SAFETY VESTS FOR JOCKEYS:
A CASE STUDY OF PRIMARY AND DEPENDENT-SECONDARY USERS AFFECTING THE EVOLUTION OF VEST DESIGN IN THE AUSTRALIAN HORSE-RACING INDUSTRY

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"*Riding in a race is a feeling like no other. Riding is of the mind, of the body and of the soul. Physically, it fills you with adrenaline and puts you in a heightened state – a zone. It also elevates your spirit, takes you to places that ordinary life is less likely to*."

(Michelle Payne in Payne & Harms, 2016, p.85)

Abstract

Using a case study method, this thesis presents new insights into key contemporary pressures that are restricting the update of the design of Australian jockeys' safety vests. The number of female jockeys has grown considerably and there has also been a consistent rate of serious injuries to jockeys; yet, despite the rapid and successful development of smart wearable technologies in the sports and health sectors, safety vests still need improvement. The Australian standards in use (ARB 1.1998 and the European Standard EN 13158) have not been significantly updated since early 2000s. The study compares the participants' perspectives and the emerging development of smart wearable technologies in order to consider the adequacy of current design standards to accommodate the next generation of safety clothing and equipment in the Australian racing context.

A qualitative research approach was adopted, which involved ethnographic methods of participant observations, a focus group and semi-structured interviews which informed the study and were compared with the relevant research literature in the field. There is extensive scientific research into factors such as health, wellbeing, physiological and cognitive function and performance whilst there is a dearth of scientific literature specifically related to safety factors such as helmet and vest design. A user-experience (UX) framework guided the present study, which differs from the existing studies by investigating the user perspectives of male and female jockeys, as well as the role of the medical staff, on whose input future smart-vest design may be increasingly dependent. Australian male and female jockeys' thoughts, along with perceptions from medical staff, have suggested future designs, generating original and significant findings that inform areas of change particularly needed in future standards.

The main original contribution of the thesis was identifying the medical staff on the racing track could not be clearly classified within a common UX framework. They were neither secondary nor tertiary users of the vests, nor could they be classified unambiguously as stakeholders, since their role was to attend to the medical needs of the jockeys. Theirs is a highly-specialised role in respect of use, especially considering the potential for a new generation of

smart wearables to enhance vest design in its medical dimension. Accordingly, the thesis recommends a revised UX framework to accommodate design dependencies more clearly in terms of a suggested Dependency-Based User-Experience (D-UX) design.

The evidence generated through this research provides a framework to assist the safety vests manufactures, those who take care of the standards and those who practice user centred /user experience design to better understand and articulate these products. In addition, it provides a foundation for further research in this field to explore the critical role of design-led innovation.

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Declaration

I declare that this dissertation does not contain without acknowledgement any material which has been accepted for the award to the candidate of any other degree or diploma, and to the best of my knowledge it does not contain any material previously published or written by another person except where due reference is made in the text of the thesis.

The thesis is less than 100,000 words in length, excluding the appendices and references. I further declare that the ethical principles and procedures specified in the Human Research Ethics Committee document have been adhered to in the preparation of this dissertation.

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Signed:

Date: 8th October 2019

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Abbreviations

AJA	Australian Jockeys Association
AJC	Australian Jockey Club
ARB	Australian Racing Board
ATC	Australian Turf Club
BETA	British Equestrian Trade Association
D-UX	Dependency-based User Experience
EN	Euro Norm/European Standard
HCD	Human Centred Design
IPI	Incremental Product Innovation
NJT	National Jockeys Trust
NPD	New Product Development
PPE	Personal Protective Equipment
RA	Racing Australia
RV	Racing Victoria
RPI	Radical Product Innovation
SHESC	Swinburne University of Technology's Human Research Ethics Committee
UCD	User Centred Design
UX	User Experience
UXD	User Experience Design
WMO	Wilson Medic One

"This poem encapsulates a great deal of the Jockey"
(Australian Jockeys' Association)

The Riders in the Stand (1903)

There's some that ride the Robbo style,
and bump at every stride;
While others sit a long way back,
to get a longer ride.
There's some that ride like sailors do,
with legs and arms, and teeth;
And some ride on the horse's neck,
and some ride underneath.

But all the finest horsemen out –
the men that Beat the Band –
You'll find amongst the crowd that
ride their races in the stand.
They'll say, "He had the race in hand,
and lost it in the straight".
They'll show how Godby came too soon,
and Barden came too late.

They'll say Chevalley lost his nerve,
and Regan lost his head;
They'll tell how one was "livened up"
and something else was "dead".
In fact, the race was never run
on sea, or sky, or land,
But what you'd get it better done
by riders in the Stand.
The rule holds good in everything in
life's uncertain fight;
You'll find the winner can't go wrong,

the loser can’t go right.
You ride a slashing race, and lose –
by one and all you’re banned!
Ride like a bag of flour, and win –
they’ll cheer you in the Stand.

Andrew Barton (‘Banjo’) Paterson

Chapter One: Introduction

Horse riding is a popular but risky activity: a New Zealand study (Buckley, Chalmers, and Langley, 1993) report an overall incidence rate of 23.7 hospitalizations per 100,000 persons per year and an overall death rate of 0.17 per 100,000 persons per year. Often horse riding is considered more dangerous than motorcycle riding: particularly, Paix (1999) found that in Australian horse racing, the injury incidence per event involved in eventing competitions was 0.88% exceeding the motorcycle injury incidence that was 0.24% for motorcycle racing. Globally, horse-related injuries have an impact in terms of cost to the public health system: in Sweden, the total cost for consultation and treatment per accident is of €1,400 per hospitalised patients while in New Zealand, the average cost per horse's fall is NZ$ 3,000. Instead, among licensed jockeys, track riders and stable helpers the insurance claims cost in excess of AU $6million per annum (Cowley, Bowman, Lawrence, 2007).

Recently, protective and inflatable vests have been developed as another personal protective equipment (PPE) for horse riders. However, protective vests still receive little attention and only a small number of equestrian wear them (Meredith, Ekman & Brolin, 2018).

Horse-related injuries represent a significant and persistent public health concern, thus Australia introduced in 1998 the safety vests for jockeys as compulsory PPE. This study examines how safety vests might be redesigned to improve protection for jockeys from the risks associated with falls in professional race-horse riding.

1.1 Scope of the study

> "What other job do you go to where the ambulance follows you around?" (Robinson, 2013)

> "When I go to work two ambulances follow me around, but with a young family at home waiting for me, it puts my mind at ease knowing the National Jockeys' Trust are there to support us in the event of a race fall." (Moy, 2018)

Despite the thoroughbred horse racing industry sharp rises to popularity, there remains a limited understanding of producing differentiated safety vests based on the gender of the users, along with the need to introduce new products and standards into the sports wearable markets. To achieve a coherent approach to vest design, the thesis provides a holistic understanding of the user and their existing safety wear in terms of how it performs on track, interacts with other wearable products, and is viewed by relevant other types of 'users' upon whom the success of the design may depend. [1]

Previous studies have focused on the severity of horse-riders' and horses' injuries, and the use of helmets as the protective equipment. There is a richness of scientific investigations into factors such as health, wellbeing, physiological, and cognitive function and performance. Instead, there is a dearth of scientific researches specifically connected to safety factors, e.g. the design of both the helmet and the safety vest. The present study has analysed safety vests on the Australian market, the current standards used in Australia and how a user-experience (UX) approach can satisfy the jockeys' needs for further protection beyond that offered by helmets.[2]

Consistent with UX concepts, this case study draws on participant observation, a focus group, and semi-structured interviews cross-referenced with relevant literature to build a coherent understanding of the factors that are placing pressure on the standards that will determine the design of and innovations used in the next generation of vests.

The size of participants in this study may be limited compared to the number of medical staff and jockeys in Australia and the time available of the involved users was a constraint. Furthermore, the timeframe and scope of the thesis meant that the framework of this study is only applicable during the concept

[1] The author notes that most texts refer to users as the people who employ the final product to accomplish a goal, and user-centred design requires knowledge of the users in order to make products that meet their unique needs and expectations. However, there is a move towards the expression "primary, secondary and tertiary users and stakeholders". The author has tried to use this categorisation wherever appropriate: in this study, primary users are the jockeys, secondary are the health professionals).

[2] While motorised-riding sports also face safety-clothing challenges, such sports were deemed outside the scope of this study. There are many significant differences between horse and motorised riding, including the weight of horses, the heights from which riders fall, the nature of the tracks and injuries, the weight and regulation standards for vests and the riding stance of the jockey, which led to the decision to exclude motorised riders from this research.

development stages. Further research is strongly required to establish how to effectively involve users through the remaining phases until a product prototyping.

1.1.1 History of horse racing

Horse racing, which today is a major worldwide industry, has a long history. Experts date it back to 4500 BC, when the nomadic tribes of Central Asia first domesticated horses (Mills & McDonnell, 2005; Anthony & Brown, 2011). The ancient Greek Olympics had both chariot and mounted horse racing and the sport was equally popular during the Roman Empire. The origins of modern racing date to the 12th century, when English knights returned from the Crusades with swift Arab horses. Over the next four centuries, an increasing number of Arab stallions were imported and bred with English mares to produce horses that possessed both speed and endurance.

In Australia, horse racing began with the arrival of the First Fleet on 26 January 1788, when the *Lady Penrhyn* docked, bringing the first horses to the country. The first horse race was held in Sydney's Hyde Park by the 73rd Regiment in October 1810 (Carlyon, 1999). By the 1830s, horse racing had become a popular sport, with more English-bred race horses being imported into Australia and racing clubs being established across New South Wales (Carlyon, 1999).

Horse riding is a popular sport that is often considered to be a leisure activity and it encloses horse-related activities such as farming and equestrian sports (e.g. thoroughbred horse racing and eventing). The horse population was recently estimated to exceed 5 million in the European Union and 1.2 million in Australia (Gordon, 2001; Liljenstolpe, 2009).

Figure 1 shows the most significant dates in Australian horse-racing history and relevant statistics about jockeys.

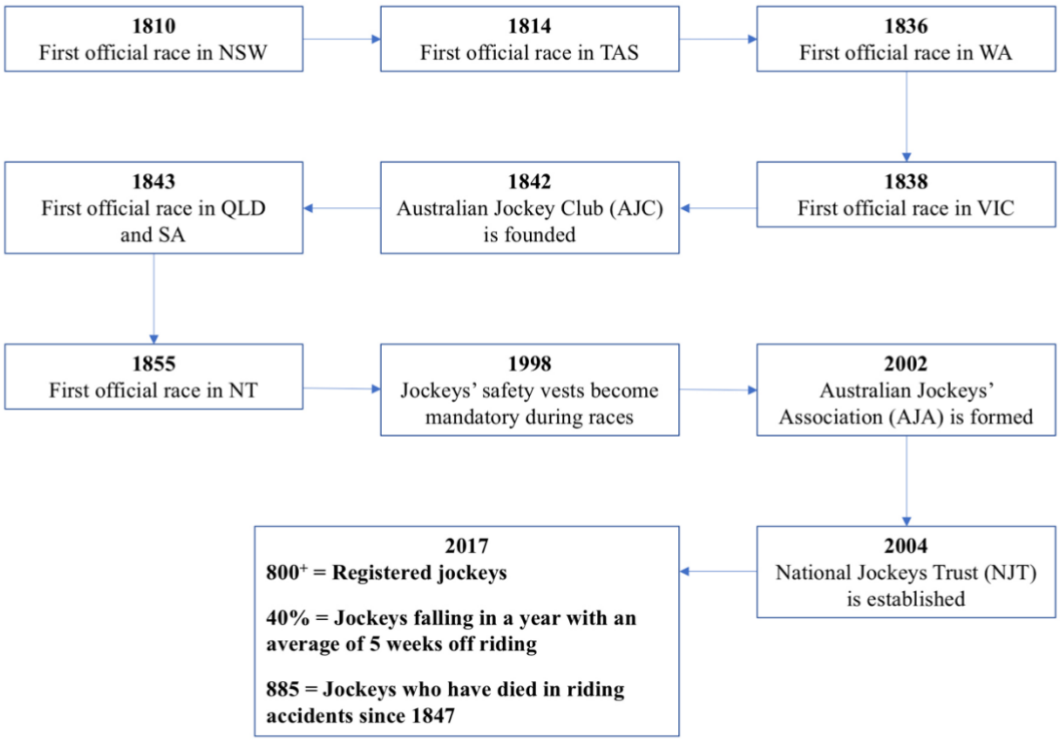

Figure 1. Significant dates in Australian horse-racing history

As per Figure 1, 1998 represented a significant year because it is when the safety vests for jockeys became compulsory during Australian races. Today, the largest and most established racing industries are in Australia, Dubai, England, France, Hong Kong, Ireland, Japan, New Zealand and the United States (Hamilton, 2015).

1.1.2 Risks to jockeys

Hitchens (2015) states that "the racing industry remains reactive to the deaths, and catastrophic or career-ending injuries suffered by both jockeys and racehorses. It is an inevitable part of racing they say." Being a jockey is a high risky occupation: horses are unpredictable animals and riding them at speed is inherently dangerous (Miko, 2017). Horses have evolved to use their natural agility and speed as escape mechanisms from dangerous situations. The mere possibility of danger can prompt a horse to halt abruptly, leap sideways, spin on the spot and gallop away from the potential source of risk. Even the weather can influence horses' behaviour. On windy days, a racehorse can be frightened by the bangs and rattles from built structures and signage (Sharkie, 2017). Poor weather conditions can also affect the communication that jockeys use during a race to avoid accidents caused by horses getting too close to each other (Sharkie, 2017).

Race riding involves a mix of adrenaline, the rush of speed and the thirst for victory. It does not matter if a jockey is racing on a country track or at a major city race meeting, getting across the line first is all that matters in the final stages of a horse race. Each victory pushes jockeys to return to the saddle day after day, risking their lives each time. Horses and jockeys have a special relationship (Fordyce, 2015) due to the time and moments shared together in training and races: there are many days of hard work, energy, love, pain and effort. Jockeys have respect to these animals but during the races, it is possible to admire just a short moment of this unique bond.

Former jockey Brian Rouse described race riding as "like driving a car with no brakes. If you make a mistake, you can't rectify it in one stride" (Oakley, 2013, p. 288). As a matter of fact, jockeys must face consequences in case of falls: for instance, Turner et al. (2012) state that jockeys, according to the injuries reported to racecourse medical professional in France, Ireland and the UK over the period 1992 – 2001, have an "incidence of 1 – 2 injuries per 1000 rides in flat racing and 6 – 12 injuries per 1000 rides in jump racing" (p.704). Even a Californian study (Hitchens, Hill & Stover, 2013) conducted over the period 2007 – 2011 state that jockeys' falls in thoroughbred races occurred at a rate of 1.99 falls per 1000 rides and ending in 51 percent jockey injury. Jockeys are aware that they are exposed every day to high risk, knowing that at some point in their career they are likely to fall and get hurt, but they cannot predict how bad their injuries will be (Polkinghorne, 2016b).

The consequences of a fall can be extreme. John Brough Scott, in an interview, captured the danger of horse racing when he described a flat-racing fall as:

> "one of the most eye-whacking horrors that any game can give. In an instant, the silk-clad jockey turns from a shiny acrobat to a puny rag doll kicked by unforgiving hooves" (Rule, 2002, online).

1.1.3 Safety vests

Thoroughbred racing is a highly dangerous occupation for the jockeys who ride the horses both on race days and in training (Hitchens et al., 2009). Regardless of the jockeys' training and skill, it is not possible to know when a jockey might fall, and a serious tumble can cause permanent, debilitating injuries or even death. The use of safety vests to protect against injuries to the torso and spine became compulsory for Australian jockeys in 1998, when the standards EN 13158 and ARB 1.1998 were introduced.[3] These standards have had only minimum revision since they were formulated; the changes do not benefit the users, nor do they allow the use of advanced technologies, such as smart fabrics or sensors, to be integrated into vests.

Since standards EN 13158 and ARB 1.1998 were introduced, the number of female jockeys has risen significantly (Norton, 2015; Parke, 2018). New Zealand Racing Chief Executive Bernard Saundry predicted in 2018 that there would be more female than male jockeys in the following five to ten years (Cook, 2018). For this shift to be accommodated, attention to the ergonomics of vests is urgently required. Studies on the nature and frequency of injuries to jockeys have called for more effective safety-vest designs (Moss, Wan, & Whitlock, 2002; Yim et al., 2007).

Australian jockeys riding in flat races face an average of one fall every 240 rides, with a third of falls resulting in injury (Hitchens, Blizzard, Jones, Day, & Fell, 2009). As a consequence of falling, jockeys most frequently reported injuries to soft tissues but even fractures, "lower limbs injuries (range, 18%-25%) followed by injuries to the face, head, and neck (range, 16%-21%); shoulder (range, 17%-18%); upper limb (15%) and back (range, 9%-14%)" (Hitchens, Hill & Stover, 2013, p. 1) .The safety vests worn by jockeys to reduce the severity of their injuries are typically made of light perforated foam strips varying in thickness and covered with mesh polyester. Some have adjustable strips or Velcro® sections on the shoulders or on waist areas to keep the vests tight on the jockeys' bodies.

[3] In the standard EN 13158:2009 (British Standards, 2009) and occasionally elsewhere, safety vests are referred to as body protectors, especially where the context for discussion is equestrian sports in general. In the Australian Standard, this piece of protective equipment is referred to as a safety vest, which will be the term used throughout the thesis.

The vests currently in use are experienced as bulky and stiff because ergonomics have not been considered during vest design and manufacturing processes. Therefore current vests are uncomfortable and restrictive when worn. Figure 2 shows examples of some current vests.

Figure 2. Some of the jockeys' safety vests in use
(LUCRF Super, 2018; Velocity Impact Protection Apparel, 2018)

Because some participants in this study did races even outsite Australia, thus they had the opportunity to may wear different safety vests' brands , the author decided to briefly investigate briefly the Descente vest, which was a popular vest brand among these professionals. Many of the jockeys discussed the Descente vest with the author and it was used during the interviews and the focus group.

Horse racing is very popular in Japan, where most jockeys wear the Descente shock-out vest when racing. Australia and Japan share similar horse-racing scenarios and traditions. Despite Japan possess positive statistics about jockeys' injuries (Horse Racing in Japan, 2017), the Descente vest failed the tests applied in Australia and therefore it is not yet approved to be used (Foote et al., 2014). More details about the Descente vest can be found in Chapter Three of this thesis.

The Racelite brand of vest is the most similar to the Descente and is approved for use in Australia. The vests employ an analogous design, but the most lightweight Descente weighs 340 grams while the lightest Racelite weighs 260 grams. The weights increase with size. The predominant colour used is black. The participants reported that the Racelite was one of the most popular vests worn on race days: thus, the author analysed it thoroughly. This vest is made of up to 70 independently hinged sections with the intention of providing flexibility, air circulation and performance (Racesafe, 2015). The vest displays Velcro® stripes on the sides of the waist to facilitate its wearability.

The design methodology that provides a solution-based approach to solving problems has been poorly applied to the development of existing jockeys' safety vests, creating a need to understand better the nature and purpose of their use in order to establish the scope to improve their performance and wearability from the perspective of the whole user experience. In contrast, contemporary product design is seen as an integrative and iterative form of problem-solving that takes previous shortcomings into account, requiring a holistic understanding of the user and the context of use, and involving interdisciplinary collaboration with technical experts to develop the most innovative and effective concepts (Bloch, 1995; Lawson, 2005; Norman & Verganti, 2012).

1.1.4 Medical professionals at the race track

Medical staff and ambulances are always present at racecourses: in the 1880s, horse-drawn ambulances attended race meetings but, by the end of the First World War, they were replaced by motor ambulances to follow the horses in larger meets (LUCRF Super, 2017). In Australia, two ambulances follow each race at a discreet distance to treat jockeys if needed. Hence, the author has included medical staff among the participants in this study in recognition of the relationship identified between primary users (jockeys), products (safety vests) and dependencies (health professionals and standards).

1.1.5 The utility of a holistic method

Inspired by Hesse – Bibier & Leavy (2010, p.7) and their statement that "a holistic approach views research as a process rather than an event" the author then acted as a researcher that continuously is "cognizant of the relationship between epistemology, theory, and methods and look at research as a process" (Hesse – Bibier & Leavy , 2010, p.13).

This thesis contributes significant knowledge to the area of user-centred product design for protective devices in equestrian sports by, firstly, showing ways to study riders in their natural settings to understand their needs and preferences, and, secondly, how the knowledge gained through these studies can contribute to design innovation.

To do this, this study employed a qualitative, ethnographic research design combining interviews, a focus group and observation in the field to establish a full picture of the interaction of jockeys and first-response medical staff with safety vests. Following Forlizzi (2008), the study employed a product-ecology framework to identify all factors that influenced user behaviour and experience around a product. Hence, the author drew on the conceptual framework of user-experience design (UXD) research, placing jockeys in the position of users of safety vests, to understand how their experiences could inform the direction that new standards should take.

1.1.6 Need for this study

Protection of jockeys from serious injury needs to be improved at a global level. According to Forero Rueda, Halley & Gilchrist (2010) French professional flat racing jockeys had lower rates of injuries/fall and injuries/ride than those in Ireland while, overall, flat racing had "the highest rates of injuries/fall (34 - 44%). Of all the injuries in both jump and flat racing populations of amateur and professional jockeys, 15% were concussive head injuries, and more than half of these involved loss of consciousness" (p. 533). In addition, a California study (Hitchens, Hill & Stover, 2016) found that "catastrophic musculoskeletal injuries to the horse are significantly associated with jockey falls and injuries" (p.55).

Head and spinal damage is the most dangerous form of injury sustained by jockeys, although the most common injuries are fractures and damage to soft tissue (Mackey-Laws, 2016; Aitken, 2017; Johnston, 2017, O'Connor, Warrington, McGoldrick & Cullen, 2017). Catastrophic injuries suffered by jockeys in falls are mainly experienced in the torso area (McCrory, Turner, LeMasson, Bodere & Allemandou, 2006; Filby, Jackson & Turner, 2012), and this brought the author to focus on the poor level of protection offered by current safety vests. Specifically, McCrory et al. (2006, p. 618) affirm that "body protectors or safety vests protect the trunk principally against soft tissue injuries and rib fractures. It will not protect the spinal column from compressive injuries nor against a massive crushing blow against the chest". McCrory et al. (2006, p.617) also state that "there are striking differences in injury rates between countries which may be explained in part by a difference in track conditions—for example, harder tracks in France—or different styles of racing—for example, larger fields of horses per race in France". This suggests that even the track conditions should be considered for the design of the vests.

The literature on racing safety contains numerous studies that have examined the injuries and fall statistics in horse racing. Despite these studies, there remains a substantial dearth of research that investigates the jockeys' perspective and the design of their safety vests (Foote, McIntosh, V'Landys, & Bullock, 2011; Foote, Gibson & McGauran, 2014).

The literature contains studies using quantitative techniques and trends to identify risk factors for injuries in the racing field (Thomas, Annest, Gilchrist et al., 2006; Altgärde, Stefan, Niclas & Peder, 2014; Hessler, 2014; Hitchens, Blizzard, Jones, et al., 2011; Hitchens, Hill & Stover, 2013; Chapman & Thompson, 2016). However, to date there is a paucity of scientific researches specifically connected to safety factors particularly, the design of both the helmet and the safety vest, but also on "professional horse racing and the injury epidemiology within this sport" (McCrory et al., 2006, p. 616). As previously stated, it is a fact that there is a high media attention given to this sport but the majority of publications are about recreational and sporting equestrian participation rather than professional horse racing (Barclay, 1978; CDC, 1990) and jockeys' safety vests. As per the author's review of the literature described in Chapter Two, there is considerable interest in the literature on paediatric's and on adolescent's age equestrian injuries (Barone & Rodgers, 1989; McCrory & Turner, 2005). Significantly, to date, no studies were found in the research literature that aimed to comprehend the intimate relationship between jockeys and their track-based health professionals for insights into how to improve vests.

