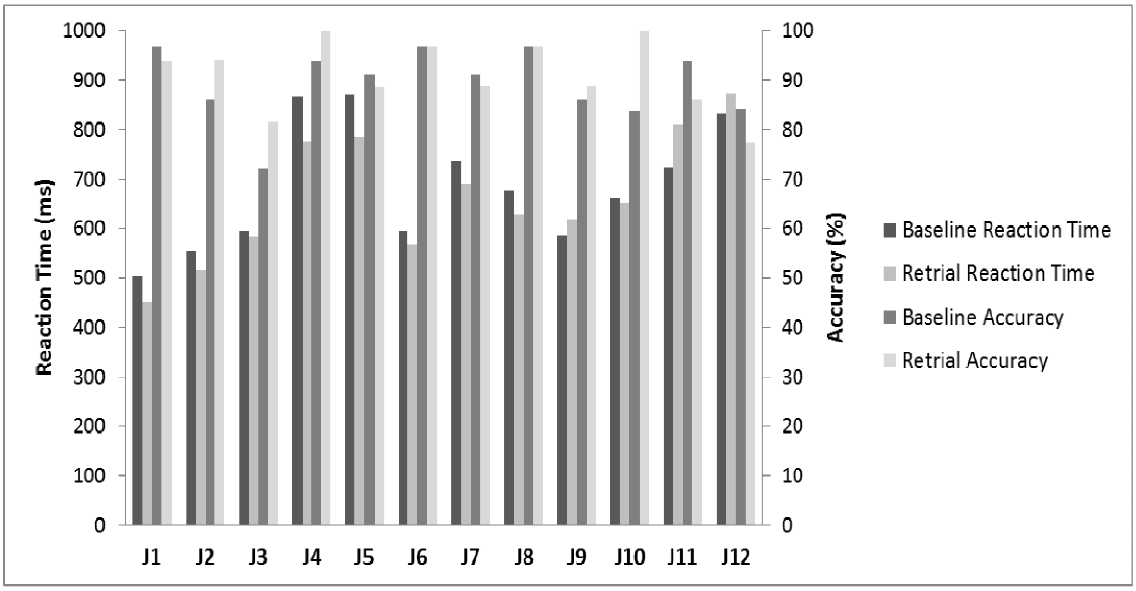
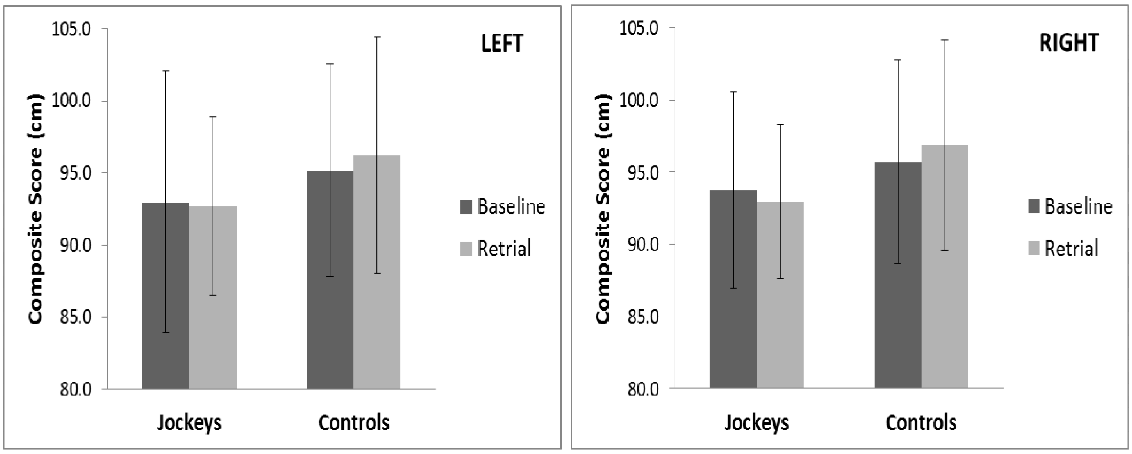


Figure 3.9: Individual Responses in CogSport One Back Card Task for Attention and Working Memory

2. *Balance*

While a slight decrease in balance was seen overall in the jockey group with the composite score decreasing from 93.0 ± 9.0 cm to 92.7 ± 7.4 cm and 93.8 ± 6.8 cm to 93.0 ± 7.0 cm for the left and right side respectively, an increase from 95.2 ± 6.2 cm to 96.2 ± 8.2 cm on the left and 95.7 ± 5.4 cm to 96.9 ± 7.3 cm on the right was apparent in the control group (figure 3.10). In both cases the magnitude of change was very small and no significant differences were found in balance for either the left or right side in either the jockey or control group ($p \geq 0.05$).



*Data presented as mean ± SD; *p ≤ 0.05 between trials, **p ≤ 0.01 between trials, ¥p ≤ 0.001 between trials, ♦p ≤ 0.05 between groups, ♦♦p ≤ 0.01 between groups, Ωp ≤ 0.001 between groups*

Figure 3.10: Left and Right Total Reach Distance Relative to Limb Length

Analysis of Individual Balance Responses in Jockeys in Group 1

Individual differences in balance between trials were further analysed within the jockey group, revealing highly individualised responses, with some association between the magnitude of change and the subjects experience in making weight (figure 3.11). An acute reduction in body mass resulted in similar changes in balance performance on both the left and right side. Six of the jockeys demonstrated an impairment in balance (Left side: range -0.7% to -7.2%; Right side: range -0.3% to -12.5%), 42% (n = 5) experienced an improvement in performance (Left side: range 0.3% to 7.6%; Right side: range 0.3% to 4.9%) and 8% (n = 1) of the cohort of jockeys exhibited no change in balance following a 4% reduction in body mass. Not all individuals experienced the same changes however for both left and right balance.

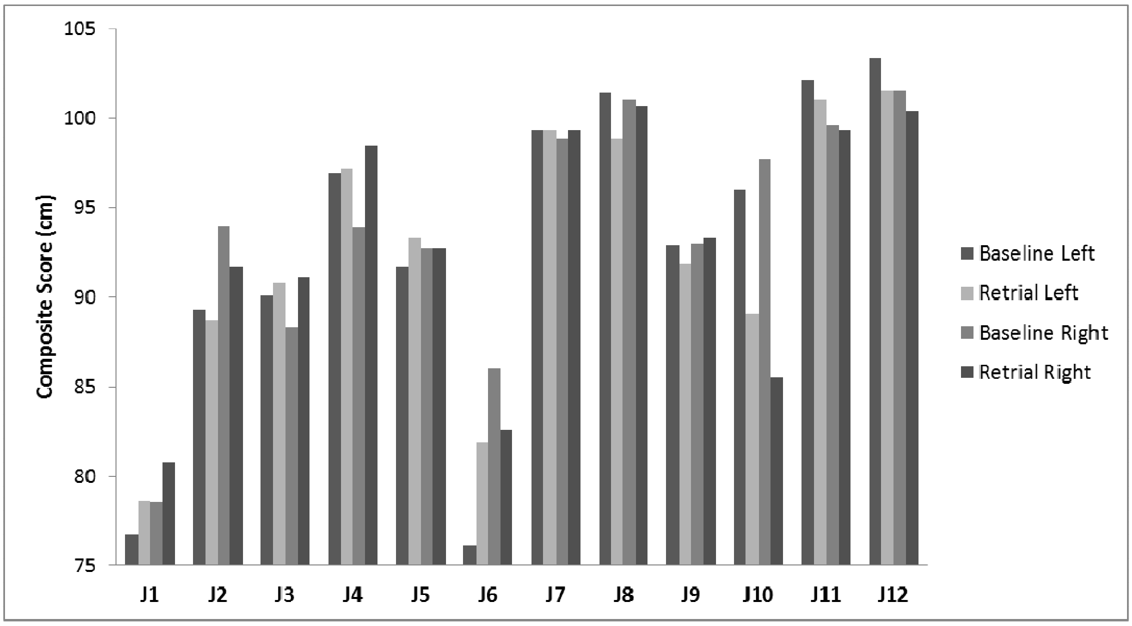


Figure 3.11: Individual differences in left and right balance between the trials in the jockey group

Subjects 2, 8, 10, 11 and 12 all demonstrated a reduction in balance in the retrial following the change in body mass and hydration status. Impairments in the left composite score of 0.7%, 2.5%, 7.2%, 1% and 1.9% were recorded for subjects 2, 8, 10, 11 and 12 respectively. Similarly for the same subjects, a 2.5%, 0.4%, 12.5%, 0.3% and 1.1% reduction in balance performance on the right side was demonstrated. While subject 8 reported not having lost weight rapidly in a while, the other 4 jockeys demonstrating impairments in balance performance on both the left and right side were new jockeys and only recently experiencing the need to 'make weight'.

In contrast, subjects 1, 3 and 4 all demonstrated an increased composite score on both sides. Subject 1 showed a 2.5% and 2.8% improvement in performance for both the left and right side respectively. Subjects 3 and 4 also experienced increases of 0.8% and 0.3% for left balance and 3.2% and 4.9% for right balance performance. Subject 5 showed an increase in balance performance on the left side with no change on the right. Interestingly, these 4 jockeys were documented as undergoing rapid weight loss on a regular basis.

To further test the hypothesis that individuals might actually be habituated to the rapid body mass loss and dehydration levels, a Wilcoxon test was conducted on the 8 individuals (subjects 2, 6, 7, 8, 9, 10, 11, 12) not regularly undergoing rapid body mass loss in preparation for racing. It revealed that the difference in balance on the right side in the retrial were approaching statistical significance (p = 0.078) with right balance decreasing from 96.5 ± 5.2 cm to 94.1 ± 7.1 cm. Performance on the left side was not significantly impaired in the retrial with balance decreasing only slightly from 95.1 ± 9.1 cm to 94.1 ± 7.2 cm (p = 0.438)

3. Anaerobic Performance

Performance variables relating to anaerobic power, anaerobic capacity and anaerobic endurance are displayed in Table 3.6. No significant differences in peak power (p = 0.769), mean power (p = 0.856) or fatigue index (p = 0.395) were found in the cohort of jockeys following the rapid reduction in body mass. The control group demonstrated a significant increased peak power in the retrial despite maintaining the same body mass (p = 0.035).

Table 3.6: Anaerobic Performance Variables

	Jockeys		**Controls**	
	Baseline	*Retrial*	*Baseline*	*Retrial*
Relative Peak Power ($W \cdot kg^{-1}$)	10.4 ± 1.4	10.5 ± 1.4	12.5 ± 1.3$^{\Omega}$	12.9 ± 1.6$^{*\,\Omega}$
Relative Mean Power ($W \cdot kg^{-1}$)	7.7 ± 0.6	7.7 ± 0.6	9.0 ± 0.6$^{\Omega}$	8.8 ± 0.8$^{\Omega}$
Fatigue Index (%)	51.4 ± 13.1	53.5 ± 10.9	52.6 ± 8.8	53.6 ± 6.7

Data presented as mean ± SD; *p ≤ 0.05 between trials, **p ≤ 0.01 between trials, $^{¥}$p ≤ 0.001 between trials, $^{\blacklozenge}$p ≤ 0.05 between groups, $^{\blacklozenge\blacklozenge}$p ≤ 0.01 between groups, $^{\Omega}$p ≤ 0.001 between groups

Analysis of Individual Anaerobic Performance Responses in Jockeys in Group 1

Similar to the results for cognitive function and balance, analysis of the individual anaerobic performance results for jockeys between the trials, revealed large individual differences. Figure 3.12 represents the individual data for relative mean power. Seven of the jockeys exhibited an impairment (range: -0.5% to -6.4%) in anaerobic capacity following the rapid reduction in body mass. Of these jockeys, 3 individuals were newly licenced jockeys (subjects 10, 11 and 12), 2 were not actively reducing weight currently (subjects 7 and 8) while the remaining 2 jockeys were classified as used to rapidly reducing weight (subjects 1 and 4). The newly licenced jockeys, subjects 10, 11 and 12, also showed the greatest impairment in anaerobic capacity with decrements of 6.43%, 4.55% and 4.58% respectively. Four individuals (subjects 2, 3, 5 and 6) had an improved mean power when assessed in the retrial. Subjects 3 and 5 were both used to wasting and both demonstrated an improvement of 5.9%, with two newly licenced jockeys, subjects 2 and 6 improving by 9.1% and 0.9% respectively. One new jockey, subject 9 showed no change between trials.

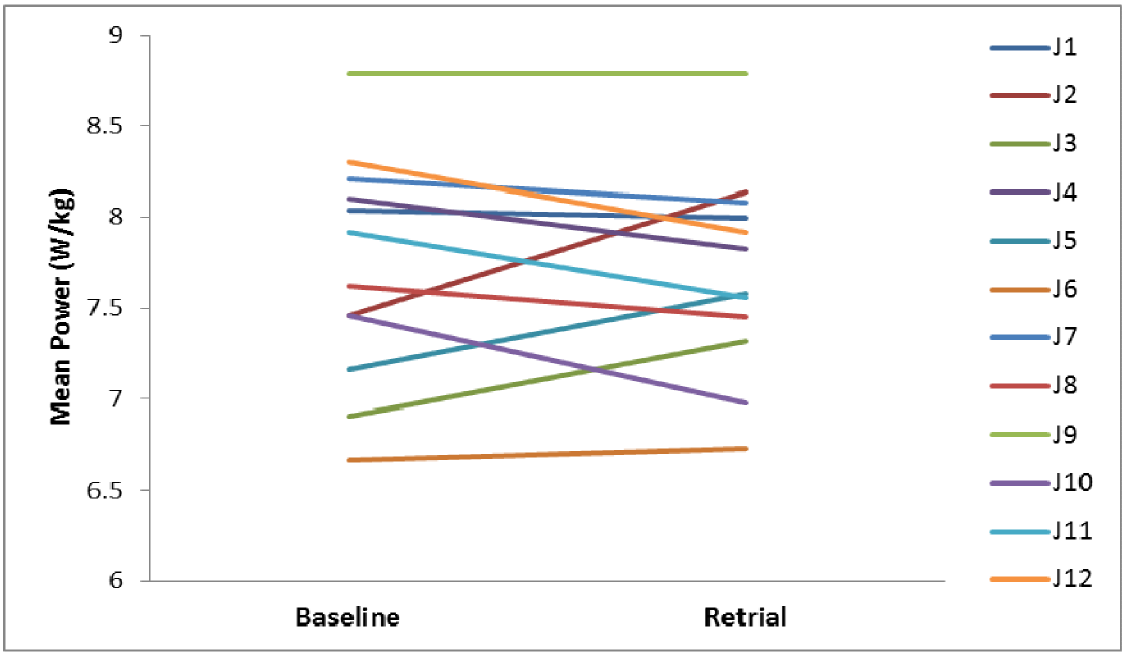


Figure 3.12: Individual Differences in Relative Mean Power between Trials in Jockeys

A reduction in anaerobic endurance was detected in many jockeys (figure 3.13). Eight of the jockeys tested had an increased fatigue index in the retrial. Five of these were the newly licensed jockeys demonstrating an increase in fatigue index of 2.5%, 1.1%, 49.1%, 20.2% and 11.9% for subjects 6, 9, 10, 11 and 12 respectively. The two individuals (subject 7 and 8) who have not "wasted" for a period of time previous to such testing also had an increased fatigue index. Three of the jockeys (subjects 1, 3 and 5) typically wasting on a regular basis showed improvements in anaerobic endurance.

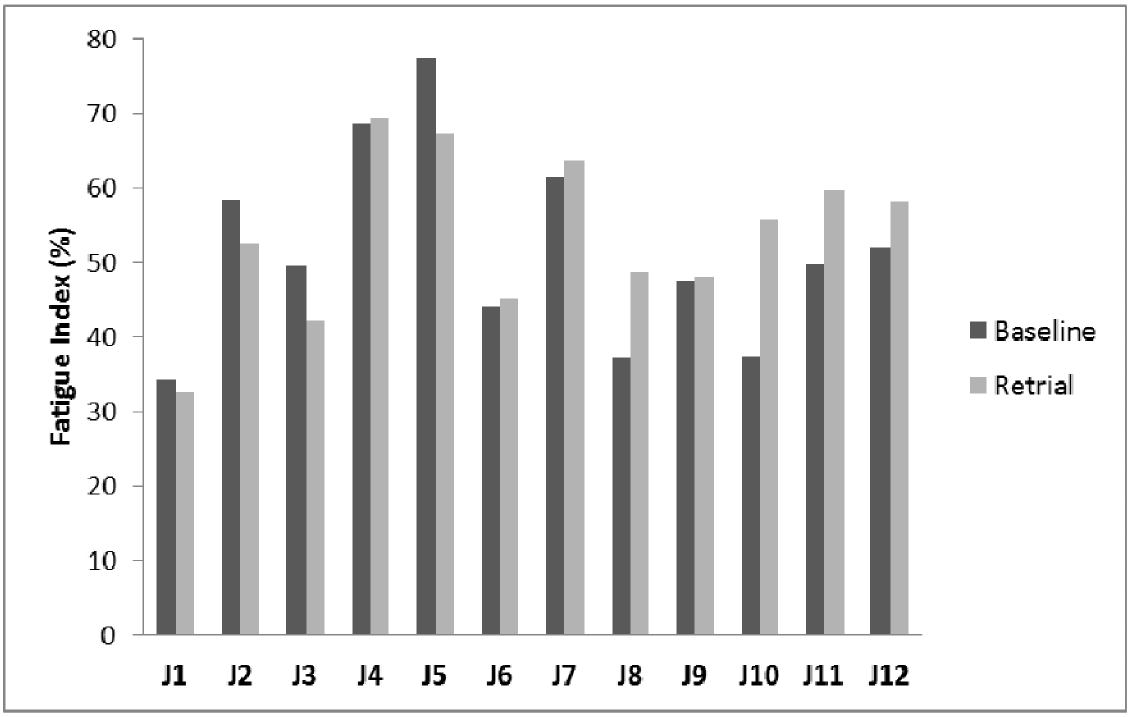


Figure 3.13: Individual Differences in Fatigue Index between Trials in Jockeys

Further analysis, using a paired sample t-test, revealed mean fatigue index was approaching a statistically significant difference in the retrial ($p = 0.079$) in the 8 individuals (subjects 2, 6, 7, 8, 9, 10, 11, 12) not regularly undergoing rapid body mass loss in preparation for racing. Fatigue index increased from 48.4 ± 8.8% to 53.9 ± 6.5% within these subjects following the rapid reduction in body mass.

Three of the jockeys (subjects 2, 3 and 5) were identified as having increased performance in all 3 anaerobic performance parameters assessed with only 1 jockey (subject 7) showing impairments across the board. Of these improvements detected, 2 of the jockeys were documented as being used to the typical weight loss methods. Despite one new jockey (subject 2) showing improvements in all anaerobic performance tests, the 5 other newly licensed jockeys and the 2 individuals not currently employing weight loss practices exhibited a performance decrement in 2 of the 3 variables tested.

3.4.1.6 Overall Performance in Cognitive Function, Balance and Anaerobic Performance

Table 3.7 displays individual performance impairments in all the variables assessed for cognitive function, balance and anaerobic performance following the reduction in body mass. Impairments in either speed or accuracy in the individual cognitive function tasks were considered as an overall reduction in performance in that particular task. The various colours represent the experience the individuals have in rapidly reducing body mass in preparation for racing. Green indicates such individuals who undergo acute weight loss on a regular basis; red represents those newly licenced jockeys while amber signifies those individuals who have not reduced weight acutely for a period of time.

Table 3.7: Individual Performance Impairments in Cognitive Function, Balance and Anaerobic Performance

TASK	J1	J3	J4	J5	J7	J8	J2	J6	J9	J10	J11	J12
BALANCE												
Left Balance						↓	↓		↓	↓	↓	↓
Right Balance						↓	↓	↓		↓	↓	↓
ANAEROBIC PERFORMANCE												
Anaerobic Power					↓			↓	↓			
Anaerobic Capacity	↓		↓		↓	↓				↓	↓	↓
Anaerobic Endurance			↓		↓	↓		↓	↓	↓	↓	↓
COGNITIVE FUNCTION												
Simple Reaction Time	↓		↓			↓	↓			↓	↓	↓
Choice Reaction Time	↓	↓	↓		↓			↓	↓		↓	↓
Attention/Visual Learning/Memory	↓	↓	↓		↓						↓	↓
Attention/ Working Memory	↓			↓	↓				↓		↓	↓

3.4.2 Part B: Competitive Racing Environment

3.4.2.1 Subject Characteristics on Assessment Days

Descriptive data for all jockeys in Group 2 tested at the race course are presented in Table 3.8. Information is provided on the two testing occasions including a day when jockeys were riding at a body mass in which they deemed comfortable (Normal) and a separate day when weight loss strategies were employed to acutely reduce body mass (Light). A significantly reduced body mass of 3.5 ± 1.1 kg equating to 5.7 ± 1.9% (range 2.9 to 8.8%) was seen amongst the jockeys when riding on the Light testing occasion ($p \le 0.001$). This reduction in body mass to meet the designated racing weight resulted in an associated significant increase in Usg ($p \le 0.001$) and individuals being classified as dehydrated on the Light day.

Table 3.8: Subject Characteristics at Baseline (Group 2)

	Jockeys (n = 10)	
	Normal	*Light*
Age (years)	23.4 ± 3.4	
Height (m)	1.65 ± 2.1	
Baseline BMI (kg·m^{-2})	22.7 ± 1.2	
Body Mass (kg)	61.8 ± 5.6	58.3 ± 5.8$^{¥}$
Hydration Status (Usg)	1.017 ± 0.005	1.026 ± 0.003$^{¥}$

Data presented as mean ± SD; $^{*}p \le 0.05$ between trials, $^{**}p \le 0.01$ between trials, $^{¥}p \le 0.001$ between trials; Baseline BMI on normal testing day

3.4.2.2 Cognitive Function Performance

Mean reaction time (ms) and levels of accuracy (%) for each task for cognitive function are presented in Table 3.9. No significant impairments in cognitive performance were detected in any of the variables assessed ($p \ge 0.05$).

Table 3.9: Mean Reaction Times and Accuracy Scores in CogSport Cognitive Function Tasks in a Racing Environment

Cognitive Function Task	Variable	*Normal Day*	*Light Day*
DET	**Speed** (ms)	325.5 ± 37.9	331.4 ± 44.7
Simple Reaction Task	**Accuracy** (%)	99.2 ± 1.3	98.4 ± 1.9
IDN	**Speed** (ms)	547.9 ± 104.6	533.5 ± 83.0
Choice Reaction Task	**Accuracy** (%)	98.4 ± 2.2	95.0 ± 6.0
OCL	**Speed** (ms)	976.1 ± 175.6	938.7 ± 144.7
Attention, Visual Learning & Memory	**Accuracy** (%)	75.5 ± 5.7	71.8 ± 10.1
OBK	**Speed** (ms)	776.9 ± 116.7	697.8 ± 92.8
Attention & Working Memory	**Accuracy** (%)	92.5 ± 7.0	96.5 ± 4.9

Data presented as mean ± SD

Analysis of Individual Cognitive Performance Responses in Jockeys in Group 2

Further analyses of the individual performances in the various tasks of cognitive function were performed to investigate individual responses. Figure 3.14 displays the mean reaction time and accuracy for each individual subject in the decision making task (IDN). It identifies that not only did subject 1 and 6 have slower reaction times (subject 1: from 468 to 540ms; subject 6: from 594 to 611ms) on the Light testing day, but they also had more errors with accuracy decreasing from 100% to 93.8% and 100% to 83.3% respectively. Subject 1 had lost 4.8% of body mass while subject 6 had lost 8% of body mass. Subject 8 demonstrated a mean faster reaction time in Light day testing having lost 4.5% of individual body mass however accuracy was decreased by 9.1% from normal day. Similarly subject 10 also exhibited reductions in accuracy of 8.9% from Normal day testing having lost 8.8% of body mass. Subject 9 (body mass loss of 3.2%) demonstrated a slower reaction time of 5.4% on Light day compared to Normal day testing showing how responses to rapid reductions in body mass are highly individual.

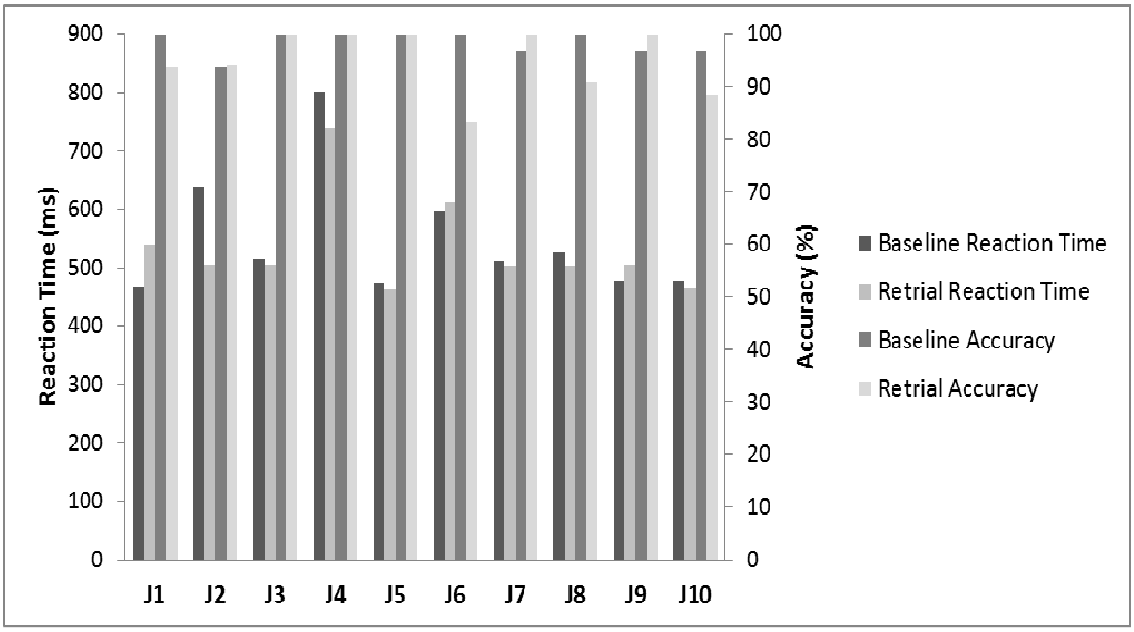


Figure 3.14: Individual Responses in CogSport Identification Task for Choice Reaction Time

Figure 3.15 represents the individual mean reaction times and accuracy scores in the task for attention, visual learning and memory and a variety of responses are displayed similar to previous figures. Subject 3 (-6.7% body mass) demonstrated a poorer mean reaction time in addition to accuracy decrements of 6.1%. Although Subject 2 (body mass loss of 6.4%) performed 17.3% faster on the Light day, this individual also had an increase in errors with accuracy decreasing from 83.3% on Normal day to 58.1% on Light day. Subject 9 (body mass loss of 3.2%) and subject 6 (body mass loss of 8%) also executed faster reaction times (from 879 to 818 ms and from 847 to 837 ms respectively) following the reduction in body mass both however this resulted in more errors being generated. Subjects 4 (-6.4% body mass), 8 (-4.5% body mass) and 10 (-8.8% body mass) all demonstrated slower reaction times while increasing accuracy.