This study aimed to offer intimate insights about the safety vests' design and thus, provided in this case by the users' involvement (jockeys and professional staff). The author took into considerations medical, epidemiological and surgical publications to only build the basis of the current study, which is about the design and the product experience offered by jockeys' safety vests. While the importance of wearing protective equipment during any activities involving horses has been demonstrated in research, there is a need to bring much more innovation to the design of jockeys’ safety vests (Gibson, Thai, Saxon & Pollock, 2008). Health professionals and jockeys have not yet been involved together in studies. It has been estimated that 200 Australian jockeys are injured each year on race tracks, that 89% of them have falls that require medical assistance, and that 40% of jockeys are not available to ride for an average of five weeks in a year (National Jockeys' Trust, 2017b).

Use of smart wearables in sports health is significantly increasing, but jockeys’ medical staff have not been involved. Better classification of jockeys’ injuries is needed to reap the benefits of this technology: integrating the cost data of jockeys’ injuries claims with the Australian Racing Industry Database may bring benefits in safety measures (Curry, Hitchens, Otahal, Si & Palmer, 2016).

However, a significant start is offered by the descriptive epidemiology study (O’Connor et al., 2017) conducted in Ireland for the period 2011 - 2015, where a medical doctor recorded (still through the standard injury-report forms) all injuries happened at every official flat and also jump race meeting. This thesis contributes to the gap in existing knowledge by drawing on the intimate experiences of both male and female jockeys to aid vest design, and by recognising that the insights of medical staff on track can contribute to smart vest blueprints. Such research can assist future revisions of the Australian and European safety-clothing standards for professional jockeys.

Although the Australian jockey population might seem small as the subject for a new product design, horse riders elsewhere and partakers in other sports could also be targets for innovative safety vests as their injuries show similarities with other sports, as mentioned in this thesis. Besides, countries such as Australia, Ireland and UK also have National Hunt (jump) racing and Pony Clubs. Table 1 was created with the aim of offering an overview of the potential horse-riding market.

Table 1. Number of jockeys and pony club members around the world
(Horse Racing Japan, 2016; Jockeys'Guild, 2016; British Horseracing Authority, 2017; Hong Kong Jockey Club, 2017; Pony Club, 2017a, 2017b, 2017c; Pony Club HK, 2017; Professional Jockeys Association, 2018)

	Equestrian Disciplines	
Country	Flat racing	Pony Club
Australia	840	26,902
HK	63	150
Ireland	192	3,000 +
Japan	283	n/a
UK	750	23,042
USA	1,023	10,000
Total	**3,151**	**63,094**

The data shown in Table 1 offer only an estimate based on a targeted market review. Data was provided by organisations in each country, but some figures may not be comparable because some countries provide only the number of professional jockeys, while others include professional, amateur and apprentice jockeys. However, the market for innovative safety vests would be larger than this, since this study demonstrated that an innovative product might bring benefits to every user with similar needs, such as motorcyclists, skiers and other athletes.

Pony clubs are part of an international voluntary organisation for young people interested in ponies and riding. Some countries open their membership to anyone up to the age of 25, others up to 21. It is estimated that pony clubs overall have a worldwide membership exceeding 110,000 members (riders and non-riders). The appearance of a new product on the market would lead to demands for a product that takes these users' needs into account. Thus, further research in this field is necessary and within a relatively quick timeframe if the aims of this study are to be achieved.

1.2. Thesis aims and proposal

This study examines the proposal that, to achieve the most benefit from safety vests for jockeys, there is a need to develop a holistic understanding of UXD (User Experience Design) and related dependencies in this field. User experience design is the process of enhancing user satisfaction with a product by refining the usability, accessibility, and desirability produced in the interaction with a product. The author provided more details about UXD and UCD (User Centred Design) models in Chapter Four, subchapter 4.2 and in Chapter Five, subchapter 5.2 of this thesis. It will be argued that a holistic understanding constitutes knowledge of how the interaction of the user, product and contextual aspects determines the significance of introducing technologies and advanced materials.

This case study approaches the investigation from a multi-dependent user view of design rather than from that of a single user, or single persona user conventionally adopted by designers employing the user-experience (UX) model. The study asserts that while maintaining the primary user at the centre of a product innovation, dependencies on other users can become evident and should be accommodated in the design investigation. These other users are not necessarily of less importance than the primary user, and incorporation of all users' needs positions the design researcher to detect critical interactions and response patterns that can reveal innovation opportunities in their target product. In certain situations, a product may be required to meet the needs of the user and a co-dependent user whose contribution to the performance and success of the design is essential, not merely desirable. In the case of jockeys' safety vests, the design is dependent for its functional purpose on jockeys as the primary users, and upon co-dependent users: the health professionals who must engage with this product to act as quickly as possible to attend to jockeys in need. Yet they are not involved in any safety-vest development or standards revision, and indeed, jockeys themselves as primary users have not been involved either.

Observers of the design of health products have long mentioned the need for user-centred design (UCD) to acknowledge secondary and tertiary users (Norman & Draper, 1986; Norman, 1993; Tenhue, 2016) but not using a definition of those users that is nuanced to make them the same as a primary user in terms of the significance of their input and access role. Norman shows frustration with the lack of acknowledgment that UCD and UX might at times require focus on secondary or even tertiary users, all of whom require equal standing for their important contribution to the success of a design. An example is the need for designers of computer interfaces to consider a medical primary and a patient secondary user of a medical screen information display. In the case of safety vests for jockeys, the secondary users (the health professionals) should have equal status with the primary users (the jockeys) in the design process because they are directly involved in the vests' use in the context of the jockeys falling during racing.

This study concentrates on the role of safety-vest design in product innovation. Therefore, examination of vest functions and standards forms the main content. The views of jockeys and health professionals are examined because they are respectively users and co-dependent users of the safety vests.

Finally, technology is considered because its role to enhance safety-vest function has not yet been analysed. Its application can transform a safety vest into a wearable technology, which brings benefits to jockeys and to health professionals. The growing popularity of activity trackers and wearable health devices has introduced the concept that the data generated by these devices could help health professionals to treat their patients. The performance of current safety vests for jockeys as devices to protect against injury during impact is not sufficient to afford demands regarding injury recovery, yet the possibility of upgrading a safety vest into a wearable device has not yet been considered.

1.2.1 Research questions

This study acknowledges that being a jockey is a unique and hazardous occupation; hence, personal protective equipment such as safety vests should help to save jockeys' lives. Research has demonstrated the importance of wearing protective equipment during any activities involving horses, yet a review of the literature demonstrates that these products are lacking in scientific researches specifically connected to jockeys' safety factors.

Although there is a broad range of literature related to horse riding, much of it is tangential rather than specific to the research topic. Specifically, no publication provides a definition of jockeys' safety vests. The standard EN 13158:2009 explains only what it is meant by "body protectors" (British Standards, 2009). Equestrian sport for leisure and competition is a huge international industry, in which the design of riding attire and equipment is driven by fashion rather than function, compromising safety but leading in product innovation to produce stylish cuts and detailing that ensure an elegant, glamorous appearance to the equestrian clothes. Aesthetics is also important for jockeys, but current safety vests fail in this aspect as well as in ergonomics.

Jockeys, as the primary users of these unique products, have never been at the centre of the vests' design innovation process. Medical professionals who help the jockeys at racetracks have not previously been considered as co-dependent users of the safety vests.

This study investigates the main research question and three sub-questions, stated below:

Main research question

What are the relevant primary and dependent-user factors that, in themselves and in combination with each other, should substantially influence product innovation in the case of safety vests for jockeys?

The research question may be broken into three parts to aid analysis.

Three sub-questions

- What are the main historical and regulatory factors that influence the design of jockeys' safety vests?
- Why is a UCD method not yet applied to enhance the effectiveness of

safety vests for jockeys, and which may offer benefits?

- Is it possible to integrate fast-changing technology and advanced materials into safety vests?

In answering four interrelated research questions set out as per above, the author examined the evolution of safety vest design in the Australian horse racing industry by identifying the case study of primary and dependent-secondary users affecting the evolution of this product's design.

1.2.2 Personal motivation

Horse racing is a profitable, multi-billion-dollar industry in Australia and around the world. Many people perceive this activity from advertisements as fun, exciting and glamorous. Many Australians experience a day at the races and placing bets on the horses as a social highlight of their lives. However, the suffering and deaths of jockeys cannot be ignored and deserve future investigations.

1.2.3 Structure of the thesis

The study follows four key phases: the research background, data gathering, conceptualisation and discussion of the findings, and the conclusion. The author has structured the thesis in the following chapters.

Chapter One: Introduction explains the background for the study. It comprises three parts: the scope of the study, the thesis aims and proposal, and definitions of terms. This chapter provides the basis of the research and highlights the case study analysed in this thesis.

Figure 3 presents the three main sections of this thesis in relation to the main research question, highlighting the relationship between the eight chapters that follow this Introduction.

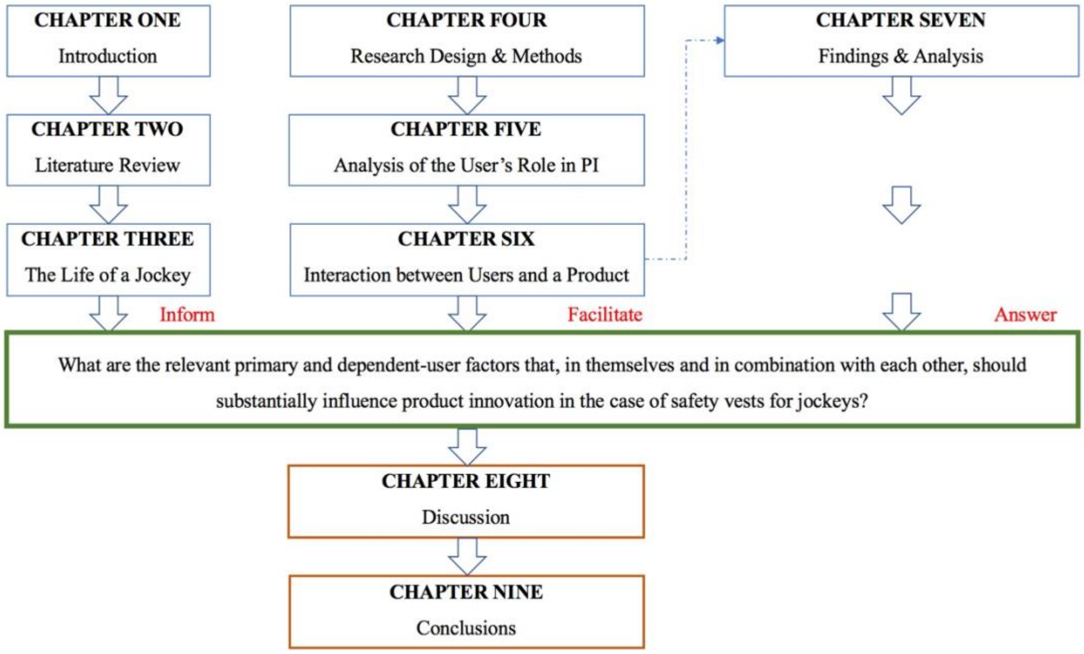

Figure 3. Flow chart of chapter thesis structure and analysis

Chapter Two: Literature Review discusses academic literature and trade publications to establish current knowledge and thinking regarding the nature and purpose of jockeys' protective clothing. The chapter identifies studies that either provide detailed statistics on injuries and fatalities involving jockeys or examine the medical responses to such injuries. This weight of evidence reinforces the importance of safety vests in race riding, with a number of papers calling for enhanced design to improve protection for jockeys. The chapter establishes the significance and original contribution of this research.

Chapter Three: Safety vest standards considers the regulation of jockeys' work in the Australian thoroughbred horse racing industry as the context for the research. The chapter discusses the jockeys' role and the equipment they use, highlighting the risks to which they are exposed. The discussion then considers the origins of the standards for the design and evaluation of safety vests, focusing on EN 13158 and ARB 1.1998, which are the current standards operative in Australia. Through a comparison of the design criteria and testing methods used in both standards, the chapter draws the reader's attention to the vicious circle that these standards create, in which the mandatory approved safety vests in Australia employ outdated materials and technology and fail to take into account gender differences, having been developed when there were few women jockeys. The chapter argues that the existing standards block design innovation and pay scant attention to ergonomics and user preferences.

Chapter Four: Field Research: Methodology and Methods sets out the scope and parameters of the study according to the research aims and objectives. This chapter establishes the case-study based approach, the data gathering methods, the selection of interviewees and focus group participants and the parameters for observing the day-to-day work of jockeys, with a focus on their use of safety vests, and of health professionals. The ethical considerations involved in the data gathering are explained, followed by an explanation of the coding techniques and schema applied in the thematic analysis of the interview data, emphasising empathic and user-centred design.

Chapter Five: Critical Analysis of the User's Role in Product Innovation establishes the importance of the application of UCD and UXD as a multi-stage problem-solving process to achieve advanced design of jockeys' safety vests. Specifically, the chapter examines the literature regarding development of new products, focusing on incremental product innovation versus radical product innovation to establish current understanding of the scope to improve the nature and use of products, with an eye to applying this theoretical knowledge to improving the protective ability and comfort of jockeys' safety vests. The author analyses the wearable tech market in a broad way and considers reasons to convert safety vests into wearable products, specifically considering the health sector.

Chapter Six: The Interaction between Primary and Secondary Users and a Product uses the concept of product ecology to map the actors, factors and organisations linked to jockeys' use of safety vests, drawing on the empirical work undertaken. As a tool for design, this mapping focuses on the interaction of jockeys and medical professionals, the two main groups linked to the use of safety vests at the levels of practice, experience and meaning. The use of a product-ecology framework establishes the value in placing the needs and experiences of jockeys and medical professionals at the centre of the design process for new safety vests and for the standards that regulate their design and testing. The chapter compares the needs and preferences of jockeys as a niche user group with those of riders in eventing, show jumping and pony clubs, which may offer a new market segment. Although the research findings aim to improve safety-vest design for all riders, this comparison shows that jockeys' needs do not match those of other riders, since use of safety vests may not be mandatory for riders in other areas and preferences may be influenced by concerns such as fashion, individual identity, lifestyle and wealth.

Chapter Seven: Findings and Analysis provides the results of the three phases of data gathering: the semi-structured interviews, the focus group and the observation in the field. This chapter is composed of Part One, in which the author describes the data collection and the main findings, and Part Two, which explains the empirical analysis of the data gathered. A clear distinction emerges within the group of participant jockeys. The less-experienced riders show a more neutral response to the current design of safety vests than the older or retired jockeys, which can be due to them having ridden only when safety vests have been compulsory, whereas the older jockeys have experienced riding without them. The chapter details the problems that female jockeys experience with the current approved designs, which do not suit their body shapes, and the difficulties faced by medical professionals when they struggle to open or remove safety vests while treating injured jockeys. These issues underscore problems with the ergonomics and function of current designs for all riders.

Chapter Eight: Discussion interprets the overall findings across all data collection phases. The chapter discusses the problems that the safety vests pose for jockeys and health professionals. Based on the findings from the qualitative empirical data, this chapter provides a set of concept designs to show how an improved safety vest for jockeys might be achieved. The author also highlights the need for future research because the UX model proves insufficient for this study as it includes only users or stakeholders, leaving out health professionals despite their reliance on the same product's design.

Chapter Nine: Summary, Conclusions and Recommendations is the final chapter and provides an overview of the research and a set of recommendations, while discussing the overall findings. This chapter also offers suggestions for further areas of inquiry because future research is highly recommended in this field.

1.3. Definition of terms

The concepts and terminology used in UCD and technology-development literature require some clarification. Terms such as “user-centred”, “user experience” and “technology” have been interpreted with different emphasis throughout the literature and in practice in international product innovation projects. To help the reader, the author created the page named “Abbreviations’, at p.16 of this thesis. A brief analysis of some of the most popular uses provides useful insights to deepen understanding of the conceptual framework of this study. Specifically, the author aimed to understand how the experiences of the safety-vest users could inform the direction that new standards should take.

Design is a work process which has a user perspective and drives development to address users’ needs. Design was considered to try to find ways to enhance jockeys’ safety, a field that showed a lack of innovation. In the English language, the word “design” has different meanings both as a noun and as a verb, but it is often used to portray the “driving force of the creative thought itself” (Giacomin, 2014, p.607).

Furthermore, design is an integrative and iterative form of problem-solving that requires a holistic understanding of the user, the context of use and interdisciplinary collaboration with technical experts to develop the most innovative and effective concepts (Bloch, 1995; Lawson, 2005; Norman & Verganti, 2012). Human-centred design and ergonomics are concepts that are also considered by the International Organization for Standardization (ISO), with special reference to ISO 9241-210. This standard covers ergonomics and computer science: through the application of human factors/ergonomics and usability knowledge, it is possible to manage the design process. Besides, the system requires the use of human-centred design principles and activities during the life cycle of computer-based interactive systems (ISO, 2015).

A UCD approach optimises the features of a product based on a set of predetermined usage patterns. Therefore the author realised the need to consider a third-party dependency situation: only in this way was it possible to achieve a design for users (Degani, 2004). A process of communication and learning offers results such as interactions and meanings: thus, design is considered a form of progress because designers can image and make, but they also research and think.

Design is a way of interacting with the world: the users of this study require a product that aims to address their needs, and to obtain that, the functionality of the products is both physical and emotional because design also means making things better for people (Seymour, 2012).

The author adopted the above-mentioned meanings and stimulated the users to understand their needs: this led to an intuitive use of the product generated by its perception, its experience and the creation of its meanings (Krippendorff, 1989; Krippendorff, 2004; Giacomin, 2014). According to Giacomin (2014), human-centred design is produced by a number of questions and answers across the physical interaction between human beings and a product to reach the metaphysical, as represented in Figure 4.

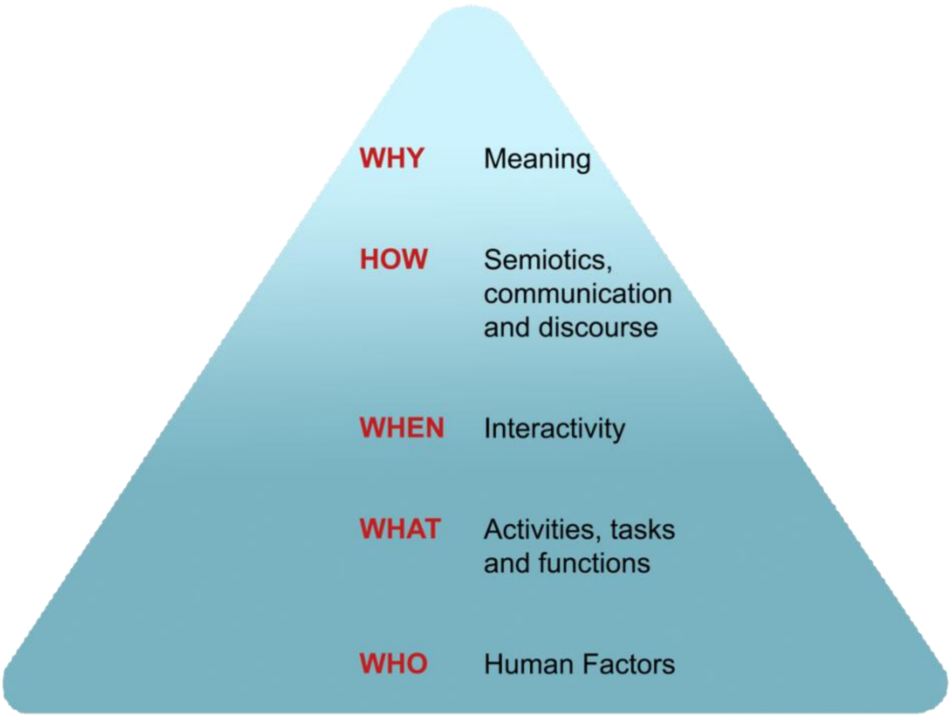

Figure 4. The human-centred design pyramid

(Giacomin, 2014)

Understanding the users' physical and emotional needs allows the creation of something new that they appreciate, because the product is able to satisfy their demands and its use is pleasurable. It is hard to forecast the future, so listening to the users can lead to the creation of a valued product: the future is full of uncertainties, where new data are always detected. The author started from these meanings in approaching the jockeys' safety-vest design.

There has been no adaptation to new materials or technology in the case of safety vests. Some brands have had almost the same product on the market since 1998. Despite requests to alter the back panels of safety vests to improve the cover for jockeys' spines, or to use lighter materials to offer greater comfort and protection, jockeys are still wearing safety vests that follow the templates shown in the standards introduced in Australia in 1998.

In 2014, the most recognised report into safety vests suggested possible improvement of the back panel to cover the jockeys' spines better (Foote, Gibson & McGauran, 2014). However, this is a case of design-thinking failure: scarce innovations have been applied to the safety-vest standards and to the product itself, but without jockey input, and trying to redesign part of the vest in isolation led to a regression in the design and left the users to suffer the consequences. Besides, the request for "innovation" or "technology" applied to safety vests has caused confusion because these words are described rather than defined.

1.3.1 New product development concepts

The author also analysed the concept of "New Product Development" (NPD), which is considered a complete process to bring a new product (tangible or intangible) to market. Hence, a market opportunity was identified in developing a new design applicable to jockeys' safety vests: this product could become available for sale if it satisfied users' needs and wants (Kahn, 2013).

As suggested by the review of the literature, a vest able to provide a higher level of protection was desired. However, to facilitate a better design, the author found that a holistic understanding of the user combined with the iterative development of creative ideas was required (Lawson, 2005). A good design fulfils its function, but also has to produce a desirable experience for the users (Bloch, 1995). A UCD approach was firstly considered by the author, but in contrast, the general literature regarding NPD focuses on the value of product innovation to create competitive advantage also for the manufacturer. For instance, Verganti (2009) states that user-centred perspectives provide powerful methods for understanding how users give meaning to existing things, whereas studies on radical innovation mostly ignore any examination of meaning, which is not considered to be part of research and development (Design Driven Innovation, 2015).

At this stage, the safety vests do not represent any meaning for the users: they are only a mandatory product that jockeys need to wear. Thus, Figure 5 sets out the factors at play in product innovation, showing that it is based on two strategies: outcomes enabled by breakthrough technologies and improved product solutions driven by better analysis of users' needs. Therefore, managing the interaction with key interpreters in the design discourse is a crucial issue still not utilised, because the users of the safety vests and their needs have never been involved in the interaction with the design discourse.