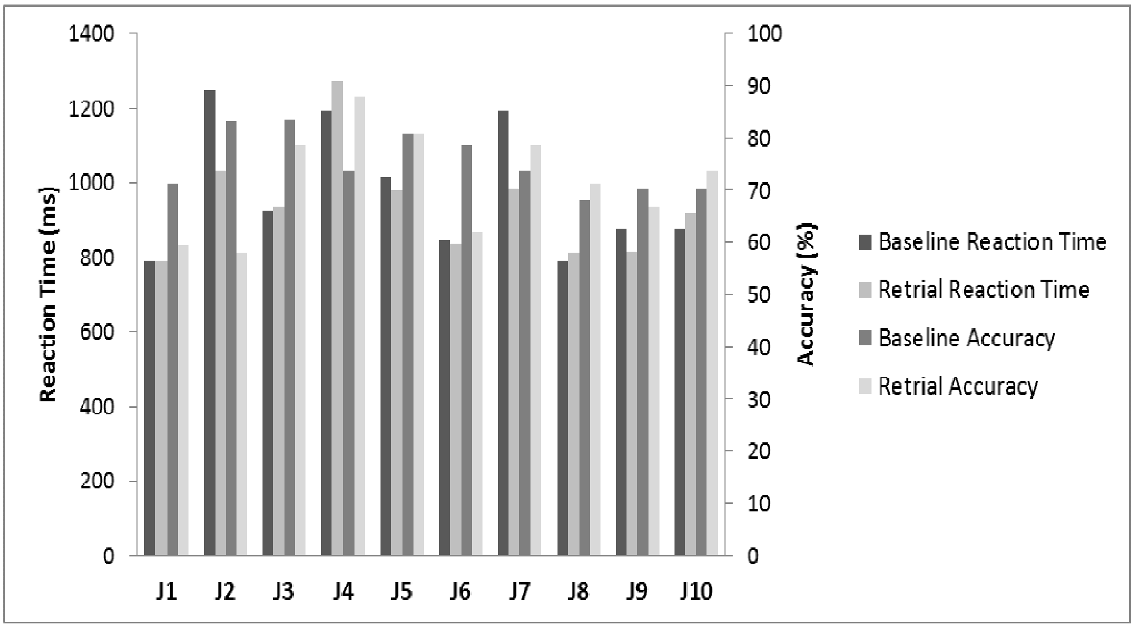


Figure 3.15: Individual Responses in CogSport One Card Learning Task for Attention, Visual Learning and Memory

Subject 5 lost the lowest amount of body mass which equated to 2.9% and was the only individual to show no impairments in any of the cognitive function tasks. This individual also demonstrated the smallest change in hydration status with Usg increasing from 1.022 on the Normal day to 1.024 on the Light day.

3.4.3 Summary

No significant change in cognitive function, balance or anaerobic performance was reported in the group of jockeys in the simulated environment (Group 1) following a 4% reduction in body mass in 48 hours however noticeable individual differences exist within the results. Elimination of the 4 participants who regularly undergo weight loss practices and focusing solely on the newly licenced jockeys and those who do not regularly utilise weight making strategies revealed results of which were approaching statistical significance both in terms of impairments in balance performance ($p = 0.078$) and an increase in fatigue index ($p = 0.079$). Large individual variations were also apparent in the results obtained for cognitive performance within the group of jockeys (Group 2) assessed prior to an actual race. While no statistical significant impairments were reached in Part A or B of this research study as a result of employing acute weight loss strategies, individual responses were highly variable.

3.5 Discussion

The purpose of this study was to investigate the effects of the acute weight loss typically seen in jockeys in preparation for racing on cognitive function, balance and anaerobic performance. In the first part of the study, a simulated environment was created to assess cognitive function, balance and anaerobic performance using a reduction in body mass of 4% and an allowed time of 48 hours between baseline testing and retesting. Following this, cognitive performance was also examined in the jockey's natural environment, immediately prior to racing on two separate occasions; a comfortable (Normal) and a light weight (Light) racing day. It was hypothesized that acute weight loss in preparation for racing would have a negative impact on cognitive and physical performance. Results from this study indicate that a rapid loss in body mass through the typical methods employed by jockeys in preparation for competition is associated with significant increases in Usg but results in no significant impairments in mean cognitive function, balance or anaerobic performance. Despite this reported lack of impact on mean results in the performance variables measured, further analysis of the results revealed a large individual variability in responses was apparent.

Severe food and fluid restriction in conjunction with acute dehydration, through both passive and active methods, were reported amongst the jockeys in this study as the typical methods used to acutely reduce body mass. These weight making strategies are in agreement with those previously reported to be regularly used by jockeys (Dolan et al., 2011, Labadarios et al., 1993, Leydon and Wall, 2002, Moore et al., 2002). While it has been found that jockeys typically accept rides that are at least 4% below their non-riding body mass, it is not uncommon to see a jockey rapidly reducing individual body mass by as much as 10.5%. Furthermore it may be necessary to achieve this with as little as 19 ± 8 hours' notice (Dolan et al., 2013). Testing in the laboratory allowed for the strict control of body mass based on previous work by Dolan et al., (2013). A 4.1 ± 0.2% reduction in body mass achieved through serious dehydration (1.028 – 1.037) was observed in the 48 hours between trials. In the real life setting, limited body mass control was achieved as individuals were required to lose different amounts of weight to align their body mass with the stipulated competition riding weights. A mean body mass loss of 5.7 ± 1.9% (range 2.9 to 8.8%) with an associated significant increase in Usg ($p \leq 0.001$) was seen amongst the jockeys at the race meetings.

3.5.1 Acute Weight Loss and Cognitive Function

Following analysis of cognitive performance on the computer tasks for all subjects, no significant differences were found in any of the domains assessed following the rapid reduction in body mass ($p \geq 0.05$). It was initially believed that the simulated environment may have stimulated the jockeys to overcome the negative influences of the rapid body mass loss with the knowledge that replenishment was to follow immediately after the testing session. For this reason, cognitive assessment was then performed immediately prior to competition at various race meetings, still with no significant cognitive impairments detected in any of the variables assessed.

Results from the current study are similar to those previously reported by Dolan et al., (2013) who also found no performance impairments for simple reaction time, decision making, attention, visual learning and working memory in a group of jockeys following a 4% reduction in body mass over a 48 hour period (Dolan et al., 2013). Initially it was believed such cognitive function assessment methods used in the study by Dolan et al., (2013) were not sensitive enough to detect such cognitive impairments. The computerised assessment tool used in the present study was CogSport which is recognised for its sensitivity shown to evaluating mild cognitive changes (Makdissi et al., 2001), however despite this no significant impairments were detected within this cohort of jockeys. Such findings are in contrast with the work of Labadarios et al., (1993) whom, despite not reporting the specific procedures and measures utilised, found a decline in performance in tasks including memory, recall and reaction times having reduced body mass by up to 6 kg in preparation for racing (Labadarios et al., 1993). Furthermore, Pruscino et al., (2007) reported significant impairments in simple reaction time in two individual case studies in which the jockeys lost in excess of 4% body mass compared to baseline.

Although it is commonly suggested that decrements in cognitive performance typically occur at a reduced body mass of 2% or more (Cian et al., 2001, Cullen et al., 2013, Gopinathan et al., 1988, Tomporowski et al., 2007), dehydration levels of as low as 1.5% have also been indicated to adversely affect cognitive function (Smith et al., 2012). Based on these previous findings it was somewhat surprising no significant cognitive impairments were observed in the present study. Closer examination of the data however revealed many individual differences between testing trials. The previous literature in this area seems to suggest that dehydration per se may not be the primary limiting factor in cognitive performance at the levels currently studied, but that the actual methods used to induce dehydration may be a key contributory factor to the typically observed decrements reported elsewhere (Grandjean and Grandjean, 2007, Lieberman, 2007, Lieberman, 2010, Lieberman, 2012). In this current study, a variety of weight loss strategies were adopted which reflected the typical practices used by each individual jockey to rapidly lose the necessary body mass in preparation for racing. The lack of uniformity and control of the weight loss practices adopted could be regarded as a limitation of the study and may be reflective in the highly individual responses observed, but the author felt it was more important to reflect real practice. While exercise and heat induced acute dehydration has been reported to result in significant impairments of specific aspects of cognitive function (Cian et al., 2001, Gopinathan et al., 1988, Tomporowski et al., 2007), these negative effects appear to be reversible (Cian et al., 2001). Cian et al., (2001) previously reported cognitive performance to be normalised 3.5 hours after dehydration induced through either passive exposure to heat or treadmill exercise, despite the continued level of hypohydration experienced. To further eliminate the various stressors that may negatively impact cognitive performance (e.g. heat, exercise, fatigue), Smith et al., (2012) reported cognitive impairments following a reduction in body mass of 1.5% induced through 12 hours of solely fluid restriction. In contrast, Szinnai et al., (2005) reported that cognitive function remained unchanged following fluid restriction to a dehydration level of 2.6% over 28 hours, independent of the effects of the various stressors. The suggested normalisation of cognitive function after 3.5 hours (Cian et al., 2001) in addition to the preservation of performance following water deprivation seen in the above study (Szinnai et al., 2005) could explain the lack of significance found amongst our results.

In order to reflect the strategies adopted by the jockeys, weight loss methods in the present study were deliberately uncontrolled and included caloric restriction as well as dehydration. Similar studies have been conducted in wrestling also yielding conflicting results. Choma et al., (1998) reported short term memory was impaired in a group of wrestlers assessed immediately post weigh in after a rapid weight loss of 6.2%. In contrast, Landers et al., (2001) reported no significant impairments in attention, visual motor, short term memory and choice reaction time following an average loss of 6.3% of total body mass and assessment taking place immediately pre weigh in. It was suggested the conflicting results may be due to the different assessment times (pre Vs post weigh in) and the associated expectation of replenishment (Landers et al., 2001). In another uncontrolled setting involving military personnel, Lieberman et al., (2005) investigated the effects of sleep loss, heat, dehydration and under nutrition on cognitive function. Following intense training for 53 hours in the heat, participants lost in excess of 4 kg and severe decrements in vigilance, reaction time, attention, memory and reasoning were reported ($p \leq 0.001$). While blood glucose was not assessed in the present study, the significant differences in baseline cognitive parameters between the jockey and control group may potentially be explained by varying blood sugars between the groups at baseline given the previously reported decrements in cognitive function as a result of hypoglycaemia (Warren and Frier, 2005) and no apparent differences in hydration status at baseline between the groups.

Evidence suggests the tasks that require attention, immediate memory and psychomotor skills are the aspects of cognitive function most negatively affected by dehydration (Adan, 2012). While no significant impairments were detected in mean cognitive performance in the present study following the rapid reduction in body mass (simulated and competitive environment), all jockeys assessed, except the individual who only reduced body mass by 2.9%, displayed some element of reduced performance in at least one of the cognitive function tasks no matter how used to weight cycling they were. The range of body mass reductions used throughout this study suggest an individual cognitive performance response exists following acute weight loss. Results from this study indicate that many jockeys may actually demonstrate impairments in some element of cognitive performance. This is of particular concern in the racing environment where jockeys are surrounded by a large number of horses in close proximity and moving at a high velocity. Split second decisions, attention, concentration and memory efficiency can mean the difference between not only winning and losing, but also may impact on the individual safety and welfare of the jockeys as they must monitor and take advantage of fleeting gaps and shifts in the field.

3.5.2 Acute Weight Loss and Balance

No significant changes in balance were detected in the jockeys after the acute reductions in body mass of 4% in 48 hours. The jockey group did show a slight decrease in balance and the controls did demonstrate an increase, but such differences were not significant ($p \geq 0.05$). The current limited literature surrounding the effects of rapid reductions in body mass on balance primarily focus on weight reductions in terms of dehydration induced both passively and actively. The research itself is however inconclusive revealing equivocal findings and as a consequence only provided a limited context on which to interpret the current results.

Despite this, the current findings are consistent with some studies in which dehydration induced by sauna exposure (Derave et al., 1998) or by exercise, heat exposure and fluid restriction (Eberman et al., 2005, Ely et al., 2013, Patel et al., 2007) revealed no significant impairments in balance performance. Eberman et al., (2005) and Patel et al., (2007) used dehydration levels of 3% and 2.5%, respectively, and similar to our study, while no significant findings were revealed in terms of performance impairments, a slight decrease in performance was seen in the dehydrated condition. In both cases it may be suggested that a greater magnitude of dehydration would result in further deficits in balance. Although the present study did use a greater loss in body mass to represent dehydration, it was not the first time the jockeys underwent rapid reductions in body mass which could have been the case within the above studies. It is however not mentioned in such studies how acclimatized the participants were to acute reductions in body mass. Ely et al., (2012) also reported no alterations in dynamic balance following the 4% reduction in body mass even having used a longer recovery period of 90 minutes to minimise the effects of the recent exercise leading to local muscle fatigue which in itself can influence balance.

Results from this study are contradictory to previous work conducted by our research group, in which a significant impairment in balance was previously observed in healthy young males of a similar age to the jockeys who underwent passive dehydration equating to a 4.2% reduction in body mass (Cullen et al., 2013). A significantly reduced composite reach score on the Y Balance test was reported for both the right ($p \leq 0.01$) and left ($p \leq 0.05$) side within participants following dehydration. Even at a lower dehydration level of 2.7% (Derave et al., 1998) and 3% (McKinney et al., 2005), balance deficits have been reported following dehydration induced by exercise, fluid restriction and heat exposure. In all cases, the dehydrated participants were significantly more unstable than when tested in the euhydrated state (Cullen et al., 2013, Derave et al., 1998, McKinney et al., 2005).

Despite the lack of significant changes in balance in the group of jockeys, differences in performance between the trials proved to be highly individual and typically based on experience in using the rapid weight loss methods. Four of the newly licenced jockey's demonstrated impairments in balance overall while the other 2 new jockeys experienced decrements in balance on either the left or right side. In contrast, the 4 jockeys with experience in rapidly losing weight for racing all showed improvements or no change in balance. When combining the 6 new jockeys with the 2 individuals not regularly undergoing acute reductions in body mass, balance on the right side showed a trend towards a reduction in balance performance ($p = 0.078$) following the 4% reduction in body mass, with right balance decreasing from 96.5 ± 5.2 cm to 94.1 ± 7.1 cm. A larger sample size could possibly have revealed a significant decrement in balance. Such results would appear to suggest that the more experienced jockeys seem to be able to tolerate higher levels of dehydration without impacting on their performance. A potential habituation may have occurred in such individuals familiar with weight cycling and as a result are capable of resisting the undesirable effects on balance.

The individual decrements in balance following the rapid reduction in body mass may be explained by a number of physiological mechanisms. Since the vestibular level is the only level of postural control regulation in which liquid intervenes in the sensory transduction mechanisms (Lion et al., 2010), modifications in endolymph volume and composition related to dehydration could be a contributing factor to the postural impairments seen amongst some jockeys in this study. The vestibular fluid modifications may alter the contribution of vestibular sensory input on balance control (Lion et al., 2010). Dehydration may also have altered muscular function through both metabolic and ionic changes and as such contribute to the individual decrements in postural performances (Montain et al., 1998). The individual decrements in balance may be further explained by the fatigue commonly associated with dehydration that could decrease muscle spindle sensitivity and hence modify the accuracy of the proprioceptive information regulating balance (Gauchard et al., 2002).

With the jockey's centre of gravity constantly changing with every stride the horse takes, it is imperative that total body control is maintained to minimise movement distractions that could potentially hinder the horse and cause a change in speed or direction or imbalances to the horse. The individual variability seen amongst the jockeys in this study would indicate that the effects of rapid reductions in body mass on balance are completely individual with the suggestion that a habituation to the effects of such losses are possible and physiological adaptations take place to resist the negative connotations that could exist.

3.5.3 Acute Weight Loss and Anaerobic Performance

No significant differences in peak power (p = 0.769), mean power (p = 0.856) and fatigue index (p = 0.395), as assessed during the standard 30sec WAnT, were found in the cohort of jockeys following the rapid reduction in body mass of 4% in 48 hours. Yoshida et al., (2002) have previously documented there is a critical level of dehydration (between 2.5% and 3.9%) and a critical duration (>30secs) that inhibits anaerobic performance. The mode of dehydration is also believed to contribute to the performance outcome (Kraft et al., 2012). Whether rapid reductions in body mass alter anaerobic performance still remains without a definite answer.

The insignificant findings in the present study in terms of no apparent impairment in peak power and mean power are in agreement with that reported by Cullen et al., (2013) and Jacobs et al. (1980). Cullen et al., (2013) reported passive dehydration by 4.2% of body mass did not alter peak or mean power as measured using a 30sec WAnT. Similarly, Jacobs et al., (1980) reported no significant difference in mean or peak power during a 30sec WAnT at dehydration levels of 2%, 4% or 5% induced via passive heat exposure. Conversely, Webster et al., (1990) reported a rapid reduction in body mass of 4.9% over 36 hours resulted in a 21.5% reduction in anaerobic power and a 9.7% reduction in anaerobic capacity during a 40sec WAnT (both $p \leq 0.05$). Furthermore, Jones et al., (2008) reported that active dehydration of 3.1% via exercise in the heat negatively affected peak power (-18.36%) and mean power (-19.20%), however no significant difference was seen in fatigue index. In contrast to the results of the present study, Cullen et al., (2013) reported a significant increase in fatigue index from 49.8 ± 8.4% to 57.6 ± 11.9% ($p \leq 0.01$) following passive dehydration by 4.2%.

Analysis of the individual results revealed 58% (n = 7) of the jockeys exhibited an impairment in anaerobic capacity following the rapid reduction in body mass. Three newly licenced jockeys and 2 jockeys not actively undergoing weight cycling were included amongst these individuals. An increase in fatigue index was seen in the retrial in sixty seven percent (n = 8) of the jockeys tested, of which included 5 of the newly licensed jockeys and the 2 individuals not currently undergoing rapid weight loss on a regular basis. Further analysis of the 8 individuals not regularly undergoing rapid body mass loss in preparation for racing revealed that fatigue index was reaching a statistically significant difference in the retrial (p = 0.079) increasing from 48.4 ± 8.8% to 53.9 ± 6.5% of which a larger sample size could potentially have allowed the finding to become significant. Two of the jockeys regularly undergoing weight loss in preparation for racing showed no anaerobic performance decrements, with another showing only impairment in 1 performance variable. Despite one new jockey showing improvements in all anaerobic performance tests, the 5 other newly licensed jockeys and the 2 individuals not currently employing weight loss practices exhibited a performance decrement in 2 of the 3 variables tested.

Based on an analysis of the individual data there is a suggestion that a dehydration threshold of 4% appears to be causing performance decrements for those individuals who are not accustomed to such rapid reductions in body mass. Generally an improvement in peak power was detected within the group which may be explained given the fact a simulated environment was used and individuals were aware it was the last test they were required to complete before they were able to refuel. This then might explain the increase in fatigue index in many individuals as although initially presuming they were capable of exerting themselves for 30 seconds, this appeared not to be the case. While the precise physiological mechanisms remain unclear, the impairments in anaerobic performance amongst some individuals may be due to the decrease in muscle contractibility as a result of the altered electrolyte concentration (i.e. loss of potassium) associated with dehydration (Yoshida et al., 2002, Jones et al., 2008) or glycogen depletion following the increased utilisation of muscle glycogen resulting from the enhanced sympathetic nervous system from prolonged dehydration (Yoshida et al., 2002). The apparent fatigue may potentially explain the individual differences in balance performance due to alterations in muscle spindle sensitivity (Gauchard et al., 2002).

Horse races vary in length from 1 to 7.2 km and may have obstacles depending on the type of race, flat versus national hunt. For the duration of the race, the jockey is perched 3m above the ground crouching over the saddle with great muscular effort required to keep in control and push the horse as necessary while moving at speeds in excess of 65 $km \cdot h^{-1}$. Lower anaerobic fitness has been reported to be associated with a greater risk of falls (Hitchens et al., 2011). Lack of muscular strength and endurance may result in the jockey being thrown out of the saddle, hindering the performance of the horse and causing it to lose balance. While it can be postulated that the jockeys who regularly undergo weight cycling in preparation for racing may actually be habituated to the chosen dehydration level of 4%, this is likely not the case for all the individuals, especially the newly licenced jockeys. Furthermore, very often body mass reductions in excess of 4% are common amongst jockeys (Dolan et al., 2013). Although no significant impairments were apparent in anaerobic performance following the rapid reduction in body mass, the individual performance decrements are a cause for concern and warrant further investigation.

3.5.4 Summary

In such a highly competitive and dangerous sport, being physically fit and mentally alert is crucial to jockeys who careers depend on the ability to acutely achieve a low body mass in order to compete. Both newly licenced jockeys with minimal experience in weight cycling to those jockeys who regularly undergo acute reductions in body mass participated in this study. While it was apparent that some jockeys did not have the ability to resist the deleterious effects of a rapid reduction in body mass, many individual differences were reported within the results of this study. A general trend existed towards individuals not accustomed to weight cycling showing impairments in balance and anaerobic performance when compared to the individuals who frequently undergo acute reductions in body mass. This suggests a potential habituation to such a level of dehydration and reduction in body mass in which the more experienced jockeys were able to tolerate higher levels of dehydration without impacting on their performance. While no direct evidence exists supporting the suggestion, Franchini et al., (2012) suggests that regular weight cycling may lead to the development of physiological adaptations in athletes allowing them to preserve performance after weight loss. Despite having no precise strategy for managing and achieving the required body mass reduction, the frequency of using acute weight loss practices to meet the stipulated racing weights throughout a long and intense year would thus suggest a possible attenuation to the expected detrimental response indicating a potential habituation to such severe body mass reductions and the associated increased level of dehydration.

3.6 Limitations

Numerous limitations are present within this study which may have impacted on the interpretation of the results.

i. Limited Access of Participants and Relevance of Control Group / Small Sample Size

The control group were used to assess the validity of the testing protocol and to ensure maintaining usual dietary and physical activity habits between trials revealed no apparent changes in any measurement made. However, a cross-over design in which the jockeys acted as their own controls or if another group of jockeys acted as the controls could have allowed enhanced identification of subtle changes in the variables assessed as a result of rapidly reducing body mass. This approach was unfortunately impractical however given the length and intensity of the racing season, in addition to the unique nature of this group of individuals that limited access to participants. The limited access of participants may have affected the homogenous nature of the jockey group and a greater sample size may have influenced the study. Thirty two percent and 26% of all male apprentice jockeys available at the time of testing were recruited for participation in Part A and B of this study respectively bearing in mind the potential pool of apprentice jockeys to be recruited was further limited by those actually receiving races and those granted permission to leave yard duties by the various trainers.

ii. Inability to Distinguish Between Individual Influences

The study design employed was similar to a small portion of the literature in which the primary concern was acute reductions in body mass (Choma et al., 1998, Landers et al., 2001, Hall and Lane, 2001). Body mass loss techniques within this study were uncontrolled and included caloric restriction, as well as dehydration. While the protocol was valid for replicating performance after acute attempts to 'make weight' as typically seen in horse racing, it remains difficult to distinguish between the individual influences and what may predominantly impact the various variables. Furthermore, body mass and hydration status were only assessed prior to each trial. Evaluation of blood glucose would provide valuable information on glycogen stores at the time of testing.

iii. Relevance of the Testing Protocols

Limitations may exist in the application of the test protocols used within this study to racing performance. Valid and reliable tests of racing performance have yet to be established. While the computerised cognitive function test (CogState Sport) used in this study is currently the cognitive function assessment used to determine concussion amongst jockeys in Ireland, specific balance and anaerobic performance assessment methods have yet to be identified for racing performance. The lack of specificity of the chosen anaerobic performance test (WAnT) could possibly be deemed as a limitation to the study however difficulties exist when measuring performance sports specifically due to the unique relationship between the rider and horse. More sport specific assessments would allow a greater insight into the impacts of rapid reductions in body mass on specific racing performance.

iv. Habituation of Jockeys to Body Mass Reductions of 4%

Part A of this study included apprentice and conditional jockeys with varying experience, some just newly licenced jockeys to others who regularly race. Part B put no limits on the necessary weight loss and only requested individuals to be tested on a day when they were subjectively riding at a comfortable weight and another when riding at a lighter weight in which they had to reduce their weight. Given the high individual variability seen within the results, it is suggested many jockeys may actually be habituated to a body mass loss of 4%. Dolan et al., (2013) previously reported the typical riding mass for both flat and national hunt jockeys was 3.6 ± 2.4% below non-riding mass, with flat jockeys typically losing 4.2 ± 1.9% of their body mass for racing and national hunt jockeys reporting a body mass loss of 3.1 ± 2.5% . Furthermore rapid reductions in body mass of up to 8% and 10.5% for flat jockeys and national hunt jockeys respectively were also reported. Typically provided with 24 to 72 hours notification of the required weight standard, as little as 19 ± 8 hours have been reported (Dolan et al., 2013). While greater reductions in body mass were seen amongst many jockeys at the races, a more controlled loss of greater than 4% body mass losses and even graded body mass losses (i.e. 2%, 4%, 6%) may be required to gain further insights into the effects of such weight making practices on various performance variables.

3.7 Conclusion

Findings from this study indicate that a rapid loss in body mass through the typical methods employed for racing in association with a significant increase in Usg results in no significant impairments in cognitive function, balance or anaerobic performance. Analysis of the individual data sets would suggest the individual variability in performance following rapid body mass reductions and the associated dehydration is a serious cause of concern, especially since any sudden change in the speed or direction of the horse could result in a serious accident for either the jockey riding the horse or the surrounding jockeys. The rapid weight reductions in this study appear to be more commonly negatively affecting the newer jockeys who only recently have begun acute weight loss practices. The many individual differences apparent within the results of this study suggest a potential habituation to such a level of dehydration and reduction in body mass. A greater reduction in body mass, as seen amongst many jockeys in racing, may be required to gain further insights into the effects of such weight making practices on various performance variables.

Further research is required to investigate the extent to which some jockeys may now be habituated to such a level of dehydration and reduction in body mass in order to encourage best practices in preparation for competition ensuring the optimisation of health, safety and performance of all jockeys on the racing track.

Chapter Four: The Long Term Health Implications of a Career in Horse Racing

Irish St Leger 2013

4.1 Abstract

Aim: Many jockeys are living and competing in a chronic energy deficient and dehydrated state for the duration of their horse racing career as a result of utilising severe rapid weight loss strategies to achieve and maintain the required low body mass. Despite this, the long term implications of such a lifestyle remain unknown. The purpose of this study was to establish the long term health impacts associated with the prolonged use of rapid weight loss strategies and an energy restricted lifestyle in a group of retired jockeys. **Methods:** Thirty seven retired male jockeys (age 63 ± 10yr; height 1.64 ± 0.04 m; body mass 71.7 ± 11.0 kg; BMI 26.5 ± 3.8 $kg \cdot m^{-2}$) attended an early morning testing session in a fasted state. Resting metabolic rate (RMR) tests, oral glucose tolerance tests and dual energy X-ray absorptiometry (DEXA) scans were performed to assess metabolism, body composition and bone health status. Fasting blood samples were also used to establish liver, kidney and thyroid function, and a bone, lipid and hormonal profile. A health and lifestyle questionnaire was also completed by all participants in a semi-structured interview format. **Results:** A large proportion of the participants experienced excessive body mass gains since retiring with 43% classified as overweight and 19% as obese; mean total cholesterol (5.64 ± 1.3 $mmol \cdot L^{-1}$) was elevated; mean absolute RMR was 1428 ± 202 $kcal \cdot day^{-1}$; mean whole body osteopaenia (T Score: -1.1 ± 0.8) was reported for the retired jockeys, Z Scores appeared normal for all sites; mean serum 25(OH) D levels (49.4 ± 25.3 $nmol \cdot L^{-1}$) were below the recommended threshold. Despite slightly raised sex hormone binding globulin (SHBG) (53. 97 ± 17.4 $nmol \cdot L^{-1}$), no other apparent abnormalities were present for kidney, liver and thyroid function as well as hormonal profile and glucose metabolism. **Conclusion:** Many retired jockeys experienced excessive gains in body mass since retiring, mean RMR was lower compared to age, gender and BMI matched individuals from various other studies and a large proportion (62%) of the individuals displayed osteopaenia in at least one of the bone sites assessed. Results suggest a life of chronic weight restriction and reliance on unhealthy weight making practices may have some long term health effects. Longitudinally analysis of individual jockeys throughout their racing career would ideally be required to assess any long term implications however results from this preliminary study provide a unique insight into the health characteristics of retired jockeys. Educational and support structures are required for both current and retired jockeys to minimise and limit any potential deleterious effects on health during their career in horse racing and beyond.

4.2 Introduction

Many aspiring jockeys typically enter the horse racing industry at the young age of 15.8 ± 0.9 years (Dolan et al., 2011) and may have careers lasting up to 40 years (Tomkinson et al., 2012). The weight restricted nature of horse racing necessitates many jockeys to consistently maintain an extremely low body mass in order to increase riding opportunities. The constant reliance on unhealthy weight making strategies amongst many jockeys are reported widely (Dolan et al., 2011, Labadarios et al., 1993, Leydon and Wall, 2002, Moore et al., 2002) inevitably leaving a large proportion of jockeys in a chronic energy deficient and dehydrated state (Dolan et al., 2011, Warrington et al., 2009).

Results from previous studies reveal a high incidence of low BMD and increased bone turnover are prevalent amongst jockeys (Dolan et al., 2012a, Dolan et al., 2012b, Greene et al., 2013, Leydon and Wall, 2002, Waldron-Lynch et al., 2010, Warrington et al., 2009). An altered hormonal profile associated with bone loss has also been described within this unique population (Dolan et al., 2012b). Such findings may have serious implications for jockeys especially in the context of the high risk nature of this sport and the frequent occurrence of falls (Warrington et al., 2009, Rueda et al., 2010, Hitchens et al., 2009a). Moreover, such findings indicate the constant reliance on unhealthy weight making strategies may restrict the achievement of individual genetic potential for peak bone mass potentially producing deleterious musculoskeletal effects in later life (Greene et al., 2013). Increasing bone mass and strength during growth is known as the primary strategy for the prevention of osteoporosis (Bonjour et al., 2009, Hernandez et al., 2003).

Unequivocal evidence exists suggesting the challenges many jockeys face making weight and the associated health issues during their career (Dolan et al., 2011, Warrington et al., 2009). For many, the struggle with weight can prematurely end a career in horse racing (Speed et al., 2001). It has been suggested that jockeys fortunate enough to have a long racing career are likely to suffer deterioration in physical health upon retirement due to the stringent demands imposed by sustaining a career in horse racing (Speed et al., 2001). Back problems, arthritis, other joint related disorders and dental problems have been reported as the most common health issues experienced by jockeys since retirement (Speed et al., 2001, Tomkinson et al., 2012). Excessive weight gain was also experienced amongst a small proportion (13%) after retiring from racing (Speed et al., 2001). Such findings were all achieved through the completion of questionnaires and very little is known on the long term health implications of a career entrenched with unhealthy practices necessary to achieve and maintain a low body mass on a regular basis. Despite the speculated impairments in bone health, many other complications may arise. Large fluctuations in body mass early in life, be it during growth or young adulthood, have been suggested to represent a risk factor for the development of insulin-related complications in later years, specifically obesity, type 2 diabetes and cardiovascular disease (Dulloo, 2005).

Ideally, longitudinal data are required to assess the long-term health effects of a lifestyle entrenched with a severe reliance on potentially dangerous weight loss practices. In the interim however, with information on the health status of current jockeys in mind, further research is required on retired jockeys to establish the potential long-term health impacts and risks factors associated with the lifestyle demands of a jockey in a weight restricted sport. The purpose of this study was therefore to describe and evaluate the physiological and health characteristics of retired jockeys and establish the potential long term implications resulting from the prolonged use of severe weight making strategies and the associated energy restricted lifestyle.

4.2.1 Aims and Objectives

The aim of this study was to establish the potential long term health impact associated with the prolonged use of rapid weight loss strategies and an energy restricted lifestyle in a group of retired jockeys.

Objective One:

To evaluate the physiological and health characteristics of a group of retired jockeys.

Objective Two:

To compare the physiological and health characteristics of a group of retired jockeys to existing data on current jockeys as well as age matched normative data.

Objective Three:

To establish the long term health effects and potential risks factors associated with the lifestyle of demands of a jockey.

Hypothesis

That as a result of a career using unhealthy weight loss strategies, retired jockeys suffer from impaired physical health inclusive of excessive weight gain, poor bone health, reduced RMR and impaired kidney function compared to age matched individuals.

4.3 Methods

4.3.1 Study Design Overview

Thirty seven retired male jockeys volunteered to participate in this research study. Participants were required to attend an early morning testing session in DCU in a fasted state where they underwent various tests including measurement of Resting Metabolic Rate (RMR), blood pressure assessment, blood tests, Oral Glucose Tolerance Test (OGTT) and a Dual Energy X-ray Absorptiometry (DEXA) scan (see figure 4.1). A health and lifestyle questionnaire was completed with the individuals, in a semi-structured interview format, to establish the past and present lifestyle practices of the individuals throughout their career as a jockey and beyond. Any medical issues that arose within the findings of this study resulted in individual referral to the Turf Club Chief Medical Officer and all participants received a complete copy of their individual results to follow up with their G.P *(Appendix F)*. Ethical approval for this study was granted by the Dublin City University Research Ethics Committee.

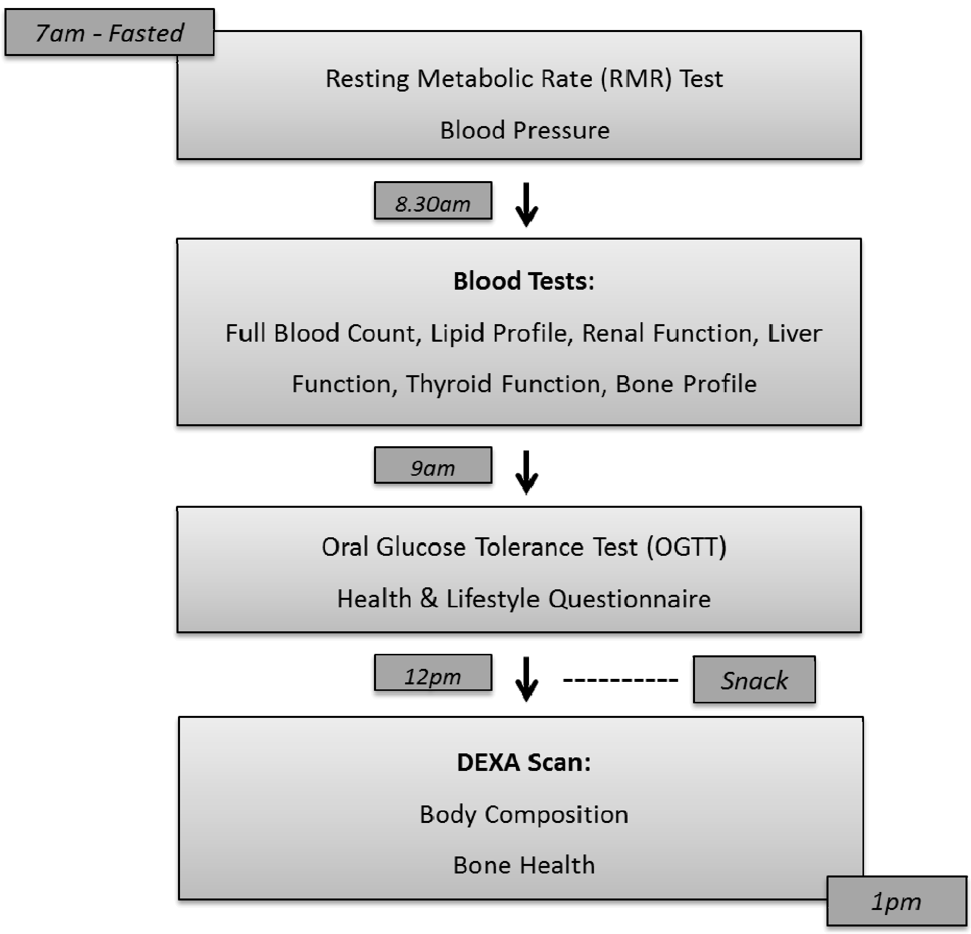


Figure 4.1: Schematic Representation of the Experimental Design completed by the Retired Jockeys

4.3.2 Participants

Thirty seven retired male jockeys were recruited to participate in this research study. As no database existed as a registry of contact details for all former jockeys in Ireland, participants were recruited via mass mailing *(Appendix D)* all retired jockeys who were receiving a pension or who had applied for a pension from the Turf Club in 2012 (n = 119). Although not all former jockeys were included in this study, the sample was believed to provide a good representation of the retired jockey population in Ireland. To receive a pension from the Turf Club required a minimum of 8 licences to be taken out during a career in racing (i.e. 8 years of professional racing) indicating the high calibre of jockeys recruited. Inclusion criteria included male retired jockeys with a minimum of 8 years racing experience (i.e. on the pension directory) and exclusion criteria included current professional jockeys or anyone with a current known temporary health issue inclusive of cold or flu. All participants were posted out a general information package *(Appendix E)* in advance of the scheduled testing session including information on attending the morning testing session in a fasted state, not having eaten or taking fluid other than water since the last evening meal (no more than 16 hours prior to testing), keeping hydrated, the appropriate clothing to be worn, not smoking on the morning of the test and not to participate in strenuous exercise the day preceding the session. The package also included a plain language statement *(Plain Language Statement, Appendix A2)* explaining the procedures, risks, possible benefits, confidentiality and contact information if the participant had any concerns. Detailed medical history *(General Health Questionnaire, Appendix C)* and written informed consent *(Informed Consent Form, Appendix B2)* were received prior to participation in this study.

4.3.3 Procedures

4.3.3.1 Anthropometric Assessment:

Body mass was assessed in minimal clothing and reported to the nearest 100g using a portable digital scales (Salter, Germany). Stretched stature was measured to the nearest mm using a portable Stadiometer (Seca, Leicester Height Measure). Body mass index (BMI; $kg \cdot m^{-2}$) was calculated by dividing the weight in kilograms by the square of the height in metres.

4.3.3.2 Resting Metabolic Rate (RMR):

Open circuit indirect calorimetry using a perspex canopy in the dilution testing mode (Vmax, Sensormedics, Italia, Milan, Italy) was used to assess RMR through the measurement of respiratory gas exchange. Before each test, the O_2 and CO_2 sensors were calibrated by using mixed reference gases of known compositions (20% O_2, 0.75% CO_2). Participants lay in a supine position in a quiet, dimly lit, thermally neutral room for 60minutes, and were instructed to avoid hyperventilation, fidgeting or falling asleep during the test (Horie et al., 2009). After 30minutes the canopy was placed over the subject's head and the ventilated hood method was used to measure O_2 consumption and CO_2 production for a further 30minute period (Gravante et al., 2001, Sjodin et al., 1996). A stream of air, determined by the subject's minute ventilation, was forced through the canopy by a pump. The dilute expired CO_2 ($FECO_2$) was then maintained between the necessary target range of (0.5%-1.0%) (Gravante et al., 2001). The mean values of VO_2 ($L \cdot min^{-1}$) and non-protein Respiratory Quotient (RQ) for the final 15 minutes of steady state at the end of the 30 minute measuring period were used for analysis. RMR was calculated from the VO_2 and non-protein RQ values using the modified Weir equation (Weir, 1949):

$$RMR\ (kcal \cdot min^{-1}) = [(1.1 * \text{non-protein } RQ) + 3.9] * VO_2\ (L \cdot min^{-1})$$

$$REE\ (kcal \cdot day^{-1}) = RMR \times 1440\ min$$

Figure 4.2: Resting Metabolic Rate Test Being Conducted as Part of the Research Study

4.3.3.3 Blood Pressure:

Blood Pressure was assessed using a digital blood pressure monitor (Omron M2 Basic, Omron Healthcare Europe B.V, The Netherlands) directly after the RMR was completed to ensure the participant was fully rested. The cuff was placed on the bare upper arm and the participant remained still and quiet as blood pressure was measured twice. The mean of the two results was used as the individual's blood pressure.

4.3.3.4 Blood Tests:

1. ***Blood Collection & Storage***

Blood samples were taken in a fasted state. A trained phlebotomist administered the cannulation of the antecubital vein from which the blood samples were then acquired for the duration of the testing session. Various vacutainers were used depending on the medium the tests being conducted would use for analysis – plasma, serum, whole blood. At baseline, a total of 20 ml of blood was taken in the following order: 3 silicone coated vacutainers (serum, red closure, 4 ml each), 1 lithium heparin vacutainer (plasma, green closure, 2 ml), 1 Ethylenediaminetetraacetic acid (EDTA) vacutainer (whole blood, lavender closure, 2 ml) and 1 sodium fluoride vacutainer (plasma, grey closure, 2 ml). Serum samples were allowed to sit for 20 minutes at room temperature before being placed on ice while all other samples were placed straight onto ice until analysis preparation took place as soon as possible. Tests requiring whole blood were directly analysed without any further processing. Samples involving both plasma and serum were centrifuged at 4°C, 3000 RPM for 15 minutes (ALC multispeed refrigerated centrifuge PK121R, Medical Supply Co Ltd, Ireland). Plasma and serum were separated into their respective eppendorfs (0.5ml) and then stored at -80°C until analysed. All samples were carefully labelled using the participants ID number, sample number and date of testing.

2. ***Biochemical Analysis***

Comprehensive haematological analyses were conducted in collaboration with a local hospital, Beaumont Hospital Dublin. Full blood counts and glucose were measured using the Randox Daytona Analyser (Randox Laboratories LTD, UK). Biochemical analysis for kidney (urea, creatinine, sodium (Na^+), potassium (K^+), chloride (Cl), bicarbonate (TCO_2), urate) and liver function (total protein, bilirubin, albumin, alkaline phosphatase (ALP), alanine aminotransferase (ALT)), lipid profiles (total cholesterol, high density lipoprotein (HDL), low density lipoprotein (LDL), triglycerides) and some bone markers (calcium (Ca), inorganic phosphorus, magnesium (Mg), ALP) were performed on the Beckman AU5400 analyser (Beckman Coulter, Ireland). Thyroid function (free thyroxine (T4), thyroid stimulating hormone (TSH)), cortisol and prostate-specific antigen (PSA) were analysed using a paramagnetic particle chemiluminescent immunoassay on the Beckman DxI immunoassay system (Beckman Coulter, Ireland). Testosterone was measured by solid phase radioimmunoassay (Spectria, Orion Diagnosticia, Finland). Sex hormone binding globulin (SHBG) was measured by a chemiluminescent microparticle immunoassay (Abbot Diagnostics, Architect, USA). Serum 25 (OH) D levels were measured using a commercially available competitive radioimmunoassay kit (DiaSorin, Stillwater, USA). Parathyroid hormone (PTH) was measured using an immunoassay on an ELECSYS 2010 analyser (Roche Diagnostics, Ireland). Estimated glomerular filtration rate (eGFR) was estimated using the Chronic Kidney Disease Epidemiology Collaboration Formula (CKD-EPI) for males: $eGFR = 141 \times (Scr/0.9)^{-0.411} \times (0.993)^{Age}$ where Scr is serum creatinine in $mg \cdot dL^{-1}$ (Levey et al., 2009).

4.3.3.5 Oral Glucose Tolerance Test (OGTT):

An oral Glucose Tolerance Test (OGTT) was used in the assessment of glucose metabolism. A blood sample (sodium fluoride vacutainer, plasma, grey closure, 2 ml) was previously obtained after cannulation for the measurement of fasting glucose. The participant then consumed 75g of glucose (in the form of dextrose) in a 300 ml solution (121 ml of Polycal Liquid Orange and 179 ml of water). A blood sample (2 ml) was then taken again after 120 minutes to determine the individual body’s response to glucose. The subject remained in a seated position for this period of time.

4.3.3.6 Health and Lifestyle Questionnaire:

The questionnaire was completed with the participants in interview format to establish further information on each participant’s health and lifestyle, both past and current. The questionnaire was based on the health and lifestyle questionnaire previously validated and administered amongst professional jockeys (Dolan et al., 2011) however it was slightly modified to include specific aspects related to retirement. Information was gathered on:

- the age they became a jockey
- length of time as a jockey
- number of winners as a jockey
- how long ago they retired
- the reason that caused them to retire
- if they ever experienced problems making weight
- how did they manage their weight
- do they monitor their weight now
- any injuries sustained as a jockey
- general health questions
- questions on physical activity, diet, smoking and alcohol

A full copy of the questionnaire can be seen in Appendix H.

4.3.3.7 Dual Energy X-Ray Absorptiometry (DEXA):

Body Composition & Bone Health

DEXA is now widely accepted and commonly used to assess BMD (Lewiecki and Borges, 2006) and has also become the standard technique for measuring body composition (Haarbo et al., 1991). All subjects received a whole body, lumbar spine and proximal femur DEXA scan for the assessment of BMD, bone mineral concentration (BMC), bone area (BA) and soft tissue composition (fat mass (FM) and fat free mass (FFM), percentage fat (%fat)). The DEXA scanner used for this research study was the Stratos dR (DMS Group, France) (Nalda et al., 2011) (Figure 4.3).

Figure 4.3: Stratos dR DEXA scanner used for the assessment of BMD and body composition

Having removed shoes, belts, jewellery, glasses in addition to any contents in the pockets, all participants remained in a supine position in the centre of the padded examination table (neutral position). Positioning for all scans was performed in accordance with manufacturer instructions (Figure 4.4). For the whole body scan, participants remained in neutral position. Lumbar spine scans (L1-L4) required the participant's leg to be supported with a small foam block to reduce curvature of the spine. Midway between the anterior superior iliac spine (ASIS) and the iliac crest along the midline of the body, the scanner laser lights were positioned for the lumbar spine scan. To achieve internal rotation of the hips for the proximal femur scan, the participant's feet were placed on a triangular brace and strapped into place with the laser light positioned approximately 5 cm below the greater trochanter along the midline of the thigh.

Figure 4.4: Body positions for whole body, lumbar spine and proximal femur scans

BMC is the amount of mineral in the specific site scanned and when divided by the area measured (BA), a value can be derived for BMD ($g \cdot cm^{-2}$). T scores were reported as provided by the Stratos dR software and in accordance with the World Health Organisation (WHO) classifications: T score for normal BMD > -1, for osteopenia -1 to -2.5 and for osteoporosis < -2.5 (Brown and Josse, 2002, WHO, 1994). From the results of the whole body scan, body composition scores were extrapolated by the Stratos dR software.

Comparisons of BMD for the whole body, lumbar spine and femoral neck were made using previously published data on professional jockeys by Dolan et al., (2012b).

4.3.4 Statistical Analysis

Data was analysed using SigmaPlot version 12.0. Descriptive statistics were found for each dependent variable and all data were expressed as mean ± SD. Normality of data distribution was tested using the Shapiro Wilks test. An independent t-test was used to establish if a significant difference was apparent between BMD for whole body, lumbar spine and femoral neck of professional jockeys and retired jockeys. Pearson's product moment correlation analysis was used to determine whether any significant relationships existed between the chosen variables of metabolism (RMR), bone health (BMD) and kidney function (eGFR) and any of the other variables assessed. A probability of $p \leq 0.05$ was considered to indicate a statistical significant relationship.

4.4 Results

4.4.1 Descriptive Data

All descriptive data and anthropometric characteristics of the participants are presented in Table 4.1. Thirty eight percent of the retired jockeys had a BMI below 25 $kg \cdot m^{-2}$, 43% had a BMI between 25-30 $kg \cdot m^{-2}$, while 19% had a BMI in excess of 30 $kg \cdot m^{-2}$. Percentage body fat ranged from 15.3% to 43% in the retired jockeys with 62% of the participants having a % body fat greater than 25%.

Table 4.1: Anthropometric and Body Composition Information

Subject Characteristics (n = 37)	
Age (yrs)	63 ± 10
Height (m)	1.64 ± 0.04
Body Mass (kg)	71.7 ± 11.0
BMI ($kg \cdot m^{-2}$)	26.53 ± 3.8
FFM (kg)	45.80 ± 6.3
FFMI ($kg \cdot m^{-2}$)	16.94 ± 2.1
FM (kg)	18.09 ± 6.47
FMI ($kg \cdot m^{-2}$)	6.70 ± 2.4
% Body Fat	26.3 ± 6.0

Data presented as mean ± SD; Body Mass Index (BMI); Fat Free Mass (FFM); Fat Free Mass Index (FFMI); Fat Mass (FM); Fat Mass Index (FMI)

4.4.2 Lifestyle Questionnaire

The majority of participants (62.2%; n = 23) had become a jockey primarily due to the love of riding and horses. Other influential factors of becoming a jockey included small stature (18.9%; n = 7), family involvement (16.2%; n = 6) and a good lifestyle (2.7%; n = 1). None of the retired jockeys questioned had attended university, 10.8% (n = 4) attained their Leaving Certificate, 32.4% (n = 12) completed their Junior Certificate with 51.4% (n = 19) of jockeys completing only primary education.

4.4.2.1 Professional Career as a Jockey

i. Career History

Amongst the retired jockeys within this study, 16.2% (n = 6) had a career in flat racing, 40.5% (n = 15) in jump racing and 43.2% (n = 16) participated in both types of racing. Information relating to the riding career of the ex-jockeys is presented in Table 4.2. The career as a jockey was reported to typically last between 8 and 34 years. While 4 individuals had a racing career lasting below 12 years, all other participants had a career lasting greater than 15 years. The oldest jockey to retire was 50 years of age. Many individuals reported winning in excess of 100 races during their racing career with the maximum amount of races won being 2000.

Table 4.2: Career as a Jockey

Career History (n = 37)	
Age became a Jockey (yrs)	16.1 ± 2.1
Years as a Jockey (yrs)	20.3 ± 5.7
No. of Winners	340 ± 490.3
Age at Retirement (yrs)	36.5 ± 5.6

Data presented as mean ± SD

ii. Weight Control

Eighty nine percent (n = 33) of the retired jockeys indicated experiencing trouble making weight over the course of their professional career. The typical weight making practices used by the individuals in this study are presented in Table 4.3.

Table 4.3: Typical Weight Making Practices

Weight Making Practices	**%**	**n = 33**
Energy Restriction	100	33
Exercise	97	32
Fluid Restriction	90.9	30
Hot Baths	78.8	26
Sauna	72.7	24
Diuretics	60.6	20
Laxatives	60.6	20
Vomiting	6.1	2

iii. Lifestyle as a Jockey

Information was gathered on the lifestyle of the participants during the course of their professional racing career (Table 4.4). The most challenging aspect of life as a jockey was weight control (45.9%) with falls, injuries and getting good horses to ride also being mentioned. Winning races was the most commonly reported positive aspect of being a jockey (91.9%).

Table 4.4: Lifestyle as a Jockey

As a Jockey (n = 37)	%	n = 37
Exercise apart from Riding	92	34
Smoke	73	27
Age Started Smoking (yrs)	15.7 ± 2.5	
Consume Alcohol	75.7	28
Bone Injuries	86.4	32
Other Injuries	59.5	22

Of those who smoked, 22 ± 15 cigarettes were reported as the quantity smoked daily. Forty three percent reported drinking 1-2 days a week, typically 5-8 units (24.3%) or 9-12 units (16.2%) consumed on those nights. Running was the main form of exercise recorded in the questionnaire as the additional exercise conducted to riding horses (78.4%; n = 29) while cycling, walking, boxing and golf were also reported. Typical bones broken included collarbone, vertebrae, fingers, wrists, leg and ribs. Other commonly reported injuries included concussion, muscle injuries and back problems.

4.4.2.2 Retirement

Age (29.7%), injury (24.3%) and weight issues (18.9%) were found to be amongst the most common reasons influencing retirement from horse racing. Twenty two percent reported other reasons related to retirement primarily involving no longer receiving any rides at the races and so necessary to retire. Lack of support and missing riding and the racing 'buzz' were mentioned amongst the biggest challenges adjusting to life after retirement.

Participants in this study have been retired for 26.8 ± 9.5 years. The current lifestyle of the ex-jockeys since retiring from racing is presented in Table 4.5.

Table 4.5: Current Lifestyle since Retirement from Racing

As a Retired Jockey	%	n = 37
Remained in the Racing Industry	91.9	34
Currently Exercise	78.4	29
Ride Horses	43.2	16
Smoke	13.5	5
Consume Alcohol	86.5	32
Currently on Medication	56.8	21

The majority of the retired jockeys (91.9%; n = 34) have remained in the horse racing industry, primarily involved in the training or breeding of horses or working as a stable hand in a training yard. Twenty seven percent (n = 10) watch their weight on a regular basis. Walking and golf were amongst the most common form of exercise mentioned amongst those individuals who currently exercise.

Those who currently smoked reported smoking 13.2 ± 9 cigarettes daily. Alcohol consumption on one to two days a week was favoured by 32.4% of retired jockeys, with 3-4 units the most frequently chosen amount of alcohol consumed. Twenty one (56.8%) of the retired jockeys in the study were currently on medication for various health conditions predominantly including high cholesterol and high blood pressure. One participant also had a kidney removed. Heart conditions were reported in 16.2% (n = 6) of the retired jockeys. Prostate cancer, stroke, arthritis, fused ankle joints, thyroid and lung problems were also mentioned. No retired jockey reported a family history of osteoporosis, 13.5% reported a family history of diabetes and 8.1% indicated a family history of thyroid problems.

4.4.3 Resting Metabolic Rate

RMR was calculated as 1428 ± 202 $kcal \cdot day^{-1}$. Values ranged from 1103 to 1831 $kcal \cdot day^{-1}$. RMR expressed relative to kg FFM was calculated as 31.38 ± 3.4 $kcal \cdot kg\ FFM^{-1} \cdot day^{-1}$.

4.4.4 Blood Pressure

Mean resting systolic blood pressure and diastolic blood pressure were 147 ± 16 mmHg and 85 ± 8 mmHg respectively. A possible white coat effect or various medications may have caused these raised blood pressure values. All participants were advised to follow up with their G.P.

4.4.5 Full Blood Count

A profile of the full blood count for the retired jockeys is presented in Table 4.6 displaying all values to be within the reference ranges.

Table 4.6: Full Blood Count Results

Full Blood Count	Results	Reference Range
RBC ($x10^{6}\cdot\mu L^{-1}$)	4.79 ± 0.34	*4 – 6 $x10^{6}\cdot\mu L^{-1}$*
Hb ($g\cdot dL^{-1}$)	14.61 ± 0.80	*11 - 18 $g\cdot dL^{-1}$*
HCT ($L\cdot L^{-1}$)	0.44 ± 0.02	*0.35 – 0.60 $L\cdot L^{-1}$*
WBC ($x10^{3}\cdot\mu L^{-1}$)	6.55 ± 1.49	*4.5 – 10.5 $x10^{3}\cdot\mu L^{-1}$*
Platelets ($x10^{3}\cdot\mu L^{-1}$)	302.73 ± 61.62	*150 – 450 $x10^{3}\cdot\mu L^{-1}$*
MVP (fL)	7.39 ± 0.64	*7.8 – 11 fL*

Data presented as mean ± SD; Red Blood Cells (RBC); Haemoglobin (Hb); Haematocrit (HCT); White Blood Cells (WBC); Mean Platelet Volume (MVP)

4.4.6 Glucose Metabolism

Results from the OGTT are presented in Table 4.7. No retired jockeys were found to have a glucose concentration at baseline or after 2 hours indicating diabetes. Six participants presented baseline glucose concentrations in excess of 6 $mmol\cdot L^{-1}$ however after 2 hours these values had all returned to normal values with the exception of one individual signifying an impaired tolerance to glucose. Three further participants showed raised concentrations of glucose post 2 hours (range 7.8 – 9.1 $mmol\cdot L^{-1}$).

Table 4.7: Oral Glucose Tolerance Test Results

Glucose Metabolism	Results	Normative Values
Fasting Glucose ($mmol^{.}L^{-1}$)	5.46 ± 0.5	*< 5.5 $mmol^{.}L^{-1}$*
After 2 Hours ($mmol^{.}L^{-1}$)	5.96 ± 1.4	*< 7.1 $mmol^{.}L^{-1}$*

Data presented as mean ± SD

4.4.7 Lipid Profile

Despite 15 (41%) of the retired jockeys being on cholesterol lowering medication, 25 (68%) of the participants displayed raised cholesterol levels. Thirteen (35%) individuals reported no medication being taken to lower cholesterol yet cholesterol was reported as high in these individuals. This information was included in their individual results file for their G.P. The complete lipid profile for the retired jockeys is presented in Table 4.8.

Table 4.8: Lipid Profile

Lipid Profile	Results	Reference Range
Total Cholesterol ($mmol^{.}L^{-1}$)	5.64 ± 1.3	*0 – 5 $mmol^{.}L^{-1}$*
HDL ($mmol^{.}L^{-1}$)	1.53 ± 0.4	*1 – 1.7 $mmol^{.}L^{-1}$*
LDL ($mmol^{.}L^{-1}$)	3.54 ± 1.2	*0 – 3 $mmol^{.}L^{-1}$*
Triglycerides ($mmol^{.}L^{-1}$)	1.26 ± 0.6	*0 – 1.9 $mmol^{.}L^{-1}$*

Data presented as mean ± SD; High Density Lipoprotein (HDL); Low Density Lipoprotein (LDL)

4.4.8 Kidney, Liver and Thyroid Function

Markers for kidney, liver and thyroid function are displayed in Table 4.9. All markers were found to be within the reference ranges.