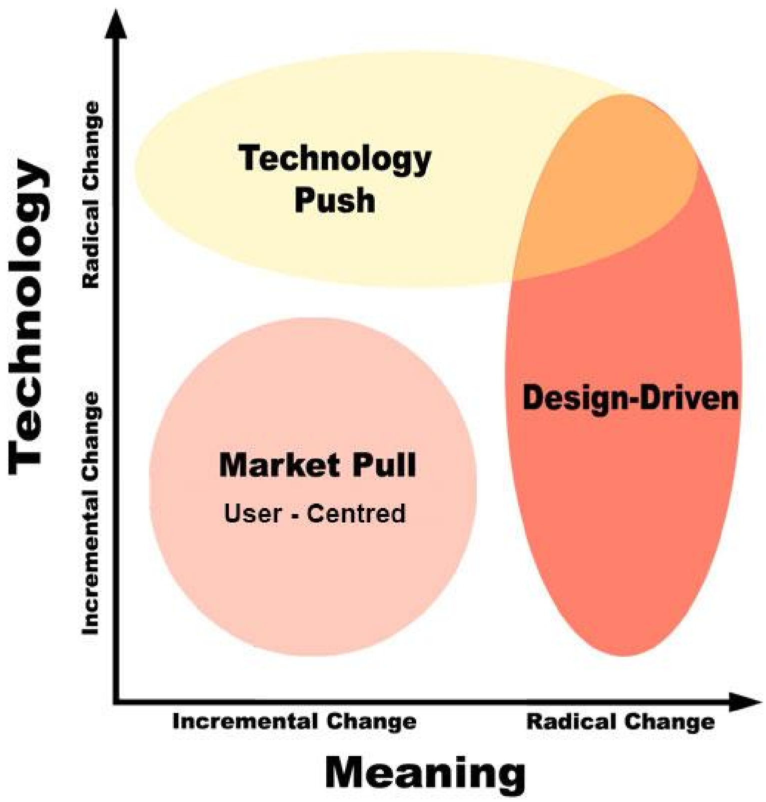

Figure 5. Schematic representation of design-driven innovation

(Design Driven Innovation, 2015)

As represented in Figure 5, the first factor at play in product innovation is radical innovation driven by technology, while the second, incremental innovation, is pulled by the market. As a starting point, this study adopted a user-centred approach to understand the end-users' experiences, mainly regarding the vests' design. During this initial phase, the author reinforced the idea that involving users was essential because design guidelines were not enough or not yet well developed. Users are the people who will use the final product but also are those with needs and expectations, so the author was certain about including the jockeys and the health professionals as the users of the safety vests. Thanks to the knowledge produced by this study, it may be possible to revise the standards applied to safety vests during future research.

Through the review of the NPD literature, a large variety of studies on the role and value of design in NPD became relevant to the aim of this study (Eco, 1978; Trochim & Land, 1982; Koenig, 1983; Aune, 1998; Lawson, 2005; Zimmerman, Forlizzi, & Evenson, 2007; Knight, 2011). At the same time, a paucity of investigation about the role of design in evaluating jockeys' safety was confirmed. Industrial and fashion designers had successfully approached the equestrian world, creating meanings and perceptions (*Daily Mail*, 2012; Liszewski, 2014; Masai of Palm Beach, 2015; Michaels, 2015; *Equestrian Lifestyle,* 2016a), but only to market the luxury side rather than to encourage ergonomics and design.

Innovation is required to upgrade the use and functions of safety vests, and design needs to be the main protagonist. A particularly effective type of innovation strategy occurs when technological breakthroughs merge with radical innovation of meanings. Even considering new technology and the latest materials, this study aimed to redefine what the vest should mean for both the medical professionals and the jockeys. This is a case study of the "design of the solution", which moves from the outside in: with a user-centred innovation approach, the work starts by observing how users interact with an existing product, when design is seen as the tool through which humans innovate the objects' meanings (Verganti, 2017). This is a means to include the experience of a design-critical third-party whose vision regarding the possible functions of a future smart-vest design on track is essential for the vest to achieve the primary users' expectation, which is that the vest will at least protect them, if not help them recover fast from injury. What is meaningful will change in a fast-changing world, but if the focus is only on solutions, the results will solve a problem that in the meanwhile has become meaningless.

Pushing innovation to what is meaningful is required because, as Verganti states, success demands design of the direction of your innovation journey before you can design a solution (Verganti, 2017). The first step in this study was to consider what was missing to produce new meanings through jockeys' vest design: this could also help to bring a successful product to market. Given that technology-push and design-driven innovation are closely linked, design is critical to develop a new successful safety vest with technology epiphany. The framework of technology epiphany is shown in Figure 6.

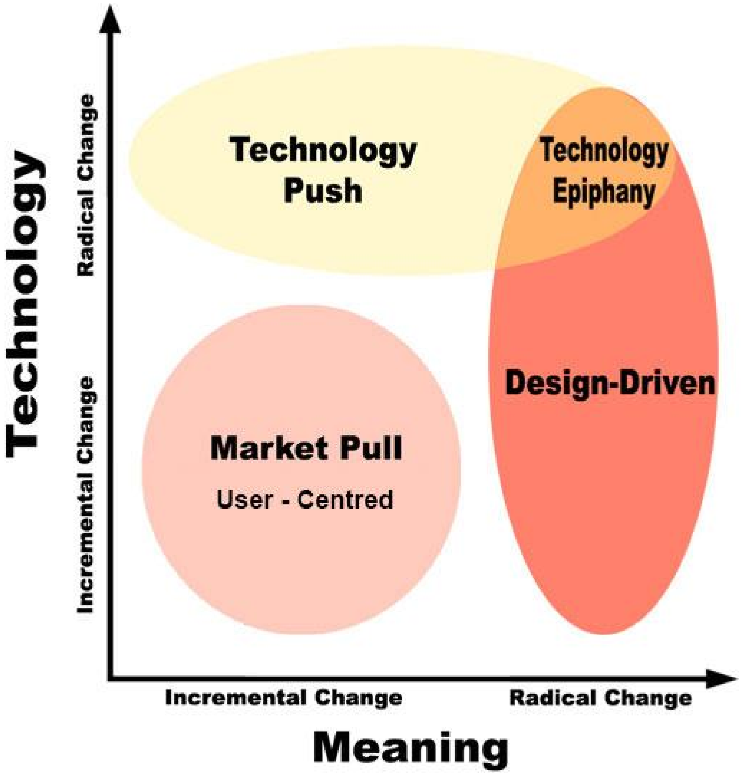

Figure 6. Schematic representation of technology epiphany
(Design Driven Innovation, 2015)

The light-orange area in Figure 6 illustrates the overlap between technology-push and design-driven innovation that represents the powerful and successful meanings enabled by a new technology (Verganti, 2011). This conjunction is named "technology epiphany" or simply "epiphany". The author found a paucity of these concepts in the field of safety vests for jockeys, and future research is recommended. Evaluating the design of safety vests may lead to applying the latest technologies to the product: in this way, safety vests may become one of several new protective smart wearables, with the aim of designing an advanced product ecology.

The term “wearable technology” refers to garments or accessories that are created or enhanced using electronics (King, 2011). Due to wearable technology’s proximity to the human body, it can be used to monitor data about a user or its surroundings (Svanberg, 2013). Users are generally considered to be passive adopters of technology, but this study aimed to reconceive the users’ role in active mode, because the users are those capable of building new meaning through the wearable interface (Samdanis & Lee, 2013).

These features are currently far removed from jockeys’ safety vests and barely considered applicable to them. It is possible to introduce innovation to safety vests if the standards are reviewed to allow that. Therefore, users are able to accept innovative products only if they have the possibility to elaborate the new, such as the material or the shape, because the evaluation of aesthetic quality is based on the context (Carbon, Faerber, Gerger, Forster, & Leder, 2013). Hence, aesthetic appreciation of innovation is dynamic and framework-dependent. However, the present study has noted that this aspect is lacking in safety vests, but it is important for the users.

1.3.2 Defining technology, product innovation and UCD

Technology is dynamic and can be defined and conceptualised in many ways. The literature offers various perspectives of the term “technology”. However, the author of this study found it more useful to consider the use of specific technology with knowledge to solve specific industrial problems, such as producing safety vests for jockeys.

Along with that, the author considered product innovation as the development and/or market introduction of a redesigned or improved product. Design was relevant because it was considered as an integral part of the development and/or implementation of product innovations.

This study examined issues associated with jockeys’ safety vests that could prevent product innovation, starting from a UCD and UX approach. According to Harte et al. (2017, p.2), UX is defined as “the perceptions and responses of users that result from their experience of using a product or service”. This definition was used to identify primary and secondary users who could affect the evolution of the safety vests’ design. Based on this definition, UCD was seen as suitable for this project rather than human-centred design, which is often used interchangeably with the UCD concept but is a more general term not suitable in this case. This deeper analysis of “user” consolidated the need to consider the health professionals as co-dependent users of safety vests.

Considerations of industrial design offered new perspectives. The author analysed how a safety vest was understood and used with the aim of designing a product which would support its users’ beliefs, attitudes, habits and values.

1.3.3 The use of empathic design

The author applied qualitative research to begin this study with the aim of producing a theory of “what is going on” (Waller, Farquharson, & Dempsey, 2016).

The possibility of combining qualitative methods was assessed, and this process led to the discovery of many related issues that needed to be addressed to solve the main problem. Qualitative research was well served by participants’ interviews, a focus group and observation conducted by the author. Use of these tools allowed the author to understand what participants thought about the topic and gather information regarding participants’ roles, but not the meanings associated with that. Both tools were used and are described in detail in Chapter Four.

The author sought to apply empathic design to this study to see the situation from the users’ point of view (Laurel, 2003). This method had not been applied in this field. This was used in tandem with a UCD approach, in which users were located at the centre of the process side-by-side with researchers, leading to a design life cycle that permitted a deep understanding of who would be the user of the product (Harte et al., 2017).

Through the UCD process, instead of asking users to accommodate their attitudes in order to learn a service or use a product, the researchers should design a service or product to support users’ needs. In this way, a product that offers an efficient, user-friendly and acceptable experience is created, producing happy users who might generate sales and customer loyalty. The author employed this approach in aiming to address jockeys' and health professionals' needs. The emotions and opinions about safety vests and motivations for wearing them needed to be understood so that vests could be designed to be experienced as natural and satisfying. Indeed, Milton and Rodgers (2013) explain that designers who empathise with users are better able to embed inclusive design for users with special conditions within the design process and produce mainstream products that are pleasurable, desirable and satisfying for everyone to use.

Designers can use devices to experience the abilities of different users to gain a deeper understanding of users' needs, issues and desires. A good product should transmit pleasure when experienced by the users. Therefore, even aesthetics has an important role, as stated by Nietzsche (1895). While stating that nothing was as beautiful as man, he added that "nothing is ugly except the degenerating man". In other words, something ugly is a sign of degeneration, which causes negative feelings for viewers. Similarly, Heskett (2005) describes design as one of the fundamental characteristics of what it is to be human, and states that design should be considered an essential determinant of the quality of human lives. Heskett argues that design is integral to daily life because it influences everyone's lives in many ways and in every detail.

Interest in design and design research has grown to the extent that the term 'design research' has become part of design language (Faste & Faste, 2012). Therefore, design is art and art is design, but defining design is almost impossible because design has so many definitions (Laurel, 2003). Design by the 20th century was seen as a problem-solving discipline because it was "a plan for arranging elements in such a way as to best accomplish a particular purpose" (Neuhart, Eames, Eames & Neuhart, 1989, p.14-15). More recently, Serges Gagnon (as quoted in De Winter, 2002) instead refers to design as the cultural appropriation of technology since the evolution of any product is conditioned by changes in technology. At the same time, empathy is at the heart of design (Brown, 2013).

According to Brown, design can be useless if not inspired by empathy: it is crucial to understand what users see, experience, listen and feel. Through empathic design, not only users' overt needs but all their contexts, fears, habits, and relationships between people can be taken into account (Interaction Design Foundation, 2016). Hence, designers can contribute to understanding the hidden needs that users have, thus progressing their experiences by a tailored product or service.

This approach is at the base of this study. Designers are responsible for creating products via empathic design, and in this way, the comprehension of how users feel, act and face problems in their lives is realised. Empathising is at the heart of a UCD process: in this case, the author acted as a design thinker to solve issues affecting a particular group of users. Hence, to achieve results and satisfy the research problem, empathy for the users and what was important for them was required (Plattner, 2012).

Design can be defined as an intrinsically holistic activity (Faste & Faste, 2012), but it can drive the users' reasons to purchase a product because body and mind are connected. This is the case where design is seen as the tool through which humans innovate the objects' meanings (Verganti, 2009) and as shown in Figure 7.

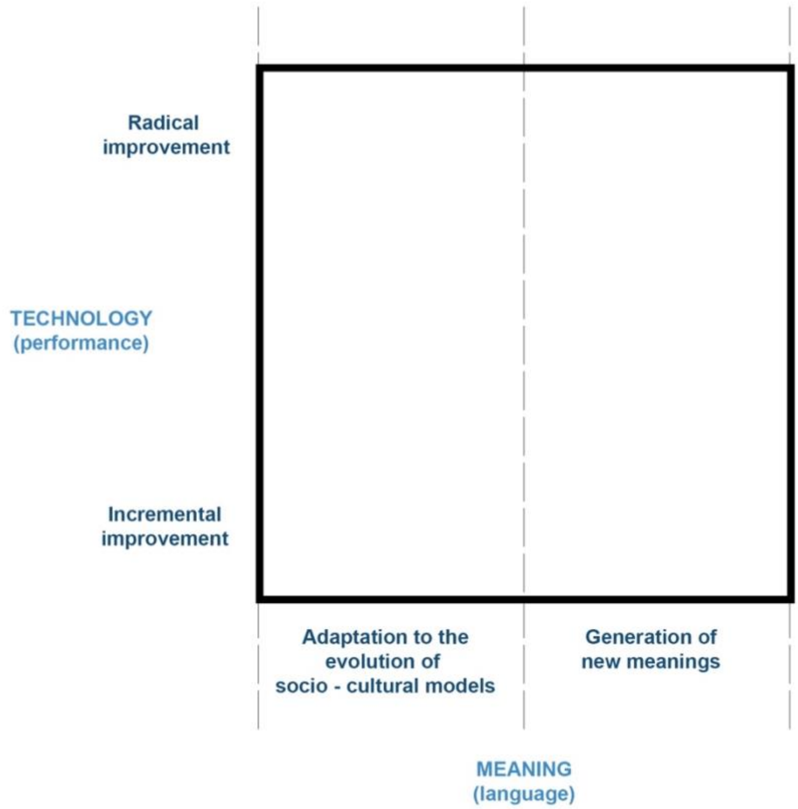

Figure 7. Technologies and meanings as dimensions of innovation

(Verganti, 2009)

Consequently to Figure 7, design acts with technologies and meanings as dimensions of innovation rather than based on use only. In this study, users' needs and the meanings they attributed to the product were considered as a guide to the design method, although in reality, design can drive the users to utilise a product in different ways, influencing their lives and producing different meanings. Users often are not sure about what they want or need and data may not provide answers. Hence, combining intellectual creativity with qualitative data-gathering leads the designer to undertake a design-thinking path successfully. Therefore, in the aims of this study, a designer is considered as someone able to create something for the users before they realise that they need it (Chawla, 2015).

Most of the time, even in the case of safety vests for jockeys, users do not think they need a new solution to satisfy or improve a certain need because they are too used to a current condition (Leonard & Rayport, 1997; Laurel, 2003). A good example is represented by popular products such as Apple's iPhone and iPad. These products were invented and placed on the market before the users knew they wanted them, but have become almost "must-have" products. Apple still represents a high-profile example of success as a disruptive innovator (Christensen, Raynor & McDonald, 2015). Hence, it is a designer's responsibility to understand the needs of users, including fulfilment, desire, pleasure and enhanced capability. Continual innovation is required when planning any product, especially if it has to be successful commercially and it has to meet users' needs, as is the case with safety vests. The fact that safety vests for jockeys and their related standards have been unchanged for what can be called a long time shows the absence of innovation and of users' involvement.

Jockeys constantly seek opportunities to ride under the lightest possible weight conditions, yet the jockeys do not think of ways to improve the vests, as the current designs are on the market and have become trusted because they satisfy the required standards. Jockeys spend most of their lives under different pressures. Hence, empathic design and resistance to introducing personal bias became imperative for the author during the data collection.

The observation of users and their comportment represented a way to empathise. Through this process of watching users as they provided core data about their behaviours, the author understood that the most incisive understanding could be drawn from observing the difference between someone's words and their actions (Plattner, 2012).The data gathering planted seeds of ideas into the jockeys' and health professionals' minds, causing them to consider safety vests in a different light, and to listen to their own needs.

Empathic design leads to the perfect combination of observing and engaging with users. Consequently, the basis of the data gathering is conversation with the main users, through which they can voice their opinions on issues that affect them in their personal and professional lives and reflect on their everyday experiences. In this study, participants were even interviewed. They contributed their perspectives and knowledge to a project that sought to understand whether and how design could help medical staff, jockeys and general horse riders to support themselves to achieve a higher level of safety.

The research was intended to be applied to other horse-riding activities or sports that registered similar injuries to those suffered in horse racing. Therefore, the author considered the role of prototyping, which is a crucial aspect of empathic design. Prototyping enables production of an elucidated concept of the new product, which is exhibited to other people, stimulating feedback and discussion with them and potential customers. Identifying new meanings combined with research offers collaboration between technological research and design research (Faste & Faste, 2012). Therefore, future research is highly recommended.

The participants often demonstrated excitement during this study because, through the empathic design approach, they were leading product development, although they were not conscious of that. Therefore, the author was able to collect data and pushed innovation with the aim to produce an upgraded safety vest through generating a deep and empathic understanding of users' needs, as outlined by Leonard and Rayport (1997).

Before to deeply analyse the life of jockeys, the author reviewed the scientific, the academic and the industry literature in Chapter Two. Specifically, to understand the importance of wearing a safety vest thus, even an overview of the medical literature was presented. The richness of scientific investigations along with the dearth of scientific analysis specifically connected to safety factors, presented in Chapter Two, confirmed the importance of this study.

Chapter Two: Literature Review

This section reviews and critically appraises academic and industry literature to define what is known and thought relevant to this study. Chapter Two considers literature on horse-riding-related injuries, jockeys and injury prevention, the nature and use of safety equipment in sport and the development of specific technologies for protection of the torso. This chapter draws attention to knowledge within sports science regarding injury prevention in relation to the nature and use of body protectors in other sports. This could then be applied to data collection and analysis and prospective design work in the thesis. Between 1993 and 2015, 59 people died from horse-related injuries in Australia (Paix, 1999; Thompson, 2017). Data regarding the risks associated with horse racing are analysed to highlight the importance of the research gap.

Literature specific to safety vests design and about how jockeys experience these products (user experience) is limited whilst there are extensive scientific publications into factors and typically echoing health, wellbeing, physiological and cognitive function, and performance of jockeys and even about horses. The author particularly investigated the role of safety vests for medical professionals with data on the site and severity of post-fall injuries, which had not previously been performed. Publications may note the risks associated with jockeys' falls or how an injured horse may influence those falls, but they usually lack in a deep analysis of the specific effects on jockeys' safety equipment (specifically, the safety vests) and how its design may reduce the severity of jockeys' injuries. Particularly, in terms of user experience dynamics and the knowledge base of products. They tend to simplistically demand future research to investigate better safety product design whilst often reporting the dramatic fall's consequences. In the scientific literature and in the Australian racing database, there is useful information that could help manufacturers to raise vests' quality and improve its safety, but this literature is isolated from the people discussing the safety vests' standards, suggesting a lack of knowledge transfer is a major problem for this field. This scarcity of knowledge also impedes the application of the latest materials and technologies into jockeys' vests.

Then, the author concentrated on the type and severity of injuries related to horse riding but focusing on jockeys: specifically, on known data about injuries sustained by jockeys in those body areas that should be protected by safety vests. The review of the academic and industry literature was conducted in terms of the findings published and relevant to the aims of this study, specifically in the past 45 years of publications.

2.1 Medical literature

The medical literature clearly establishes the danger of horse riding and shows that even the most experienced, well-trained jockeys can fall, thereby suffering injuries that may cause lasting injuries to their bodies (Ingemarson, Grevsten, & Thoren, 1989; Mills & Whitlock, 1989; Buckley, Chalmers & Langley, 1993; Donohoe, 2015; Nicholson and Manley, 2015; Eddy, 2016a; Hall, 2016; Kelly, 2016f; Kermeen & Searle, 2016). This indicates the need to enhance safety measures and standards: however, the author focused on the importance of enhancing the design of jockeys' safety vests.

Falls are not preventable due to the interplay between horse and rider, which can result in unpredictable and unsightly events (Cripps, 2000a). Therefore, scientific publications investigated the wellbeing of thoroughbred horses with the aim to predict their falls and bring safety to jockeys (Waller, Daniels, Weaver & Robinson, 2000; Cowley, Bowman & Lawrance; 2007; O'Meara, Bladon, Parkin, Fraser & Lischer, 2010; Hitchens et al., 2012; O'Connor, Warrington, McGoldrick & Cullen, 2017; Donati, Fürst, Hässig & Jackson, 2018). Specifically, Maeda , Hanada & Oikawa (2016, p.91) request that further studies can predict "the risk of fracture on the basis of objective parameters, such as exercise and racing history (effects of cumulative exercise distance and speed) or early diagnosis of fatigue-related bone damage (fatigue or stress fracture), as fractures of this type occur when bone damage exceeds bone repair and pre-existing lesions can be precursors of catastrophic fractures (pathologic fracture)". Hence, there are several publications about the epidemiology of jockeys' falls and horses' injuries instead, this study aimed to give an intimate insight about users (Australian jockeys and medical professionals) and a product (safety vests).

International published studies indicate that horse riding is more dangerous than motorcycle riding and automobile racing (Gierup, Larsson & Lennquist, 1976; Firth, 1985; Nelson, Rivara, Condie & Smith, 1994). Particularly, Hitchens et al. (2011) state that being a jockey is a hazardous occupation and their study has confirmed that "it is feasible to measure physiological attributes of jockeys and track-work riders that are predictive of the risk of falling" (p.6); thus, being a jockey is mental and physically demanding.

Jockeys' riding position and the horses' speed predispose them to risk of injuries: according to Waller et al. (2000) state that almost 1 in 5 jockeys' injuries (18.8%) back in the period 1993 – 1996 was to their head or neck. However, injuries were also found in jockeys' leg (15.5%), foot/ankle (10.7), back (10.7%), arm/hand (11%), and shoulder (9.6%). Instead, the majority of jockeys' injuries to their back (55.1%) and chest (49.6%) were caused by being thrown from the horse. This US study (Waller et al., 2000) concludes demanding improvements to jockeys' protective equipment.

Even Great Britain and Ireland show similarities: specifically, the most common injuries sustained by jockeys involve soft-tissue damage and fractures (Turner, McCrory & Halley, 2002). Particularly, Turner, McCrory & Halley (2002) assert that jockeys experienced muscle contusions, muscle and ligament strains. Instead, the most common serious injury was fracture, mainly to the upper limb and clavicle (73% in flat racing and 71% in jump racing). This 73% of upper limb and clavicle fractures reported by jockeys in Great Britain and Irelan is relevant because these body areas should be protected by safety vests. Besides, even there, jockeys must wear a safety vest to the European Standard EN 13158:2000, which became compulsory in 2001 and it is also in use in Australia. Significantly, Turner, McCrory & Halley (2002) affirm that " body protectors are solely to reduce the incidence of fractured ribs and soft tissue injury. They were originally referred to as spinal protectors but they were never designed to fulfil this function. In essence, they are a padded vest with shoulder pads" (p.405). It is relevant to consider that Australia introduced safety vests as mandatory safety equipment during races in 1998.

Still the Australian study conducted by Curry, Hitchens, Otahal, Si & Palmer (2016) affirms that jockeys' fall occurring during races had the highest average claim cost. Significanlty, in flat racing although "intra cranial injury was associated with 7% of claims overall, it was responsible for 32% of the total cost of claims. Apprentice jockeys had more claims for intracranial injury (12 versus 7%, $P < 0.05$) and other head/facial injuries (15 versus 7%, $P < 0.01$) than experienced jockeys and experienced female jockeys had more claims for joint dislocation than their male counterparts (6 versus 2% of males, $P < 0.05$)" (p. 225). Due to the nature of this study, even Curry et al. (2016) confirmed that actual safety vests need improvements because of the significant percentage of jockeys' injuries related to those areas that should be protected by these products.