Table 4.9: Markers of Kidney, Liver and Thyroid Function

Markers of Kidney, Liver and Thyroid Function	Results	Reference Range
Kidney Function		
Urea ($mmol^{.}L^{-1}$)	5.45 ± 1.2	*2.5 – 7.8 $mmol^{.}L^{-1}$*
Creatinine ($\mu mol^{.}L^{-1}$)	79.7 ± 16.4	*64 – 104 $\mu mol^{.}L^{-1}$*
eGFR (CKD-EPI) ($ml^{.}min^{-1.}1.73\ m^{-2}$)	92.12 ± 10.9	*>90 $ml^{.}min^{-1.}1.73\ m^{-2}$*
Urate ($\mu mol^{.}L^{-1}$)	353.32 ± 68.0	*200 – 430 $\mu mol^{.}L^{-1}$*
TCO_2 ($mmol^{.}L^{-1}$)	24.94 ± 2.0	*22 – 29 $mmol^{.}L^{-1}$*
Sodium ($mmol^{.}L^{-1}$)	138.95 ± 2.1	*133 – 146 $mmol^{.}L^{-1}$*
Potassium ($mmol^{.}L^{-1}$)	4.64 ± 0.5	*3.5 – 5.3 $mmol^{.}L^{-1}$*
Chloride ($mmol^{.}L^{-1}$)	102.78 ± 2.4	*95 – 108 $mmol^{.}L^{-1}$*
Liver Function		
Total Protein ($g^{.}L^{-1}$)	73.19 ± 3.9	*60 – 80 $g^{.}L^{-1}$*
Bilirubin ($mmol^{.}L^{-1}$)	10.7 ± 4.1	*<17 $mmol^{.}L^{-1}$*
Albumin ($g^{.}L^{-1}$)	43.18 ± 2.3	*35 – 50 $g^{.}L^{-1}$*
ALP ($U^{.}L^{-1}$)	86.19 ± 32.7	*42 – 121 $U^{.}L^{-1}$*
ALT ($IU^{.}L^{-1}$)	26.3 ± 23.6	*<35 $IU^{.}L^{-1}$*
Thyroid Function		
Free T4 ($pmol^{.}L^{-1}$)	9.91 ± 1.4	*7 – 16 $pmol^{.}L^{-1}$*
TSH ($mIU^{.}L^{-1}$)	2.23 ± 1.6	*0.5 – 4.2 $mIU^{.}L^{-1}$*

Data presented as mean ± SD; Estimated Glomerular Filtration Rate (eGFR); Alkaline Phosphatase (ALP); Alanine Aminotransferase (ALT); Thyroid Stimulating Hormone (TSH)

4.4.9 Endocrine Information

Hormonal data are presented in Table 4.10. All variables were within the reference ranges. SHBG was at the higher end of the reference range with 15 (41%) of the retired jockeys displaying elevated SHBG levels. Six participants displayed elevated PSA levels.

Table 4.10: Hormonal Profile

Hormone Profile	Results	Reference Range
Testosterone (nmol·L^{-1})	19.10 ± 6.5	*(10.3 – 34.5 nmol·L^{-1})*
SHBG (nmol·L^{-1})	53. 97 ± 17.4	*(13 – 56 nmol·L^{-1})*
Cortisol (nmol·L^{-1})	360.54 ± 71.1	*(185 – 624 nmol·L^{-1})*
PSA (ng·ml^{-1})	1.99 ± 6.5	*(0 – 3.1 ng·ml^{-1})*

Data presented as mean ± SD; Sex Hormone Binding Globulin (SHBG); Prostate Specific Antigen (PSA)

4.4.10 Bone Health

BMD of the whole body, lumbar spine and proximal femur are presented in Table 4.11. Based on the WHO classifications, 51% of the retired jockeys showed whole body osteopaenia, 41% displayed osteopaenia of the lumbar spine and 44% showed osteopaenia of the proximal femur. Osteoporosis of the whole body, lumbar spine and proximal femur was displayed in 3%, 5% and 6% of the retired jockeys respectively. Sixty two percent of all retired jockeys had a T score ≤ -1 for one or more of the whole body, lumbar spine or proximal femur scans. A hip replacement was also seen in 16.2% (n = 6) of individuals, with 2 of these ex-jockeys having both hips replaced. Z scores were normal.

Table 4.11: Bone Mineral Density, T- and Z-scores for Retired Jockeys

Bone Health		
Whole Body		
	BMD (g·cm^{-2})	1.103 ± 0.149
	T score	-1.1 ± 0.8
	Z score	-0.5 ± 0.8
Lumbar Spine		
	BMD (g·cm^{-2})	1.005 ± 0.157
	T score	-0.7 ± 1.1
	Z score	-0.1 ± 1.1
Proximal Femur		
	BMD (g·cm^{-2})	0.979 ± 0.173
	T score	-0.8 ± 0.9
	Z score	-0.5 ± 1.2

Data presented as mean ± SD; T score: normal bone mineral density: > -1; osteopaenia: -1 to -2.5; osteoporosis: < -2.5 (WHO, 1994)

Comparison of BMD for the whole body, lumbar spine and femoral neck were made using previously published data on professional jockeys (n = 20; age 25.9 ± 3.26; height 1.7 ± 0.07 m; body mass 61.1 ± 5.4 kg; BMI 21.36 ± 1.8 $kg \cdot m^{-2}$; % bodyfat 11.4 ± 5.6%) from Dolan et al. (2012b). Significant differences are apparent between both groups for lumbar spine BMD ($p \leq 0.01$) and femoral neck BMD ($p \leq 0.001$).

Table 4.12: Comparison of BMD between Professional Jockeys and Retired Jockeys

Bone Health	**Retired Jockeys** (n = 37)	**Professional Jockeys** (n = 20) *(Dolan et al., 2012b)*
Whole Body BMD ($g \cdot cm^{-2}$)	1.103 ± 0.149	1.134 ± 0.052
Lumbar Spine BMD ($g \cdot cm^{-2}$)	1.005 ± 0.157	1.112 ± 0.079**
Femoral Neck BMD ($g \cdot cm^{-2}$)	0.881 ± 0.143	1.061 ± 0.098¥

*Data presented as mean ± SD; *p ≤ 0.05 between groups, **p ≤ 0.01 between groups, ¥p ≤ 0.001 between groups*

A bone profile including markers of bone health along with micronutrient information are presented in Table 4.12.

Table 4.13: Markers of Bone Health and Micronutrients

Bone Health	**Results**	**Reference Range**
Calcium ($mmol \cdot L^{-1}$)	2.41 ± 0.1	*(2.2 – 2.6 $mmol \cdot L^{-1}$)*
PO4 ($mmol \cdot L^{-1}$)	1.04 ± 0.1	*(0.7 – 1.5 $mmol \cdot L^{-1}$)*
Magnesium ($mmol \cdot L^{-1}$)	0.86 ± 0.1	*(0.6 – 1 $mmol \cdot L^{-1}$)*
Alkaline Phosphatase ($U \cdot L^{-1}$)	86.19 ± 32.7	*(42 – 121 $U \cdot L^{-1}$)*
PTH ($pg \cdot ml^{-1}$)	39.74 ± 11.6	*(15 – 65 $pg \cdot ml^{-1}$)*
25(OH) D ($nmol \cdot L^{-1}$)	49.4 ± 25.3	*(>75 $nmol \cdot L^{-1}$)*

Data presented as mean ± SD; Parathyroid Hormone (PTH)

Mean serum 25(OH) D levels were below the recommended threshold of 75 $nmol \cdot L^{-1}$ (Holick et al., 2011) in the group of retired jockeys. Eighty four percent of participants had serum 25(OH) D levels below 75 $nmol \cdot L^{-1}$ with 57% of these even below 50 $nmol \cdot L^{-1}$. Values as low as 9.59 $nmol \cdot L^{-1}$ were reported.

4.4.11 Correlation Analysis

Pearson's product moment correlation analysis with RMR, BMD and eGFR showing significant associations with the other variables assessed are presented in Table 4.14.

Table 4.14: Correlation Analysis with RMR, BMD and eGFR

Dependent Variables	Associated Variables
RMR ($kcal \cdot day^{-1}$)	Age ($r = -0.375$; $p \le 0.05$); Body Mass ($r = 0.763$; $p \le 0.001$); BMI ($r = 0.732$; $p \le 0.001$); Lean Body Mass ($r = 0.717$; $p \le 0.001$); Fat Mass ($r = 0.586$; $p \le 0.001$); % Body Fat ($r = 0.344$; $p \le 0.05$); Whole Body BMD ($r = 0.341$; $p \le 0.05$); Proximal Femur BMD ($r = 0.334$; $p \le 0.05$)
Whole Body BMD ($g \cdot cm^{-2}$)	Body Mass ($r = 0.427$; $p \le 0.001$); BMI ($r = 0.451$; $p \le 0.001$); Lean Body Mass ($r = 0.537$; $p \le 0.001$); RMR ($r = 0.341$; $p \le 0.05$)
Lumbar Spine BMD ($g \cdot cm^{-2}$)	Total Protein ($r = 0.405$; $p \le 0.05$); TSH ($r = 0.670$; $p \le 0.001$)
Proximal Femur BMD ($g \cdot cm^{-2}$)	BMI ($r = 0.434$; $p \le 0.01$); Lean Body Mass ($r = 0.379$; $p \le 0.05$); RMR ($r = 0.334$; $p \le 0.05$)
eGFR ($ml \cdot min^{-1} \cdot 1.73\ m^{-2}$)	Age ($r = -0.708$; $p \le 0.001$); Systolic Blood Pressure ($r = -0.405$; $p \le 0.05$); PTH ($r = -0.681$; $p \le 0.001$); Urea ($r = -0.504$; $p \le 0.001$); PSA ($r = -0.351$; $p \le 0.05$)

Resting Metabolic Rate (RMR); Body Mass Index (BMI); Estimated Glomerular Filtration Rate (eGFR); Thyroid Stimulating Hormone (TSH); Parathyroid Hormone (PTH); Prostate Specific Antigen (PSA)

4.4.12 Summary

The retired jockeys in this study reported relying on similar unhealthy weight loss practices throughout their career, necessary to reach the stipulated racing weights, as those commonly reported amongst current jockeys. Participants in this study reported the constant struggle with weight, along with injuries sustained, was the biggest challenge of being a jockey. Having been retired for 13 to 46 years (mean = 26.8 ± 9.5 years), more than half of the participants (62%) are currently classified as overweight or obese. No abnormalities were apparent in the functioning of the liver, kidney or thyroid as well as the hormonal profile and all blood analysis are within the clinical reference range. Furthermore no participant had a glucose tolerance test result indicative of diabetes. An elevation in mean total cholesterol was reported in 68%

of the participants. More than half (62%) of the participants were classified as osteopaenic in one or more of the bone sites assessed. Inadequate vitamin D was reported in a large proportion (84%) of the participants.

4.5 Discussion

The purpose of this study was to establish the potential long term health impact associated with the prolonged use of rapid weight loss strategies and an energy restricted lifestyle in a group of retired jockeys. Previous studies have focused primarily on apprentice and professional jockeys, specifically the negative physiological (Dolan et al., 2012a, Dolan et al., 2012b, Dolan et al., 2011, Leydon and Wall, 2002, Waldron-Lynch et al., 2010, Warrington et al., 2009) and performance (Dolan et al., 2013, Wilson et al., 2013b) consequences associated with the severe weight making practices utilised by many jockeys to maintain the required low body mass. Despite this, the long term health impacts of the lifestyle demands of a jockey remain largely unknown. Only two previous studies have investigated retired jockeys, one in terms of the welfare of retired jockeys in Australia (Speed et al., 2001) and the other establishing the incidence of musculoskeletal pain in a group of retired jockeys in the UK (Tomkinson et al., 2012), both of which were conducted through self-reported surveys or questionnaires instead of a direct measurement. It was hypothesized in this study that retired jockeys suffer from physical health problems as a result of a career using unhealthy weight loss strategies. Results from this study suggest many jockeys have experienced body mass gains since retirement. Furthermore many participants displayed osteopaenia in at least one of the bone sites assessed according to the WHO classification of the T Score. Findings from this study suggest potential long term effects associated with a life of chronic weight restriction and reliance on unhealthy weight making practices previously reported in these athletes (Dolan et al., 2011).

Unequivocal evidence exists suggesting the challenges many jockeys have with weight problems and health issues during their career (Dolan et al., 2011, Warrington et al., 2009). Eighty nine percent (n = 33) of the retired jockeys indicated experiencing trouble making weight over the course of their professional career with 46% reporting weight control as the most challenging aspect of being a jockey. Weight making strategies similar to those of today (Dolan et al., 2011) including restricted food intake (100%), exercise to induce sweating (97%) and sauna (73%) and hot bath use (79%) were reported amongst the retired jockeys. While the typical age the current retired jockeys reported commencing their career as an apprentice jockey was 16.1 ± 2.1 years, results reveal the retired jockeys were 36.5 ± 5.6 years of age at retirement, with one individual riding up until the age of 50 years indicating a long period of time in which many jockeys were required to achieve a low body mass to reach the designated racing weights. The duration of the career as a jockey was reported as 20.3 ± 5.7 years (range 8 - 34 years) comparable to the extent of the riding career of the retired jockeys in Australia (19.8 ± 9.3 years; range 4 – 45 years) (Speed et al., 2001). For many participants, the struggle with controlling body mass meant the end of a career in racing. Similar to the retired jockeys surveyed in Australia (Speed et al., 2001), weight management difficulties as well as injuries, were amongst the most common reasons influencing retirement from horse racing.

In accordance with the WHO classifications for overweight/obese (WHO, 2000), 43% of the participants in the present study were classified as overweight (BMI > 25 $kg \cdot m^{-2}$) with a further 19% categorised as obese (BMI > 30 25 $kg \cdot m^{-2}$). The level of obesity in this study was somewhat lower than that previously reported for Irish males of a similar age. The National Adult Nutritional Survey (NANS) previously reported that 43.6% of males aged 51-64 years (n = 133; body mass 90.7 ± 16 kg; BMI 29.7 ± 4.8 $kg \cdot m^{-2}$) were overweight with a further 42.1% classified as obese (IUNA, 2011). In a group of males greater than 65 years of age (n = 85; body mass 82.4 ± 13.3 kg; BMI 28.1 ± 4.2 $kg \cdot m^{-2}$), 58.8% were classified as overweight while 24.7% were obese. However despite this, at a younger age jockeys display lower than normal physical characteristics suggesting a greater relative gain in body mass and subsequent BMI. Dolan et al., (2012b) reported a group of professional jockeys aged 25.9 ± 3.26 years had a body mass of 61.1 ± 5.4 kg and BMI of 21.36 ± 1.8 $kg \cdot m^{-2}$ while in a similar age group (18-35 years; n = 255) in NANS, body mass and BMI were reported as 82.5 ± 14.2 kg and 25.8 ± 4 $kg \cdot m^{-2}$ respectively.

Conflicting evidence exists as to whether weight cycling during a career in a weight category sport results in a gain in body mass after retirement from sport competition. Marquet et al., (2013) reported 35% of the retired weight category athletes interviewed were overweight and obesity was apparent in 3% however similar patterns of BMI changes were observed in the retired athletes and in the general population indicating weight cycling to have no particular effect on subsequent weight gain in retirement. Conflicting evidence suggests weight cycling may predispose individuals in a weight category sport to obesity given the proportion of obese participants was greatest among the weight cyclers (Saarni et al., 2006). The inconsistencies reported in the current literature is suggested to result from the high level of physical activity performed in some retired athletes which may potentially limit the gain in body mass observed after retirement (Marquet et al., 2013). Cessation of physical activity in retirement in former elite athletes has previously been linked with significantly higher mean values in body mass, BMI, % body fat and total cholesterol in sedentary older athletes compared to that of active older athletes and sedentary older non-athletes (Dey et al., 2002). While limited information was gathered on the precise number of hours spent participating in exercise on a weekly basis, a large proportion of the participants (78%) in the current study reported partaking in regular exercise namely in the form of walking or golf and 43% still ride horses on a daily basis. Despite performing regular exercise, results from this study suggest a large proportion of the participants are currently overweight. Similarly, Speed et al., (2001) reported the struggle with weight for many retired jockeys appears to continue into retirement with 13% experiencing excessive weight gain after retiring from racing in Australia.

Large fluctuations in body mass early in life, be it during growth or young adulthood, have been reported to represent a risk factor for the development of insulin-related complications in later years, specifically obesity, type 2 diabetes and cardiovascular disease (Dulloo, 2005). While type 2 diabetes was not observed in any participant in the current study, results from this study suggest obesity and cardiovascular disease may potentially be a problem within this cohort of retired jockeys. In addition to the mean value for BMI (26.53 ± 3.8 $kg \cdot m^{-2}$) indicating overweight, a corresponding accumulation of excess body fat (26.3 ± 6.0%) was also apparent in a large proportion of participants with 62% categorised as being overweight, 24% of which were actually obese based on previous age adjusted body fat percentage guidelines (Gallagher et al., 2000). Furthermore, mean total cholesterol (5.64 ± 1.3) was elevated above normal values amongst the participants in the present study. Blood pressure was reported as being high, however this was believed to be unreliable due to the possible “white coat” effect. Fifty seven percent of the retired jockeys in the current study were on medication for various health conditions predominantly including high cholesterol and high blood pressure. While cardiovascular function was not directly assessed in the current study, heart conditions were reported in 16% (n = 6) of the retired jockeys. Potential mechanisms by which weight cycling may contribute to cardiovascular disease have been suggested to include total body and visceral fat accumulation, alterations in adipose tissue fatty acid composition, insulin resistance, hypertension and dyslipidaemia (Montani et al., 2006). Results from this study in relation to many individuals (62%) classified as overweight or obese in conjunction with mean elevated total cholesterol and potentially high blood pressure, would suggest further research is required to assess the impact of long term weight cycling on the cardiovascular system.

Based on the WHO classifications (1994), mean results from the current study indicated whole body osteopaenia (mean T Score: -1.1 ± 0.8) in the retired jockeys. Fifty one percent of the retired jockeys showed whole body osteopaenia with one participant displaying whole body osteoporosis. Forty one percent displayed osteopaenia of the lumbar spine and 44% showed osteopaenia of the proximal femur. Osteoporosis was also identified in 2 individuals at the lumbar spine and proximal femur. While the Z scores were not exceptionally low amongst the participants in this study, suggesting no real impairment in bone health compared to age matched individuals, 62% of all retired jockeys had a T score ≤ -1, indicative of osteopaenia, for one or more of the whole body, lumbar spine or proximal femur scans. While not all individuals with osteopaenia develop osteoporosis, it is considered a precursor to osteoporosis (Anonymous, 1993) and so results from this study suggest a greater number of participants in this study than the previously suggested 1 in 5 men over the age of 50 are at risk of developing osteoporosis (Khosla, 2010).

Compared to the whole body, lumbar spine and proximal femur BMD reported in previous work on jockeys in Ireland (1.134 ± 0.05 $g \cdot cm^{-2}$, 1.11 ± 0.08 $g \cdot cm^{-2}$ and 1.06 ± 0.098 $g \cdot cm^{-2}$ for whole body, lumbar spine and proximal femur BMD respectively (Dolan et al., 2012b)), results in the current study appeared to be somewhat similar for whole body BMD (1.103 ± 0.149 $g \cdot cm^{-2}$) despite the typical bone loss associated with ageing (Khosla, 2010). The retired jockeys did show significant reductions in lumbar spine BMD (1.005 ± 0.157 $g \cdot cm^{-2}$; $p \leq 0.01$) and proximal femur BMD (0.979 ± 0.173 $g \cdot cm^{-2}$; $p \leq 0.001$) when compared to professional jockeys. It is worth noting that since retirement, 6 participants have received hip replacements, 2 of which had both hips replaced. Further analysis revealed 4 of these individuals had previously participated in national hunt racing while 2 in flat racing with no specific trauma to the region in question reported. Previous BMD for the whole body, lumbar spine and proximal femur reported in current jockeys were however representative of a group displaying compromised musculoskeletal health. Participants in the present study had been retired for a mean 26.8 ± 9.5 years during which lifestyle habits were modified as indicated in the lifestyle questionnaire in which only 27% of the participants reported watching their body mass on a regular basis. Of particular interest, smoking was a habit that 73% of the retired jockeys participated in while riding professionally, typically starting smoking from the age of 15.7 ± 2.5 years in order to aid in the control of a low body mass, however in retirement this figure dropped to only 13.5% participants currently smoking. Smoking has been identified as a key risk factor for osteoporosis (Yoon et al., 2012). Such alterations in lifestyle factors in later life may have potentially positively influenced any further adverse changes in bone health.

Results from previous studies reveal a high incidence of low BMD and increased bone turnover are prevalent amongst jockeys (Dolan et al., 2012a, Dolan et al., 2012b, Greene et al., 2013, Leydon and Wall, 2002, Waldron-Lynch et al., 2010, Warrington et al., 2009). Evidence has highlighted that childhood and adolescent years provide a 'window of opportunity' to maximise bone mass and strength (Greene and Naughton, 2006). Jockeys typically commence their apprenticeship to racing during mid-adolescence (15.8 ± 0.9 years) (Dolan et al., 2011). Aspiring jockeys strive to attain an extremely low body mass at this imperative stage in their maturation to attract more rides and establish a reputation. Such jockeys are still experiencing growth and may be engaging in activities that restrict the achievement of individual genetic potential for peak bone mass (PBM) (Greene et al., 2013) since PMB has been reported to occur by the end of the second or early in the third decade of life (Baxter-Jones et al., 2011). While genetics may predominantly determine baseline bone strength (~80%) (Matkovic and Ilich, 1993), it has been suggested that the exercise, nutritional and other lifestyle habits of jockeys may not be conducive to the development of optimal bone health (Warrington et al., 2009). A number of lifestyle factors previously identified amongst jockeys have been suggested to be detrimental to bone health (Dolan et al., 2011) namely low energy availability (Ihle and Loucks, 2004), inadequate calcium (dietary intake (Bass et al., 2005) or loss through excessive sweating (Shirreffs and Maughan, 1997)) and vitamin D (Bass et al., 2005), high prevalence of smoking (Yoon et al., 2012) and alcohol consumption (Maurel et al., 2012). While the loading nature of horse racing remains largely unknown, it has been suggested that horse riding may not provide a significant osteogenic stimulus (Cullen et al., 2009) and limited information is available on the additional exercise to riding performed by jockeys. Any factors that negatively influence the development of optimal PBM or promote loss of bone may increase the risk of developing a fracture in the future (Cashman, 2007). Increasing bone mass and strength during growth is the primary strategy for the prevention of osteoporosis (Bonjour et al., 2009). Hernandez et al., (2003) predicted a 10% increase in PBM would delay the onset of osteoporosis by 13 years. Although more commonly associated with female athletes, Dolan et al., (2012b) suggested male jockeys may also be susceptible to elements of the 'female athlete triad' given the reported low energy availability in jockeys (Dolan et al., 2011), along with evidence on alterations to gonadal and reproductive hormone function and low bone mass (Dolan et al., 2012b). Women who were diagnosed with the 'female athlete triad' syndrome as adolescents and young adults in the 1990s have been reported to suffer from low BMD at 30 and 40 years of age (Thein-Nissenbaum, 2013). Despite apprentice jockeys being afforded the 'window of opportunity' to enhance musculoskeletal health, the emphasis on weight restriction at this early stage in life with the potential susceptibility to the 'female athlete triad' could explain the slightly higher incidence of compromised musculoskeletal health prevalent amongst participants in this study.

Results from examination of the micronutrients and electrolytes revealed mean serum 25(OH) D levels in the group of retired jockeys (49.4 ± 25.3 $nmol \cdot L^{-1}$) were below the recommended threshold of 75 $nmol \cdot L^{-1}$ (Holick et al., 2011). 25(OH) D levels were taken to provide an indication of vitamin D nutritional status and it has been suggested that to maximise the effect of vitamin D on calcium, bone and muscle metabolism, serum 25(OH) D concentration should exceed 75 $nmol \cdot L^{-1}$ (Holick et al., 2011). Eighty four percent of participants had serum 25(OH) D levels below 75 $nmol \cdot L^{-1}$ with 57% of these even below 50 $nmol \cdot L^{-1}$. Results were similar to the recently published representative data on vitamin D status for Irish adults (Cashman et al., 2013). The prevalence of serum 25(OH) D concentrations < 50 $nmol \cdot L^{-1}$ in the 51 – 64 years age category and the 65 – 84 years age category were 55.4% and 48.1%, respectively, in the winter, a similar season to the data collection in the current study. Winter prevalence rates for serum 25(OH) D concentration < 75 $nmol \cdot L^{-1}$ in the entire cohort of Irish adults (n = 1132) was 84%. Similar to the study on professional jockeys by Dolan et al., (2012) in which a deficiency in vitamin D was diagnosed (43.9 ± 15.5 $nmol \cdot L^{-1}$), subsequent analysis did not show vitamin D to be a predictor of BMD in any of the bone sites assessed and so it is unlikely to be a contributory factor to the any compromised musculoskeletal health reported in the current study.

The decline in RMR with advancing age has been suggested to be greater than what can be explained by FFM and FM and may be due in part to slowed organ metabolic rates (St-Onge and Gallagher, 2010). Absolute RMR for the retired jockeys in this study was reported as 1428 ± 202 $kcal \cdot day^{-1}$ which was somewhat lower than that reported elsewhere in male individuals aged 67 ± 5 years (1622 ± 179 $kcal \cdot day^{-1}$) (Luhrmann et al., 2001) and aged 69 ± 5 years (1606 ± 164 $kcal \cdot day^{-1}$) (Krems et al., 2005) despite the comparable BMI of the retired jockeys to these separate groups of older men (Krems et al., 2005, Luhrmann et al., 2001). Gravante et al., (2001) suggest the variation in RMR among individuals with the same physical characteristics may be genetically explained and processes such as sympathetic nervous system activity, thyroid hormone activity and Na^+-K^+ pump activity all in response to exercise training can potentially influence RMR and contribute to the individual variation. Given that 78.4% of the retired jockeys reported performing regular physical activity, a comparable RMR to other studies was expected. Limited information exists on the RMR of current professional jockeys however results from the present study would suggest a possible reduction in the RMR of the retired jockeys, compared to RMR suggested in age gender and BMI matched individuals, potentially resulting from the chronic energy restriction and unhealthy making weight practices utilised during their career as a jockey.

RMR has previously been estimated within a cohort of professional jockeys using the equation developed by Mifflin-st Jeor which was based on a sample of normal weight and obese individuals (Mifflin et al., 1990). Estimated RMR in the group was reported as 1479 ± 124 $kcal \cdot day^{-1}$ (flat: 1393 ± 47 $kcal \cdot day^{-1}$; national hunt: 1614 ± 71 $kcal \cdot day^{-1}$) (Dolan et al., 2011). A large proportion of jockeys have been reported to employ energy restriction as a predominant method to control weight and an associated low availability of energy has been suggested for the sustainment of usual daily and metabolic process (Dolan et al., 2011). A possible overestimation of RMR in the group of jockeys was suggested due to the impact a metabolic state of energy imbalance may have on RMR (Dolan et al., 2011). Prolonged energy restriction has been suggested to have a suppressive effect on RMR (Weyer et al., 2000). However, conflicting evidence exists relating to the effects of participation in weight cycling on RMR in weight category athletes. Melby et al., (1990) reported a significant reduction ($p \leq 0.05$) in RMR during the season when wrestlers had lost weight for competition however RMR returned to preseason values at the end of the weight cycling season following the final weight regain (preseason: 1974 ± 64 $kcal \cdot day^{-1}$; during the season: 1645 ± 63 $kcal \cdot day^{-1}$; post season: 2031 ± 91 $kcal \cdot day^{-1}$). In contrast, Steen el al., (1988) showed weight cycling was related to a lowering in RMR (-14%) in adolescent wrestlers despite no apparent differences in age, height, body mass and body fat between the group of weight cycling and non-weight cycling wrestlers. Moreover, such negative effects on RMR may be counterbalanced by the various other lifestyle practices of jockeys including exercise training and smoking. While the chronic metabolic effects of smoking have not been fully elucidated, it is believed smoking leads to an increase in RMR (Chiolero et al., 2008). Several studies indicate that RMR is significantly higher in physically active individuals than those who are inactive independent of changes in body composition and increases in FFM (Speakman and Selman, 2003, Gravante et al., 2001). The positive effects physical activity elicits on RMR may actually overcome the potential negative effects of caloric restriction and weight cycling on RMR within this unique population of jockeys however further research is required to determine the extent to which the lifestyle demands of a jockey may impact on RMR. Results from the current study suggest RMR may be reduced in the long term and without further information on the present professional jockeys it may be suggested that attempting to maintain a low body mass for over 20 years (20.3 ± 5.7 years) through prolonged energy restriction and weight cycling might be a contributing factor to the reduced RMR seen within the retired jockeys.