Other studies (Waller et al., 2000; Barss, Addley, Grivna, Stanculescu & Abu-Zidan, 2009; Mackey-Laws, 2016; Aitken, 2017; Johnston, 2017) also highlight head and spinal injuries as the most dangerous. Deadly, crippling or career-ending injuries occur mostly to the torso: again, these body areas should receive better protection by safety vests to minimize jockeys' injuries rather than the poor protection currently offered as stated by literature. Information regarding injuries to jockeys on race tracks is often buried within details of injuries sustained by all horse riders. Relevant studies published over the last 45 years offer comprehensive and varied information on horse-riders' injuries, less about race-track jockeys, and little that captures race-track jockeys' views on their safety or discussions about vest design.

The first major study (Barber, 1973) investigated 154 patients with horse-related injuries severe enough for them to be admitted to the Radcliffe Infirmary in the United Kingdom. In 1973, use of safety equipment was not compulsory during horse riding and it was not often worn. Barber (1973) found that the common and severe type of injuries were comparable with those sustained by motorcyclists. The main body areas affected were the head, vertebrae, pelvis, chest, legs and arms. Barber argued that attitudes towards the use of protective headgear in particular should change and that young riders were often insufficiently supervised and protected when riding.

Horse riders are often compared with motorcyclists or car drivers in the literature. However, this is like an apple-orange comparison. Horses are unpredictable creatures, despite their high level of training. They are huge (average weight around 500kg) compared with tiny and skinny jockeys (around 55kg). Besides, when jockeys ride using the ‘Martini glass’ posture, the centre of gravity on a galloping horse is further forward than that on a trotting or cantering horse. Jockeys adapt and develop their techniques, using short stirrups that are considered good support so that they are able to be forward over the horse’s shoulder, moving their centre of gravity closer to that of the horse.

Moreover, horses and jockeys are not comparable scientifically with cars and car drivers. Horses do not have interchangeable body parts, as cars have. Motorcycles and cars run on flat surfaces, while the jockeys and their horses worldwide run a natural grass surface, better known as turf. Instead, in North America, the most common surface where jockeys run is a harrowed surface which is made of a mixture of sand and local soil. In winter, most of the flat races in Britain and other parts of the world with similar weather conditions, are run on a synthetic surface, generally, a blend of sand with synthetic fibre and/or rubber, often coated with wax or a similar substance. (Lesovoy, 2009; Allin, 2011). Falls may affect any well-trained and skilled jockey and are almost impossible to foresee (Sharman & Wilson, 2015), whereas car crashes are more foreseeable and the driver has some protection due to the vehicle.

The author found a lack of reference to advanced materials and the latest technologies being applied to jockeys’ safety vests, whereas the opposite was discovered in the literature related to motorbikes and cars. For instance, new materials are built into the body panels of cars involved in the United States’ National Association for Stock Car Auto Racing (NASCAR) competition, to lighten their weights and therefore theoretically increase their speeds (Lemasters Jr, 2015). According to Lemasters Jr (2015), instead of a widespread use of sheet steel, carbon fibre and Kevlar® are integrated into the coats or shells of the latest vehicles. NASCAR vehicles and jockeys share the same aim: to ride at the lightest weight possible and be the fastest to win, so the car innovations may provide inspiration regarding the materials used in jockeys’ safety vests.

The next relevant study of riding-related injuries was published 13 years after Barber’s, in the form of Hickling’s (1986) investigation into the design of head protection for horse riders. This was motivated by calls for professional jockeys to wear full-face helmets as motorcyclists did. Hickling was the first author to highlight the need for head protection in race riding. Hickling considered absurd the idea that jockeys should wear motorcycle helmets because the weight brought risks and the jockeys needed peripheral vision and to hear horses coming up behind to be safe. Hickling argued that the design of head protection for jockeys should balance safety and functional performance.

Much of the subsequent literature focuses on the need for head protection as the prime safety measure for jockeys and other horse riders. In 1989, Ingemarson et al. investigated the risks of injury among horse riders in Sweden and noting the importance of wearing helmets to avoid cranium-cerebral injuries, which were the most common type of trauma (Ingemarson et al., 1989). Subsequently, Silver and Parry (1991) reported a British survey-based study on the severity and increasing incidence of horse-riding accidents, finding that inexperienced riders and the behaviour of horses were the main contributors to accidents. They identified the spine and the lower cervical areas as the most common sites of injuries, noting the danger of this for jockeys, who could fall from a height of about three metres while moving at speeds of up to 65 km/h and might have a horse of up to 500kg fall or roll on top of them.

An important New Zealand study (Buckley et al., 1993) considered the epidemiology of injuries caused by falls from horses, reviewing 54 fatalities between 1977 and 1986, the high rate of hospitalisations among injured riders and the severity of injuries. They noted the similarities between these injuries and those caused by playing rugby. Their findings confirmed the predominance of head injuries reported in previous studies, and that these were more frequent among young horse riders.

Hitherto, the review of the literature demonstrated the popularity of equestrian sports, and the significant incidence of severe injury even among jockeys: thus, the evaluation of current safety equipment is vital to reduce or prevent the number and severity of injuries (Firth, 1985; Ingemarson, 1989). Press, Davis, Wiesner, Heinemann, Semik & Addison (1995) were among the first to investigate injuries incurred by professional jockeys. They reported the findings of a survey on the nature, incidence and underlying causes of injuries suffered by professional horse-racing jockeys in the United States. The main causes they reported were: the jockeys' precarious riding positions; a fall of a horse which could place a jockey in danger of being trampled by other horses; or jockeys hitting the starting gate or rails around the course. The authors recommended that improving jockeys' safety should be prioritised.

A study by Quinn and Bird (1996), despite it involved equestrian riders and not just jockeys, drew specific attention to the design of saddles as a possible cause of lower back pain in riders. However, they commented that each equestrian discipline had its own characteristics and the riders in each discipline had different needs. Tsirikos et al. (2001) investigated the long-term consequences of race riding on the cervical and lumbar spine of jockeys. Over a 13-year period, they observed 32 jockeys, concluding not only that professional race riding presented a high risk of direct spinal injury if a fall occurred, but that jockeys were exposed to progressive spine degeneration because of repetitive trauma, including general physical stress on the spine.

A wide collection of medical publications have analysed horse-riders' posture, especially that of jockeys, to understand the high incidence of risks to which they were exposed (Roberts, 1993; Roy Britt, 2004; Siebenga, Segers, Elzinga, Bakker & Patka, 2006; Callaway, 2009; Pfau, Spence, Starke, Ferrari & Wilson, 2009; Guyton, Houchen-Wise, Peck & Mayberry, 2013; Wilson et al., 2013). Siebenga et al.'s (2006) study from the Netherlands reported a total of 32 patients with horse-related injuries in the period from December 1990 to December 2003, comprising five deaths, 36 spine fractures and a male to female victim ratio of 1:7. Those who suffered spinal and pelvic trauma were at the greatest risk of long-term effects, including permanent disability.

Safety vests should protect the jockeys' spinal area, aiming to reduce or avoid such severe injuries (Minchin & Bartley, 2005; Butler, 2011; Kelly, 2016a, 2016b; Cleary, 2017). At the time of this study, safety vests have not changed and still failing in provide adequate protection to the jockeys in case of falls, which are still experiencing the injuries often reported in the medical investigations as previously mentioned in this chapter.

2.1.1 The effectiveness of jockeys' vests in Australia

In 1995, the Australian Racing Board (ARB) collaborated with engineers and doctors to investigate how best to protect jockeys' safety (Gibson, 1996, 1998; McLean, 2004). A result was that wearing safety vests during races became compulsory in 1998, after which the number of jockey deaths fell. According to Hitchens, Blizzard, Jones, Day & Fell (2009), flat racing jockeys are more exposed to fatalities and "occupational fatalities to jockeys occurred at a rate of 2.31 (95% CI, 2.06–2.58) deaths per year between 1878 and 2007, but jockey mortality in the past 25 years has stabilised at 1.27 (95% CI, 0.98–1.64) deaths per year. Before 1963, the mortality rate was 2.86 (95% CI, 2.52–3.24) deaths per year" (p.84).

However, the effectiveness of the vests came under scrutiny in an Australian study conducted by Roe et al., (2003) which considered the degenerative effects of repetitive trauma caused by falls from horses and general physical stress on the spine based on examination of riders' cervical, thoracic and lumbosacral spinal injuries. The researchers identified the need for safety education for all riders and recommended that the effectiveness of safety vests should be evaluated. In 2014, a two-year collaboration between the ARB and the Rural Industries Research and Development Corporation (RIRDC) produced a report entitled *Evaluation of Safety Vests – Health and Safety in Australian Racing* (Foote et al., 2014), which recommended improvements in safety-vest design (Australian Horse Industry Council, 2014) along with Andres , Bushau-Sprinkle, Brier & Seger (2018) and Hitchens (2014).

The study of Foote et al. (2014) was the most pertinent to the present work as it included information regarding tests on safety vests, and considered vest designs used around the world during the 20 years leading up to publication. Its conclusions demanded more investigation and improvement of vest designs, though no changes have yet been produced.

Foote et al.'s research (2014) included insights gained from an anonymous survey among Australian jockeys, the results of which indicated their dissatisfaction with the performance of the vests in terms of protection, heat retention, restrictive nature and lack of flexibility due to the materials used (see Table 2).

Table 2. Vest performance as rated by surveyed riders

(Foote et al., 2014)

	OzVest	Vipa Tech	Hows Racesafe
Protective capabilities from falls	50%	42%	28%
Heat retention of each vest	50%	45%	43%
Restrictiveness of each vest	38%	48%	53%
Flexibility of each vest	50%	58%	70%
Most frequently worn in racing	6%	20%	39%

As set out in Table 2, jockeys rated their dissatisfaction about experiences with the safety vests according to the brand they wore during their careers. However, no deeper understanding was sought to find out what had prompted their ratings. According to Degani (2004), the best way to improve outcomes for users is to understand in detail the bond between the product and the approach to optimisation of product design through a user-centred perspective.

The data in Table 2 represent a rarity among the items published because they offer user-perspective information, but these data are very broad and take into consideration only some of the approved vests used in Australia. The author addresses this rarity in the literature by giving user-experience a central place in this study. Future research may consider the whole range of safety vests used in the country and even a more extensive population of participants to investigate these products' design to satisfy users' needs.

2.1.2 Paediatric medical publications

Some consider equestrian activities as high-risk sports and most of the children experiencing horse-related injuries report long term disabilities (Dekker et al., 2004; Cuenca et al., 2009). Despite that, there is a paucity of horse-related injuries presentation especially when children are involved and Craven (2008) suggests to "these severe injury presentations are supported by a limited trauma team response, which activates on the mechanism of injury. The effectiveness of this as a contingency system needs to be evaluated".

A European study (Hessler et al., 2014) stated that the number of equestrians riding with helmets was increasing, yet the horse-riders' willingness to wear body protectors was not so positive. These researchers discovered that, of 169 riders injured over a 12-month period in connection to riding, only 66 were wearing a helmet and only 14 wore a body protector. The authors highlighted the fact that wearing protective headgear reduced the risk of injuries while the data gathered were insufficient to confirm the effect of wearing body protectors. Along with that, the injured riders who were wearing safety vests reported more injuries to the upper body than those who were not wearing them. In addition, the youngest of those injured (27.8% were aged 18 years or younger) showed extreme confidence in their skills, leading the study authors to highlight the importance of supervision, teaching and correct use of protective equipment to prevent severe injuries.

Various investigations found that young horse riders (less than 25 years old, which is when most jockeys start their careers) were more exposed to risks and thus injuries because they were over-confident of their skills. Hence, many authors recommended greater supervision and lessons dedicated to the use of safety equipment to prevent major injuries (Campbell-Hewson, Robinson & Egleston, 1999; Wilmoth, 2007; Draper, 2013; Bartley, 2014; Hessler et al., 2014).

In a United States study, Christey, Nelson, Rivara, Smith and Condie (1994) highlighted the exposure of children, teens and young adults to the risk of severe injury, promoting the importance of wearing safety gear, regular inspection of safety equipment and adequate adult supervision. These concepts were confirmed by another US investigation (Cuenca et al., 2009) dedicated to horse riders of paediatric age (0-18 years old), which established that equestrian activities should be considered high-risk sports and safety education was crucial to reduce the severity of injuries.

Other studies (Ball et al., 2007; Graham, Rivara, Ford & Mason , 2014; Hessler et al., 2014) compared the severe injuries suffered by jockeys after falls with those reported in other sports, such as motocross, skiing and cycling. Other common injuries to jockeys were caused by hitting the barriers or running rails, or being kicked, struck or trampled by a horse. The consequences could be injuries to the face, lower limbs, the intracranial space, the neck and/or shoulder, multiple injuries or fractures (Triantafyllopoulos, Panagopoulos, Curry & Sapkas, 2013; Hitchens, Otahal, Si & Palmer, 2015).

In Australia, the first reported equestrian death of a child was in 1830, and throughout the years, trauma, including from horse-related injuries, was the most common cause of morbidity and mortality in children (Holland et al., 2001). The horse riders investigated were younger than 18 years old, lived in rural areas and experienced horse-related traumas, which were a significant problem for such young riders. Therefore, the authors called for improved safety equipment to address this issue.

The minimum age at which Australian apprentices can start race riding is 16 years old and ideally, their weight is 45-48 Kg for boys while is 45 kg for girls. Still in 2003, Lim et al., report serious and meaningful injuries among equestrian activities riders, especially those not wearing a helmet. However, Lim et al. (2003) confirm the importance of wearing protective equipment (e.g. helmet and safety vest) during equestrian activities to reduce facial, head and spine injuries. This sustains the importance of this study in investigating the design of jockeys' safety vest to avoid such dramatic injuries, among adults and children horse riders.

2.1.3 Medical publications about injuries among Australian jockeys

A significant range of scientific studies reported meaningful numbers of injuries in Australia among licensed jockeys, track riders and stable hands resulting from falls, kicks or being trodden on by horses (Finch, Smith & Williams, 1995; Cripps, 2000b; Moss et al., 2002; Flood & Harrison, 2006; Cowley, Bowman, Lawrance & Turner, 2007; Hitchens et al., 2009 & 2010; Hitchens, 2011; Curry et al., 2015; Curry et al., 2016; Wylie, McManus, McDonald, Jorgensen & McGreevy, 2017).

A study of Roe et al. (2003) reported the incidence of acute spinal-cord injuries (ASCI) from all forms of horse riding in patients in New South Wales hospitals between 1976 and 1996, concluding that:

> "No measures were defined to improve spinal safety in any form of horse riding. The possible role of body protectors warrants formal evaluation. Continued safety education for all horse riders is strongly recommended" (Roe et al., 2003, p.331).

Of the broad literature on injuries to horse riders, only a small percentage is dedicated to jockeys and their specific safety needs and equipment. Almost every publication considered during the review of the academic literature recommended the wearing of safety helmets during activities with horses, while only a few mentioned the importance of wearing safety vests.

Contributions to the literature come from all over the world, but the small number of studies regarding jockeys does not consider well the different conditions of each geographical area (for instance, weather conditions, track status or different types of safety vest worn) and how this might affect the jockeys and their injuries. The majority of publications are from England and Wales (Lloyd, 1987; Silver & Parry, 1991; Turner, McCrory & Halley, 2002), as well as from the United States (Waller, Daniels, Weaver & Robinson, 2000; Ball, Ball, Kirkpatrick & Mulloy, 2007), and Australia (Paix, 1999; Hitchens, Blizzard, Day & Fell, 2010). Track conditions, weather conditions and standards applied in each country need to be considered because they may influence the safety vest design and thus the consequences of jockeys' falls. For instance, Australia has different weather conditions than the UK. At the time of this study, the literature present general considerations and comparisons among worlds country, particularly about the relation user (jockeys) and safety product (safety vest).

According to Maeda et al., (2016) the fall incidence rate for thoroughbred jockeys in flat races is similar in Japan and California, at 1.62 falls per 1,000 rides, and even in Australia, where it is 1.43 per 1,000 rides. However, the overall injury incidence rate for thoroughbred jockeys in California was 1.02 per 1,000 rides, in Australia 1.12 and in Europe 1.19 to 1.76, per 1,000 rides. In addition, the authors (Maeda et al., 2016) registered the injury incidence rate per fall for thoroughbred jockeys at 51% in California, 25% in Australia, and 34% to 44% in Europe.

Even if includes horse riding injuries that required hospital treatment in Victoria, the author must mentioned the study conducted from 2002-2003 to 2015 -2016 by O'Connor, Hitchens & Fortington (2018). In this study dedicated to Victoria horse riders, female riders (47.3 Emergency Department and 10.1 Hospital Admission per 100 000 person-years) and those aged between 10 and 14 years (87.8 Emegency Department and 15.7 Hospital Admission per 100 000 person-years) had the highest incidence rates. Thus, according to O'Connor, Hitchens & Fortington (2018), Hospital Admission and Emergency Department incidence rates have increased over the last 14 years. Even in this case, a revision and enhancement of countermeasures were recommended to reduce the severity of injuries.

The literature highlights the risks of being a thoroughbred horse-racing jockey and the sustained number of career-ending injuries and even death (Eddy & Edwards, 2002; Australian Asssociated Press, 2017a; Thomas, 2017). A good portion of the literature focuses on the injuries suffered by the horses as a cause of jockeys' injuries (Hitchens et al.,2015; Wylie et al., 2017). For instance, racing and training on a firm turf track carries a bigger risk of musculoskeletal injury in horses, and this increases the risk for the jockeys riding them (Lin, Wright, Bushnik & Shem, 2011; Collar et al., 2015; Maeda, Hanada & Oikawa, 2016).

During this study, the author did not find any investigation focused on a possible link between horses' injuries and jockeys' safety vests, and what could be done to mitigate the risks. Jockeys have their bodies mostly parallel to the horses' heads and necks for most of a race: this exposes them more to falls because of the speed and the turf conditions (Cowley, Bowman & Lawrance, 2007; O'Connor, Warrington, McGoldrick & Cullen, 2017; Turner, McCrory & Halley, 2002) . In the literature, the risk of spinal injury was considered high for a jockey who led a race and accidentally slipped (Ashman, 2013). The review of scientific publications confirmed that data for both Australian horse fatality and related jockey injury were comparable with those estimated from other international countries.

The review of the literature detected many reports of injuries and deaths from horse-related activities, even if most of these publications belonged to the time when the use of jockeys' safety vests during horse racing and track work was not compulsory. Since such a specific safety product for jockeys has rarely been investigated (Gibson, Thai, Saxon & Foote, 2007; Gibson et al., 2008), this study dedicated to its design may offer original contributions to improve jockeys' safety.

2.2 Protective clothing in sports

Personal protective equipment (PPE) plays an essential role in maintaining the safety of an athlete participating in a sport. PPE for sports includes helmets, body protectors, gloves and mouth guards. Each sport has its risks of injury, but the use of PPE is linked mainly to the risk of traumatic injuries (Daneshvar et al., 2011; Graham, Rivara, Ford & Spicer, 2014). The use of protective clothing is compulsory in many professional and amateur sports leagues, including American football, baseball, auto racing, cricket, fencing, horse racing and hockey. However, this is still not compulsory in rugby, though many clubs require it.

The PPE literature discusses ways in which design innovation and the latest materials have been applied to protect athletes from injury, although there is no literature in this respect specifically on safety vests for jockeys. According to Sports Medicine Australia (SMA), about 50% of sports injuries are preventable with appropriate and properly fitted protective equipment, clothing and footwear (Sports Medicine Australia, 2008).

Although wearing protective equipment may reduce the number and severity of impact injuries, the literature identifies that in an emergency situation it can act as a barrier to the chest, face and head, interfering with the ability of medical crews to stabilise properly the spine or head, especially where immobilisation on a spine board is necessary (Casa & Stearns, 2015).

This is the case for jockeys, who need to wear safety vests and helmets during races and, in the case of a fall, are helped by medical professionals at the track. Therefore, the product (safety vests) for specific users (jockeys) also should meet the needs of co-dependent users (medical staff), and its design influences its performance in such critical situations. Horse racing is unique because the protective equipment used by jockeys forms part of their weight allowance therefore there is a requirement for it to be lightweight without compromising its protective qualities.

2.2.1 Helmets

Despite horse riders and thus jockeys use helmets and safe riding practices, they are exposed to severe injuries if they experience a fall (Cleary, 2017; Masenhelder, 2017a, 2017b). However, the literature (Casa & Stearns, 2015) also shows that helmets such those used in American football, ice hockey and lacrosse can impede airway access during the management of injuries. This indicates that the helmets fail in providing adequate safety in sports, yet the wearing and design of them is the focus of the PPE literature, leading horse riders and jockeys to consider the helmet as the primary safety equipment to wear (Fletcher, Davies, Lewis & Campbell, 1995; McIntosh, Patton & Thai, 2012; Timms, 2015; Fuernschuss, Kandare, Sabo & Pang, 2016).

Some athletes and helmet companies became aware of the figures for long-term concussion despite the increased use of helmets following educational campaigns. This led to makers of the most popular helmet brands taking inspiration from studies dedicated to concussion and general head injuries in sports, to develop advanced headgear products for activities such as hockey (Krest, 2015), lacrosse and skiing (Sport Shieldz Inc., 2015) and motocross (Forcite, 2018).

The Sports-Related Concussions in Youth: Improving the Science, Changing the Culture (2014) report confirmed that helmets reduced the risk of injuries such as skull fractures as they were designed to dissipate and distribute the energy of impact and guard against penetration of the head. However, the report also revealed that marketing material for some PPE stated effects such as the reduction of concussion risk without any scientific foundation for such a claim.

Concerns about the helmets' use and efficiency in the thoroughbred industry were raised in 2014. Following the death in a race fall of the fourth female rider in 14 months, former Racing Australia chief executive Peter McGauran declared that something was wrong with the helmets worn by jockeys because they seemed not to work properly on turf (Mann, 2014). Racing Australia is the rule-making body for thoroughbred horse racing in Australia. The ARB then started a special investigation into jockeys' helmets, including data and statistical analysis to understand why 16 of the last 22 injured jockeys had died because of traumatic head injuries (Hitchens, 2015).

A new standard (HS2012) was introduced by the ARB (Australian Racing Board, 2013), but McGauran has stated that the helmets on the market do not satisfy this standard. Jockeys often experience brain injuries when a fall occurs, highlighting the lack of complete protection from helmets (Brisbane Times, 2014; Rose, 2017; Wood, 2017). Along with that, Australian jockeys are sometimes their own worst enemies, challenging the recommendations on procedure following a concussion. They are told to follow the method used by Australian Football League (AFL) players in the instance of a concussion, which is to rest for seven days and then pass a cognitive test prior to undertaking any sports activities (Clark, 2017). However, after top jockey Craig Williams was rendered unconscious on the track by concussion, he sought an earlier cognitive test to return to the saddle sooner (Clark, 2017),and was duly allowed to compete at a major race day in Sydney in April 2017 (Sheehan, 2017b).

Gierup et al. (1976), in one of the first publications about horse-riders' safety, argued that many of the severe injuries studied could probably have been avoided if improved safety equipment had been used. This message has often been repeated since, yet the main innovations introduced have been lighter helmets instead of the hard shell caps of the past, and colourful and stylish stirrups (Barakat, 1998).

Helmets used by jockeys follow a similar design to that used for helmets worn by cyclists and skiers. The development of PPE began with the fatal accident suffered by international cyclist Harry Elkes on 30 May 1903. Elkes's death came when cycle races were the epitome of modernity, which led to debates regarding the need for riders to wear helmets during races. Inspired by the headgear of pioneering aviators, the first helmets for drivers of cars, bicycles and motorcycles were simple head-coverings in soft leather.