A comprehensive haematological analysis was performed in the cohort of retired jockeys in the current study for the assessment of kidney, liver and thyroid function. Despite the constant reliance on the severe acute dehydrating mechanisms combined with poor dietary practices over an extended period, as previously discussed, to maintain a low body mass, no major haematological abnormalities were present in the retired jockeys and values were within the clinical reference ranges. Mean eGFR in the current study (92.12 ± 10.9 $ml \cdot min^{-1} \cdot 1.73\ m^{-2}$) was similar to that previously suggested amongst a small group of men without any signs of chronic kidney disease (age 50-59 years: 93 $ml \cdot min^{-1} \cdot 173\ m^{-2}$; age 60-69 years: 85 $ml \cdot min^{-1} \cdot 1.73\ m^{-2}$; age 70+ years: 75 $ml \cdot min^{-1} \cdot 1.73\ m^{-2}$) (Coresh et al., 2003). Such findings were lower when compared to that previously reported in a group of jockeys in a study by Wilson et al. (2013) (flat 112.6 ± 11.3 $ml \cdot min^{-1} \cdot 1.73\ m^{-2}$; national hunt 116.8 ± 14.3 $ml \cdot min^{-1} \cdot 1.73\ m^{-2}$). While 35% of the participants in the present study had an eGFR below the threshold, subsequent analysis indicate a significant strong negative correlation between age and eGFR ($r = -0.708$; $p \leq 0.001$). Mean eGFR was still greater than the reference range threshold of 90 $ml \cdot min^{-1} \cdot 1.73\ m^{-2}$ and was expected to be lower than that of current jockeys given the steady decline commonly reported in eGFR with ageing, typically beginning at the age of 30-40 years with an accelerated rate of decline after the age of 65-70 years (Glassock and Winearls, 2009).

An altered hormonal profile associated with bone loss has previously been described within a population of professional jockeys (Dolan et al., 2012b). Dolan et al., (2012b) reported significantly higher SHBG levels in professional jockeys compared with controls (41.21 ± 9.77 $nmol \cdot L^{-1}$ vs. 28.24 ± 7.87 $nmol \cdot L^{-1}$), and proposed SHBG as one of the primary regulatory determinants of whole body and lumbar spine BMD. Elevated SHBG has previously been correlated with increased bone remodelling markers, low bone mass and an increased risk of fracture (Legrand et al., 2001, Lormeau et al., 2004). SHBG results must always be interpreted in the context of the reference range for the particular method in use (Bukowski et al., 2000) which limits the comparison of SHBG between professional jockeys and retired jockeys due to the difference in assessment methods. In the present study, mean SHBG (53. 97 ± 17.4 nmol·L^{-1}) was at the higher end of the clinical reference range (13 – 56 nmol·L^{-1}) and 41% of the participants displayed elevated SHBG. From about 30 years of age however, plasma levels of SHBG increase by ~1.2% annually with an associated decline in testosterone constantly by ~1% annually (Bjerner et al., 2009). With this in mind, data on professional jockeys and controls in the study by Dolan et al., (2012b) were manipulated from the age of professional jockeys to that of the retired jockeys in the current study and expected increases in mean SHBG for jockeys and controls were 59.34 nmol·L^{-1} and 41.5 nmol·L^{-1} respectively according to a 1.2% increment annually in SHBG. Such a mean value for professional jockeys would place them outside the reference range used for that particular method of assessment (10 – 55 nmol·L^{-1}). While results from the retired jockeys reported no significant correlations were present between SHBG and any bone variables or SHBG and age, SHBG appears to be higher than would be expected for males of that age. Milewicz et al., (2013) proposed normative reference values for SHBG in relation to age and gender and for males these were: 55-59 years: 41 nmol·L^{-1} (39.3 – 44.1 nmol·L^{-1}); 65-69 years: 45.3 nmol·L^{-1} (42.0 – 47.9 nmol·L^{-1}); 70-74 years: 50.3 nmol·L^{-1} (47.7-53 nmol·L^{-1}); 75-79 years: 53.2 nmol·L^{-1} (50.6-56 nmol·L^{-1}). With a mean age of 63+10 years for the retired jockeys, mean SHBG of 53.97 + 17.4 nmol·L^{-1} would be considered high despite a slight expected variability taken into account due to difference in methods used. The alterations in endocrine hormones and various factors related to nutrition, metabolism and bone (Dolan et al., 2012b) typically recognised as being adversely affected during times of reduced energy availability (Haspolat et al., 2007, Ihle and Loucks, 2004, Loucks and Thuma, 2003) that are apparent in professional jockeys may have long term implications for such individuals.

Both age (63 ± 9.8 years; range: 45 to 83 years) and years since retiring from a career in horse racing (26.8 ± 9.5 years; range 13 to 46 years) varied considerably amongst the participants and each may have confounding effects on the results. While 89% of the participants in this study reported having difficulty reaching the stipulated riding weight throughout their career as a jockey, such difficulties may not have been as extreme as amongst the jockeys today given the more intense racing schedule as well as the somewhat smaller stature of the retired jockeys (1.64 ± 0.04 m) in this study to that seen in current studies on jockeys in Ireland with stature previously reported as 1.67 ± 0.1 m (Dolan et al., 2011), 1.7 ± 0.07 m (Dolan et al., 2012b), 1.69 ± 0.06 m (Dolan et al., 2012a) and 1.68 ± 0.05 (Dolan et al., 2013) in various groups of jockeys. This may be partly explained by reports on the secular increase in the mass and stature of the Irish population over the last 30 years (Whelton et al., 2007) and inconsistent changes in minimum weight structures. Analysis of the records of the trainee jockeys entering the RACE has revealed that since 1978 the mean body mass of apprentice jockeys has increased by 47%, rising from 37 kg to 54.5 kg in 2012. Yet the minimum weight allocation for flat jockeys has risen by just 10%, from 47.7 kg to 52.7 kg in the same time period. Little change in the stipulated racing weight limits throughout the years, the increased stature amongst the present jockeys and associated increased difficulty in making weight, in addition to the heavy racing schedule may mean the retired jockeys in this study did not undergo weight making practices as regularly as the present jockeys and so the results may not truly reflect any negative repercussions associated with such a lifestyle. Ideally, it would be advisable to follow jockeys longitudinally throughout their racing career and beyond to establish if any long term health implications are associated with the current lifestyle of a professional jockey.

4.5.1 Summary

The weight restricted nature of horse racing necessitates many jockeys to consistently maintain an extremely low body mass in order to increase riding opportunities. As a result of using unhealthy making weight strategies to attain the necessary low body mass for racing, many jockeys may be in a chronic energy deficient and dehydrated state for the duration of their racing career. While previous studies have revealed the adverse physiological and performance effects of such a lifestyle on apprentice and professional jockeys, the long term implications on health and well-being remain relatively unknown. Furthermore the limited information available was gathered through self-reported surveys or questionnaires rather than direct measurement (Speed et al., 2001, Tomkinson et al., 2012). In the current study, a comprehensive health screen was performed on all subjects in order to provide a detailed objective profile of the health characteristics of retired jockeys. Many individuals were classified as overweight or obese and this in conjunction with elevated mean total cholesterol may have serious implications in terms of long-term cardiovascular disease however this was not investigated in the current study. Compared to age, gender and BMI matched individuals in other studies, participants in this study displayed a lower RMR suggesting some potential impact of such a weight restricted lifestyle. No individual was reported to be diabetic. Despite a large proportion of jockeys living and competing in a dehydrated and energy deficient state, no adverse long-term implications on kidney, liver and thyroid function as well as hormonal profile appeared evident in this study. Many (62%) participants displayed osteopaenia in at least one of the bone sites assessed based on T Score classification (Anonymous, 1993). Despite apprentice jockeys being afforded the 'window of opportunity' to enhance musculoskeletal health, the emphasis on weight restriction to attract more rides and establish a reputation at this imperative stage in their maturation could explain the slightly higher incidence of compromised musculoskeletal health prevalent amongst participants in this study. A life of chronic weight restriction and reliance on unhealthy weight making practices may have some long term health effects as described in the retired jockeys assessed in this study.

4.6 Limitations

There are a number of limitations in this study which may have affected the findings and interpretation of the results.

i. Lack of a Control Group

While this is the first study of its kind amongst retired jockeys and the aim was to describe the health characteristics of retired jockeys, limitations arose when comparing the results to the current normative data. The acceptable ranges available for many of the variables appear to be quite large and very often the results of the participants fell within the standard values. The presence of a control group could possibly have highlighted additional health impairments indicative of a career laced with dehydration and chronic energy deficiency however the nature of the group assessed made it difficult to identify an appropriate control group and so it was decided to compare all data to clinical norms.

ii. Use of DEXA Scanning

Although widely used, DEXA scanning provides an incomplete view of actual bone health and strength due to the two-dimensional nature of the imaging. DEXA was the only form of bone densitometry available for use in this study however future research should consider the use of peripheral quantitative computer tomography (pQCT) in order for a more comprehensive view of bone architecture and strength to be provided. Compared to DEXA, pQCT is a three-dimensional imaging tool that allows the evaluation of bone size, bone geometry and bone strength, and also has the capabilities of evaluating volumetric BMD in addition to providing transversal geometric bone characteristics and distinguishing between cortical and trabecular bone (Dowthwaite et al., 2009).

iii. Use of Various Medications

A large proportion (56.8%) of the participants in this study were on some form of medication. It was not advisable to take participants off their prescribed medication for the purpose of this study and some medications may have therefore inexplicably affected the results.

iv. *Participant Selection*

As no database existed as a registry of contact details for all former jockeys in Ireland, participants were recruited via mass mailing all retired jockeys who were receiving a pension or who had applied for a pension from the Turf Club in 2012 (n = 119). While the sample in the study represented 31% of the total population of registered retired jockeys on such lists, a mixed sample of retired jockeys were recruited for participation in this study. A wide range in age amongst the subjects was apparent and current age as well as the number of years elapsed since retiring from a career in horse racing may have had confounding effects on the results. Furthermore, participants were only assessed at one time point rather than longitudinally. Ideally longitudinal analysis of jockeys throughout their career would be advisable to allow the evaluation of any long term health implications associated with the current lifestyle of a professional jockey.

v. *Lack of Bone Turnover Markers*

All haematological analyses were conducted in collaboration with a local hospital. Unfortunately unavoidable delays in the analysis of various markers of bone turnover (bone formation marker serum total procollagen type 1 amino terminal propeptide (P-1NP) and bone resorption maker serum collagen type-1 cross-linked C-telopeptide (CTX)) resulted in such data not available for use within this research which unfortunately limited further explanations of the pattern of BMD as well as the comparison of bone health data to that seen in previous studies of current jockeys (Dolan et al., 2012b). Once this data is available it is proposed to incorporate this in the study for publication.

4.7 Conclusion

Results suggest a large proportion of the retired jockeys experienced excessive body mass gains with many classified as overweight or obese and elevated mean total cholesterol was also reported. Participants also displayed a lower RMR compared to individuals with the same physical characteristics. No long term adverse implications on kidney, liver and thyroid function as well as hormonal profile and glucose metabolism were reported however many participants displayed osteopaenia in at least one of the bone sites assessed. A life of chronic weight restriction and reliance on unhealthy weight making practices may have some long term health effects. This study is the first of its kind to evaluate the health characteristics of retired jockeys and building on the existing data available in current apprentice and professional jockeys provides a novel insight of the potential long term effects of chronic weight cycling in this high risk sport. Tracking a jockey longitudinal would ideally be required however to assess the long-term health effects of a lifestyle entrenched with a severe reliance on potentially dangerous weight loss practices. Structures are required to be put in place to support retired jockeys upon retirement, providing appropriate education relating to adjustment to life following a career in racing and so allowing individuals to take control of their health. The development of a jockey pathway and the aligning of support services based on the capacities identified at each phase have recently been initiated in Ireland. It is necessary to implement the essential educational and other support programmes amongst the apprentice jockeys who are at a crucial stage of their maturation to limit any metabolic or musculoskeletal damage in later life.

Chapter Five: The Physiological Demands of Horse Racing

Irish Derby 2013

5.1 Abstract

Aim: Despite the international popularity of horse racing, the physiological demands and energy requirements of the challenging lifestyle associated with being a jockey remain largely unknown. The purpose of this study was to determine the physiological demands and energy requirements of racing, training and other daily activities associated with flat jockeys. **Methods:** This study consisted of 3 phases involving 3 separate groups depending on the requirements of the task to be completed. Part A: Thirty apprentice jockeys completed a daily physical activity questionnaire. Part B: Eighteen male trainee jockeys (age 16 ± 1yr; height 1.67 ± 0.1 m; body mass 55.7 ± 5.5 kg; BMI 19.9 ± 1.7 $kg \cdot m^{-2}$; % body fat 8.1 ± 1.7%; VO_2peak 57.1 ± 4.7 $ml \cdot kg^{-1} \cdot min^{-1}$; HRpeak 188 ± 12 $beats \cdot min^{-1}$) performed a race simulation trial on a horse racing simulator for the typical time duration to cover a race distance of 1400 m at the maximum simulator velocity of 30 $km \cdot hr^{-1}$. An outdoor riding trial was completed by 11 of these participants at 3 of the different equine gaits: walk, trot and canter, during which mean VO_2 and HR were recorded for each gait. Part C: Eleven male apprentice jockeys (age 18 ± 1yr; height 1.69 ± 0.04 m; body mass 54.9 ± 2.9 kg; BMI 19.2 ± 1.1 $kg \cdot m^{-2}$; % body fat 7.4 ± 1.3 %; VO_2peak 54.0 ± 3.3 $ml \cdot kg^{-1} \cdot min^{-1}$; HRpeak 185 ± 7 $beats \cdot min^{-1}$) wore physiological monitoring devices (Equivital, SenseWear Armband) for the duration of a non-race day. Eight of these apprentice jockeys also wore the devices for a race day inclusive of the race itself. **Results:** Questionnaire results revealed jockeys typically 'ride work' 3.4 ± 1.7 days a week with the majority of riding time in training spent at a walk, trot and canter. Riding at a walk, trot and canter in training had associated MET intensity values of 2.4 METs, 6.2 METs and 7.7 METs respectively. During the simulated race over 1400 m, VO_2 and HR reached 75 ± 11% and 86 ± 7 % of the VO_2peak and HRpeak, respectively, previously attained in maximal cycle ergometer test. A typical race of 1400 m expends 22.1 ± 4.5 kcal with an associated MET value of 9.4 METs. In competitive racing, peak HR was 189 ± 5 $beats \cdot min^{-1}$. Total estimated energy expenditure (EEE) was found to be 3068 ± 232 $kcal \cdot day^{-1}$ and 3424 ± 507 $kcal \cdot day^{-1}$ for a race day and non-race day respectively. **Conclusion:** Results from this study should allow sport specific recommendations to be developed regarding appropriate nutritional and training strategies, to limit the reliance on antiquated weight making practices and assisting jockeys in enhancing their health, wellbeing and overall performance throughout their sporting career, and beyond.

5.2 Introduction

Paramount to jockeys is the need to chronically maintain a low body mass, necessary to attain the stipulated competition riding weights, whilst maintaining a sufficient level of physical conditioning in order to compete in several races each day. With no defined off-season in horse racing, many jockeys are required to 'make weight' all year round in order to maximise riding opportunities which often necessitates the adoption of unhealthy acute weight loss practices including the use of saunas, exercising to induce sweating and restricting energy intake (Dolan et al., 2011). Such weight loss strategies appear to result in jockeys living and competing in a dehydrated and energy deficient state (Dolan et al., 2011, Warrington et al., 2009) with many associated negative health and performance connotations for jockeys including poor bone health and a high incidence of osteopenia (Warrington et al., 2009, Dolan et al., 2012a, Dolan et al., 2012b, Greene et al., 2013, Waldron-Lynch et al., 2010) in addition to impaired physiological function and compromised aerobic capacity (Dolan et al., 2013, Dolan et al., 2012b) and mental health (Caulfield and Karageorghis, 2008). Understanding the physiological and energy demands of a sport can allow the development of specific nutritional and training guidelines, information which appears to be of critical importance for jockeys, whose careers depend on making designated weights. However, despite the international popularity of horse racing, the specific physiological demands and energy requirements of this challenging lifestyle remain largely unknown.

While horse racing has been suggested to be a physically demanding sport (Trowbridge et al., 1995, Wilson et al., 2013c), limited research is available pertaining to the specific physiological demands of racing, training and other daily activities of jockeys. An optimal level of physical fitness would likely influence performance, the ability to recover from a ride and potentially reduce the likelihood of injury resulting from physiological fatigue (Hitchens et al., 2011, Trowbridge et al., 1995). It has been suggested that optimal performance in national hunt races requires jockeys to be both aerobically and anaerobically fit (Trowbridge et al., 1995). Lower anaerobic and aerobic fitness in jockeys have been associated with a greater risk of falls (Hitchens et al., 2011). To the authors knowledge no information is currently available relating to the physiological demands of jockeys involved in flat racing.

Chronic energy restriction has been suggested to be prevalent amongst jockeys given the reported low energy intakes (Dolan et al., 2011, Leydon and Wall, 2002). Dolan et al., (2011) reported a mean daily intake of 1803 ± 564 kcal for jockeys which appeared to be only 22% (1.2 times) above the estimated RMR of 1492 ± 114 $kcal \cdot day^{-1}$. Total daily energy expenditure on a competitive flat race day was previously reported to be a relatively high value of 3952 ± 577 $kcal \cdot day^{-1}$ (Dolan et al., 2008). An insufficient availability of energy (lower than 30 $kcal \cdot kg^{-1} FFM \cdot day^{-1}$) required for the sustainment of typical daily and metabolic processes has been shown for professional jockeys on a competitive race day (Dolan et al., 2011). While limited data regarding jockeys on non-race days are currently unavailable, reduced energy expenditure (EE) is expected (Dolan et al., 2011). Wilson et al. (2013c) estimated total daily EE on a non-racing working day in a group of national hunt jockeys to be 2689.40 $kcal \cdot day^{-1}$. It has been suggested the potential increased availability of energy on non-race days may be unlikely to compensate for the energy deficit on race days however further research is required (Dolan et al., 2011).

Based on previous research revealing some worrying trends relating to the health (Dolan et al., 2012a, Dolan et al., 2012b, Dolan et al., 2011, Greene et al., 2013, Leydon and Wall, 2002, Waldron-Lynch et al., 2010, Warrington et al., 2009) and performance of jockeys (Dolan et al., 2013, Wilson et al., 2013b), many strategies have been put in place to encourage best practice in recent years namely raising the stipulated competition weight standards, the availability of a dietician to all jockeys, providing an educational programme for apprentice jockeys (Waldron-Lynch et al., 2010) and most recently the implementation of a new minimum weights structure for apprentice jockeys in Ireland. Further research is required in order to specifically quantify the physiological demands and energy requirements of the racing, training and daily activities typically undertaken by jockeys, thereby giving a scientific evidence base for the provision of sport-specific nutritional and training recommendations. This would subsequently allow the introduction of best practice strategies to optimally equip and prepare jockeys for a career in horse racing while reducing the endemic reliance on such unhealthy weight making practices. The purpose of this study therefore was to determine the physiological demands and energy requirements of racing, training and other daily activities in a group of flat jockeys.

5.2.1 Aims and Objectives

The aim of this study was to evaluate the physiological demands and energy requirements of jockeys during training, racing and other daily activities.

This aim was achieved by completing the following objectives in the various phases of the study:

Part A:

Objective One:

To establish a profile of the typical daily activities of jockeys.

Part B:

Objective Two:

To determine the physiological demands and estimated energy requirements of a simulated race as assessed on a racehorse simulator.

Objective Three:

To evaluate the physiological demands and estimated energy requirements of the typical riding gaits (walk, trot, canter) undertaken throughout the day in training.

Part C:

Objective Four:

To determine the physiological demands and estimated energy requirements of an actual race.

Objective Five:

To estimate the typical daily energy expenditure of jockeys on a non-race and a race day.

Hypothesis

1. That the typical daily activities undertaken by a jockey have a high physiological demand.
2. That the estimated energy demands are greater on a non-race day when compared to a race day.

5.3 Methods

5.3.1 Study Design Overview

(See figure 5.1)

Part A:

Thirty apprentice jockeys completed a daily physical activity and lifestyle questionnaire detailing the typical daily lifestyle patterns of a jockey. More details will be provided on this questionnaire in the procedures section (Section 5.3.3.1).

Part B:

Eighteen male trainee jockeys were recruited to participate in this study. Participants performed a maximal incremental cycle ergometer test to volitional exhaustion to determine maximal aerobic capacity (VO_2peak) and maximum heart rate (HRpeak). On a separate day, participants performed a race simulation trial on a horse racing simulator for the typical time duration to cover a race distance of 1400 m. Eleven of these participants subsequently completed an outdoor riding trial at each of the different equine riding gaits: walk, trot and canter. Physiological function was assessed through measurement of respiratory metabolic measures and HR with the mean VO_2, HR and EE recorded in all tests.

Part C:

Eleven apprentice jockeys volunteered to wear physiological monitoring systems for the duration of a non-racing day. Eight participants also wore these devices on a racing day, leaving only the Equivital on for the actual race. The subjects recruited for this study had previously completed a maximal cycle ergometer test to volitional exhaustion to determine maximum heart rate (HRpeak). HR, respiratory rate (RR) and EE were determined for training, racing and other daily activities through both the Equivital and SenseWear Armband.

Ethical approval for this study was granted by the Dublin City University Research Ethics Committee.

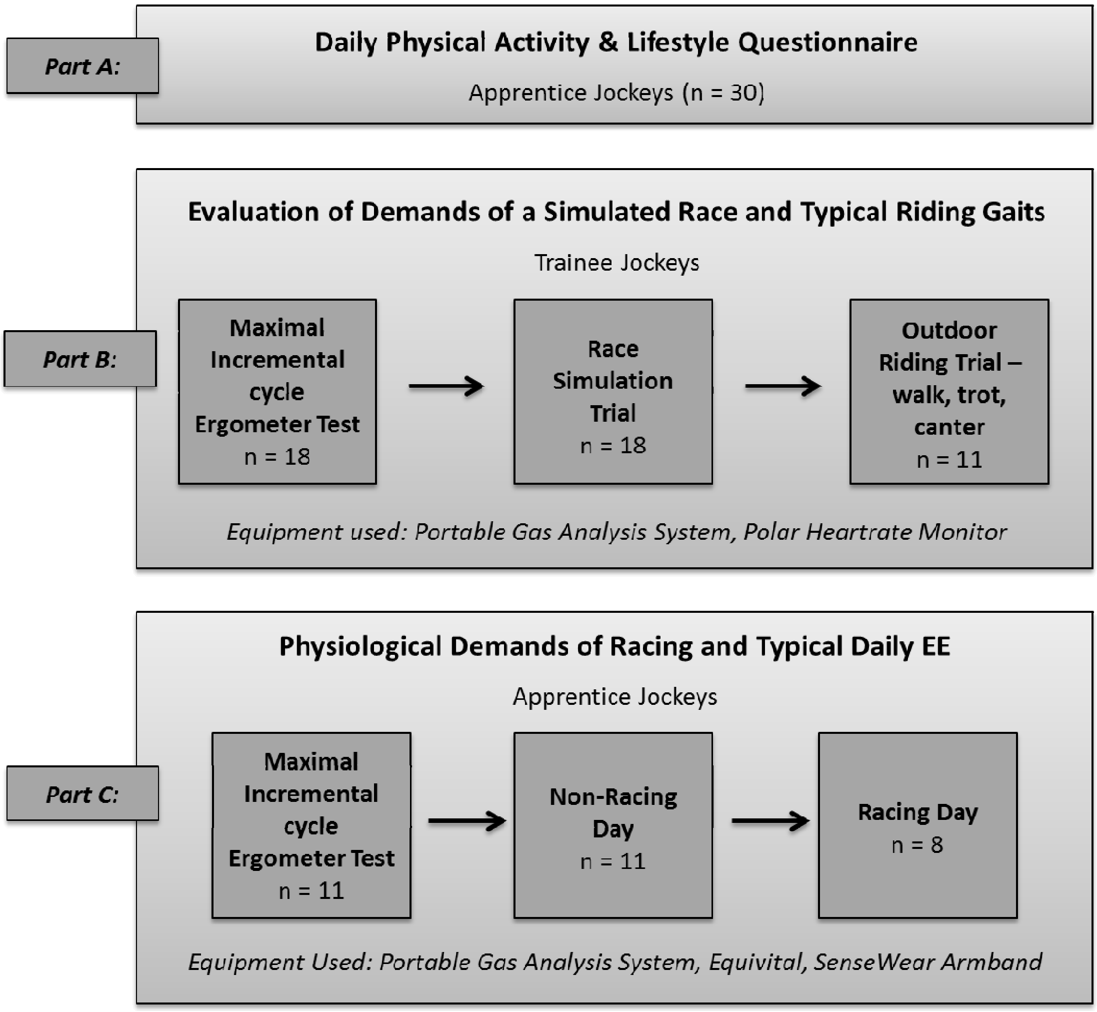


Figure 5.1: Schematic Representation of the Research Study

5.3.2 Participants

Part A:

Thirty apprentice jockeys, representing 56% of all licenced apprentice jockeys at the time of testing, volunteered to complete the daily physical activity and lifestyle questionnaire detailing the typical daily lifestyle patterns of a jockey. Participants were recruited at various race meetings around Ireland. Inclusion criteria included male apprentice jockeys regularly racing while exclusion criteria included female jockeys, trainee or professional jockeys and those apprentice jockeys not regularly racing.

Part B:

Eighteen male trainee jockeys (representing 78% of all male trainee jockeys), residing at RACE, were recruited to participate in Part B of this research study. Parental consent was provided for all participants under the age of 18. Only 11 of the participants completed the outdoor riding trial due to timing restrictions within RACE. Trainee jockeys were used for this section to allow ease of data collection in a controlled environment in RACE. This would not have been possible in a training yard with apprentice jockeys. Inclusion criteria included male trainee jockeys from RACE who were free of injury while apprentice and professional jockeys as well as female jockeys were excluded.

Part C:

Eleven male apprentice jockeys (29% of all male licenced apprentice jockeys at the time of testing) were recruited to undergo Part C of this research study. Participants were recruited via mass mailing *(Appendix G)* all apprentice jockeys in the Turf Club directory and through the Turf Club Chief Medical Officer. Inclusion criteria required male apprentice jockeys to be released by the individual training yard at requested times, to be regularly racing at various race meetings throughout the country and willing to wear sensing devices in races. Exclusion criteria included professional jockeys and those apprentice jockeys not given permission to leave training duties and not racing regularly.

All subjects provided written informed consent *(Informed Consent Form, Appendix B3)* and medical history *(General Health Questionnaire, Appendix C)* prior to participation in this research study (Part B and C). Any participant who was absolutely contraindicated from exercise participation was excluded from the study. All participants were requested to abstain from alcohol and from any unusual and strenuous physical activity for 24hours prior to the collection of data.

5.3.3 Procedures

5.3.3.1 Daily Physical Activity and Lifestyle Questionnaire:

This questionnaire was completed with individuals in a semi-structured interview format by the same researcher at the various race tracks around Ireland. The questionnaire was developed by the research team and contained both open- and closed-ended questions in order to gather information on the typical daily activities of jockeys including the days worked per week, the number of hours worked daily at a yard, the chores completed, the number of horses ridden out, the time spent on each horse, how often 'work' is ridden, typical number of races obtained at a race meeting, additional exercise if any performed and the purpose for the exercise. A copy of the questionnaire is included in Appendix I.

5.3.3.2 Anthropometric Assessment:

i. Body Mass and Stature

Body mass was assessed in minimal clothing and reported to the nearest 100g using a portable digital scales (Salter, Germany). Stretched stature was measured to the nearest mm using a portable Stadiometer (Seca, Leicester Height Measure). Body mass index (BMI; $kg{\cdot}m^{-2}$) was calculated by dividing the weight in kilograms by the square of the height in metres.

ii. Body Composition

Body composition was assessed using surface anthropometry. A Harpenden skinfold callipers (Cambridge Scientific Industries, UK) was used to measure the double thickness subcutaneous adipose tissue at the following 7 sites: biceps, triceps, subscapular, supraspinale, abdominal, mid-thigh and medial calf. All measurements were taken in accordance with previously published guidelines (ACSM, 2006). A minimum of 3 repeated measures were taken at each site on the right side of the body and additional measures were taken if any measurement varied by more than 1 mm. The order of measurement was repeated on a rotation basis and the mean of the triplicate measurements was reported. Percent body fat was then estimated using the sum of the seven skinfold measurements in the regression equation for body density as previously described (Withers et al., 1987).