These were followed by the 'Cromwell' helmet modelled on those worn by British soldiers in the 17th century, but the technical evolution in headgear, mainly for motorcycle use, began in the 1950s. Designers and technicians worked together to develop new designs with new materials, and this work led to the application of vulcanised fibre, polyester and fibreglass in 1954. The possibility of painting these materials led to the emergence of the customised helmet, principally as a way for spectators to identify their favourite racers. The celebrated motorcycle rider, Valentino Rossi, is a big fan of these custom products, and his helmet blends safety and self-promotion, contributing to the popularity of motorcycle races.

The most popular cycling helmets available on the market at the time of this study are shown in Figure 8. They incorporate materials such as expanded polystyrene and polycarbonate, a multi-directional impact protection system (MIPS) and aerodynamics into the design. Nevertheless, the extent and rate of head injuries need constant helmet improvement for all users (Australian Racing Board, 2013; Racing Australia, 2018).

Figure 8. Best road cycling helmets in 2016

(Banino & Beach, 2016)

The helmets in Figure 8 represent a proper application of the latest materials while providing protection but restricting the airflow for extra warmth, and enough ventilation to limit the sweat of the user. In this case, users experience is satisfied with the correct design and addressing users' needs.

In contrast, high-contact sports such as American football still follow a basic design and a conservative application of materials, such as hard plastic for the helmet shell and plastic-coated metal bars for the facemask. A better design is offered by hockey helmets, in which the shell is usually made of vinyl nitrile that helps to disperse the force of an impact, while the liner may be manufactured in either vinyl nitrile foam or expanded polypropylene foam, to reduce the effect of impact.

Skiing helmets were introduced in the 1970s when skiers began to wear leather headgear like that formerly worn by motorcycle riders, albeit primarily to protect the head from low temperatures. From 2006, protective helmets became compulsory for all ski and snowboarding competition. In some countries, such as Italy and Austria, helmets are compulsory for children. The use of advanced materials and technologies, with fashion-conscious designs, has encouraged people to wear helmets in skiing and snowboarding.

Uvex helmets for show jumping and dressage are stylish and lightweight (Uvex, 2017). The well-known Dainese brand, dedicated to winter and equestrian sports, motorcycle riding and cycling, show style and quality, yet jockeys have not benefited from such products (Dainese, 2018a). Dainese products take inspiration from medieval armour and its use of geometry. The company claims to combine various clothing components optimised for light weight and performance to offer head-to-toe protection. The company owns a technology centre where engineers and designers collaborate to create safety equipment for various sports.

2.2.2 Body Protectors

Protective vests are still receiving little attentions among horse riders but they are very popular in the eventing competitions. Equestrian sports report a high incidence of injuries and fatalities compared to other sports: Brolin & Wass (2016) conducted a pilot study to assess the safety vests' protective capacity under different scenarios. This model simulated the condition of being trampled by a horse, resulting in a risk of injury is higher for hoof impact close to the sternum compared to more lateral locations that had up to 25% less risk. Brolin & Wass note that the safety vest offered protection against horse kicks, with the chest withstanding 125 to 175Ns compared to no vest worn at 225Ns. However, the vest provided no protection under rotational falls in case of a horse lands on top of the rider. Every horse-related discipline has different needs and thus the riders: jockeys represent a unique niche of horse riders that have particular needs to safety perform. Hence, the author briefly considered sports body protectors as a basic comparison to safety vests for jockeys.

For instance, the Dainese Balios 3 Beta ADJ body protector: it is not specifically designed for jockeys, but it can offer "ergonomics, freedom of movement and safety on horseback complying to the strictest safety standards CE EN 13158:2009 and BETA 2009 level 3. The protector is complemented by a comfortable elastic system that permits the fastening of the vest to the lower body for improved positioning in all phases of use" (Dainese, 2018c).

The Balios design shape is very similar to the safety vests used by Australian jockeys and even its hexagonal foam pieces have the shape that can be often found in those vests. Figure 9 shown the Dainese body protector named Balios 3 Beta ADJ, which is available for women and men.

Figure 9. The Gilet Balios 3 Beta ADJ by Dainese

(Dainese, 2018c)

According to Dainese, the Gilet Balios 3 Beta ADJ shown in Figure 9 incorporates features such as lightness, comfort and breathable protection. Specifically, the use of its Flexagon technology through the application of hexagonal soft protective pieces of Crash Absorb® memory retention foams allow the body protection to follow the torso movements.

This product is designed to satisfy the European EN 13158:2009 and British Equestrian Trade Association (BETA) 2009 horseback safety standards. In Australia, only the vests satisfying the EN 13158 and ARB 1.1998 standards are allowed to be worn by jockeys in races.

The Racelite Pro vest (refer to Figure 10), which is approved to be used in Australia, shows a similar design and features, but is reminiscent of an ancient military vest. The Racelite tags carry warnings rather than instructions, such as "limited impact protection" and "do not guarantee the wearer's protection", which do not inspire confidence for users.

Figure 10. The Racelite Pro safety vest

Style is the main driver of the design of equestrian products, followed by comfort and lightness, and with all three played off against protection from fall injuries. Jockeys must wear safety vests but most of them, according to Hitchens (2014), rely on the belief that an unfortunate incident will not happen to them. Alternatively, they hold a fatalistic view, as explained by Ned Wallish, former honorary secretary of the Australian Jockeys' Association:

> "We know it is a dangerous profession and losses every now and then are inevitable… I don't think there's any other profession in the world whereby two ambulances are in attendance for everything you do" (Minchin & Bartley, 2005, online).

There is considerable literature available on the epidemiology of injury and its prevention in sports (Finch et al., 1995; Campbell & Stone, 1996; Institute of Medicine and National Research Council, 2014; Hessler et al., 2014; Casa & Stearns, 2015), but there is little published on ways to improve the design and quality of safety gear, especially regarding safety vests for jockeys (Gibson, Thai, Saxon & Pollock, 2008; Foote, McIntosh, V'Landys & Bullock, 2011; Safety Solutions, 2014). Two papers include data on the nature and causes of a series of injuries to jockeys: a study from Britain (Edixhoven, Sinha, & Dandy, 1981) and another from the United States (Press et al., 1995). The author of this thesis often referred to these studies during the practical work because they brought information on injuries to the chest and abdomen, body areas at least partially protected by safety vests. Only Press et al., (1995) specifically reviewed the injuries to professional jockeys. Scientific studies need to investigate the design of PPE, particularly safety vests for jockeys, to enhance their safety.

2.3 The evaluation of safety vests

The author did not discover a precise definition of 'safety vest' in the literature. However, the most relevant studies in this field have been considered in order to analyse this product in more detail.

Two Australian studies (Foote et al., 2011; Foote et al., 2014) established similarities between the incidence of injuries to jockeys in Australian racing with others experienced elsewhere and described by different publications, such as Edixhoven et al. (1981), Waller et al. (2000), Turner et al. (2002) and Hitchens (2009). However, the standards in use in Australia may have differed from those applied in Japan, in Europe and in the United States: hence, a comparison of the quantitative data from these studies ended in the absence of a denominator data.

Track conditions around the world are also different. This may have interfered with the consequences of a fall and thus with the data reported. For instance, there are four Japanese grades employed to classify the track surface conditions; besides, Japan bases judgment of the track on levels of moisture on the track, for both Japanese dirt courses and turf courses (Maeda, Tomioka, Hanada & Oikawa, 2012), which is not the case in Australia, where there are 10 numerical rating for turf tracks (Racing Australia, 2019b). These numbers start indicating a firm track (1 = firm = dry hard track) up to a heavy condition (10 = heavy = heaviest category rack, very wet, towards saturation). Instead, for sand or dirt track ratings, Australia use fast, which means ‘compact/firm and at optimal efficiency’, good, soft and wet fast, that means ‘rain, affected, track has surface water but base is solid and surface is compact (accounting for times similar to a fast track)’.

The track surface has significant influence on the incidence of fractures in horses (Boden, Anderson, Charles, Morgan, Morton et al., 2006; Maeda et al., 2016), and this affects jockeys’ safety as the injured horse falls and throws the jockey. Bone fractures in racehorses are the most common issue experienced in the racing industry worldwide (Jeffcott, Rossdale, Freestone, Frank & Towers-Clark, 1982; Nunamaker, Butterweck & Provost, 1990; Mourouzis & Koumoura, 2005; Martig, Chen, Lee &Whitton, 2014; Rossdale, Hopes, Digby & Offord, 1985; Robinson et al., 1988). According to Maeda et al. (2016), there are changes in the way to analyse risk and injuries among racing horses, specifically:

> “Current research on equine epidemiology is moving away from descriptive studies to analytical epidemiological studies to identify the causes of and risk factors for racing injuries. Thus, there have been an increasing number of studies using analytical techniques to identify risk factors for racing

> injuries; these are mainly musculoskeletal injuries, but include cardiac sudden death, paroxysmal atrial fibrillation, and epistaxis, as well as miscellaneous and fatal injuries of unknown causes, with many focused on catastrophic or fatal injuries (resulting in the horse's direct death or euthanasia) due to racing fractures" (Maeda et al., 2016, p. 84)

Hence, the literature affirms that it is important to maintain appropriate track hardness and its cushioning effect for both horses' and jockeys' safety (Cheney, Shen & Wheat, 1973; Clanton, Kobluk, Robinson & Gordon, 1991; Peterson & McIlwraith, 2008). These data may be analysed for the development of jockeys' safety vests and the choice of its materials.

Focusing on Australia, the main analysis of the health and safety of jockeys was performed in 2011 by the RIRDC. The report of this study investigated the injuries and risk factors endured by jockeys involved in thoroughbred racing, and the associated appraisal of safety equipment and standards (Foote et al., 2011). The project confirmed the paucity of data regarding the incidence and type of injuries sustained by jockeys, despite the claim that occupational health and safety were of paramount importance in Australian racing. The most relevant results from that project were about the safety vests (experienced by jockeys as very restrictive and poorly breathable) and the helmets (improvements were required to afford better protection). Jockeys expected protection, while flexibility, lightness, comfort and freedom were needed to move and roll in case of a fall.

The report highlighted the importance of wearing safety vests and helmets, which were indeed compulsory. However, according to Racing Australia (2019a), the standards applied are different: the safety vests must comply with the ARB 1.1998 and the EN 13158 standards, while the helmets must comply with AS/NZS 3838:2006, US ASTM F11 63-01, BS EN 1381/1996 onwards, US ASTM F11 63-04a (reapproved 2011), PAS 015:2011 and VG1 01.040. This indicates that two important safety products are required to meet different standards, which may lead to different levels of products experience for the users.

No previous study has considered the importance of developing a standard to accomplish the creation of both helmets and safety vests, which may help to satisfy users' needs. The jockeys have to wear these products and due to their riding posture, the safety vest may have an impact on the helmet. This study aimed to demonstrate the importance of using a user-centred design method, specifically about the jockeys' vests.

The publication *Evaluation of safety vests. Health and safety in Australian racing* (2014), funded by the racing industry and the Australian government, investigated the effectiveness of safety vests for jockeys and track-work riders. This indicated increasing approval of safety vest use among jockeys, yet many of them showed doubts about the performance and comfort of these products. Foote et al (2014) found there was no evidence that an observed increase in neck and spinal injuries was related to the safety vests worn during riding activities, although jockeys suspected there was such a relationship. A review of race-day footage by a biomechanical engineer indicated instead that these kinds of injuries were the result of jockeys diving forward directly onto the track.

The report called for revision of the standards and better definition of the protective capacity of safety vests. Of the 138 participants (apprentices, fully qualified and former jockeys) who contributed to a survey that was part of the study, 78.3% were in favour of revising the standards to allow the use of other vests (Foote et al., 2014). The authors also suggested that standards be amended to suit better the range of Australian weather conditions and to improve protection of jockeys from the type of injuries sustained. This report (Foote et al., 2014) remains the most important study dedicated to the safety of jockeys in Australia and the one that gives the most attention to safety vests. It did not, however, result in broad changes to the standards EN 13158 and ARB 1.1998. As with many of the studies reviewed, importance was given to falls, their consequences and the treatments experienced by horse riders and thus jockeys.

Once again, the main recommendation was that helmets be worn during any activities with horses. Safety vests had become compulsory wear in 1998, yet the report (Foote et al., 2014) shows that in 2014, the number and severity of jockeys' back and trunk injuries were in line with the pre-vest situation, while the number of head and neck injuries increased. Even Hitchens et al. (2009, p.84) stated that jockey mortality "in the past 25 years was stabilised at 1.27 (95% CI, 0.98 – 1.64) deaths per year. Before 1963, the mortality rate was 2.86 (95% CI, 2.52 – 3.24)".

The review of the literature demonstrated that through the compulsory use of safety equipment during races, the number of jockeys' fatalities has decreased. However, both the Australian studies (Foote et al., 2014; Hitchens et al., 2009) have required more investigations to increase safety in the Australian thoroughbred racing industry.

Another meaningful finding from the report by Foote et al. (2014) concerned jockey riding style, which was found to increase the likelihood of neck and spine injuries because it involved placing just the toes in the stirrup irons as opposed to the balls of the feet, leading to a greater likelihood of diving over the horses' heads in falls. As a matter of fact, to increase jockeys' safety, "all principal racing authorities in Australia require apprentices to ride with at least their ball of their foot in the irons until they have gained adequate experience" (Hitchens et al., 2011).

Jockeys' riding styles have evolved over the years, but this is rarely mentioned in the literature and there is a paucity of information that links this to the evolution of safety vests. Nevertheless, the author decided to dedicate a specific section to this as described in Chapter Three of this thesis, because it should be taken into serious consideration when designing safety vests for jockeys.

Safety vests currently in use by jockeys are short in the front to protect the ribcage, and a bit longer in the back. They are not designed to protect the core or lumbar zones, which are below the vest coverage in the front and back, or the neck. Jockeys are worried about the risk of injury to their necks, spines and trunks, which can lead to severe consequences or death (Auerbach, 2014; Brisbane Times, 2014; Daily Telegraph, 2014; Cottell, 2015; Steward, 2015; Marcuson, 2016; Scadden, 2016b).

The author found that jockeys' safety vests rarely are the main topic of published investigations, instead referring to them as a comparison in a study, but they often highlight the need for improvements in this field. There is little in terms of protecting jockeys from the effects of falls, and almost nothing regarding ways in which the vests might provide post-fall information for medical professionals about jockeys' injuries, such as their location or severity.

A good number of scientific studies report deaths and injuries from horse-related activities that have happened in Australia and around the world (Danielsson & Westlin, 1973; Hitchens, Blizzard, Jones, Day & Fell, 2009; Ingemarson et al., 1989; Bixby-Hammett & Brooks, 1990; Paix, 1999; Guyton et al., 2013, Stirk, 2017). The different types of falls and causes generate dissimilar kinds of injuries: however, a broken collarbone is considered the most common injury for jockeys, and the majority of them experience this injury or accept that it will happen before their retirement (Costello, 2016).

Analysis of the academic and industry literature demonstrated quantitative but almost no qualitative research on jockeys, and their safety vests and designs. Most of the medical literature investigated body protectors and sometimes jockeys' safety vests, but only to examine the injuries and types of surgery required by horse riders following falls. Jockeys were seldom the primary subject of medical studies and no reports considered their injuries in relation to the evolution of jockeys' riding styles and, thus, what qualities might be needed in their safety vests.

2.4 Evidence of a significant research gap

Falls are unpredictable and can happen during track work or races. Several studies broadly examine the injuries and statistics regarding falls that happen in horse racing, but few investigate jockeys and the design of their safety vests. Previous studies have focused on factors that contribute to falls by horses to identify risk factors for jockeys' injuries in the racing field. To date, there is little information on jockeys' falls and there is no study completed on the role of safety-vest design for jockeys.

The medical professionals who attend every race meeting with the aim of assisting injured jockeys when required have not been investigated in prior studies. The review of the literature showed that a rich quantity of information regarding jockeys' injuries had been analysed from a medical point of view, including their hospitalisation and surgery, or from a statistical concept (Balendra, Turner & McCrory, 2008; Cullen et al., 2015; Curry et al., 2015; Dolan et al., 2012; Waller, Daniels, Robinson, 2000; Williams, Cartwright-Hatton, et al., 2006). In contrast with the author' study, there was no identification of a link between the medical staff, the jockeys and the safety vests: thus, the author highly recommended further investigation.

2.4.1 Summary of key findings

This study aims to fill the gap in the existing scientific literature around the design and use of jockeys' safety vests by increasing the focus on users' needs and the context of use while extending the concept of the user to medical first responders, rather than the primary users of the vests only. To this end and considering the gap discovered during the review of the literature, this study examined the following:

a) **Safety vests approved to Level-1 by the ARB do not satisfy jockeys' needs.** The vests are light in weight but stiff, and the level of protection is insufficient to avoid torso injuries, leaving jockeys with concerns regarding their freedom of movement and ability to roll out of the way of other horses when on the ground after a fall. A thick vest could be taken to signify safety, but the solid design of currently mandated vests does not convince jockeys that the vests are safe and they perceive the thickness as restricting them in race riding. Jockeys' perceptions should not be dismissed, since many body injuries occur even when jockeys wear safety vests (Hessler et al., 2014; Kijak, 2015; Kelly, 2016c; Quotidiano, 2016; Sheehan, 2016). Even an important published investigation such as that by RIRDC (Foote et al., 2014) requested a new design for the safety vest, but the design has never been at the centre of any research. Instead, this study oppositely approaches the problem: the design has played a core role in developing concept designs for a new safety vest generated from the intimate experiences gathered among the users.

b) There is an abundance of literature reporting injury statistics for jockeys, but relatively little on injury prevention and almost none on the efficacy of body protective gear (Whitlock, 1999; Cuenca et al., 2009; Wilson et al., 2013). Published studies have not connected consideration of ways to protect jockeys from the effects of falls with information on the location and severity of injuries. No previous study has gathered qualitative data about jockeys' post-fall experiences or the experience of medical staff in treating injuries on race day. This study investigates the possible role of vests in a safety service system, where using embedded sensing and digital technology in vests would allow first-responder medical staff to understand better the site and severity of injuries.

c) **Limited research has been conducted into ways in which technology can be used to drive innovation in safety vests.** Small cameras have been added to jockeys' helmets to film races from the jockeys' perspectives, but there is little evidence of new materials and technologies being used to improve jockeys' safety in falls or in treatment after a fall (Loughery, 2010; Pateman, 2015). Recently, a camera was added to jockeys' goggles by the manufacturer Horsecall Japan to monitor horses' heart rates and display their speeds (NZ Racing Desk, 2017). Therefore, this study investigates the feasibility of applying sensors and advanced materials to safety vests, with the aim of improving the safety of jockeys and the user experience.

d) No previous study has gathered qualitative data about jockeys' post-fall experiences or those of ambulance staff in treating injuries on race day. This research includes such information in order to propose ways to enhance vest design. Of particular note, previous investigations developed statistics data on jockeys' injuries and fatalities, excluding any intimate insights about safety equipment, offered only by the users' involvement. This is the first study to draw jockeys and medical professionals into the research, since they have much insight to contribute as users in a study that takes a user-centred approach.

2.5 Contributions to existing knowledge

In responding to the research questions, this thesis provides a novel empirical study on the design and needs of jockeys' safety vests. This study then proposed a set of conceptual solutions that could be used to support product enhancement. A contribution to the existing knowledge is made by applying a pragmatic, real-life and user-centred approach with jockeys and related medical professionals to consideration of the safety vest's use and its application for injury prevention. Specifically, this study examines how products intended for one group of users can in some situations be required to meet the needs of a group of co-dependent users, whose contribution to the performance and success of the product's design is essential and not merely desirable.

A further contribution of the study is to build a powerful method for jockeys and medical staff to explore design ideas to reduce fall injuries. This study aims to extend traditional and innovative design methods linked to injury prevention to create an empowering design product (safety vest) possibly supported by technologies.

Finally, the study proposes design suggestions to develop a new vest prototype that uses advanced materials to provide greater freedom of movement to jockeys while maintaining superior energy absorption. This may also clarify the definition of what safety vests for jockeys should be and how evolution of the product can be continued, based on users' needs.

Significantly, this study provides the first detailed, contextually-specific and, primary and secondary-dependent users oriented study on the evolution of vest design in the Australian thoroughbred horse-racing industry. The strong practical orientation of this case study will have direct implications for both industry and academia, with this thesis contributing to the problem researched through such a unique framework and thus, ensuring that important parts such as a more holistic approach and users' involvement factors are not overlooked.

2.6 Literature review outcomes

The medical and sports literature provides the following findings:

- Any activities that involve horses expose the riders to risks, which include falling from horses, being kicked, being bitten and being thrown from the animal. Horses' unpredictable behaviour should not be underestimated.
- Horse riders' heads, necks and torsos are the most common areas affected by injuries.
- No study has investigated the injuries experienced by jockeys wearing different safety vests.
- No study has highlighted the needs of female jockeys and the views of health professionals about safety vests.
- Jockeys' riding positions affect the likelihood and severity of injury. The crouched riding style has possibly influenced the design evolution of the safety vests, yet they continue not to satisfy users' needs. The author discusses this issue in detail in Chapter Six, despite a paucity of knowledge regarding this issue in the literature.
- The solid design of current safety vests hinders jockeys' ability to roll away from horses' hooves after a fall.
- The European Standard EN 13158 (British Standards, 2009) covers the whole range of protective equipment dedicated to the body and shoulders that must be worn for equestrian use. This group includes horse riders, those working with horses, horse drivers and jockeys (p.33). However, this broad range of users differs in needs. Instead, each group should have dedicated equestrian gear and standards.
- The literature dedicated to horse riders often reports injuries such as fractures, dislocations, and head and neck injuries while less serious injuries like soft tissues may be underreported. Instead, fractures, dislocation, and spine injuries are easily diagnosed and reported (Young, Gelbs, Zhu, Gallacher, Sutton & Blaine, 2015). In regards to jockeys, spine injuries indicate that current vests are not providing enough protection and thus, this reinforces the need for future research as requested by this study.
- Current vests are described as offering inadequate protection for

jockeys' necks and barely any to the spine (Young, 2005; Horse Talk, 2014).

- Wearing protective equipment is considered the most important safety measure for horse riders (Watt & Finch, 1996; Thompson, McGreevy & McManus, 2015; Ikinger, Baldamus & Spiller, 2016).
- The scope for innovation in design has not been explored beyond the call for manufacturers to provide improved options.
- The standards EN 13158:2009 and BETA 2009 for safety vests, which apply in Australia, have been in use for a long time and have scarcely been revised, despite the potential to include advanced materials and technologies.
- No study has investigated how to provide a quick response to jockeys' injuries utilising the collaboration of related medical staff.

The literature contains medical data and injury statistics, but relatively little on injury prevention (Bixby-Hammett & Brooks, 1990; Finch & Watt, 1996; Whitlock, 1999; Cuenca et al., 2009; Foote et al., 2011) and almost nothing on safety vests, which where firstly introduced as padded jackets with the aim to provide protection to the trunk, but have yet to be evaluated (Firth, 1985). It has also emerged that safety vests can't protect against spinal or chest injuries (Bixby-Hammett & Brooks, 1990; Young et al., 2015). However, these products are useful in reducing the severity of soft tissue injuries and rib fractures, and for safeguarding "the acromioclavicular joint of the shoulder" (Nelson et al., 1994). However, a common denominator among the literature was that safety vests are still perceived by jockeys as uncomfortable to wear because these products are still bulky with the aim to absorb the force of falling from a horse.

Besides, publications about the epidemiology of injury relate to equestrian sports in general, with many of these on the prevention of injuries and few dedicated to jockeys. A good body of literature relates to helmets as a means of preventing injury in equestrian sports, with some studies offering similarities and comparisons with other sports because of similar injuries sustained by these athletes. Due to the unpredictable nature of falls and the associated injury guaranteeing injury prevention would be impossible. The purpose of protective equipment such as helmets and safety vests should be to seriously minimise injury risk. It is also important to abolishing the common dislike of wearing helmets and safety vests because of perceived poor design (Mills & Whitlock, 1989; Foote et al., 2011; Forero Rueda, Cui & Gilchrist, 2011; McIntosh et al., 2012; Timms, 2015). According to Chapman & Thorton (2016) it is relevant to "discuss the different dimensions of risk during human–horse interaction: the risk itself, animal, human and environmental factors and their combinations thereof….the Workplace Health and Safe (WHS) framework as a tool for reducing (a) situation-specific hazards, and (b) the risks inherent in and arising from human–horse interactions. Whilst most—if not all—horses are unpredictable, the majority of horse-related injuries should be treated as preventable….A WHS framework has significant potential to reduce the risks inherent in, and arising from horse and human interaction, regardless of whether they occur in work, private, public, amateur or professional contexts". Every aspect of the human-horse interaction should be taken into consideration even when developing a jockeys' safety vest.

Despite the introduction of safety vests in 1998, spine and torso injuries are still commonly sustained by jockeys (Waller et al., 2000; Barss, Addley, Grivna, Stanculescu & Abu-Zidan, 2009; Donohoe, 2015; Nicholson and Manley, 2015; Hitchens et al., 2016; Mackey-Laws, 2016; Aitken, 2017; Johnston, 2017). The consequences of falls incurred by jockeys are usually severe (Manley & Russell, 2015; Pengilly, 2015; Fairfax, 2016; Scadden, 2016a; Sheehan, 2016; Cleary, 2017). However, according to Turner et al. (2012) the common denominator in epidemiological jockey falls and injury studies are usually the race starts. In addition, Australia has different tracks than America and Japan or even Ireland: track conditions data do not represent a common denominator in past studies and this should be considered when data is analysed. Hence, a safety vest should protect jockeys throughout their entire journey: from the starting gates, during the flat race, until they cross the finish line, and until they return to the jockeys' room. Track conditions should be analysed and considered during the safety vests design production.

More recently, the epidemiological study conducted in Ireland by O'Connor et al. (2017) stated that professional horse racing is a popular but risky sports around the world. In Ireland, the rate of injuries in flat racing during the period 2011-2015 was 352.8 per 1000 falls. As consequency of these falls, the most popular injuries reported by jockeys were soft tissue (61.54%), fractures (15.38%), lower limb (32.89%) and concussion. Particularly, O'Connor et al. (2017, p. 1140) conclude requesting "further research to identify risk factors for injury, design and investigate the feasibility of injury-prevention strategies, and document their effects on fall and injury incidence".

The publications considered demonstrate that there is a richness of data related to the variety of injuries that horse riders face during their careers. These data were used to reinforce the background of this study, but the author found an absence of conjunctions between the injuries analysed, the geographical areas where the studies were conducted and their duration. For instance, every country has its own weather conditions, regulations, track conditions and brands of safety vests in use that may affect the findings of a study.

The academic and industry literature generally consisted of quantitative research with very few qualitative studies, but there was also a significant disconnection between medical and design publications, meaning that safety vests were very rarely the main topic of the published knowledge.

The review of the literature also confirmed that there is a good number of the epidemiology of horse-related injury reports, especially in the pony club sports while there is not such a large amount of equestrian sports injury countermeasures studies, particularly about jockeys' safety vests. However, there are investigations to suggests applying countermeasure to the use of protective helmets but only very few of the countermeasures proposed or utilized for the prevention of horse-related injuries have been scientifically assessed by case-control or other investigations. This won't be an issue if epidemiological records will continue to consistently demonstrate a reduction in injury frequency. Besides, the extensive amount of epidemiological studies published offered ample evidence to confirm the severity of equestrian injuries which often are severe, disabling or fatal. More information about safety equipment (e.g. helmets, safety vests, stirrups) must be collected to improve these data to inform the development of new and improved safety standards. Trials and formal evaluations of new safety measures are recommended, even through case-control studies, to prevent such catastrophic injuries experienced by jockeys.

Throughout the literature, education is often referred as a common countermeasure for the prevention of most injuries however, even educational material should be evaluated and users should be involved to determine the strengths and weaknesses of the material used. Focusing on jockeys, the same suggestions should be applied in teaching falling techniques: the correct use of falling techniques can help in mitigating jockeys' injuries after a fall. It was clear the gap in using a user centred approach in investigations about jockeys' safety, particularly regarding how users experience safety vests. Hence, this gap reinforced the significance of this study.

Jockeys' injury rate was considered low in the literature, especially compared to the past: however, the severity of injuries still experienced by jockeys is high. The horses' behaviour still affects the possibility of totally predict a jockey's fall. Besides, scientific studies utilised jockeys to analyse their spinal injuries or head injuries. Of course, there are worldwide publications about jockeys related to the history of horse racing and thus to their lifestyle. Minor attention was paid to the evolution of jockeys' postures and the evolution of horse riders' safety gear, which mainly covered helmets, safety vests and shoulder protection.

The review of the literature states that horse-related injuries provides a major publich health concern. Often, the investigation of horse-related injuries imply young females that experienced falls from horseback. Along with that, older men are also at risk of these injuries, despite the overall numbers is lower than for young females (Meredith, Ekman & Brolin, 2018). Head injuries were considered to be the most common cause of fatality: despite some horses' veterinary and epidemiology studies, yet none of the riders' investigations has examined predictors of fatalities. Head injuries were found to be frequently experienced in non-fatal cases and also occurring in falls from the horses and even when the riders being kicked by them. Helmets' introduction generated a reduction of the incidence of head injury, while in the case of jockeys' safety vests a need for further improvement was confirmed.

The data emerged from the review of the literature were used to highlight the importance of wearing a safety vest and to understand how and why these products still show a basic design. The author dedicated Chapter Three to deeper understand jockeys' life, their riding style, the safety vests and its standards in use to build a stronger basis for this study.

Chapter Three: The Link between the Jockeys and the Safety Vest Standards

The literature review established the rate and nature of injuries to jockeys as a result of race falls, including calls to improve their protection from the effects of falls through better designs for mandatory protective equipment (Waller, 2000; McLean, 2004). To date, studies on existing safety vests for jockeys have focused on jockeys' preferences for one vest over others, their experiences with the vests and their criticisms of the vests' performance (Foote et al., 2014; *Horse Talk,* 2014; Safety Solutions, 2014). Training in how to fall is also recommended. Special programmes such as those provided by Racing Victoria and Racing New South Wales offer education and training to prepare professional jockeys from a young age, or during their apprenticeships (Racing Victoria, 2016b; Racing NSW, 2018).

Despite the potential for design to drive improvements in safety vests for jockeys, this has scarcely been researched in respect of the following terms:

- Macro level: safety vests in current use provide a lack of protection, with jockeys reporting injuries in areas that should be protected by these products, such as the torso, spine, ribs and collarbone (Waller et al., 2000; Barss, Addley, Grivna, Stanculescu & Abu-Zidan, 2009; Mackey-Laws, 2016; Aitken, 2017; Johnston, 2017). The international standards, which are also applied in Australia, have undergone only minor revisions since their creation.
- Meso level: no specific study exists in which jockeys and their safety vests were analysed in terms of User Centred Design (UCD) or radical product innovation. The design of the vests has not been properly investigated.
- Micro level: jockeys and related medical staff have never been involved at the same time in a study to improve jockeys' safety and possibly the design of their vests.

3.1 The thoroughbred horse racing industry in Australia

Horse racing began in 1788 in Australia, and by the 1830s it was a popular sport. Its popularity prompted the formation of the Victorian Jockeys' Association in March 1858 (Chisholm, 1963). A total of 19 jockeys signed up at the first meeting, including Australian-born riders Alice Hawthorn and Stephen Mahon, and the English-born champion Sam Holmes.

Australia has two thoroughbred racing categories: flat racing and jump racing (Shaw, 1984). Flat races are run over distances from 800 metres (m) to 3,375m on mainly turf tracks. Jump races are run over distances from 3,200m up to 7,200m. Australia has 400 racecourses, more than any other country, and 2,634 race meetings were held during the 2016/17 season for a total of AU$603,762,196 in prize money (Racing Australia, 2017). Only the United States and Japan offer more prize money.

The main financial base of horse racing is the betting, which mostly focuses on which horse will win a race. In the 2015/16 season, thoroughbred racing generated AU$15,718.33 million, while the 2016 Melbourne Cup Carnival contributed AU$44.3 million from retail and fashion spending (Racing Australia, 2017; Winter & Frew, 2018). To make race results less predictable and therefore foster betting, some horses carry lead weights of different amounts in their saddlecloth. The weight a horse carries influences how quickly it can gallop, with weight being allocated to give more horses a chance to win, and to take account of each horse's age or ability with the aim of giving every horse an equal chance of winning. In some races, horses are weighted according to their age. In handicap races, horses are penalised for previous success.

As previously stated, the thoroughbred horse-racing industry in Australia is well established and its prominence as confirmed by the fact that there are 364 race clubs, while the total thoroughbred wagering turnover in the country was AU$18.063 billion in the 2016/17 season (Racing Australia, 2017). Horse racing is the second most attended sport in Australia after Australian Rules Football (Top End Sports, 2015).

During the 2016/17 season, 19,235 races were run, involving 842 jockeys and 35,309 horses: overall, the returns were AU$671,161,279 (Racing Australia, 2017). According to the Fact Book 2015/16 (Racing Australia, 2017), 48,680 full-time-equivalent jobs were related to the racing industry, comprising 700 bookmakers, 4,700 TAB staff, 1,280 trainers, 9,900 breeders, the staff employed by each of these groups and more than 1,000 jockeys.

Most jockeys are self-employed, attracting a fee for each race they ride and a percentage of any prize money a horse wins in a race. In 2015, there were 840 licensed jockeys, of whom 27% were women (Norton, 2015). According to Norton (2015), female jockeys were not allowed to compete professionally in Australian horse racing until the 1970s. However, much of public opinion considered women not tough enough to compete against men. At the time of this study, in the state of Victoria, one in five jockeys was a woman (Burgess, 2015; Norton, 2015). This is significant because original safety-vest designs did not account for the possibility of female jockeys, yet the same vests are worn by male and female jockeys.

The ARB stresses that jockeys' safety is of paramount importance, and the rules of racing in all states and territories incorporate a set of common practices, conditions and principles to ensure jockey safety (ARB, 2015; Racing Australia, 2017, 2019). Protective measures include the application of random drug and alcohol testing programmes during race day, trials and track work, and a limit of ten rides per race meeting (Steward, 2015; Scadden, 2016a). However, protective measures are not consistent between jurisdictions.

Modern tracks, compulsory safety equipment and minor policy improvements have made race riding and track work safer for jockeys, but major injuries and deaths continue to occur (Berry, 2003; Australian Associated Press, 2014b & 2017b; Rule, 2015; Wakatama, 2016; Calver, 2017; Eddy, 2017; Racing, 2017a; Racing, 2017b). These events have been described poignantly through a jockey's eyes as: "There were always jockeys on the sideline nursing serious injuries, waiting to come back, forced to retire through injury, and worse. Some sad, some disappointed, some shattered. Some no longer with us." (Payne & Harms, 2016, p.86).

The jockey is part of a special duo in their profession, the rider and the horse. There is respect between the jockey and the horse, during the training and even in the races. For instance, jockeys barely move in relation to the horses in order to support the horse to beat “adversities” such as the wind, that can be an obstacle in speeding especially during a race. When jockeys ride, their surroundings are composed only of the sound of wind and hooves. However, jockeys live under constant pressure to be successful and therefore to earn enough prize money to sustain them once their comparatively short careers are over and to enrich the horse owners who engage them.

Jockeys train each day like other athletes, but they work hard to keep their body mass as light as possible. Australian flat racing jockeys need to maintain a body mass between 49kg and 54kg. As stated by Sports Dietician Australia (SDA), the “minimum riding weights in Australia are 53 kg for jockeys riding in the city or provincial areas and 54 kg for country tracks. Riding weight includes the saddle and associated riding equipment excluding the whip and skull cap. Although riding weights range from the minimum up to approximately 61 kg, many jockeys strive to be the minimum weight as this maximises their opportunity of taking any ride at a given race meeting” (SDA, 2018, online). This requirement means that jockeys usually have similarities in their figures, such as being shorter than average and very light in weight. However, everyone is different.

Thoroughbred horse racing has “a long history of gender discrimination” (Von Hippel, Rutherford & Keys, 2017, p.1) but Von Hippel, Rutherford & Keys focus on the fact that women are generally less tall than me thus, women “can more often meet racing’s weight requirements while maintaining a weight that is healthy for their height” (p.3). Hence, despite both men and women has to respect the physical requirement of being low in weight, and despite the fact that women have a different body shape because of their gender, however, they are more flexible to ride horses in a crouched posture than men (Pfau et al., 2009). Besides, female jockeys have higher bone density, but greater metabolic energy, and lower risk of underweight (Von Hippel, Rutherford & Keys, 2017, p. 5). Both genders differ from each other due to characteristics such as age, height, weight, and thus per their body shapes.

Jockeys interact with horses that weigh between 500kg and 600kg, while they spend most of their life striving to reach the lightest weight possible. Weights are set to the kilogram: the top weight assigned for handicap flat races must not be less than 59kg, while it cannot be less than 58kg for Group 1 handicap races (Racing Australia, 2019a). Many women jockeys weigh less than these figures. Jockeys race huge thoroughbreds at speeds approaching 60 km/h, and if they fall at this speed, they can be hurled 15m from their horses in a second.

Nevertheless, Racing Australia, on p.67 of *Rules of Racing* (2019a), considers some special occasions when weight exceptions can be applied to riders:

> AR.103. (1) The top weight allocated for handicap flat races must not be less than 59 kilograms, except for Group 1 handicap races and races in which 2 [year-olds] only can run, for which the allocated top weight must not be less than 58 kilograms. [amended 1.8.08]
>
> (2) Notwithstanding the provisions of subrule (1), if at the declaration of acceptances for a handicap flat race the weight allocated to the highest-weighted acceptor (including any extra weight by way of re-handicap or penalty) is less than 58 kilograms (57 kilograms for Group 1 handicap races), or less than a higher weight determined by a Principal Racing Authority, then allocated weights for the race must be increased until the highest-weighted acceptor is weighted at not less than 58 kilograms (57 kilograms for Group 1 handicap races). Provided further that the Principal Racing Authority concerned may, in its sole and absolute discretion, provide an exemption from this subrule for Group 1 handicap races.
>
> [amended 10.9.09] [amended 1.10.15] [amended 1.3.16] [amended 1.10.17]
>
> (3) The minimum weight allocated for handicap flat races must not be less than –
>
> (a) 50 kilograms for the Melbourne Cup and Caulfield Cup;

> (b) 52 kilograms for Group 1 handicap races other than the Melbourne Cup and Caulfield Cup;
>
> (c) 53 kilograms for Group 2 handicap flat races;
>
> (d) 54 kilograms for all other handicap flat races (provided that a Principal Racing Authority may in its discretion approve a minimum of 53 kilograms for the purposes of this subrule). [amended 1.10.16]
>
> Provided further that the Principal Racing Authority concerned may approve applications made by racing clubs for a minimum weight of 50 kilograms for Group 1 handicap races other than the Melbourne Cup and Caulfield Cup (paragraph (b) of this subrule) and also for 2-year-old and/or 3-year old horses in open-age handicap races to be allocated lower minimum weights than those prescribed by paragraphs (a), (b), (c) and (d) of this subrule. [amended 1.10.16] [rule deleted and replaced 1.1.07] [rule deleted and replaced 1.1.12] [amended 1.10.15].

Riding weights include the saddle, the girth, the stirrups, the safety vest, the breastplate, a lead bag required to hold any additional weight a horse may be allocated to carry, as well as the jockey. Hence, the weight of the safety vests influences jockeys' choices, and they can compromise safety to be lighter in weight. Occasionally, they can adopt extreme measures to preserve their light body weight: top jockey Zac Purton (Stensholt, 2015) confessed that he hardly ate before big races such as the Melbourne Cup, while biographies of former jockeys, such as Roy Higgins (Bartley, 2014) and Rod Griffiths (Wilmoth, 2007), describe the methods they employed to fight their bodies to maintain the lightest riding weight. There is also an abundance of scientific publications (Dolan, Cullen, McGoldrick, Warrington, 2013; Moore, Timperio, Crawford, Burns, Cameron-Smith, 2002; Wilson, Chester, Eubank, Crighton, Drust, Morton & Close, 2012; Wilson, Hawken, Poole, Sparks, Bennett, Drust, Morton & Close, 2014; Wilson, Drust, Morton et al., 2014) about how jockeys reduce their weight and the related implications that might affect their riding style and wellbeing.

Reduce jockeys' body mass may become an obsession for these professionals. Jockeys must weigh 'out' prior to each race and this weight includes their equipment riding gear, race saddle, and a lead bag required to hold any additional weight a horse may be allocated to carry. After each race, jockeys are weighed 'in' with the same equipment to ensure that their horse carried the weight advertised.

Thus, jockeys are often required to reduce their body mass to meet the stipulated racing weight of the horse they are riding. This contributes to health-related risks (Cullen et al., 2015). Trainers and owners are influenced to use young jockeys for their smaller stature and extremely light weight. Jockeys may follow regimens of rapid weight loss for race days (Wilson, Drust, Morton & Close, 2014). They often ride in a dehydrated and energy-deficient state with adverse implications for their immediate performance and safety, and their long-term health and psychological status (Warrington et al., 2009; Dolan et al., 2011; Dolan et al., 2012; Wilson et al., 2013; Cullen et al., 2015). Their stressful lives sometimes end in alcohol and drug abuse (Carlyon, 1999; Wilmoth, 2007; Bartley, 2014).

The pressure to maintain a light weight is recognised as exposing jockeys to higher risks of injury and also to eating disorders (Fordyce, 2015). The extreme regimen can cause other dramatic consequences: jockeys are often focused on how to fix a problem to get back on the saddle as soon as possible, engaging in self-sacrifice and exposing themselves to different risks (e.g. poor bone health, abnormal mood profiles, mentally unfit for safely ride) that influence their wellbeing (Hanson, 2004; Racing and Sports, 2007; Wilmoth, 2007; Bartley, 2014; Rule, 2015). Some jockeys suffer fragile self-esteem and fear of failure, so they are not favourable towards, nor prepared for, nor open to criticism, even if constructive criticism is the most esteemed form of communication (Ferroni, 1990).

Hence, to motivate themselves to pursue their goals and to build confidence, some jockeys cover their bodies with tattoos. This trend helps those jockeys to show off their bodies covered by ink, fixing memories of an injury successfully overcome or childhood remembrances (Kelly, 2016d). The career of a jockey is mostly full time. It requires sacrifice and keeps the jockeys away from the ‘normal’ world, ending with most of them only knowing the trackside fraternity (Wilmoth, 2007).

To be successful early in their lives, jockeys start their careers in their early teens, with 82% of Australian jockeys in 1995 having left school before the age of 15 (Wilmoth, 2007). This happens because, prior to obtaining a full licence, all jockeys in Australia must complete a four-year apprenticeship indentured to a trainer. During this time, apprentice jockeys are employed full-time and receive a fortnightly wage in addition to income from riding in races. The most renowned apprentice plans are the Racing Victoria and the NSW Apprentice Jockey Training Programmes (Australian Jockeys' Association, 2016; Racing, 2016; Racing Victoria, 2016a, Racing Victoria 2016b; Racing NSW, 2018).

These schools for apprentices offer a variety of courses that include introductions to racing, riding technique, exercise and diet, protocols for interference and stewards’ enquiries (Payne & Harms, 2016). The apprentices’ day starts around 4am, riding about ten horses during track work before riding in jump-outs. They try to lose weight before attending country meetings. They aim to be at home by about 8pm. Apprentice jockeys’ workloads and young ages have become controversial in the industry. The experienced jockey Stephen Baster comments:

> “These kids are just doing too much. It’s a wonder they aren’t causing accidents; they need to be better looked after. They are an accident waiting to happen. They’re on the go 16 hours a day and then we’re expecting them to be at their best when they’re riding. It is just too much. Every other sports person turns up fresh for their game day, but look at what we’re asking apprentices to do. They can’t be fresh with that workload” (Dunn, 2016b, online)

In Australia there are four licence categories for jockeys: full licence (professional), apprentice, amateur and cross-country (jumps). In this study, only professional, apprentice and former jockeys were considered in relation to safety vests.

Those who hold a full licence are professional jockeys, and do not have any restrictions on their riding, although they are generally required to obtain a permit to ride at race meetings in states or territories other than that which issued the licence (Racing Australia, 2019a). Once training is completed and a jockey licence is issued, they can travel all over Australia and to many parts of the world to compete in races: hence, they may wear different safety vests that adhere to different safety standards.

Authorities such as Racing Victoria and Racing New South Wales support the jockeys through a team that helps them with exercise, weight management, psychological health and rehabilitation (Racing Victoria, 2014/15; Racing NSW, 2016). However, after the American Hall of Fame jockey Randy Romero needed a kidney and liver transplant due to years of dieting (Hanson, 2004), he called for racing industries internationally to increase the weights carried by horses, which had not changed in 100 years (Hanson, 2004). Only at the end of 2018, Horse Racing Ireland (HRI) has modified the weights, particularly weights for flat races have to respect that “a) no horse shall carry less than 8st 4lb in a Flat race, except when a rider's allowance is claimed. b) No horse shall carry less than 8st 7lb in a Weight For Age flat race, handicaps excluded, except when a rider's allowance is claimed” (HRI, 2018, online).

3.2 The jockeys’ role and injury risks

> “These jockeys often clock thousands of kilometres a week to ride at several meetings and might only take home meagre money in the process. It’s the toughest of tough gigs. Before we start questioning why these incidents have happened, let me say there has been an enormous amount of progress made in the area of jockey safety in the past 10 years. The two main jurisdictions I ride in, Racing NSW and Racing Victoria, have been on the front foot in regards to this area alongside Racing Australia. There is no doubt we have come a long way, but there is always room for improvement. And we must keep exploring every avenue we can to improve the safety of all jockeys and track riders. Horse racing is a speed sport, and unfortunately in speed sports accidents

occasionally happen". (Bowman, 2017, online)

Jockeys are exposed to significant risk in their work. It is estimated that 40% of registered Australian jockeys will face a fall that will prevent them from riding for an average of five weeks (Eddy, 2016b; National Jockeys' Trust, 2017b). The average time lost due to injuries as a consequence of falls is more than 500 hours per incident, with a total annual claim cost of all injuries due to a fall from a horse amounting to approximately AU$3 million (Foote et al., 2014).

In Australia, being a jockey is the second-deadliest job after offshore fishing (Hitchens, Blizzard, Jones, Day & Fell, 2009; Schell, 2009). As a result of these dangers, Australia-made safety vests became compulsory in 1998, and several jockeys credited that ruling for saving them from serious injury after a fall (Australian Broadcasting Corporation, 2013).

Overall, 889 Australian jockeys have been killed in race falls since 1847 (Kijak, 2015; Taggart & Ractliffe, 2016; National Jockeys' Trust, 2017a). A fall occurs once in every 240 race rides, at a rate of 0.42 per 100 rides in flat racing and 5.26 per 100 rides in jumps racing (Hitchens, 2014). Due to the frequency and severity of injuries to licensed jockeys, track riders and stable hands in Australian thoroughbred racing, the premiums and claims costs for these workers is the highest of those in all professional sports (Cowley et al., 2007). For instance, New South Wales registered almost 2,000 claims related to horse racing between 2011 and 2016, generating a cost of more than AU$14 million (Australian Broadcasting Corporation, 2016).