5.3.3.3 Maximal Incremental Cycle Ergometer Test:

Aerobic capacity was assessed through performance on a Wattbike cycle ergometer (Wattbike Ltd, Nottingham, UK) using a continuous incremental test to volitional exhaustion. The test protocol began with a 5 minute warm up at 60 watts followed by three minute stages commencing at 60 watts and increasing in 25 watt increments until volitional exhaustion.

Cosmed K4b2 (Cosmed, Italy) was used to measure aerobic capacity and peak VO_2 (VO_2peak) was determined. HR was measured continuously throughout the test via telemetry using Polar HR monitor (Polar, Finland) and peak HR (HRpeak) was recorded. A subjective rating of perceptual effort was also measured according to Borg's rating of perceived exertion (RPE) scale, ranging from 6 to 20 with 7 being very very easy to 19 being very very hard (Borg, 1982). VO_2peak and HRpeak were attained when the subject had reached an RPE of 20 and volitional exhaustion was achieved. Ventilatory threshold (VT) was estimated using the V-Slope method (Beaver et al., 1986).

Figure 5.2: Incremental Test Completed on the Wattbike Ergometer

5.3.3.4 Race Simulation Trial:

A simulated race for the typical time duration (168 sec) equivalent to a race distance of 1400 m (a common sprint distance in flat racing) was completed on a mechanical race horse simulator (Racewood Ltd, Cheshire, GB) at the maximum simulator velocity of 30 $km \cdot h^{-1}$ (figure 5.3). For the time period equivalent to the final 300 m (36 sec) of the race, individuals were encouraged to provide maximal effort adopting the "racing position" and to use a single hand grip to enable the use of the whip. Individuals remained seated for a 5 minute period following the simulated race. Physiological function was assessed through measurement of respiratory metabolic measures (Cosmed K4b^2, Cosmed, Italy) and HR (Polar, Finland). Mean and peak values for VO_2 and HR for the complete race were established for comparison purposes to the previous peak physiological data attained from trainee jockeys. Respiratory Exchange Ratio (RER) was estimated during the trial and also in the recovery period following the simulated race. Total EE was estimated from the breath-by-breath metabolic measurements using Cosmed K4b^2 which utilises the Weir equation to predict EE (Weir, 1949).

Figure 5.3: Race Simulation Trial

5.3.3.5 Outdoor Riding Trial:

Subjects completed an outdoor riding trial during 3 different equine riding gaits namely a walk, trot and canter (figure 5.4). Since the physiological assessment of each equine gait was incorporated into a typical morning of training, each gait was performed in succession to each other. Time in each gait varied slightly however a minimum of three minutes of data were used for each gait to compute mean VO_2 and HR using a portable gas analysis system (Cosmed K4b2, Cosmed, Italy) and a HR monitor (Polar, Finland). The physiological data collected was analysed in relation to the peak physiological data previously attained from trainee jockeys in the incremental cycle ergometer test. Respiratory metabolic measures (Cosmed K4b2, Cosmed, Italy) for the same period were used to estimate absolute EE using the Weir equation (Weir, 1949). An estimate for the velocity attained during each equine gait was provided by a wrist worn Global Positioning System (GPS) (Garmin Forerunner 405).

The different riding gaits in this study were assigned a MET value. Metabolic equivalents (METs) represent the varying intensity of a physical activity and are used as a shorthand method of estimating EE during various physical activities. One MET is defined as the energy expended at rest (i.e. RMR; 1 MET = 3.5 $ml \cdot kg^{-1} \cdot min^{-1}$) (Haskell et al., 2007). Physical activities are often classified as light (<3 METs), moderate (3-6 METs), vigorous (6-9 METs) or very vigorous intensity (>9 METs) (Ainsworth et al., 2011).

Figure 5.4: Outdoor Riding Trial

5.3.3.6 Physiological Demands of Racing and Daily Activities:

Apprentice jockeys wore two sensing technologies for both a racing day and a non-racing day.

1. ***Equivital Physiological Monitoring System***

The Equivital physiological monitor (EQ02, Hidalgo, Cambridge, UK) was used to capture data relating to the physiological demands of training, racing and other daily activities throughout the period of a racing and non-racing day. The EQ02 sensor belt provided a comfortable fit on the jockeys and it is considered a valid and reliable sensor for ambulatory monitoring of multiple physiological parameters (Liu et al., 2013, Weippert et al., 2013). Subjects received a demonstration and instructions on how to wear the Equivital monitoring device in accordance with the manufacturer's specifications and then fitted the device themselves when they got up in the morning before work and removed the system before they went to bed at night (figure 5.5). Featuring a system of sensors and electrodes embedded in novel textiles, the sensor belt recorded HR, RR (chest expansion) and body motion (through a tri-axial accelerometer). Data was later downloaded onto a computer and converted into .xls files for data analysis.

Figure 5.5: Equivital Physiological Monitoring Belt with the Sensor Electronics Module (SEM) (right) that fits into the grey section of the chest belt to sense, record, store and process information

The Equivital device was the only sensor to remain on the individual in the actual horse race. The researcher attended all race meetings to ensure the device was worn correctly. A note was made of the exact time of the race, allowing easy subdivision and processing of the race data at a later time to calculate HR and RR during the competitive race.

2. SenseWear Pro3 Armband

Total EE for a racing and non-racing day were estimated using the SenseWear Pro3 Armband (SWA, BodyMedia, Inc.) (figure 5.6). The SenseWear armband has been suggested to have the potential to provide a practical assessment of free-living energy expenditure (Fruin and Walberg Rankin, 2004) as well as valid and reliable estimated resting and exercise EE when compared to indirect calorimetry (Fruin and Walberg Rankin, 2004, King et al., 2004). While providing accurate measurements for EE during low-to-moderate intensity physical activities, the SenseWear armband has been reported to have a threshold for accurate measurements at an exercise intensity of 10 METS (Drenowatz and Eisenmann, 2011). Participants placed the SenseWear armband on the back of the tricep of the left arm when they arose first thing in the morning and wore the multisensor body monitor for a 24 hour period removing only for the actual race, bathing and sauna use. Utilising a 2-axis accelerometer, heat flux sensor, galvanic skin response sensor, skin temperature sensor and a near body ambient temperature sensor, physical activity and EE were continuously and conveniently tracked throughout the day (Liden et al., 2002). The armband design render it practical to be worn in any situation, while the multiple sensors allowed this device to overcome many limitations of the more singular means of estimating EE (Fruin and Walberg Rankin, 2004). Data was later analysed using SenseWear Professional version 6.1.

Figure 5.6: Sensewear Pro3 Armband worn on the tricep of the left arm

5.3.4 Statistical Analysis

Data was analysed using SigmaPlot version 12.0. Descriptive statistics were calculated for each dependent variable for each task and all data were expressed as mean ± SD. Normality of data distribution was tested using the Shapiro Wilks test. A one way ANOVA was performed to determine if any difference existed between the physiological measures attained for each riding gait assessed in training. A pairwise comparison identified the location of the significant difference if present. The Bonferroni procedure was used to calculate the acceptable level of significance. Significance was accepted at the level of $p \leq 0.05$.

5.4 Results

5.4.1 Part A

5.4.1.1 Physical Activity and Lifestyle Questionnaire

A summary of the typical daily physical activity and lifestyle patterns of a jockey are presented in Table 5.1. Thirty apprentice jockeys, representing 56% of the 54 licenced apprentices, completed the questionnaire.

Six days of work in the training yard each week was typically reported while 20% (n = 6) of the jockeys completed 7 days of work every alternate week. The usual start time reported was between 7 am and 7.30 am. Despite 30% (n = 9) not having to perform work in the afternoon, all other jockeys (n = 21) reported leaving the yard for lunch at 12.30 pm and returning to the yard for additional afternoon duties between 3 pm to 5 pm. Jockeys typically only ride 'work' 3.4 ± 1.7 days a week with the majority of riding time by the jockey each day being spent at a walk, trot and canter. A mean of 6 ± 3 horses were ridden each day for a period of 36 ± 15 minutes per horse.

On a race day, jockeys were still expected to attend work in the training yard. Although typically depending on the location of the races and whether it was a day meeting or evening meeting, all jockeys completed morning duties in the training yard with only 20% (n = 6) returning for afternoon duties in the yard if the race meeting was in the evening. Jockeys reported generally securing up to 4 rides (range 1 to 7) at a race meeting independent of whether it was a day or evening meeting.

Table 5.1: Typical Daily Work and Exercise Patterns amongst Jockeys

	n = 30
Number of working days a week *(days)*	6 ± 1
Number of hours worked per day *(hours)*	6.6 ± 1.3
Number of horses ridden	6 ± 3
Length of time on each horse ridden *(minutes)*	36 ± 15
Number of days each week riding 'work' *(days)*	3.4 ± 1.7
Typical number of races ridden in at a meeting	3.6 ± 2
Performing additional exercise to riding *(%)*	40%

Data presented as mean ± SD

Seventy three percent of jockeys (n = 22) reported undertaking additional exercise to riding when weight loss was necessary, while 40% (n = 12) reported performing exercise on at least 3 days each week. Running was the predominant form of exercise reported for all jockeys, typically conducting 41.2 ± 16.5 minutes (range 30 to 80 minutes) of running on 3.6 ± 1.6 days (range 2 to 7 days). Other methods of exercise mentioned included soccer, cycling, swimming, skipping, boxing, walking, gym work – stepper/cross trainer/row machine, simulator. One individual performed sit ups 3-4 times a week.

5.4.2 Part B

5.4.2.1 Subject Characteristics

Descriptive data for all trainee jockeys are presented in Table 5.2.

Table 5.2: Descriptive and Anthropometric Characteristics and Peak Physiological Data of Trainee Jockeys

	Trainee Jockeys (n = 18)
Age (years)	16 ± 1
Height (m)	1.67 ± 0.1
Body Mass (kg)	55.7 ± 5.5
BMI ($kg \cdot m^{-2}$)	19.9 ± 1.7
Sum of 7 Skinfolds (mm)	45.7 ± 7.5
% Body Fat	8.1 ± 1.7
VO_2peak ($ml \cdot kg^{-1} \cdot min^{-1}$)	57.1 ± 4.7
HRpeak ($beats \cdot min^{-1}$)	188 ± 12
VT (%)	81.2 ± 5.4%

Data presented as mean ± SD; Ventilatory Threshold (VT)

5.4.2.2 Physiological Demands of a Simulated Race

Physiological data for the simulated race over 1400 m are reported in Table 5.3. During the simulated race, peak VO_2 reached 75 ± 11% of VO_2peak which was just below the mean VT which occurred at 81.2 ± 5.4% VO_2peak during the incremental cycle ergometer test.

Table 5.3: Physiological Data during the Simulated Race

Physiological Variable Assessed	Trainee Jockeys (n = 18)
Mean VO_2 (ml·kg^{-1}·min^{-1})	32.92 ± 6.4
Relative Mean VO_2 (%VO_2peak)	58 ± 10
Peak VO_2 (ml·kg^{-1}·min^{-1})	42.74 ± 5.6
Relative Peak VO_2 (%VO_2peak)	75 ± 11
Mean HR (beats·min^{-1})	144 ± 15
Relative Mean HR (%HRpeak)	77 ± 7
Peak HR (beats·min^{-1})	161 ± 16
Relative Peak HR (%HRpeak)	86 ± 7
Peak RER during exercise	1.07 ± 0.1

Data presented as mean ± SD

Peak RER reached 1.39 ± 0.1 immediately post exercise. The simulated race was classified as a very vigorous activity (9.4 METs). Total EE during the 1400 m simulated race on the race horse simulator was estimated to be 22.1 ± 4.5 kcal with a further 25.45 ± 3.4 kcal expended in the 5 minutes following the race when at rest.

5.4.2.3 Physiological Demands of Typical Riding Gaits

Mean VO_2 and HR cumulated for the steady-state period in each riding gait is given in Table 5.4. A progressive significant increase in VO_2 and HR is observed from walk to trot to canter.

Table 5.4: Physiological Data during the Various Riding Gaits

Physiological Variable Assessed Trainee Jockeys (n = 11)	**Walk**	**Trot**	**Canter**
Mean Velocity ($km \cdot h^{-1}$)	*~4.6 ± 0.7*	*~7.3 ± 1.2*	*~28.4 ± 1.0*
Mean VO_2 ($ml \cdot kg^{-1} \cdot min^{-1}$)	8.3 ± 2.1$^{¥}$	21.7 ± 3.3$^{¥*}$	26.8 ± 5.0$^{¥*}$
Relative Mean VO_2 (%VO_2peak)	15 ± 4$^{¥}$	38 ± 6$^{¥*}$	45 ± 9$^{¥*}$
Mean HR ($beats \cdot min^{-1}$)	91 ± 9$^{♦}$	115 ± 11$^{♦}$	135 ± 15$^{♦}$
Relative Mean HR (%HRpeak)	48 ± 6$^{♦}$	60 ± 6$^{♦}$	71 ± 7$^{♦}$

Data presented as mean ± SD; Mean VO_2 and Relative Mean VO_2 was significantly different amongst gaits; $^{*}p \leq 0.05$ between canter and trot; $^{¥}p \leq 0.001$ amongst other gaits; Mean HR and Relative Mean HR was significantly different amongst gaits; $^{♦}p \leq 0.001$

Walking required the lowest estimated EE with a value of 2.25 ± 0.6 $kcal \cdot min^{-1}$ (2.4 METs; light intensity activity) and it was significantly lower to trotting at 5.72 ± 1.0 $kcal \cdot min^{-1}$ ($p \leq 0.001$; 6.2 METs; vigorous activity), and cantering at 7.10 ± 1.8 $kcal \cdot min^{-1}$ ($p \leq 0.001$; 7.7 METs; vigorous activity). Estimated EE was also significantly different between the riding gaits of trot and canter ($p \leq 0.05$).

5.4.3 Part C

5.4.3.1 Subject Characteristics

Descriptive data for apprentice jockeys are presented in Table 5.5.

Table 5.5: Descriptive and Anthropometric Characteristics and Peak Physiological Data of Apprentice Jockeys

	Apprentice Jockeys (n = 11)
Age (years)	18 ± 1
Height (m)	1.69 ± 0.04
Body Mass (kg)	54.9 ± 2.9
BMI ($kg \cdot m^{-2}$)	19.2 ± 1.1
Sum of 7 Skinfolds (mm)	42.0 ± 8.0
% Body Fat	7.4 ± 1.3
VO_2peak ($ml \cdot kg^{-1} \cdot min^{-1}$)	54.0 ± 3.3
HRpeak ($beats \cdot min^{-1}$)	185 ± 7

Data presented as mean ± SD

5.4.3.2 Physiological Demands of an Actual Race

Physiological data for a typical race is presented in Table 5.6. During a typical race, the mean HR was 97.8 ± 3.5% of HRpeak when compared to the peak physiological data attained from the apprentice jockeys in the incremental cycle test. Recorded peak HR exceeded that of which was recorded in the maximal incremental cycle test and reached 103 ± 3.8 % of HRpeak.

Table 5.6: Physiological Data of an Actual Race

	Apprentice Jockeys (n = 8)
Mean HR ($beats \cdot min^{-1}$)	180 ± 6
Peak HR ($beats \cdot min^{-1}$)	189 ± 5
Mean RR ($breaths \cdot min^{-1}$)	43 ± 5
Peak RR ($breaths \cdot min^{-1}$)	50 ± 7

Data presented as mean ± SD

5.4.3.3 Physiological Demands during Daily Activities

According to the SenseWear armband, total daily EE was estimated as 3068 ± 232 $kcal \cdot day^{-1}$ and 3424 ± 507 $kcal \cdot day^{-1}$ for the 24 hour period of a race and non-race day respectively. Further investigation into a typical non-race day revealed the duration of the actual non-racing day was 14.9 ± 1.5 hours (~7am to 10pm) and during this time period 47.7 ± 11.8% of the day was spent in a sedentary state (0-3 METs), while 41.6 ± 12.5%, 9 ± 3.5% and 0.3 ± 0.8% was spent completing moderate (3-6 METs), vigorous (6-9 METs) and very vigorous activities (above 9 METS) respectively. Forty four percent (43.9 ± 4.2%) of the total daily 24 hour EEE corresponded with the morning duties undertaken in the yard (6.1 ± 0.5 hours) with only 10 ± 3.2% of the total daily EEE representing afternoon duties (2.3 ± 0.4 hours). Mean EEE during morning work was 4.1 ± 0.6 $kcal \cdot min^{-1}$, while peak EEE reached 8.4 ± 1.9 $kcal \cdot min^{-1}$. The mean MET level for the morning and afternoon activities were 4.5 ± 0.6 METs (moderate) and 2.6 ± 0.9 METs (light) respectively.

Physiological data for a typical morning of 'riding work' are reported in Table 5.7. During 'riding work' on a typical morning, the mean HR was 74.5 ± 5.5 % of HRpeak when compared to the peak physiological data attained from the apprentice jockeys in the incremental cycle test. Peak HR reached 90.7 ± 8.4 % of HRpeak throughout the morning.

Table 5.7: Physiological Data during Morning Training in the Yard when 'Riding Work'

	Apprentice Jockeys (n = 11)
Mean HR ($beats \cdot min^{-1}$)	138 ± 10
Peak HR ($beats \cdot min^{-1}$)	168 ± 16
Mean RR ($breaths \cdot min^{-1}$)	33 ± 5
Peak RR ($breaths \cdot min^{-1}$)	41 ± 6

Data expressed as mean ± SD

5.4.4 Summary

Questionnaire results revealed apprentice jockeys typically 'ride work' 3.4 ± 1.7 days a week with the majority of riding time in training spent at a walk, trot and canter. Riding at a walk, trot and canter in training had associated MET intensity values of 2.4 METs, 6.2 METs and 7.7 METs respectively. During the simulated race over 1400 m, VO_2 and HR reached 75 ± 11% and 86 ± 7 % of the VO_2peak and HRpeak, respectively, previously attained in maximal cycle ergometer test. A typical race of 1400 m had an EEE of 22.1 ± 4.5 kcal with an associated MET value of 9.4 METs. In competitive racing, peak HR was 189 ± 5 $beats \cdot min^{-1}$. Total daily EEE was found to be higher on a non-race day with EEE reported as 3068 ± 232 $kcal \cdot day^{-1}$ and 3424 ± 507 $kcal \cdot day^{-1}$ for a race day and non-race day respectively.

5.5 Discussion

Based on previous studies which have revealed some worrying trends in relation to the adverse effects of making weight on physiological function (Dolan et al., 2012a, Dolan et al., 2012b, Dolan et al., 2011, Greene et al., 2013, Waldron-Lynch et al., 2010, Warrington et al., 2009, Leydon and Wall, 2002) and performance (Dolan et al., 2013, Wilson et al., 2013b), many strategies have been put in place to encourage best practice amongst the jockeys (Waldron-Lynch et al., 2010). In this context the current study was designed to create a scientific evidence base to further enhance the strategies that have previously been put in place by allowing the future development of sport-specific nutritional and training strategies to meet the lifestyle demands of a jockey. The aim of this study therefore, was to evaluate the physiological demands and energy requirements of jockeys during training, racing and other daily activities in order to provide a greater insight into the lifestyle demands of a jockey. Results from this study suggest the lifestyle of a jockey including training and racing is physically demanding. The need to maintain a constant low body mass to achieve the stipulated competition riding weights often render the use of many unhealthy weight loss practice amongst jockeys (Dolan et al., 2011, Labadarios et al., 1993, Leydon and Wall, 2002, Moore et al., 2002) which may have many deleterious effects on physical and mental health (Dolan et al., 2012b, Warrington et al., 2009, Dolan et al., 2011, Dolan et al., 2012a, Caulfield and Karageorghis, 2008) and performance (Dolan et al., 2013). The results from this study may be used, alongside the limited previously collected data on the physiological demands and energy requirements of jockeys during training and racing (Dolan et al., 2011, Wilson et al., 2013c, Trowbridge et al., 1995), as guidelines to optimise horse racing performance and control the required low body mass amongst jockeys.

The findings of the current study would suggest that horse racing is evidently a physically demanding sport as depicted in both the competitive races and simulated races conducted within this research study all of which require a high cardiovascular effort. With the 8 apprentice jockeys in this current study reaching a peak HR of 189 ± 5 $beats\cdot min^{-1}$ and RR of 50 ± 7 $breaths\cdot min^{-1}$ in the various races assessed, a marked stress is suggested to be placed on the cardiovascular system. Furthermore, during the simulated flat race distance of 1,400m, jockeys were required to perform at a high relative exercise intensity (75 ± 11% VO_2peak and 86 ± 7% HR peak) with peak RER immediately following cessation of the simulated race recorded as 1.39 ± 0.1. Despite participants encouraged to provide maximal effort, the slightly lower physiological demand compared to competitive racing may have been the result of the simulated environment and specifics of the race horse simulator itself. While no study has previously evaluated the physiological demands of competitive flat racing, the findings of this current research are in agreement with the high aerobic requirement previously reported in national hunt jockeys (Trowbridge et al., 1995), the only other study assessing the demands of competitive race riding. In the 30 national hunt races studied, Trowbridge et al. (1995) reported the 7 professional jockeys reached a max HR of 184 beats$\cdot$min^{-1} (range 162 to 198 beats$\cdot$min^{-1}) while mean HR was always above 80% of the measured max HR for the duration of the races. Furthermore, having monitored consecutive races typically separated by a time interval of 30-35 mins, the HR always remained elevated above resting levels. This may have implications on the many jockeys who have numerous races throughout a race meeting. Limited access to jockeys in the current study in the time period immediately after the race inhibited the assessment of anaerobic requirements, as is typically estimated objectively by post exercise peak blood lactate levels (Jacobs, 1986), however performing just below the VT in the simulated race of 1400 m would suggest an anaerobic requirement during the activity (Beaver et al., 1986). Trowbridge et al., (1995) suggested it is necessary for a jockey to be anaerobically fit in order to be a successful rider given the high peak post-race lactate concentrations (ranged from 3.5 to 15 mmol$\cdot$L^{-1}).

In Ireland, flat racing generally lasts from 1 to 3 minutes in duration (1 to 4km). Results from the simulated race conducted on the race horse simulator reveal the very commonly raced distance in flat racing of 1,400m was estimated to result in EE of 22.1 ± 4.5 kcal, without taking the associated excess post-exercise oxygen consumption (EPOC) into account. These findings are comparable to the EE estimated during a simulated 3.2 km race in a group of national hunt jockeys (Wilson et al., 2013c). Wilson et al. (2013c) previously report an EEE in 9 national hunt jockeys on a manual mechanical race horse simulator as 43 kcal for the 3.2 km simulated race. The results on EEE during a simulated race provide a guide for individuals on caloric expenditure during competitive racing. The laboratory based protocol used in the current study and by Wilson et al., (2013c) may not have accounted for the additional energy demands associated with the physical exertion of restraining a horse plus the hormonal response in a competitive racing environment and so a slightly under estimation of the EEE of a real competitive race could be suggested with the reported results of this study. Despite such limitations, absolute mean MET intensity during the simulated race of 1400 m in the current study was presented as 9.4 METs, a value classifying the activity as vigorous and comparable to other sports such as running between 8.5 and 9.5 $km \cdot h^{-1}$ (9-10 METs), boxing and sparring (9 METs), competitive football (9 METs) and orienteering (9 METs) (Ainsworth et al., 2000).

The questionnaire results provided an insight into the typical lifestyle and training undertaken by jockeys. Results revealed jockeys typically 'ride work' 3.4 ± 1.7 days a week. On these particular mornings, peak HR reached 168 ± 16 $beats \cdot min^{-1}$ (90.7 ± 8.4% HR peak) with mean HR at 138 ± 10 $beats \cdot min^{-1}$ (74.5 ± 5.5% HR peak) and mean RR was 33 ± 5 $breaths \cdot min^{-1}$. The majority of riding time in training each day is spent at a walk, trot and canter with a mean of 6 ± 3 horses ridden each day for a period of 36 ± 15 minutes per horse. These riding activities repetitively completed are typically associated with a relatively low physiological demand compared to peak physiological data collected. Similar to Devienne et al., (2000), energy demand was demonstrated to increase as the riding pace progressed from a walk, through to a trot and to a canter. In the current study, mean VO_2 (15 ± 4% VO_2peak, 38 ± 6% VO_2peak, 45 ± 9% VO_2peak for a walk, trot and canter respectively) and HR (48 ± 6% HRpeak, 60 ± 6% HRpeak, 71 ± 7% HRpeak for a walk, trot and canter respectively) during the various gaits were shown to be somewhat lower to those previously observed in recreational riders. Westerling et al., (1983) found 13 experienced riders (riding 3-14 hours/week) were working at over 60% of their maximal aerobic power during a trot and canter, an exercise intensity at which some training effects would be expected. Riding experience and the amount of riding undertaken weekly may explain the apparent differences in the current study results and those seen in recreational riders. Westerling et al., (1983) also assessed a group of 3 elite riders typically riding 16-30 hours per week similar to what would be seen in the jockeys in the current study. A similar mean VO_2 of 14 ± 3% VO_2peak, 41 ± 8% VO_2peak, 46 ± 11% VO_2peak and HR of 47 ± 8% HRpeak, 64 ± 13% HRpeak, 71 ± 16% HRpeak for a walk, trot and canter respectively were reported in the study by Westerling et al., (1983). The variability in EE according to both the rider and horse has also been emphasized in a study in which participants completed riding trials on 4 different horses of varying dispositions including a lethargic horse requiring additional pushing, an easy horse and a nervous horse that had to be restrained (Devienne and Guezennec, 2000). As a result, rider EE appears to vary according to the horse ridden.

Reported MET values reported during the equine gaits during training in the current study are in accordance with those previously reported for horse racing in the Compendium of Physical

Activities namely walking at 2.6 METs, trotting at 6.5 METs and galloping at 8 METs (Ainsworth et al., 2000). In the present study, walking was classified as a light intensity activity at 2.4 METs and may be comparable to other activities including darts and stretching. Trotting and cantering were presented with a vigorous MET intensity of 6.2 METs and 7.7 METs respectively. According to the Compendium of Physical Activities, trotting was deemed similar in intensity to tennis doubles, cycling leisurely with a light effort at 16-19 $km \cdot h^{-1}$ or walking uphill at 5.6 $km \cdot h^{-1}$ while cantering was equivalent to tennis singles, cycling leisurely with a moderate effort at 19-22 $km \cdot h^{-1}$ or running at 8 $km \cdot h^{-1}$ (Ainsworth et al., 2000). Such equine riding gaits are performed for the duration of morning training and those jockeys that return for afternoon duties would engage in free living duties involving cleaning, grooming, 'mucking out', carrying equipment and various other laborious tasks.

Similar to other studies, data suggest a large proportion of jockeys (73%) use additional exercise to riding when a rapid reduction in body mass is necessary to meet the required stipulated weight (Dolan et al., 2011, Labadarios et al., 1993). Questionnaire results reveal however only a small percentage of apprentice jockeys (40%) regularly (2-7 days/week) undertake additional exercise to riding in order to maintain a constant low body mass and level of physical fitness. Running was the predominant form of exercise reported for all jockeys with no sport-specific training programme performed. Such results are similar to a previous study investigating a group of New Zealand jockeys, whom aside from normal work activities, only 22% of the jockeys participated in other forms of exercise, namely running (Leydon and Wall, 2002). A number of jockeys in the study believed exercise increased muscle mass resulting in weight gain and for this reason exercise was restricted to work activities only. In contrast in a study by Labadarios et al., (1993) investigating South Aftrican jockeys, found that aside from riding for 4 hours most mornings, extra exercise was recorded as being a predominant feature in their lifestyle with running, walking, swimming and squash performed 2-3 times per week for up to one and a half hours. Currently no sport-specific guidelines are available in the literature regarding the most beneficial forms of exercise to be conducted amongst jockeys to both optimise performance whilst maintaining a low body mass. Results from this research may help inform the development of such guidelines to meet the lifestyle demands of the jockey.