According to Taggart and Ractliffe (2016), jockeys earn less than AU$60,000 per year before expenses, excluding an elite few. To make a living, jockeys race horses every week of the year and travel throughout the nation (Sharkie, 2016).

Injuries can have both a physical and mental impact on jockeys' lives (Coletta, 2016; Byrne, 2017). When a fall happens, the jockey is exposed to the risk of head impact with the track and associated neck injuries, with the greatest number of injuries being concussion (Clark, 2017). Other horses can hit or trample a prone jockey on the ground, causing serious injuries to any part of the body: bone fractures, injuries to internal organs and paralysis are common results of race falls (Parry, 1993; Turner et al., 2002; McCrory et al., 2006). In flat racing, the more severe injuries occur during races, but most falls occur pre- or post-race. In jumps racing, most falls occur at a jump, with 9.7% of falls resulting in a significant injury (Hitchens, 2014).

The track itself can contribute to a fall, influencing the performance of horses on race days (McCrory et al., 2006). Official stewards rate the firmness or softness of the track surface prior to a race on a 10-point system where firm is one and heavy is ten (Australian Racing Board, 2014; Racing, 2014; Racing Australia, 2016f, 2019). Hard tracks can cause horses' legs to fail so that they fall. Horses have delicate and skinny legs (Payne & Harms, 2016).

As with the jockeys, the horses are exposed to pressure and fatigue: hence, the health of horses needs to be preserved to improve the safety of jockeys. These animals easily injure themselves and their most frequent health concern is soft-tissue injuries (Larson, 2017).

The hooves of a horse weighing almost 500kg experience around 5.4kg/m2 force when it stands still (Hiraga & Sugano, 2017; Faramarzi, Nguyen, Dong, 2018). Horses experience force from the hooves' impact with the different kinds of ground. When the impact occurs, it is possible to observe an opposite reaction force returning up the horses' pastern because of this impact. Through a zoom of the video makes it possible to see these opposite force (waves) move upward (Sky Sports UK, 2010). These data must be taken into consideration when designing a safety vest: jockeys should be protected from the impact with horses' hooves and with the track if a fall occurs.

Along with that, heavy tracks can be slippery and cause horses to become more quickly fatigued, also creating the potential for falls. On a decline, horses go slower and the anatomical shape of their front legs, which are a limit to weight support and stability, may cause a fall (Self, Spence & Wilson, 2012). When horses increase their speed, the time of overlap between their legs is reduced, producing a sequential limb function (Witte, Hirst & Wilson, 2006). This increases speed and saves energy due to the aerial phase duration which is not increased, but speed can cause horses to clip their own heels, creating potential for a fall. At speed, horses are also less controllable and can buffet each other in a race. Apart from falls and impacts with the turf, jockeys can be hit by hooves and become helplessly trapped in the legs of the horses coming from behind.

Jockeys perform many races at each meeting but each race lasts for only a short period in which they must ride at their best, but especially manage their horses. Jockeys adopt the ‘Martini glass’ riding style because they can speed up their horses, while managing their animals to the finish line (Pfau et al., 2009). The jockeys communicate with each other during races, and this represents a form of safety and esteem. Communication during a race helps jockeys to understand and maintain their position, while helping them to avoid involuntary contact with each other. This supports their safety because jockeys often fall off their horses because of contact or of heel interference. According to Hitchens et al. (2013) in 2009 an Australian study stated that only 4.9% of jockeys experienced falls during the race due to horse catastrophic injury while 2.2% were caused by being hindered by a previously fallen horse or rider. However, the study (Hitchens et al., 2013, p.4) attributed most of the pre-race jockeys' falls to the “fractious behaviour of the horse”. Even Wylie, McManus, McDonald, Jorgensen & McGreevy (2017) associated the horses’ injuries to jockeys’ falls, particularly the risks of racehorse fatality, fatal musculoskeletal injury and spontaneous death because “most racehorse fatality associated jockey injuries occurred to the limbs (17/32, 53.1%), particularly the upper limb” (p.1).

When an incident occurs, multiple horses can collapse on the track and this exposes several jockeys to risks, such as being crushed or trampled by their own mount or those following (Navarra, 2015). Hence, doctors and paramedics attend all race meetings to monitor the wellbeing of riders, including looking for signs of fatigue. The ambulances that follow jockeys during races are each staffed by a doctor, two ambulance officers and a registered critical care nurse (Racing, 2008; Australian Harness Racing, 2015;Wilson Medic one, 2015).

3.3 Jockeys’ attire and equipment

Horses are identified as they race by the colourful, traditional silk shirts and helmets their jockeys wear, these representing the horses’ owners. The colours need to be significantly different to serve this purpose and are registered by each Australian state's Principal Racing Authority (PRA) (Racing Australia, 2019a). Many of the silks bear chequered patterns, polka dots, stripes or icons such as quatrefoils (LUCRFSuper, 2016a). The wearing of silks originated in the United Kingdom. They were first mentioned in 1515, and the current system was formally established in the 1700s.

The silks of famous jockeys, horses and owners can fetch high prices at auction, suggesting the esteem in which history and tradition are held in horse racing. Although Racing Australia requires that all jockeys wear approved helmets and safety vests, race goers are unaware of this latter safety equipment as it is worn beneath the silks. Jockeys also wear a 'skivvy' under the silks. On race days the skivvy chosen is a lightweight mesh or microfibre bodysuit, sleeved or sleeveless, whereas for track work, a more heavy-duty version may be worn. Figure 11 shows more details of jockeys' clothing during races.

Figure 11. The jockey's attire

(LUCRFSuper, 2016a)

Racing Australia approves the following safety-vest brands: Hows Racesafe, Ozvest, Racelite, Vipa, USG Flexirace and Airowear Swift (Racing Australia, 2019a). These vests employ a very lumpish design, mainly along the spine area, ending in a sort of tortoise-shell shape. The materials used are mainly perforated foams to provide a thick layer of protection. The choice of material rather than the thickness can increase the safety level.

3.4 The risks in jockeys' riding position

Jockeys ride in a crouched style that was introduced by the American jockey Tod Sloan in 1897. This contributed to the evolution of jockeys' postures to reach what is nowadays known as the 'Martini glass' (see Figure 12). Analysis of this posture is considered relevant to this research because it is adopted by most jockeys, especially when they ride the last 400m in a race to allow the horse to stride freely with a minimum of weight on its back.

Jockeys can adopt the 'toe-in' riding style after at least 500 to 1,000 rides and constant training, according to Frank Muratore, a former jockey and director of apprentice training, (Bourke, 2003). There are many risks associated with this style. Jockeys can fall, be rolled on by their own horse or trampled by those behind them, as stated before, and the speed at which they hit the turf places them at their most vulnerable. The forces at work during a fall require consideration in order to offer the jockey greater support from a radically innovated design of safety vest.

Injuries can also result from falling backward and hitting a jump rail, falling forward and hitting the shoulder or an outstretched hand or arm, landing flat or landing with a twisted body (Equestrian Medical Safety Association, 2015). Therefore, jockeys need to wear safety vests that offer the required freedom to ride perfectly in a Martini-glass posture, while being capable of absorbing the blows from pounding hooves or the weight of a horse's body. However, current vests do not cover the jockeys' core muscles, which support their bodies in this riding style: a jockey needs flexibility in the lumbar and core areas, but safety needs to be guaranteed. In this position, a jockey uses very short stirrups to perch in a balanced position above the horse's back, with their centre of gravity moved forward, over the horse's shoulders (Yong, 2009).

Foote et al. (2014) believe that the Martini-glass riding style may advantage the horses, as the jockeys intend, but because jockeys are perched almost horizontally over the horses' heads, their likelihood of falls is far greater. Cleary (2017) states that a fall from the jockeys' positions two metres above the ground without an appropriate landing can cause severe injuries.

This position increases the speed of the horses by five% to seven%. Motion tracking technology shows that this is a result of the jockey moving less than the horse (Pfau, Witte, & Wilson, 2006; Ferrari, Pfau, Spence, Starke & Wilson, 2009). Hence, a skilled jockey can lessen the work the horse has to do, resulting in an increase in speed (Ferrari et al., 2009). Experienced and trained jockeys have a stronger technique which should reduce the risk of falling and, with the Martini-glass posture, the jockey is balanced, so the horse is more balanced too because it is not dealing with a wobbly jockey (Stock, 2015).

To reach and maintain the Martini-glass posture during races, jockeys target their training on the core, lower body and legs. To control the horse, upper body training and extremely strong balancing skills are needed. Jockeys train on a simulator to sense the movements of a race. The Martini-glass style has become an international success and the normal posture, as shown in Figure 12.

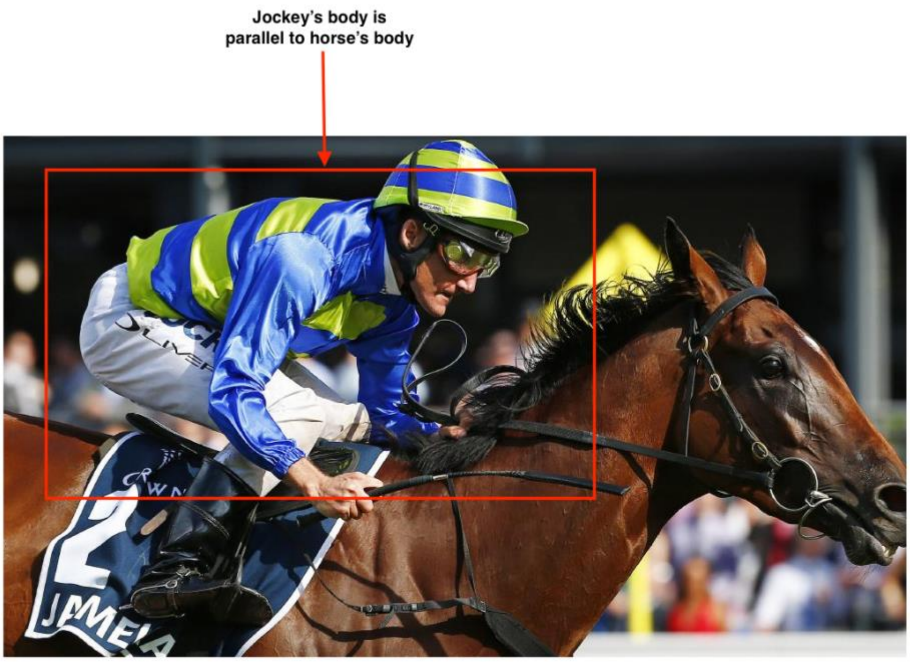

Figure 12. "Martini glass" riding style at Caulfield Cup

(Stewart, 2016)

Pfau et al. (2009) measured the acceleration and calculated the displacement of horse and jockey during a race that employed this riding style. A jockey represents about 13% of a horse's body mass, so a reduction in movement of the jockeys compared with the horses reduces the weight felt by the horse and explains the success of the crouched posture.

The mean of the jockeys' up-and-down movement is 6cm, compared with 15cm in the horse. For forward and backward movements, jockeys move about 2cm and the horses 10cm (Pfau et al., 2009). Hence, through the current riding style, the horses use less than two% of their muscles to overcome the extra drag represented by the jockey. They have to support the weight of the jockeys, but they do not have to accelerate or decelerate the jockeys through each stride cycle, so the horses save a considerable amount of energy (Kluger, 2009).

This evolution of the jockeys' riding style is important because it also influences the design of their safety vests, which should protect the jockeys while they ride in the crouched style, but leave their hips and core muscles free to move as the jockeys wish. This balance between safety and comfort seems to be missing in the design of current vests. Jockeys need to consider the horses' behaviours and for that, they rely on spurs to keep control or to persuade the horses to move forwards or even to receive support while loading the horses into the barriers or coming out of them (Russell, 2016).

Jockeys do a substantial mechanical job to overcompensate for the motions of their horses. Figure 13 shows the way in which horses support the jockeys' weights without accelerating and decelerating them through each stride cycle. Hence, the jockeys' kinetic energy and the horses' system might be a little smaller than that of the horse alone.

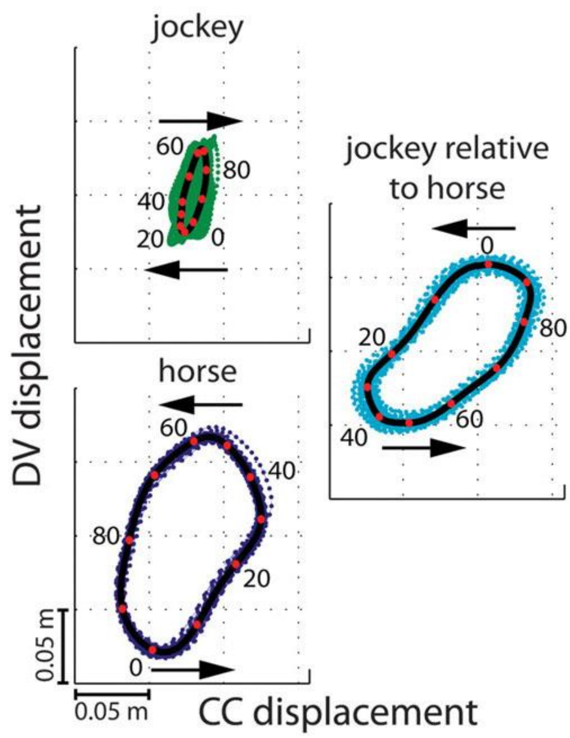

Figure 13. Movements of jockey and horse

(Pfau et al., 2009)

Figure 13 epitomises the movements of both jockey and horse, and the movements of the jockey relative to the horse. The black lines indicate the mean stride, and the arrows indicate direction of movement. The dots indicate the phase in relation to contact of the non-lead front leg (0%). As demonstrated by Pfau et al. (2009), the race time is decreased, the jockeys are well trained and able to achieve high speeds, while the horses are doing less work than in the past.

High-definition race videos allow jockeys to review their technique constantly. Jockeys use their legs and arms as pistons to drive the horses forward throughout a race while using their legs to grip for more stability. For this reason, jockeys are subject to dynamic and static joint loading, impact loading and injuries associated with acceleration and deceleration from racing. The force needed to maintain the forward-leaning position can lead to the jockey being propelled over the head of the horse in the event of a sudden stop or stumble, slamming or spearing the jockey into the ground (Centers for Disease Control and Prevention, 2006).

The present riding style is often used during gallops but also practices during trotting (De Cocq, Muller, Clayton & VanLeeuwen, 2013). Increased training means that jockeys are able to hold their posture longer than in the past even if they are now wearing the safety vests (Hamilton, 2009).

3.5 Safety vest standards

Jockeys’ safety vests cover the ribcage and part of the abdomen. Initially, vests and their standards were developed in the United Kingdom where, since 2001, all jockeys have been required to wear safety vests of the European Standard EN 13158 (Balendra, Turner, McCrory & Halley, 2007). Jockeys in the United Kingdom have been required to wear safety vests since 1986 but the construction showed wide variation before the adoption of the EN standard.

The British Equestrian Trade Association (BETA) and Shoe and Allied Trades Research Association (SATRA) standards represent the United Kingdom’s history in racing safety. The author will briefly introduce them to explain the Australian standards, which originated from those used in the United Kingdom. The BETA standard was issued in 1991 and was created by a consortium of equestrian groups but assisted by a medical consultant. The standard has been revised, with a more elaborate impact test method being added and an extra area being required at the back of the vests to cover the bottom vertebra of the cervical spine, the C7 (McLean, 2004; BETA, 2013).

BETA meets all the requirements of the European standard (currently EN 13158:2009) and it requires annual re-testing of the garments by an approved laboratory such as those run by SATRA to guarantee the quality of the materials. Specifically, it includes “revised specifications for dimensions and for test procedures, but does not alter the impact performance requirements” (BETA, 2013, p.2). These changes affect the manufacturing of safety vests because great attention needs to be paid to the zip to pass the tests, while the centre-back panels need to be in one piece from top to bottom and at least four inches wide. Particularly, this influenced a change in design towards garments that featured smaller blocks of material. This is the design followed by most current brands on the market.

The BETA standard has three classes for different conditions of use:

- Level 1, Black 2009 is designed to meet the weight restrictions applicable to licensed jockeys while racing, offering a lower level of protection.
- Level 2, Brown 2009 is designated as suitable to be used only in low-risk situations and jumping, when riding on the roads, riding young or excitable horses or by inexperienced riders.
- Level 3, Purple 2009 is designated as suitable to be used by normal horse riders and by those working with horses.

Figure 14 shows the vest labels used to indicate that garments meet BETA 2009. Their shape distinguishes between vests for riders and for carriage drivers.

Figure 14. BETA 2009: colours of the labels and swing tickets

The BETA standards encompass the criteria for shock absorption in the body areas that need to be protected by the vests, guaranteeing only the gaps necessary between the protective foam panels. In addition, the BETA Body Protector General Committee and the BETA Standard Committee have riders’ representatives with the right to vote for or against changes that may affect the safety vests, which is not the case in Australia.

Around the world, there are many standards used for the design and testing of equestrian safety vests, but BETA remains a United Kingdom certification based on the EN 13158 standard.

The difference between the two standards is the annual re-test requirement that can be performed through BETA-approved laboratories such as SATRA, which is an independent research and testing organisation that tests a range of protective goods, such as clothing, leather goods, home ware, materials, furniture and toys. SATRA was established in the United Kingdom in 1919. The SATRA standard to check that padded vests were appropriate for jockeys to be used in both flat racing and jumping was introduced in 1996, having been developed by the organisation's Safety Product Centre in conjunction with the United Kingdom Jockey Club. The standard was revised in 1999 to add minor changes to vests' coverage.

In 1996, Racing Australia developed specific standards for safety vests to be used in Australia with the assistance of the company Human Impact Engineering, and mainly based on the SATRA standard (McLean, 2004). The main motivation to develop the Australian standard ARB 1.1998 was the perceived significance of climatic differences between Australia and the United Kingdom. Most of the original wording of SATRA was kept (McLean, 2004). According to McLean (2004, p.7), the changes made were:

> "to the impact attenuation requirements to allow a more flexible vest, to ensure adequate performance in wet and hot conditions and to ensure a minimum of water retention in wet conditions."

Subsequently, the Australian standard was changed to require testing of vests for hot weather performance at 40°C instead of 50°C, as Gibson's suggestion (McLean, 2004). In addition, Gibson recommended that the top back area of the vests be reduced in height by 2.5cm to 3cm to facilitate the clearance of the vest from the jockey's helmet, especially considering jockeys' crouched position during races (Gibson, 1998; McLean, 2004).

ARB 1.1998 was certified by Standards Australia in 1998: it sets out criteria for minimum performance of jockeys' safety vests, coverage and manufacture.

The *Australian Rules of Racing* drawn up by Racing Australia state that:

> every rider shall when mounted on a horse wear a properly fastened approved or permitted safety vest, the standard of which has been prescribed by Order of the Board. Provided that every such Approved or permitted safety vest shall be in satisfactory condition and shall have attached to it a manufacturer's label that states that it complies with the relevant standards prescribed by the Board. *[amended 14.6.07 & 1.8.07]* (Racing Australia, 2019a, p. 62).

The rules have several subsections dedicated to the standards for safety vests, which shed light on the lack of innovation in vest design and which may represent an obstacle in the way of future revisions to their design.

According to Foote et al. (2014), the standard EN 13158:2000 Level 1 is dedicated to jockeys and is the lowest level of protection offered by the standard. Therefore, its testing for impact performance is judged as the most complete. Hence, the author decided to consider only tests performed to meet the criteria applicable to jockeys' safety vests. An excursus to consider the ways in which safety vests are tested adds value to the aims of this study in terms of understanding the best materials in case of a prototype or the revision of vests' dimensions.

The EN13158 standard requires impact performance tests in two impact test configurations. Both need to be met to satisfy Level 1. Test 1uses a flat circular impactor of 80mm diameter on the vest and through an anvil with a dome of 150mm radius with a surrounding guard ring level with the top surface. The test is executed at a drop energy of 25 Joules (J). The second test creates the impact through a narrow bar of 80mm x 20mm. In this case, the anvil has a 150mm radius dome but it is surrounded by a guard ring raised to 10mm above the top surface and it is performed at a lower drop energy of 20J.

The SATRA standard has different impact performance requirements. The first test is the same as that applied to meet the EN 13158:2000 (Level 1) standard, while the second test is similar but uses an anvil with a domed top of 100mm radius, the guard ring is 10mm above the anvil and the test is performed at a drop energy of 30J. The third test required by SATRA is the same as the second test performed under the standard EN (Level 1) but the drop energy is 15J. In contrast, the ARB Standard (Issue I) requires that vests meet only one of SATRA tests 1 or 2. All tests are summarised in Table 3.

Table 3. Testing for impact performances

(Foote et al., 2014)

STANDARD	TESTING	DESCRIPTION	TOOLS USED	DROP ENERGY
EN 13158 Level 1	Test 1	A flat circular impactor crashes on to a vest through an anvil with a surrounding guard ring level to the top surface.	The impactor has a diameter of 80mm. The anvil has a radius dome of 150mm.	25J
	Test 2	A narrow bar impactor crashes on to a vest. The anvil is surrounded by a guard ring suspended at 10mm above the top surface.	The narrow bar is 80x20mm. The anvil has a radius dome of 150mm.	20J
SATRA M6 Issue 5	Test 1	A flat circular impactor crashes on to a vest through an anvil with a surrounding guard ring level to the top surface.	The impactor has a diameter of 80mm. The anvil has a radius dome of 150mm.	25J
	Test 2	A flat circular impactor crashes on to a vest. The anvil has a surrounding guard ring level to the top surface.	The impactor has a diameter of 80mm. The anvil has a radius dome of 100mm.	30J
	Test 3	A narrow bar impactor crashes on to a vest. The anvil is surrounded by a guard ring suspended at 10mm above the top surface.	The narrow bar is 80x20mm. The anvil has a radius dome of 150mm.	15J

Racing Australia deleted the SATRA standard from 1 July 2014 and continued with the ARB standard, which was based on the SATRA standard, and EN 13158 standard (Australian Racing Board, 2014). The main difference between the standards in use currently in Australia (ARB 1.1998 and EN 13158) is the

ARB requirement that vests be tested at an elevated temperature to meet the national climate conditions (Foote et al., 2014).

Although the ARB standard originated from the SATRA standard, the narrow bar impactor test required by SATRA and by EN 13158 is not required by the ARB standard. This possibly allows scope to design a better safety vest. In contrast, the EN 13158, which integrates the BETA standards, preserves all its elements. SATRA and ARB standards also require a minimum area of padding coverage that is different from that specified by the EN standards, as per Figure 15.