Data collected using the SenseWear armband on a typical race day and non-race day suggest a flat jockey would expend 3068 ± 232 $kcal \cdot day^{-1}$ and 3424 ± 507 $kcal \cdot day^{-1}$ for a race day and non-race day respectively. Dolan et al., (2008) previously estimated total EE on a competitive flat race day to be 3952 ± 577 $kcal \cdot day^{-1}$ (Dolan et al., 2008). However in contrast, total EE was estimated to be 2689.40 ± 356 $kcal \cdot day^{-1}$ on a typical non-racing working day in a group of national hunt jockeys when assessed using a commercial heart rate monitor (Polar RS400) (Wilson et al., 2013c). Training for national hunt racing would be expected to be more demanding given the longer racing distances and the requirement to jump over hurdles and fences. It could be suggested that daily EEE on a race day would be expected to be higher given the high intensity of the individual races and with many jockeys riding in between 1 and 7 races at each race meeting. Very often however on race-days, jockeys typically do not perform various afternoon non-racing related tasks and therefore may result in a lower daily EEE as seen in the present study. Dolan et al., (2011) suggested a lower EEE and potentially increased energy intake on non-race days may partially compensate for the deficit in energy availability previously reported on competitive race days however it would not be fully compensated due to the chronic restriction of food for subsequent race days. This study suggests total daily EEE is higher on a non-race day and so causing a greater worry for the previously suggested low energy availability amongst jockeys and the associated presence of elements of the female athlete triad (Dolan et al., 2012b, Dolan et al., 2011, Waldron-Lynch et al., 2010). The female athlete triad refers to an interrelationship between energy availability, menstrual function and BMD which may have many clinical manifestations including eating disorders, functional hypothalamic amenorrhea and osteoporosis (Nattiv et al., 2007). Although commonly associated with female athletes, Barrack et al., (2013) suggest males may also experience the adverse metabolic, hormonal and physiological effects of low energy availability. Chronic energy restriction to maintain a low body mass within the stringent weight limits may be the predominant contributor to such a condition in jockeys (Dolan et al., 2011) in which evidence of associated alterations to gonadal and reproductive hormone function (Dolan et al., 2012b) as well as low bone mass (Dolan et al., 2012a, Dolan et al., 2012b, Greene et al., 2013, Leydon and Wall, 2002, Waldron-Lynch et al., 2010, Warrington et al., 2009) have been reported amongst jockeys indicating that many jockeys may be susceptible to such a condition (Dolan et al., 2012b).

5.5.1 Summary

The lifestyle of a jockey may be characterised by long and unusual hours requiring a unique and remarkable dedication to the sport. Results suggest apprentice jockeys work most if not all mornings throughout the week and the majority of apprentice jockeys also work in the afternoons which is comparable to the typical lifestyle of a jockeys in other countries (Labadarios et al., 1993, Leydon and Wall, 2002). Jockeys must travel to the various race courses around Ireland at very short notice and despite where the races are on, morning work in the yard is always completed. Of the 350 race meetings last year, flat jockeys could have been expected to attend up to 171 of these meetings (119 flat and 52 combined flat and national hunt race meetings) with anything from 1 race up to 7 races at each meeting. This hectic lifestyle would suggest a difficulty may arise when attempting to get accustomed to any sort of regular routine and may explain the reliance on unhealthy weight making practices. Both performance and safety on the race track may be acutely affected by the use of such practices, as well as additional health parameters primarily as a result of living in a state of dehydration and low energy availability. The development of sport-specific nutritional and training strategies is now a necessity in this industry to optimise performance and to maintain the stipulated low body mass, inevitably improving the overall health, well-being and safety of jockeys. This study offers novel data by providing the first to report the physiological demands of the various equine training gaits used by jockeys; the associated physical demands of a competitive race and simulated race throughout a distance commonly raced in flat racing; and also the EEE during a simulated race and during daily living on both a race and non-race day in flat jockeys. The novel data collected in this study on the physiological demands and energy requirements of jockeys during training, racing and other daily activities may be used as guidelines for jockeys, which are critical not only to their riding success in terms of performance and making weight, but more importantly may influence their growth, development and overall health.

5.6 Limitations

Although the present study has provided novel data, there are a number of limitations in this study that should be acknowledged and addressed in future studies.

i. Various Study Groups

Due to time constraints within the various training yards and the busy schedules of jockeys, it was not possible to get apprentice jockeys to complete all parts of this study. For this reason, trainee jockeys in RACE performed Part B of the study. The trainee jockeys were approaching the end of the 42 week training course with many ready to sign on as apprentice jockeys so for this reason it was believed the trainee jockeys were at an appropriate standard to complete the various trials.

ii. Small Sample Size

The potential pool of apprentice jockeys to be recruited for this study was limited by those actually receiving races and those granted permission to leave yard duties by the various trainers. Difficulties arose when attempting to encourage jockeys to wear various devices in races. While the Equivital physiological monitoring system was carefully chosen due to the light and unrestricting fit, many jockeys still viewed the slight extra weight unfavourably given the constant pressure to be a certain body mass. No race is ever deemed unimportant to a jockey as they must always report to either the trainer or owner after every race. For these reasons, this study was completed with a relatively small sample size.

iii. Lack of an Actual Simulated Race

Use of the race horse simulator to replicate a real racing environment has its limitations. Having a set velocity on the race horse simulator meant that although verbal encouragement was provided it was up to the discretion of each rider the effort that was put into the simulated race. A true repeatable simulated race in which respiratory metabolic measures could be assessed in a controlled outdoor environment to ensure the collection of reliable and repeatable data was not possible within this research study due to the lack of suitable horses in RACE or time constraints in the various training yards.

iv. Variance of Estimated Energy Expenditure with Each Horse and Race

Devienne et al., (2000) has previously highlighted the variability in rider EEE according to the horse being ridden. This is also assumed to be true for the various races in which they ride. Each rider must adjust their technique to the particular horse they are riding whether the horse is lethargic and needs to be pushed or lively and needs to be restrained. Jockeys were only assessed in one race or on one horse in the present study. Gathering information on jockeys over numerous days, races and on various horses would allow more specific conclusions to be drawn.

5.7 Conclusion

It is proposed that the novel data collected during this study may be useful in developing more sport-specific nutritional and training guidelines to assist jockeys in achieving and maintaining the stipulated competition racing weights and enhancing performance. Results from this study provide a greater insight into the physiological demands and energy requirements of jockeys during daily training and racing and across an entire race and non-race day. The study's findings indicate that the high total EEE on a non-racing day may further exacerbate the deleterious effects of living in a state of low energy availability as previously reported by our research group (Dolan et al., 2011) and not provide any suggested energy deficit compensation on a racing day. While many strategies have previously been put in place to encourage the adoption of healthier weight making practices amongst jockeys, results from this study provide a scientific evidence base with essential information to allow the introduction of best practice strategies to optimally equip and prepare jockeys for a career in horse racing. Results from this study may allow sport specific recommendations to be developed regarding appropriate nutritional and training strategies to meet the lifestyle demands of a jockey, and in doing so limit the reliance on unhealthy weight making practices and assist jockeys in enhancing their health, wellbeing and overall performance throughout their sporting career, and beyond. Despite the novel findings reported in the current study, further research is required to investigate the physiological demands of an actual race with the individual variability in rider EEE according to the horse being ridden in mind. Further information on jockeys over numerous racing days and races of varying lengths and on various horses would allow more sport specific conclusions to be drawn.

Chapter Six: Summary, Conclusion and Recommendations

Irish Oaks 2013

6.1 Summary

This study was broken into 3 distinct but inter-related studies: Study 1 was designed to further investigate the acute effects of the common weight loss practices used to rapidly reduce body mass in preparation for racing with a specific focus on cognitive function, balance and anaerobic performance. Being the first study of its kind, Study 2 evaluated the potential long term health impact associated with the prolonged use of rapid weight loss strategies and an energy restricted lifestyle in a group of retired jockeys. The novel collection of data in Study 3 attempted to determine the specific physiological demands of horse racing in the controlled environment of a horse racing simulator as well as during actual racing. It was intended that the findings of this research would provide a scientific basis for the development of specific guidelines to assist jockeys making weight for competition as well as improving their overall lifestyle and subsequently health, well-being and performance throughout their racing career and beyond.

Study one examined the effect of acute body mass loss in preparation for racing on cognitive function and physical performance in a group of jockeys in a simulated (Part A) and competitive environment (Part B). In part A, participants were required to complete a battery of tests assessing cognitive function, balance and anaerobic performance and following this they were instructed to reduce their body mass by 4% of their baseline measure in a euhydrated state using methods typically adopted in preparation for racing, returning 48 hours later for repeat-testing in a dehydrated state. A separate group of apprentice jockeys participated in Part B in which they completed a test battery assessing cognitive performance at a race course immediately prior to actual racing on two separate occasions, at a normal body mass and at a light body mass having attempted to 'make weight'. Findings from this study indicate that a rapid loss in body mass, of the magnitude typically used by jockeys prior to racing (~4%), results in no significant impairments in cognitive function, balance or anaerobic performance. While it was apparent that some jockeys did not have the ability to resist the deleterious effects of making weight, many individual differences were reported within the results of this study. This study demonstrates that the majority of jockeys are affected by acute reductions in body mass and the associated dehydration in some way, whether it is in cognitive function, balance or anaerobic performance. Analysis of the individual data sets would suggest that the rapid weight reductions in this study appear to be more commonly negatively affecting the less experienced jockeys who only recently begun to adopt acute weight loss practices. The varied individual differences apparent within the results of this study suggest a potential habituation effect to such a level of dehydration and reduction in body mass in which the more experienced jockeys were able to tolerate higher levels of dehydration without impacting on their performance however this warrants further investigation. With no precise strategy for managing and achieving the required body mass reduction and the frequency of using acute weight loss practices to meet the stipulated racing weights throughout a long and intense year would thus suggest a possible attenuation to the expected detrimental response in the variables assessed. This study indicates a potential habituation to such severe body mass reductions and the associated increased level of dehydration with highly individual responses.

While previous studies have revealed the adverse physiological and performance effects of such a lifestyle on apprentice and professional jockeys, the long term implications remain relatively unknown. Study two described the health characteristics of a group of retired jockeys and made comparisons to available existing data on jockeys and on age matched population normative values. Participants were required to attend an early testing session in a fasted state in order to complete the following assessments: RMR, OGTT, DEXA scan for bone health body composition and fasting blood samples were also used to establish liver, kidney and thyroid function, and a bone, lipid and hormonal profile. Results from this study suggest a life of chronic weight restriction and reliance on unhealthy weight making practices may have some long term health effects. Results revealed 62% of retired jockeys experienced excessive gains in body mass since retiring, mean total cholesterol was elevated in 69% of the participants, mean RMR was lower compared to age matched individuals with the same physical characteristics and a large proportion of the individuals (62%) displayed osteopaenia in at least one of the bone sites assessed. Despite apprentice jockeys being afforded the ‘window of opportunity’ to enhance musculoskeletal health, the emphasis on weight restriction to attract more rides and establish a reputation at an imperative stage in their maturation could explain the slightly higher incidence of compromised musculoskeletal health prevalent amongst participants in this study. Mean serum 25(OH) D levels were reported to be below the recommended threshold however no correlation existed between vitamin D and any bone variable assessed. No apparent abnormalities were present for kidney, liver and thyroid function as well as hormonal profile and glucose metabolism with all values within the clinical reference ranges. Results from this study provide a novel insight into the health characteristics of retired jockeys suggesting the lifestyle demands of a jockey may have potential adverse health implications beyond a career in racing and on into retirement.

In order to limit the reliance on antiquated weight making practices, it is necessary to build on the existing scientific evidence base and further encourage the adoption of healthier weight making practices amongst jockeys. Study three evaluated the physiological demands and energy requirements of jockeys during training, racing and other daily activities. Both apprentice and trainee jockeys participated in this study depending on the task to be completed. A profile of the typical daily activities of jockeys was established through the completion of a questionnaire and physiological data was collected during training, a simulated race, an actual competitive race and throughout a racing and non-racing day using various sensing devices. Results from this study suggest the lifestyle of a jockey including training and racing is physically demanding. Riding at a walk, trot and canter in training had associated MET intensity values of 2.4 METs, 6.2 METs and 7.7 METs respectively; mean VO_2 was recorded as 14.5 ± 4.1% VO_2peak, 37.9 ± 6% VO_2peak, 45.3 ± 9.4% VO_2peak for a walk, trot and canter respectively and HR was 47.7 ± 5.5% HRpeak, 60.3 ± 5.5% HRpeak, 70.9 ± 7.0% HRpeak for a walk, trot and canter respectively. In both simulated and competitive racing, results suggest the requirement of a combined high level of both aerobic and anaerobic fitness. A typical simulated race of 1400 m on the race horse simulator expends 22.1 ± 4.5 kcal with an associated MET value of 9.4 METs and peak VO_2 and HR reached 75 ± 11% and 86 ± 7%, respectively, of the peak physiological data previously attained. Competitive racing resulted in maximal HR of 189 ± 5 $beats \cdot min^{-1}$ and RR of 50 ± 7 $breaths \cdot min^{-1}$. The study's findings indicate that the high total EEE on a non-racing day (due to a greater training volume without race meetings) may further exacerbate the deleterious effects of living in a state of low energy availability as previously reported by our research group (Dolan et al., 2011) and may not provide any suggested energy deficit compensation on a racing day. By providing the first data to report the physiological demands of the various equine training gaits used by jockeys; this study offers a unique insight into the associated physical demands of a competitive and simulated race throughout a distance commonly raced in flat racing; and also the EEE during a simulated races and during daily living on both a race and non-race day in flat jockeys. The novel data collected in this study on the physiological demands and energy requirements of jockeys during training, racing and other daily activities may be used as guidelines for jockeys, and allow sport specific recommendations to be developed regarding appropriate nutritional and training strategies to meet the lifestyle demands of a jockey.

As a whole, this complete research study aimed to further investigate the acute and chronic effects of the common weight making strategies used regularly amongst jockeys to achieve the designated racing weights and subsequently to determine the physiological demands of the lifestyle of a jockey in an attempt to improve the health, well-being and overall performance of jockeys throughout their racing career and beyond. Results from this research suggest that the acute and chronic implications of making weight are highly individual without any specific conclusions being drawn. This individual variability in the results of this study is a serious cause of concern in terms of the health, well-being and performance of jockeys and necessitated the determination of the physiological demands of the typical lifestyle of a jockey to allow the development of sport specific nutrition and training guidelines to encourage jockeys to utilise healthier forms of weight maintenance and thereby assisting jockeys in enhancing their health, wellbeing and overall performance throughout their sporting career, and beyond.

6.2 Study Implications and Conclusion

Making weight and remaining at the stipulated body mass throughout the prolonged racing season represents a major challenge to the jockeys who compete in this challenging weight category sport. This research study aimed to further investigate the acute and chronic effects of the common weight loss practices used to rapidly reduce body mass in preparation for racing, building on the existing knowledge and subsequently attempting to improve the health, well-being and performance of jockeys throughout their racing career and beyond. In such a highly competitive and high risk sport, being physically fit and mentally alert is crucial to jockeys however results from this research demonstrate making weight adversely affected the majority of jockeys assessed in some way, whether it was in cognitive function, balance or anaerobic performance which is a serious cause of concern, especially since any sudden change in the velocity or direction of the horse could result in a serious accident for either the jockey riding the horse or the surrounding jockeys. Furthermore, a life of chronic weight restriction and the reliance on unhealthy weight making practices was suggested to have some negative long term health implications as described in the retired jockeys assessed in this study. At such an imperative stage in their maturation, the reliance on unhealthy weight making strategies needs to be limited amongst jockeys. As a direct consequence of this current research, a new minimum weights structure for apprentice jockeys has now been brought into Ireland to encourage the adoption of best practice making weight strategies, minimising the prevalence of acute large reductions in body mass prior to racing. All apprentice jockeys have now been assigned a minimum riding weight based on their physical characteristics as well as previous riding weights so they can no longer accept rides below an individually set weight threshold. In conjunction with this, the physiological demands of the lifestyle of a jockey were determined in this research to allow the development of a scientific base of necessary information so that sport specific nutritional and training guidelines could be provided to the individual jockeys to encourage the adoption of healthier weight making strategies and the ability to constantly maintain a low body mass through appropriate nutrition and exercise interventions. The core capacities and requirements during critical phases of a jockey's career have also been identified in the format of a Jockey Pathway as well as now currently aligning appropriate support structures to address the necessary requirements.

Whilst the current scientific evidence would strongly suggest a need to revise upwards the minimum weight structure for jockeys, increasing the current minimum riding weight in Ireland alone may create a competitive disadvantage for the Irish jockeys when they attend race meetings in various other countries operating at a lower a stipulated minimum weight. For this reason, an international collaboration and consensus is necessary on the minimum weight structures to ensure the health, safety and well-being of jockeys as a whole. Until such time that international standards are established, there is a need to establish evidence based educational and other support structures for both current and retired jockeys focusing on such issues as healthy eating, physical fitness as well as the risks associated with chronic energy restriction and making weight. Information and support systems need to be readily available to jockeys to encourage the adoption of healthier making weight strategies, assisting jockeys in enhancing their health, wellbeing and overall performance throughout their sporting career, and beyond.

6.3 Recommendations for Future Research

Results from this research demonstrate the current methods used to 'make weight' may have negative implications on the acute and chronic health and performance of jockeys, with the vast majority of jockeys not being appropriately educated and equipped to meet the demands of their sport in terms of body mass maintenance and performance optimisation. As a result, many jockeys have no precise strategy for managing and achieving the required low body mass. While this research provided many novel findings and outputs, it also generated many unanswered questions of which warrant further investigation.

While no significant impairments in cognitive function, balance or anaerobic performance were demonstrated within this research, many individual differences were apparent. Without any valid and reliable tests of racing performance, the application of the testing protocols used within this research, specifically the Y Balance Test and WAnT, to racing performance may have limitations. Future development of more sport specific tests is required to allow a greater insight into the impacts of rapid reductions in body mass on specific racing performance. Furthermore, the individual variability seen within the results requires further investigation to determine the extent to which some jockeys may now be habituated to such a level of dehydration and reductions in body mass. Assessment of graded body mass losses (i.e. 2%, 4%, 6% and 8%) may be required to gain further insights into the effects of such weight making practices on various performance variables and to identify the threshold of body mass loss at which performance decrements occur. Such information may aid the development of more appropriate weight management strategies within this group of athletes.

Despite being the first study of its kind to investigate the long term health effects of making weight amongst jockeys, the population of retired jockeys assessed may not have had to undergo the weight making practices as severely and as regularly as the present jockeys given the reasons previously discussed in relation to smaller stature and less intense racing schedule when such participants were jockeys as opposed to those of today in addition to factors such as the current age and years elapsed since retiring from a career in horse racing. With only minimal adverse effects noted amongst the retired jockeys, the results may in fact not truly reflect the severity of the negative repercussions associated with such a lifestyle. The number of years the participants were retired from racing in this study (26.8 ± 9.5 years) far outweigh the number of years involved in racing (20.3 ± 5.7 years), giving the opportunity for the effects of weight cycling to be diminished by lifestyle behaviour modifications adopted by the jockeys in retirement. It is recommended that jockeys should be tracked longitudinally to establish if any long term health implications are associated with the current lifestyle of a professional jockey. Accurate and regular collection of data at critical time points throughout the career of a jockey and into retirement may provide a more precise profile of the physiological and health consequences associated with the lifestyle demands of a career making weight.

The current research primarily focused on the body mass and bone health status of the retired jockeys, many endocrine and hormonal factors as well as RMR, glucose metabolism and the functioning of the kidney, liver and thyroid. While it was not within the scope of this research study, cardiovascular health is also an area that warrants further investigation amongst retired weight cycling athletes. Nitzke et al., (1992) previously reported 23% of retired wrestlers had developed heart problems. Sixty two percent of the participants in this study were classified as overweight or obese, 69% had elevated cholesterol levels and observations of the medical history questionnaire revealed 16.5% of the retired jockeys have previously had heart problems. Future research is required to further investigate cardiovascular health amongst retired athletes involved in repetitive weight cycling for a prolonged period of time to determine the long term implications. Due to the limitations with DEXA, pQCT should be used as a future method of assessing bone health while bone metabolism markers would also provide crucial information.

Results from this research provide an indication of the physiological demands and energy requirements of jockeys during training, racing and their daily activities. Both in the racing and training environment, jockeys were only monitored on the same horse in this study. Energy expenditure however is highly variable according to the horse being ridden given the necessary adjustments in technique and effort to match the particular horse. EEE is also problematic due to the impact of the horse and the necessity to separate the energy demands of the jockey from that of the horse. For this reason, future research is necessary to gather information on jockeys over numerous days, races and on various horses to allow more specific conclusions to be ascertained and the implementation of strategies, both nutritional and training, to be put in place to further assist jockeys.

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Appendices

APPENDICES

A: Plain Language Statements

A1: Study 1

A2: Study 2

A3: Study 3

B: Informed Consent Forms

B1: Study 1

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C: General Health / Medical History Form

D: Recruitment Letter for Retired Jockeys for Study 2

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Appendix A: Plain Language Statements

A1: STUDY 1

PLAIN LANGUAGE STATEMENT

Introduction to the Study

Making weight is very often associated with many negative health and performance implications. In such a highly competitive and dangerous sport, being physically and mentally fit is imperative to jockeys. The purpose of this study is to examine the effects making weight may have on the physical and cognitive capabilities of jockeys.

Participant Requirements:

You will be required to attend two testing sessions 48 hours apart in RACE. You will complete a series of computer tests to assess different aspects of cognitive function i.e. reaction time, decision making skills. You will complete a test of balance, in which you will have to reach in various directions and finally you will perform an exercise test on a bike to assess your anaerobic capacity. For the test, you will be required to give maximal effort for the 30 second testing period. You will be given 2 days to reduce your weight by 4% before returning to RACE to complete all tests again.

Participant Responsibilities:

Information you possess about your health status or previous experiences of heart-related symptoms with physical effort may affect the safety of your exercise test. Your prompt reporting of these and any other unusual feelings with effort during the exercise test itself is of great importance. You are responsible for fully disclosing your medical history, including any history of longstanding or chronic musculoskeletal injuries or surgery, predisposing cardiovascular or cardio respiratory conditions, and/or no heat- related illness or injury within one year preceding today, as well as symptoms that may occur during the test. You are also expected to report all medication (including non-prescription) taken recently and, in particular, those taken today, to the testing staff.

Potential Risks:

You may experience some muscle soreness in your legs or nausea following the maximal exercise test. You may also feel faint and/or dehydrated having reduced your body mass however it will be no more than you would normally feel when racing.

Benefits to Participants from Involvement:

The results obtained from the series of tests that you will carry out may assist in the evaluation of your physical conditioning and provide feedback for future training. You will receive a full report detailing your personal results on both testing occasions.

Protecting Confidentiality of Data

Participant's identity and other personal information will not be revealed, published or used in further studies. Each participant will be assigned an ID number under which all personal information will be stored in a secure file and saved in a password protected file in a computer at DCU. Only the listed investigators and the project medical coordinator will have access to the data. Confidentiality is insured, but you must be aware that confidentiality of information provided can only be protected within the limitations of the law - i.e., it is possible for data to be subject to subpoena, freedom of information claim or mandated reporting by some professions.

If participants have concerns about this study and wish to contact an independent person, please contact:

The Secretary, Dublin City University Research Ethics Committee, c/o Office of the Vice-President for Research, Dublin City University, Dublin 9. Tel 01-7008000

A2: STUDY 2

PLAIN LANGUAGE STATEMENT

Introduction

The long term health effects associated with the weight making practices typically used throughout a jockey's career remain largely unknown. The purpose of this research is to conduct a detailed analysis of the health characteristics of ex-jockeys to provide a greater understanding of the long term effects of prolonged exposure to the typical lifestyle of being a jockey.

Participant Requirements

Participants will attend DCU early in the morning in a fasted state. Your height and weight will be taken and you will be asked to lie down for 1 hour wearing a mask to allow us to measure your resting metabolic rate. After this, a trained phlebotomist will insert a small cannula into a vein in your arm and this will allow blood to be taken easily and more comfortably for the duration of the session. Blood will then be taken to allow us to determine kidney function, liver function, thyroid function, bone health, cholesterol levels, fasting glucose levels and PSA levels. You will then take a sugary drink and rest in a bed for 3 hours during which blood will be taken every 30minutes to see how well your body reacts to this sugary drink. This test assesses diabetes risk. While you are resting, we will take your blood pressure and a questionnaire about your past and current lifestyle will be filled out with you by the researcher. We will then bring you to have a DEXA scan to determine bone health and body composition. Sessions are typically from 7am-1pm.

Participant Responsibilities

Information you possess about your current health status, medication or medical history should be passed onto the researcher on arrival.

Potential Risks to Participants

There may be a small bit of discomfort initially when inserting the cannula for the blood samples. A small bruise may develop at the site of puncture. Extremely low doses of radiation will be emitted during the DEXA scanning, however such doses are less than a standard chest x-ray. Otherwise the risks associated with this study are no greater than those undertaken by individuals in everyday life.

Benefits to Participants

Each participant will be provided with individual feedback on their health. All information is strictly confidential however if any medical issues arise, individuals will be referred to the Turf Club Chief Medical Officer.

Protecting Confidentiality of Data

Participant's identity and other personal information will not be revealed, published or used in further studies. Each participant will be assigned an ID number under which all personal information will be stored in a secure file and saved in a password protected file in a computer at DCU. Only the listed investigators and the project medical coordinator will have access to the data. Confidentiality is insured, but you must be aware that confidentiality of information provided can only be protected within the limitations of the law - i.e., it is possible for data to be subject to subpoena, freedom of information claim or mandated reporting by some professions.

If participants have concerns about this study and wish to contact an independent person, please contact:

The Secretary, Dublin City University Research Ethics Committee, c/o Office of the Vice-President for Research, Dublin City University, Dublin 9. Tel 01-7008000

PLAIN LANGUAGE STATEMENT

Introduction

The purpose of this study is to examine the physical demands of horse racing and to determine the total energy expenditure during horse racing and the other activities jockeys undertake during daily living to evaluate the status of energy balance. To date, the physical demands and energy requirements of horse racing remain relatively unknown. This causes difficulties when providing specific nutritional and training advice to jockeys who are required to compete at a strict weight limit. Analysing the physiological demands of horse racing will provide a clearer insight and understanding of what is required of such athletes during training and competition. Specific nutritional advice will be available to the jockey, encouraging the maintenance of energy balance, increasing health and optimizing performance.

Participant Requirements

Participants will complete a maximal test on a bicycle, which will give us maximal data, allowing all riding information to be examined in relation to your maximal data. Participants will then wear small pieces of equipment for the duration of a race and non-race day. From morning until night, participants will wear a small camera, an armband and a belt around the chest, with only the chest belt remaining on for the actual race. These devices will allow the measurement of the energy that is used. Minimal interference is provided by all equipment, so typical daily activities may be resumed as normal.

Participant Responsibilities

Information you possess about your health status or previous experiences of heart-related symptoms with physical effort may affect the safety of your exercise test. Your prompt reporting of these and any other unusual feelings with effort during the exercise test itself is of great importance. You are responsible for fully disclosing your medical history, as well as symptoms that may occur during the test. You are also expected to report all medication (including non-prescription) taken recently and, in particular, those taken today, to the investigators.

Potential risks to participants from involvement in the Research Study
Muscle soreness in the legs or nausea may be experienced following the maximal exercise test.

Benefits (direct or indirect) to participants from involvement in the Research Study
The results obtained from this study will provide information on the physical demands of racing and the energy used on a daily basis. This information will be used to provide specific training and nutritional plans for jockeys.

Protecting Confidentiality of Data
Participant's identity and other personal information will not be revealed, published or used in further studies. Each participant will be assigned an ID number under which all personal information will be stored in a secure file and saved in a password protected file in a computer at DCU. Only the listed investigators and the project medical coordinator will have access to the data. Confidentiality is insured, but you must be aware that confidentiality of information provided can only be protected within the limitations of the law - i.e., it is possible for data to be subject to subpoena, freedom of information claim or mandated reporting by some professions.

If participants have concerns about this study and wish to contact an independent person, please contact:

The Secretary, Dublin City University Research Ethics Committee, c/o Office of the Vice-President for Research, Dublin City University, Dublin 9. Tel 01-7008000

Appendix B: Informed Consent Forms

B1: STUDY 1

INFORMED CONSENT

Investigators involved: Dr. Giles Warrington (Jockey Research Project Coordinator), **SarahJane Cullen** (Turf Club Research Fellow), **Dr. Adrian McGoldrick** (Chief Medical Officer Turf Club) and **Kate O Brien** (Research Assistant)

Horse racing is a high risk sport and currently with no precise strategy for managing and achieving the required body weight reduction, many jockeys may be placing themselves at an increased risk of reduced physical and mental performance with many associated negative health and performance implications. Dehydration and reductions in body mass of just 2% has been reported to result in both physical and cognitive performance impairments. Although many jockeys typically lose in excess of 2% of their body mass in very short time periods, it is believed many jockeys may actually be habituated to such severe levels of dehydration. In such a highly competitive and dangerous sport, being physically and mentally fit is imperative to these athletes who careers depend on making weight. For these reason, it is necessary to further investigate the effects of making weight on cognitive function, balance and anaerobic performance in jockeys.

Participant – please complete the following *(Circle Yes or No for each question)*

Have you read or had read to you the Plain Language Statement	*Yes/No*
Do you understand the information provided?	*Yes/No*
Have you had an opportunity to ask questions and discuss this study?	*Yes/No*
Have you received satisfactory answers to all your questions?	*Yes/No*

Participation in this study is voluntary and all participants may withdraw at any point. There will be no penalty for withdrawing before all stages of the study have been completed. Participant's identity, or other personal information, will not be revealed or published. Subjects will be assigned an ID number under which all personal information will be stored in a secure file and saved in a password protected file in a computer at DCU. The investigators alone will have access to the data. Data will be stored for 12-months following the completion of the project, in line with University regulations for examinations. The data will be destroyed by the principal investigator. Confidentiality of information provided can only be protected within the limits of the law. It is possible for data to be subject to subpoena, freedom of information claim or mandated reporting by some professionals.

I have read and understood the information in this form. Therefore, I consent to take part in this research project.

Participants Signature: ______________________________

Name in Block Capitals: ______________________________

Witness: ______________________________

Date: ______________________________

B2: STUDY 2

INFORMED CONSENT

Involved in this Study: Dr. Giles Warrington (Jockey Research Project Coordinator), **SarahJane Cullen** (Turf Club Research Fellow), **Dr. Adrian McGoldrick** (Chief Medical Officer Turf Club), **Alex Donohoe** (DCU Research Assistant**), Barry Smyth** (DCU Research Assistant)

One of the focuses of the current phase of the research programme is to conduct a detailed analysis of the health characteristics of retired jockeys. Given the pressures associated with making weight, jockeys can find themselves in an energy imbalanced and dehydrated state almost daily for the duration of their career. Research has shown jockeys to be a group who are at a significant risk of developing premature osteoporosis. The long term health effects associated with such weight making practices remain largely unknown. In order to further investigate the possible long term health impacts of making weight over prolonged periods of time, we will conduct a medical screening on ex-jockeys.

Participant – please complete the following *(Circle Yes or No for each question)*

Have you read or had read to you the Plain Language Statement	*Yes/No*
Do you understand the information provided?	*Yes/No*
Have you had an opportunity to ask questions and discuss this study?	*Yes/No*
Have you received satisfactory answers to all your questions?	*Yes/No*

Participation in this study is voluntary and all participants may withdraw at any point. There will be no penalty for withdrawing before all stages of the study have been completed. Participant's identity, or other personal information, will not be revealed or published. Subjects will be assigned an ID number under which all personal information will be stored in a secure file and saved in a password protected file in a computer at DCU. The investigators alone will have access to the data. Data will be stored for 12-months following the completion of the project, in line with University regulations for examinations. The data will be destroyed by the principal investigator. Confidentiality of information provided can only be protected within the limits of the law. It is possible for data to be subject to subpoena, freedom of information claim or mandated reporting by some professionals.

I have read and understood the information in this form. Therefore, I consent to take part in this research project.

Participants Signature: ______________________________

Name in Block Capitals: ______________________________

Witness: ______________________________

Date: ______________________________

B3: STUDY 3

INFORMED CONSENT

Investigators involved: Dr. Giles Warrington (Jockey Research Project Coordinator), **SarahJane Cullen** (Turf Club Research Fellow) and **Gillian O Loughlin** (Turf Club Dietician) from the School of Health and Human Performance DCU and **Dr. Adrian McGoldrick** (Chief Medical Officer Turf Club)

Without knowing the physiological demands of horse racing, difficulty arises when suggesting nutritional and training requirements for the horse racing jockey. By determining the physiological demands of horse racing, specific nutritional advice will be available to the jockey, encouraging the maintenance of energy balance, increasing health and performance. The purpose of this study is to analyze and evaluate the specific physiological demands of horse racing and to determine the total energy expenditure during horse racing and the other activities jockeys undertake during daily living to evaluate the status of energy balance.

Participant – please complete the following (Circle Yes or No for each question)

Have you read or had read to you the Plain Language Statement	*Yes/No*
Do you understand the information provided?	*Yes/No*
Have you had an opportunity to ask questions and discuss this study?	*Yes/No*
Have you received satisfactory answers to all your questions?	*Yes/No*

Participation in this study is voluntary and all participants may withdraw at any point. There will be no penalty for withdrawing before all stages of the study have been completed. Participant's identity, or other personal information, will not be revealed or published. Subjects will be assigned an ID number under which all personal information will be stored in a secure file and saved in a password protected file in a computer at DCU. The investigators alone will have access to the data. Data will be stored for 12-months following the completion of the project, in line with University regulations for examinations. The data will be destroyed by the principal investigator. Confidentiality of information provided can only be protected within the limits of the law. It is possible for data to be subject to subpoena, freedom of information claim or mandated reporting by some professionals.

I have read and understood the information in this form. Therefore, I consent to take part in this research project.

Participants Signature: ______________________________

Name in Block Capitals: ______________________________

Witness: ______________________________

Date: ______________________________

Appendix C: General Health / Medical History Form

HEALTH SCREENING FORM

Name: ______________________________ **Phone No:** __________________________

Emergency Contact Name and No: ____

D.O.B. _______________ **Age:** ________

<u>Please tick as appropriate:</u>

	Yes	No
Do you suffer from any illnesses or injury?	___	___

If so please list: ____

	Yes	No
Are you presently taking any medication?	___	___

If so please list: ____

____

Do you now or have you suffered from any of the following?
(Please tick as appropriate)

	Yes	No
1. Any heart conditions or Family History of heart Disease	___	___
2. High Blood Pressure	___	___
3. High Blood Cholesterol	___	___
4. Asthma	___	___
5. Dizziness or Fainting	___	___
6. Diabetes	___	___
7. Muscle, Joint or Back disorder	___	___
8. Recent Surgery	___	___
9. Do you smoke?	___	___
10. Lung Problems?	___	___
11. Heat Related Illnesses?	___	___

Do you have any other medical problems we should be aware of? If so, please state below.

____

____

Signature: ___________________________________ **Date:** ________________________

Appendix D: Recruitment Letter for Retired Jockeys for Study 2

DCU

THE TURF CLUB

Health Check & Medical Screening for Ex–Jockeys

As you may be aware, the School of Health and Human Performance at Dublin City University (DCU) is currently conducting an extensive study into jockeys on behalf of the Turf Club. One of the focuses of the current phase of the research programme is to conduct a detailed analysis of the health characteristics of retired jockeys. Given the pressures associated with making weight, jockeys can find themselves in an energy imbalanced and dehydrated state almost daily for the duration of their career. Research has shown jockeys to be a group who are at a significant risk of developing premature osteoporosis. The long term health effects associated with such weight making practices remain largely unknown. In order to further investigate the possible long term health impacts of making weight over prolonged periods of time, we are running a medical screening for all retired jockeys.

At present, we are seeking to recruit retired jockeys to take part in this research. Volunteers would be required to attend DCU in a fasted state for an early morning session (7am-1pm) where you will complete a small number of tests to find out about your health status.

- **Resting Metabolic Rate Test** – you will be required to lie down for 1 hour wearing a mask to allow us to measure how much energy you use at rest.
- **Glucose Tolerance Test** – you will take a sugary drink and then rest in a bed for 3 hours during which bloods will be taken every 30minutes from your arm to see how your body reacts to this drink. This test determines the risk of developing diabetes.
- **Blood Tests** – such tests will allow us to determine your cholesterol level, as well as further information on your kidney, liver and thyroid function, bone health, PSA level.
- **Lifestyle Questionnaire** – this will allow us to establish some background information regarding your typical lifestyle as a jockey as well as your current lifestyle.
- **DEXA Scan** – this scan will allow us to determine your bone health and your body composition (the percentage of fat on your body).

Each volunteer will be provided with individual feedback and advice. All information will be strictly confidential however if any medical issues arise, individuals will be referred to the Turf Club Chief Medical Officer.

Please contact SarahJane, Turf Club researcher fellow, before Friday Feb 8th to book in:

Tel: **087 6954750** ***Email:*** **sarah.cullen6@mail.dcu.ie**

Also involved on this project: Dr Adrian McGoldrick (Chief Medical Officer Turf Club)
Dr Giles Warrington (Jockey Research Project Coordinator)

Appendix E: Pre-testing Confirmation Letter for Retired Jockeys in Study 2

Health Check & Medical Screening for Ex–Jockeys

Many thanks for agreeing to take part in this research study on retired jockeys.

Your appointment is: _________________

The screening will occur on DCU Campus (the Collins Ave Entrance), in the Science (X) Building in the basement in Room XB23 (tutorial room). This is where we will meet you for your appointment. There is parking in the Multi-Storey Car Park (Car Park 1) on Campus which I will give you a ticket to cover charges when you leave. I have enclosed a copy of the DCU Campus Map and directions for getting to DCU for further details.

We request you do not exercise the day before your appointment. It is also important that you are fasting for this appointment consuming no food or drinks (except water) for 10 hours before the test. Drink plenty of water over the 24-hour period prior to the test to ensure you are adequately hydrated. Also if you smoke please don't consume any cigarettes on the morning of the test.

You will be sitting down for a lot of the time so please wear comfortable clothes and also bring some entertainment (i.e. book, computer etc.) should you require. You will have an opportunity to eat before going for your DEXA Scan, so it is recommended to bring a small snack. We will hopefully have you completed by 1pm.

Please complete the Health Screening Form and Informed Consent and bring them with you on the morning of your test. Please arrive on time for your testing session.

If you have any problems locating us on your appointment day, making the allocated appointment time or require further information, please do not hesitate to contact me on 087 6954750.

Best wishes and look forward to meeting you,

____

SarahJane Cullen

Turf Club Research Fellow

Appendix F: Cover Letter and Results Template for Results Sent to Retired Jockeys in Study 2

Date

Name, Address

Dear NAME,

Many thanks for taking part in the study looking at the health characteristics of retired jockeys. Sincere apologies for the delay in reverting to you with your results, it has taken longer than expected to get the bloods analysed.

We were delighted with the response we received, with 37 retired jockeys participating in the study, with an average age of 63 years (range 45 - 83 years). Racing experience ranged from 8 to 34 years, with individuals being retired for an average of 27 years (range 13 – 46 years). Thirty three of the 37 participants indicated they experienced trouble making weight over the course of their professional career.

Due to the pressures associated with making weight, many jockeys find themselves in an energy deficient and dehydrated state, almost daily, for the duration of their career. Research carried out by the Turf Club Research Group has shown jockeys to have poor bone health compared to other athletes. Ideally we would like to monitor jockeys health throughout their careers and into retirement. For now this study has allowed us to get an initial insight into any long term health complications that may arise from a career in racing. Interesting findings from this study included 84% of the participants were low in vitamin D and will require supplementation, 62% displayed bone thinning (osteopaenia) in the whole body, spine or hip, 69% had high cholesterol and 16% had a raised PSA value (prostatic blood test).

I enclose two copies of the results of your health check in DCU – one for your own records and one for your GP. I would recommend that you consult your G.P regarding your results as you need to have your __________________ rechecked and further discuss _______________. I have enclosed a sheet explaining the results of the tests should you require more information. Please do not hesitate to call me to discuss these further if you have any queries.

Once again thank you for taking part in this research study. Hopefully you have found it beneficial.

Best wishes,

SarahJane Cullen
Turf Club Research Fellow
(087 6954750)

Dr. Adrian Mc Goldrick
Turf Club Senior Medical Officer
(087 2424404)

RESULTS – NAME

DATE OF BIRTH: ____________

HEIGHT: ____________ WEIGHT: ____________

BMI: ____________ *(A healthy BMI is below 25 kg·m^{-2})*

% BODY FAT: ____________ *(A healthy % Body fat is below 22% for people under 60 years and below 25% for those over 60 years of age)*

BLOOD PRESSURE: ____________ *(possible white coat effect)*

RESTING METABOLIC RATE: ____________ *(Usually between 1200 - 1800 kcal·day^{-1} for a healthy adult)*

CHOLESTEROL: You have a normal/slightly raised cholesterol value *(total cholesterol should be below 5 mmol·L^{-1})*

	Your Score
Total Cholesterol	__ mmol·L^{-1}
LDL (bad) Cholesterol	__ mmol·L^{-1}
HDL (good) Cholesterol	__ mmol·L^{-1}

RISK OF DIABETES: Your glucose tolerance test was normal/slight impaired *(glucose level should be below 6 mmol·L^{-1} at fasting and 7.8 mmol·L^{-1} at 2 hours)*

	Fasting	At 2 hours
Glucose Level	__ mmol·L^{-1}	__ mmol·L^{-1}

BONE HEALTH: Your bone density was normal/low and you are classified as Osteopaenic *(A score greater than -1 is ideal)*

	Your T score
Whole Body	__
Lumbar Spine	__
Hip	__

Your Vitamin D level was __ nmol·L^{-1} which is within/below the desired minimum value of 75 nmol·L^{-1}. It would be recommended that you take 1000 units of vitamin D daily for the rest of your life.

KIDNEY FUNCTION: Your test showed normal function

LIVER FUNCTION: Your test showed normal function

THYROID FUNCTION: Your test showed normal function

PSA VALUE: Your test showed a reading of __ ng·mL^{-1} which is within/just outside the current recommended standard of 0 to 3.1 ng·mL^{-1}.

Appendix G: Recruitment Letter for Apprentice Jockeys for Study 3

THE TURF CLUB

Finding it Difficult to Make Weight?

DCU

We need your help so we can help you!

Do you know many calories you use

During training? During a race? In a whole day?

We can tell you!

Knowing this information could help you control your weight for races.

Unlike other sports around the world in which such information is known, we are presently unsure of the demands and energy requirements of jockeys during horse racing and other daily activities. Knowing the amount of energy being used is necessary in order to provide accurate nutritional and training advice, helping jockeys to regulate their weight whilst meeting the demands of the sport.

What do you need to do?

Resting Test	***Bicycle Test***	***Wear devices on a Race Day & Non Race Day***
Early one morning, we will need you to lie down and rest for 1 hour in RACE, whilst wearing a mask. You will need to skip breakfast that morning. This test will tell us how many calories you require before you exercise and will allow us to accurately calculate your total daily calorie requirements.	This maximal test is the most accurate method of assessing your current fitness level, information required before we commence. This would be completed in RACE after the resting test and would take no more than 40mins (test only about 12mins).	For both a race day and non-race day, we will need you to wear a few little devices, which will enable us to get an overall picture of the demands of your sport. We will determine the amount of calories you use on a daily basis, during a race and other daily activities.

How will you benefit?

Each participant will be given an individualised breakdown of their results outlining the precise amount of calories used at rest, during a race and other daily activities, providing you with crucial information when attempting to make weight. By increasing our understanding of the physiological demands and energy requirements of jockeys during horse racing and other daily activities, it will therefore be possible to put in place strategies, both nutritional and training, to assist you in enhancing your health, wellbeing and overall performance throughout your sporting career, and beyond.

All results will remain strictly anonymous and confidential. The information gathered will be used for research purposes only, and will be analysed as group average data and not individually.

If you are interested in taking part, or have any further questions, please feel free to contact SarahJane on 087 6954750 or sarah.cullen6@mail.dcu.ie.

Appendix H: Questionnaire on the Past and Current Health and Lifestyle Practices of Retired Jockeys

An Investigation into the Past and Current Health and Lifestyle Practices of Retired Jockeys

Nutritional, Health and Lifestyle Questionnaire

Subject ID: _________

- **SECTION A: PERSONAL INFORMATION**

1. **Gender** (please ✓) Male ☐ Female ☐
2. **Age** _____ yrs **Year of birth** __ __ __ __
3. **Marital status** (please ✓)

Single (never married)	☐
Married	☐
Separated/Divorced	☐
Other (please specify) ___________________________	

4. **Do you have children?** (please ✓) Yes ☐ No ☐
   number of males: _____ number of females: _____
5. **Country of birth** (if Ireland, what town) ___________________________________
6. **If you were not born in Ireland, how many years have you lived in Ireland?** ____ yrs
7. **Highest level of formal education reached** (please ✓)

Primary school	☐
Intermediate/Junior certificate	☐
Leaving Certificate	☐
University or other 3rd level institution	☐

- **SECTION B: BECOMING A JOCKEY**

8. **At what age did you become a jockey?** _____yrs
9. **Please explain briefly how you were introduced to horse racing?**

____

10. **Did you take part in other sports prior to specialising in horse racing?** Yes☐No☐
11. **What reason(s) <u>most</u> influenced your decision to become a jockey?**

	✓	Rank
Good lifestyle	☐	______
Small stature (size)	☐	______
Family involvement	☐	______
Love of riding/horses	☐	______
Like travelling	☐	______
Publicity/media involvement	☐	______
Felt I was unsuited to other occupations	☐	______

- **SECTION C: LIFE AS A JOCKEY**

12. For how many years were you a jockey? ______ yrs

13. Were you a flat or jump jockey? __________

14. How many winners did you have over the course of your racing career? ________

15. What was the most difficult aspect of being a jockey?

____

16. What was the best aspect of being a jockey?

____

17. How did a career as a jockey meet your expectations? (please ✓)

	Much better than expected	Better than expected	As expected	Worse than expected	Much worse than expected
Financial rewards	☐	☐	☐	☐	☐
Public recognition	☐	☐	☐	☐	☐
Personal enjoyment	☐	☐	☐	☐	☐
Lifestyle	☐	☐	☐	☐	☐
Travelling opportunities	☐	☐	☐	☐	☐
Work conditions	☐	☐	☐	☐	☐

18. What weight did you typically ride at? ________

19. Did you ever have trouble making weight? Yes □ No □

20. What making weight practices did you use?

Sauna	Yes ☐	No ☐
Hot Baths	Yes ☐	No ☐
Exercise	Yes ☐	No ☐
Fluid Restriction	Yes ☐	No ☐
Skipping Meals	Yes ☐	No ☐
Vomiting	Yes ☐	No ☐
Diuretics	Yes ☐	No ☐
Laxatives	Yes ☐	No ☐

21. **To <u>control weight</u> did you** (please ✓)

	Yes	No
Not eat between meals	☐	☐
Not eat breakfast	☐	☐
Not eat lunch	☐	☐
Not eat dinner	☐	☐
Follow your own diet	☐	☐
Weigh yourself every day	☐	☐
Exercise to use up calories	☐	☐
Exercise to sweat	☐	☐
Exercise excessively	☐	☐
Select low calorie foods	☐	☐
Keep busy to avoid eating	☐	☐
Drink coffee	☐	☐
Drink fluids before meals to feel full	☐	☐
Restrict food intake	☐	☐
Prepare your own food	☐	☐
Avoid situations where there will be food	☐	☐
Avoid eating with the family	☐	☐
Take advantage of illness to avoid eating	☐	☐
Use natural laxatives e.g. prunes, bran	☐	☐
Vomit after meals	☐	☐
Smoke cigarettes	☐	☐
Use fluid tablets (diuretics)	☐	☐
Chew food and spit it out	☐	☐
See a doctor/psychologist	☐	☐
See a dietician	☐	☐

22. **What <u>short-term</u> effects did you experience from your behaviour to make weight for a race** (please ✓)

	Yes, I experienced	**No, I didn't experience**
Headache	☐	☐
Backache	☐	☐
Fatigue/tiredness	☐	☐
Dizziness	☐	☐
Faintness	☐	☐
Hunger	☐	☐
Thirst	☐	☐
Decreased performance	☐	☐
Decreased concentration	☐	☐
Decreased sexual interest	☐	☐
Swelling of hands/feet	☐	☐
Disturbed sleep	☐	☐
Increased infection/illness	☐	☐
Dry skin	☐	☐
Dehydration	☐	☐
Down in mood	☐	☐
Light headedness	☐	☐
Lack of coordination	☐	☐
Tension	☐	☐
Irritation	☐	☐
Agitation	☐	☐
Hyperactivity	☐	☐
Psychologically good	☐	☐
Physically good	☐	☐

23. What <u>long-term effects</u> do you think the <u>lifestyle as a jockey</u> has had on your <u>health</u>?

	Very bad effect	Bad effect	Good effect	Very good effect
Bone density (thickness)	☐	☐	☐	☐
Joints (arthritis)	☐	☐	☐	☐
Kidney function	☐	☐	☐	☐
Body's energy control (metabolism)	☐	☐	☐	☐
Brain function	☐	☐	☐	☐
Heart	☐	☐	☐	☐
Infection control (immune system)	☐	☐	☐	☐
Gastro intestinal function (gut)	☐	☐	☐	☐
Body's control of cancer	☐	☐	☐	☐
Psychological / mental health	☐	☐	☐	☐
Physical health	☐	☐	☐	☐

24. What effects do you think your lifestyle as a jockey has had on the following? (please ✓)

	Very bad effect	Bad effect	No effect	Good effect	Very good effect	Not applicable
Relationships with partner	☐	☐	☐	☐	☐	☐
Relationships with children	☐	☐	☐	☐	☐	☐
Relationship with family	☐	☐	☐	☐	☐	☐
Family life	☐	☐	☐	☐	☐	☐
Social life	☐	☐	☐	☐	☐	☐

25. Did you do exercise apart from riding as a jockey? Yes □ No □

26. Apart from riding, what exercise did you regularly partake in and for what reason?

Activity	Recreation	Weight control	Fitness	To keep busy	Other (please specify)
	☐	☐	☐	☐	________________
	☐	☐	☐	☐	________________

27. Did you take any vitamin-mineral supplements while racing? Yes□ No□

	Daily	Weekly	Occasionally
Multivitamin	☐	☐	☐
Vitamin C	☐	☐	☐
Antioxidants	☐	☐	☐
Iron	☐	☐	☐
Zinc	☐	☐	☐
Other (please specify)	________________________________		

28. Did you smoke cigarettes, cigars or a pipe as a jockey? Yes ☐ No ☐

29. At what age did you start smoking <u>regularly</u>? ________yrs

30. How much <u>did</u> you smoke? ________

31. Did you drink alcohol? Yes ☐ No ☐

32. How often did you drink alcohol? (please ✓)

< once a week	1-2 days	3-4 days	5-6 days	every day	don’t drink alcohol
☐	☐	☐	☐	☐	☐

33. When you drank, on average, how many units of alcohol did you have? (please ✓)

1-2 units	3-4 units	5-8 units	9-12 units	13-20 units	> 20 units
☐	☐	☐	☐	☐	☐

Note: 1 unit=one measure of spirits, one small glass of wine, one glass of beer/cider. 1.5 units=long neck bottle of beer/cider. 2 units=1 pint of beer/cider

- **SECTION D: RETIREMENT**

34. In what year did you finish your career as a jockey? _____ Age _____

35. What reason(s) <u>most</u> influenced your decision to retire from being a professional jockey?

	✓	Rank
Pressure of the job	☐	______
Weight Issues	☐	______
Injury	☐	______
Age	☐	______
Family Reason	☐	______
Other ___________________________________		

- **SECTION E: LIFE AFTER RACING**

36. What did you find was the biggest challenge in adjusting to life without racing?

____

37. Have you remained involved in the racing industry since your retirement? Please explain.

____

38. Do you watch your weight now? Yes □ No □

39. Do you currently exercise? Yes □ No □

40. Do you currently ride? Yes □ No □ If yes, hours per week? _____ hrs

41. Apart from riding, what exercise do you regularly partake in and for what reason?

Activity	Recreation	Weight control	Fitness	To keep busy	Other (please specify)
	☐	☐	☐	☐	_______________
	☐	☐	☐	☐	_______________

42. **Do you currently take vitamin/mineral supplements?** Yes ☐ No ☐

	Daily	Weekly	Occasionally
Multivitamin	☐	☐	☐
Vitamin C	☐	☐	☐
Antioxidants	☐	☐	☐
Iron	☐	☐	☐
Zinc	☐	☐	☐
Other (please specify)	______________________________		

- **SECTION F: GENERAL HEALTH**

43. **Have you ever been told that you have any of the following?** (please ✓)

High blood pressure	☐	Heart trouble	☐
Stroke	☐	High cholesterol	☐
High triglycerides	☐	Diabetes	☐
Asthma	☐		

44. **Are you currently on prescription medication?** Yes ☐ No ☐

If yes, please list ____

45. **Has anyone in your family had problems with <u>diabetes</u>?** Yes ☐ No ☐ Unsure ☐

46. **If yes, who in your family had diabetes?**

Parent ☐ Grandparent ☐ Sibling ☐ Other ______________

47. **Were they on insulin?** Yes ☐ No ☐ Unsure ☐

48. **Did their diabetes start late in life?** Yes ☐ No ☐ Unsure ☐

49. **Has anyone in your family had <u>thyroid problems</u>?** Yes ☐ No ☐ Unsure ☐

50. **If yes, who in your family had thyroid problems?**

Parent ☐ Grandparent ☐ Sibling ☐ Other ______________

51. **Was it:** Overactive thyroid ☐ Under active thyroid ☐ Unsure ☐

52. **Has anyone in your family had <u>bone problems</u>?** Yes ☐ No ☐ Unsure ☐

53. **If yes, who in your family had bone problems?**

Parent ☐ Grandparent ☐ Sibling ☐ Other ______________

54. **Was it:** Osteoporosis ☐ Pageants disease ☐

55. **Do you have difficulty in getting to sleep?** (please ✓)

Always		Most of the time		Some of the time		Never	
	☐		☐		☐		☐

56. **How many hours sleep, per night, do you typically get?** _______ hrs

57. **What health problems have you suffered over your racing career and how did you managed these problems (e.g. doctor, physiotherapist, dietitian etc.?** (please ✓)

	Self-management	Doctor	Other (please specify)
Bone injuries (fractures)	☐	☐	____________________
Muscular injuries	☐	☐	____________________
Back problems	☐	☐	____________________
Concussion	☐	☐	____________________
Eye problems	☐	☐	____________________
Digestive/Gall bladder	☐	☐	____________________
Ulcer	☐	☐	____________________
Diabetes	☐	☐	____________________
Heart problems	☐	☐	____________________
Cold/flu/virus	☐	☐	____________________

Other (please specify)

____

58. **Do you smoke cigarettes, cigars or a pipe regularly?** Yes ☐ No ☐

59. **At what age did you start smoking <u>regularly</u>?** ________yrs

60. **How much <u>do</u> you smoke?** ________

61. **Do you drink alcohol?** Yes ☐ No ☐

62. **How often do you drink alcohol?** (please ✓)

< once a week	1-2 days	3-4 days	5-6 days	every day	don't drink alcohol
☐	☐	☐	☐	☐	☐

63. **When you drink, on average, how many units of alcohol do you have?** (please ✓)

1-2 units	3-4 units	5-8 units	9-12 units	13-20 units	> 20 units
☐	☐	☐	☐	☐	☐

Note: 1 unit=one measure of spirits, one small glass of wine, one glass of beer/cider. 1.5 units=long neck bottle of beer/cider. 2 units=1 pint of beer/cider

Appendix I: Physical Activity and Lifestyle Questionnaire for Apprentice Jockeys

PHYSICAL ACTIVITY & LIFESTYLE QUESTIONNAIRE

As part of a new study we are doing in the School of Health and Human Performance in Dublin City University on behalf of the Irish Turf Club, we are really interested in finding out about the specific lifestyle and performance challenges you face as a jockey in preparation for racing.

The questionnaire should take no more than 5 minutes to complete with the researcher. All responses will remain strictly anonymous and confidential. Replies will be used for research purposes only, and will be analysed as group average data and not individually.

1. **How many days a week do you typically work in the yard?** _____ days

2. **Describe your typical day:**

	Non-Race Day	**Race Day**	
		Day Meeting	*Evening Meeting*
Working Hours (e.g. 7am-12.30pm/3pm-5pm)			
Number of Horses Ridden Out			
Approximate Time Spent on Each Horse (mins)			
Typical Number of Races Ridden at a Meeting	_______		

3. **How many days a week do you typically ride work?** _____ days

4. **Do you do any other exercise apart from horse riding?** Yes ☐ No ☐

Please give a full list of physical activities you typically do below:

Include type of exercise / how intense it is / how long you do it for / how many times a week / main purpose for doing it.

Exercise	*Intensity*	*Duration*	*Per Week*	*Main Purpose*
E.g. Running	*Low/Med*	*40mins*	*3 times*	*Making Weight*
E.g. Soccer	*High*	*45mins*	*2 times*	*General Fitness*

Please give a brief summary of workout in the gym if listed

____

If you <u>do not</u> engage in any form of physical activity other than horse riding, please give the reason:

____

Thank you for taking the time to fill in this questionnaire.