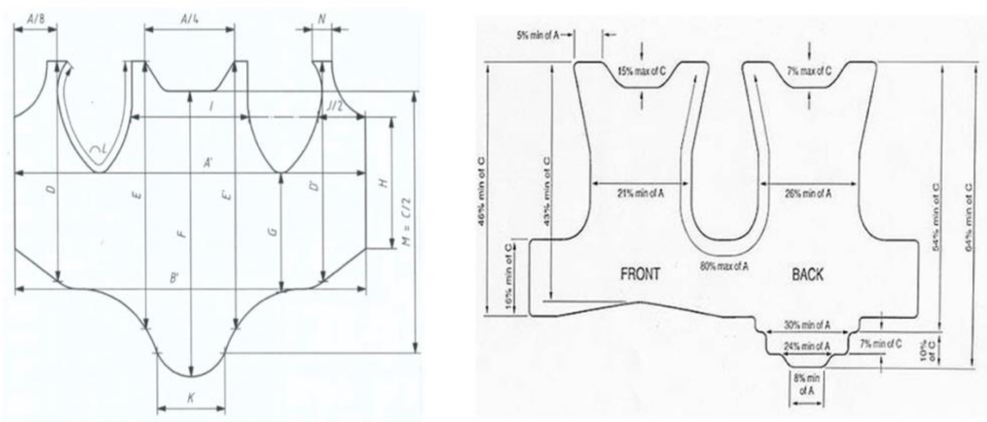

Figure 15. Coverage area templates applied to EN (left) and SATRA/ARB (right) Standards

(Foote et al., 2014)

The SATRA impact test is executed on the whole of the safety vest, but specific tests can be performed on weak points such as the zip areas and hinged points (SATRA, 2016). The thickness and the kind of material used as padding determine its impact performance. For instance, foam can absorb energy if compressed and should be thick enough not to mash under testing. The energy absorption level and the amount of compression are determined by the stiffness of the foam.

The impact test is conducted at ambient temperatures. There is also an option to run an additional test at 30°C. But human body temperature is normally around 37°C and jockeys' bodies reach higher temperatures under race conditions. Gibson (1996) highlights the high daytime temperatures that often reach in excess of 30°C in Australia during the summer. The thickness of the vests and the materials they use affect the heat transfer between the riders' bodies and the environment (Dlugosch, Hu & Chan, 2013).

The latest European Standard EN 13158:2009 requires that the impact performance requirements be applied to the whole safety vest, while the weak areas such as the zip closures need to be tested with two impact tests as set out in Table 4.

Table 4. Impact energy for testing to performance levels 1, 2 and 3

(British Standards, 2009)

	EN 13158:2009			
TEST CONDITIONS	CLAUSE	IMPACT ENERGY FOR THE PERFORMANCE LEVEL J		
		LEVEL 1	LEVEL 2	LEVEL 3
Flat impactor on body protectors and the torso region of protective jackets. Guard ring, 0mm.	5.8.2	25	30	35
Narrow bar impactor on body protectors and the torso region of protective jackets. Guard ring, 10mm.	5.8.3	20	32.5	45
Wide bar impactor on shoulder protectors and the shoulder region of protective jackets. No guard ring.	5.8.4	60	60	60

The main criticism of EN 13158:2009 is that it does not consider the specific proportions and riding postures of jockeys at an ergonomic level, thus compromising comfort in use. Frequently, the standard refers to EN 340, which is a European standard that offers general requirements for:

> "ergonomics, innocuousness, size designation, ageing, compatibility and marking of protective clothing and the information to be supplied by the manufacturer with the protective clothing" (Odin Wear, 2004, online).

This can confuse ergonomics with comfort and does not take into account that one size does not fit all female and male jockeys.

According to Falzon (2005, p.2), the International Ergonomics Association Council states:

> "Ergonomics (or human factors) is the scientific discipline concerned with the understanding of the interactions among humans and other elements of a system, and the profession that applies theoretical principles, data and methods to design in order to optimize human wellbeing and overall system performance. Practitioners of ergonomics, ergonomists, contribute to the planning, design and evaluation of tasks, jobs, products, organizations, environments and systems in order to make them compatible with the needs, abilities and limitations of people".

However, both the ARB 1.1998 and EN 13158:2009 standards take an inappropriate approach to ergonomics of safety vests, and both standards support safety vests that disregard the gender and age of jockeys.

3.6 The Australian standards and testing methods

Revisions to the Australian standards ARB 1.1998 and EN 13158 since they were imposed have introduced only minimal changes to jockeys' safety vests or to adjustments of the impact tests conducted.

Gibson (1996) shows that high temperatures, such as those present in the Australian climate, may affect the materials used in safety vests. Sepe (2011) shows that different plastic materials are sensitive to the environment, becoming soft and showing reduced performance if they become hot. Following the RIRDC's commissioned evaluation of the effectiveness and suitability of safety vests used in Australia, Foote et al.'s (2014) investigation proposed that vests should be conditioned at 40°C prior to conducting any impact performance tests to meet the ARB 1.1998 Standards. This aimed to reproduce the body heat and sun load typical of Australia in order to help to satisfy jockeys' needs. Instead, the EN 13158:2009 standard requires conditioning a vest at 30°C± 2°C to meet the impact performance criteria and 37°C ± 5% relative humidity for at least two days before impact testing (British Standards, 2009). Conditioning a vest for at least four hours in a temperature chamber at 40°C helps to determine its sensitivity to temperature.

This report (Foote et al., 2014) generated still unanswered questions about the racing standards because these require the gaps between padding pieces to be not greater than 15mm, and jockeys seek a less restrictive vest that is easier to put on and take off, allowing easier movements. Tests conducted by Foote et al. (2014) on approved vests found that the panels covering the spinal column needed to be strengthened to protect jockeys from indirect injuries caused by multi-axial loading.

All the standards for safety vests apply similar criteria for testing the energy absorption of their padding materials. The aim of all the tests is to create an impact similar to that which could be experienced by jockeys' torso areas to set some required level of energy absorption for the padding materials. Thus, a mass drops on to a vest to measure the transmitted impact force or acceleration of the impact experienced within the vest. However, the measure of the energy absorbed varies during the different impact tests.

According to EN 13158:2000, the average force transmitted through a jockey's vest during the tests cannot be greater than 4 kiloNewtons (kN). According to Kroell, Schneider & Nahum (1974), the 4kN requirement seemed to have been chosen as it was similar to the compression stiffness of a tensed human cadaver chest when hit by a 150mm diameter, 23kg impactor at a velocity of 6.7m/s. These data were developed from tests that Kroell et al. (1974) performed on a tensed human cadaver, and are still used. Kroell et al. used a rigid and flat impactor with a diameter of 150mm and a mass of 23.4kg to validate the performance of frontal validation tests, with the human cadaver in a sitting position without back support. The subject was placed right in front of the impactor, the centre line of which was aimed at the mid-line of the subject's sternum between the fourth and fifth ribs, with impact speeds of 4.9m/s, 6.7m/s and 9.9m/s (Cihalova, 2009). However, these tests do not replicate the situation of falling jockeys.

Different test methods that could replicate better the jockeys' situation are used by ASTM International, an international standards organisation based in the United States that develops technical standards to improve confidence in products (ASTM, 2016). It is developing standards with similarities to those of SATRA. In 2007, part of the ASTM International Committee F08 on sports equipment and facilities started the development of a proposed new standard named WK 14824 (ASTM, 2007), which specifically took into account the jockeys' position. The proposed WK 14824 new standard was developed with the aim of addressing the unique needs of users in equine competition and racing events. Racing Australia has not yet approved this standard, but it has approved the ASTM F11 63-01 and the ASTM F11 63-04 (2011) standards in regard to jockeys' helmets (Racing Officials Accreditation Program, 2013; Racing Australia, 2019a).

Based on the review of the literature, it is possible to state that the aim of all the standards is similar, and their tests provide a combination of energy absorption and bending strength for the vest materials (Racing Officials Accreditation Program, 2013; Foote et al., 2014; Racing Australia, 2019a). In addition, the ARB standard requires the flat impactor test for the impact performance requirement, but it excludes the narrow bar impactor test, which is responsible for determining bending stiffness. The exclusion of this test may allow production of flexible and comfortable vests for the users. Further investigation of this issue was suggested in 2014 (Foote et al.), but in Australia, to date nothing has been developed.

On 1 July 2014, the ARB ceased use of the SATRA standard due to a review of evidence that it was unreliable and not used in any other major racing authorities (ARB, 2014). The operative standards for safety vests have been EN 13158:2009 or ARB 1.1998 since then (Harness Racing Australia, 2004; Racing Australia, 2019a). Two new vest brands were added to the approved vests list: the USG Flexi Race and the Airowear Swift. The Tipperary vest was dropped from the approved list for no longer meeting the safety standards (Racing Australia, 2015).

The significant omission from the approved list is the Descente safety vest (Descente, 2018), which was developed in conjunction with the Japan Racing Association and featured significant flexibility that allowed it to mould to and move with the jockey's body. Production of the Descente vest offered the first example of a manufacturer applying a user-centred approach to the vest design process, producing significant improvements (Japan Racing Association, 2017). Top jockeys who had the opportunity to race wearing the Descente vest appreciated its comfort, its light weight and the feeling of safety. For this reason, the author has taken its design as a starting point for the next generation of safety vests.

This Japanese vest comprises pieces of material of variable density with a thickness of about 12mm, each made up of two layers, a super foam and a polyester film (Japan Racing Association, 2017). Most of the foam pieces are hexagonal, but those covering the spine are rectangular. The pieces around the neck and armholes are soft compared with those on the chest and back areas, to provide comfort. The vest has a stretchable band around the edges to mould it to the jockey's body. The zip is covered with rubber to absorb shock. The vest has a detachable lower back, or tail, made of shock-absorbing and gripping materials to prevent the riders slipping. Figure 16 shows some details of the Descente vest.

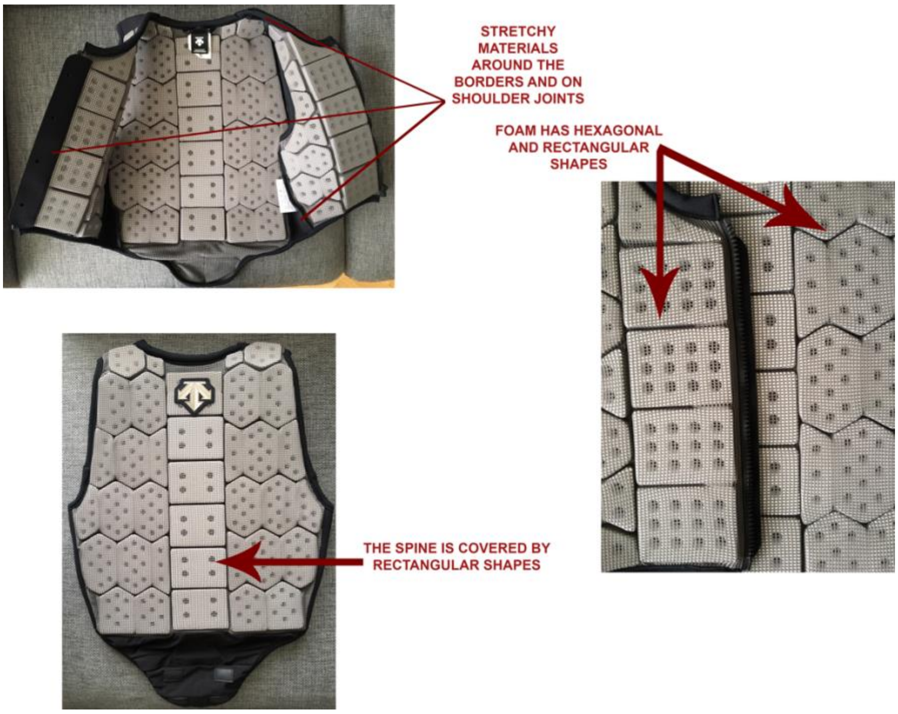

Figure 16. The Descente safety vest

The vest shown in Figure 16 is based on the Japan Racing Association (JRA) standard (ARAI), according to the International Agreement on Breeding, Racing and Wagering (International Federation of Horseracing Authorities, 2016). Foote et al. (2014) tested the Descente vest to gauge its compatibility with the Australian standards after receiving positive feedback on its comfort and light weight from jockeys who had used it overseas. The comfort and lightness are achieved through the use of soft foam pieces around the arm and neck holes.

Foote et al. (2014) found that the areas of the Descente vest which contained thicker or harder foam pieces, such as the back, performed poorly in impact tests. However, the areas made of softer pieces showed positive results, even though thinner foam pieces might be expected to transmit a higher level of force to the riders. The Japanese vest also did not satisfy the gap test requirements of the standards. The stretchy material produced large blanks between padding pieces, and no padding was present on the shoulders or behind the front zipper (Foote et al., 2014).

The Descente vest is innovative in terms of the different thicknesses of the pieces of foam and the use of a stretchy material. However, this vest is made in one piece, and this is significant when considering the second users (medical professionals) who may need to interact with it when providing aid to jockeys on the track. The author has found no other vests that have taken inspiration from the Descente to challenge the standards and meet jockeys' needs.

Although high-profile jockeys ride internationally, they are required to use the approved equipment of the country in which they are riding. The International Federation of Horseracing Authorities (IFHA, 2018) reports that most countries do not apply the JRA Standard, with which the Descente vest complies, but rather apply the EN 13158: 2009 standard. Japanese standards are not applied in many countries other than Japan. Jockeys desire the best possible mix of safety and comfort, but the Australian standards preclude innovation as they rely on information that dates back to 1996.

3.7 Current jockeys' safety vests

The author considered the currently approved products in use and their history because, based on the analysis of the current safety vests design, the need for product innovation was confirmed.

Jockeys' safety vests were first developed in the mid-1980s for steeplechasing in the United Kingdom. These races involve travelling over long distances and jumping over diverse fences and ditches. United Kingdom competitors began experimenting with padded vests (Colton, 2009) to protect them from the risk of being run over by following horses in the case of a fall. The safety vests worn did not much differ from current styles: the design remains similar and only the padding shapes and materials vary.

The *Australian Rules of Racing* (Racing Australia, 2019a, p.61-63) do not include a clear definition of a safety vest, but the articles quoted here outline the requirements for safety equipment including helmets and safety vests.

> AR.87. Every licensed or registered person or permit holder shall when mounted on a horse wear a properly affixed helmet which conforms to one of the standards that have been approved by Racing Australia [amended1.10.00][amended 3.11.03][amended 1.10.06]
>
> Note: Pursuant to AR.87 the Australian Racing Board has ordered that –
>
> (a) The following standards are approved by the Australian Racing Board:
>
> (i) AS/NZS 3838 2006;
>
> (ii) United States (US) ASTM F11 63-01;
>
> (iii) British Standards (BS) EN 1384/1996 onwards;
>
> (iv) United States (US) ASTM F11 63-04a (reapproved 2011);
>
> (v) PAS 015:2011;
>
> (vi) VG1 01.040, Recommendation for Use, 12/12/2014. [replaced 1.11.11] [amended 21.4.16]
>
> (b) all helmets must be fitted with a nylon interlocking chinstrap clip attachment.
>
> (c) all helmets must be clearly marked with a date of manufacture.
>
> (d) the use of helmets is subject to the conditions of Australian Rule of Racing 87AA. [amended 1.10.06]

AR.87A. (1) While being ridden every horse shall be properly bridled and saddled and every saddle used in official trials, jump-outs, tests or trackwork shall be equipped with safety irons of a design approved by the Stewards. Provided that in official trials or jump-outs if a rider wears race boots the saddle shall be equipped with race irons. [replaced 1.8.04] [amended 1.9.09]

(2) While being led outside the confines of any stable premises every horse shall have a bit in its mouth, which bit shall be attached to a lead or a stallion chain. [deleted & replaced 1.11.99][amended 1.8.18]

(3) Every person leading or attending a horse shall wear fully enclosed and substantial footwear of a standard approved by the Stewards. [subrule added 1.9.09]

AR.87AA. (1) Every rider shall be responsible for the care and condition of his helmet.

(2) A helmet is not regarded as serviceable and must be immediately replaced by the rider when –

(a) a period of 5 years has expired since its date of manufacture, or

(b) it sustains a severe impact, or

(c) the wearer suffers from concussion following a fall.

(3) The Stewards may at any time take possession of a helmet for inspection and may at their absolute discretion confiscate any helmet that does not comply with the requirements of this rule and/or the requirements of AR.87. [added 1.8.99] [subrule (3) replaced 1.12.05][rule amended 1.10.06]

Note: Pursuant to AR.87B, the Australian Racing Board has ordered that the following two standards of safety vests only are prescribed: ARB Standard 1.1998 and European Standard EN 13158. [replaced 1.7.14]

> AR.87AAA. Every licensed or registered person or permit holder shall when mounted on a horse during darkness have affixed to his helmet a safety warning light of a type approved by the Stewards. Provided that this Rule does not apply to any location where Stewards have ruled that sufficient artificial lighting exists. [added 1.6.04][amended 1.8.04][amended 1.10.06]
>
> AR.87B. (1) Every rider shall when mounted on a horse wear a properly fastened Approved or permitted safety vest the standard of which has been prescribed by Order of the Board. Provided that every such Approved or permitted safety vest shall be in a satisfactory condition and shall have attached to it a manufacturer's label that states that it complies with the relevant standard prescribed by the Board. [amended 14.6.07 & 1.8.07]
>
> (2) Notwithstanding compliance with subrule (1), no safety vest may be worn in a race, official trial or jumpout unless it is an Approved safety vest. Such Approved Level 1 safety vests are: Hows Racesafe, Ozvest, Racelite Pro, Vipa, Vipa 1, USG Flexi Race and Airowear Swift. [amended 1.8.14][amended 1.5.15][amended 1.2.16]
>
> (3) The Stewards may confiscate or order the satisfactory repair of any safety vest that does not comply with the requirements of subrules (1) and (2). [rule replaced 1.3.2000] [subrule (2) added 1.12.05][amended 1.8.07][rule replaced 1.7.14]
>
> Note: Pursuant to AR.87B, the Australian Racing Board has ordered that the following two standards of safety vests only are prescribed: ARB Standard 1.1998 and European Standard EN 13158. [replaced 1.7.14].

The author found relevant that there is not an official definition of safety vest for jockeys. The absence of an official document clearly stating the meaning of 'safety vest for jockeys' along with a definition of what should be used to produce this product reinforces the need of further research in this field. Besides, the manufactures know that have to respect the EN and SATRA/ARB standard templates in terms of coverage area and measurements (see Figure 15, p. 106). Considering Australia, a safety vest must satisfy the two standards in use (ARB 1.1998 and EN 13158).

A missing official document about a professional definition of safety vest allows creating misunderstanding, almost forcing the manufactures to produce safety vests with a traditional design that excludes innovation because the standards are yet not updated to accommodate the use of advanced materials and/or latest technologies. Hence, this study originally offered intimate insights about the experience that the two main users, jockeys and medical professionals, have with the safety vests.

The author combined all the approved Level 1 safety vests by Racing Australia in Figure 17. These vests satisfy the ARB Standard 1.1998 and the European Standard EN 13158, as requested by Racing Australia. The current approved vests are: Hows Racesafe, Ozvest, Racelite Pro, Vipa, Vipa I, USG Flexi Race and Airowear Swift.

Figure 17. Level 1 jockeys' safety vests approved by ARB (2019a)

There have been calls around the world for safety vests to be replaced every three to five years, because the impact absorption properties of the foam panels may decline (Harness Racing Australia, 2004; Horse Illustrated, 2014; British Equestrian Trade Association, 2016). The rules listed above show that helmets must be replaced five years after the date of manufacture.

The approved design and materials used in safety vests block a more sophisticated use of ergonomics, including the accommodation of different body shapes such as those of female jockeys. This is mainly caused by the no application of a user centred design process in producing these products, along with standards that are yet too old and not taking into consideration latest innovations that could be applicable to safety vests.

The current vests are available in different sizes made from the same template. Approved safety vests are bulky on the back due to the use of thicker foam padding that aims to improve support of the spine. However, some body areas are not well protected, such as the neck, spine, and lower back, where jockeys often report injuries (Young, 2005; Manley & Russell, 2015; Clark, 2016; Dunn, 2016a).The neck and spine are the areas of most concern for jockeys (Young, 2005; Timms, 2015; Horse Talk, 2014; Kelly, 2016a). However, there are new, impact-absorbing materials that would be less limiting to jockeys' movements and which could offer adequate protection for vital areas of the body (Waters, 2012; Australian Broadcasting Corporation, 2015; Steward, 2015; Wakatama, 2016; Polkinghorne, 2016a; Guerin, 2018).

The approved safety vests for Australia show a very similar 'jacket look' and do not differ much in shape, design or materials. They vary in weight from 400g to 700g, which is within the 1kg weight allowance for vests. Some are differentiated from others in the shape of the neckline, which can be deeper at the front or shallower on the back.

Most current vests do not satisfy requests for a deeper neckline on the back to avoid interference with the helmet (Gibson, 1998; Foote et al., 2014). Instead, tight necklines on the back of vests such as the Vipa or Hows Racesafe aim to improve support for the spines and necks of riders (Australian Racing Board, 1998; Timms, 2015), but it is recognised that this can restrict the jockeys' ability to look around to observe other horses and their freedom to roll in case a fall occurs (Mills & Whitlock, 1989; McLean, 2004).

Some safety vests are produced in a laminate of perforated foams (Hows Racesafe), or in air-mesh (Vipa), or in high-density foam (Airowear Swift) to provide lightness and comfort. Vipa is the only brand that produces a safety vest without adjustable shoulder straps for snug fit and comfort. The Vipa side lacings ensure a tight fit (Velocity Impact Protection Apparel, 2018). The Vipa is made of Nitrex foam (Eva Glory, 2016b) to absorb and reduce the effects of any impact but also offering strength and ventilation. Nitrex foam is applied to many pieces of sports equipment such as those used in winter sports, equestrian and motorcycle sports: it is a viscoelastic polymer foam that uses a composite body-armour technology to protect users from impacts (Eva Glory, 2016a).

Overall, the safety vests in use show many similarities in respect of the standard template and materials, while the differences between brands are minimal. However, jockeys voice concerns about the design of these products. Australian former champion jockey Simon Marshall has commented on the need for manufacturers to invest more money into the further development of safety vests (Banks, 2014).

There are more differences in cost, waist-side adjustments, and optional coverage for parts of the body, with some having laced fitting sections with little or no energy-absorbing material. Horse riders can purchase extra shoulder and collarbone protective pieces to match their safety vests but, in the case of jockeys, this option increases weight without adding any clear safety benefit.

Safety vests for eventing and show jumping incorporate more innovation in design and technology as these follow different standards and horse riders have different needs compared with jockeys. For example, the Japanese Hit Air jackets and Point Two safety vests are available in various styles for children, leisure riders and competition riders. The Japanese Hit Air jacket is represented in Figure 18, while the Point Two is shown in Figure 19.

Figure 18. The Japanese Hit Air jockey jacket

(www.hit-air.com)

Figure 19. Point Two air jockey jacket
(www.point-two.co.uk, 2009)

The inflatable vests shown in Figures 18 and 19 take inspiration from those used by motorcyclists and have become popular despite the elevated price (Thomas, 2010). These air vests inflate automatically within seconds when riders are thrown. Cords are attached to the saddles which are pulled tight if the riders fall, puncturing cartridges of carbon dioxide to inflate the vests. The safety vest can be reused after the cartridge is replaced but the manufacturers suggest servicing these products once a year.

Another inflatable vest, the American Hit Air, aims to satisfy different riders' needs, thus showing a basic approach to ergonomics. Its advertising states: "keep in mind that the 'fit' size is not always right for everyone. Everyone has a different height, weight and size" (Hit Air, 2018). This vest is shown in Figure 20.

Figure 20. The American Hit Air jockey jacket
(Hit Air, 2018)

These air jackets can absorb some of the impact of a fall, but doubts have been raised about the safety and efficacy of the inflation mechanisms, and the fright of the horses due to the sound of the vests inflating (Rhodes, 2016). The air bags rely on mechanical technology and only work properly if the horse riders fall in ways for which the vests have been designed. This system is not appropriate for jockeys for several reasons: the air jackets do not meet the approved safety standards; jockeys are constantly in and out of the saddle and the airbag mechanism could interfere with this movement; they need light equipment and these vests would add weight; and if they fall, they need the best protection possible (Leggat, 2016). Jockeys' safety vests show conservative design, failing to harness innovations in materials, prototyping and manufacturing processes, or in design creativity which is usually considered integral to industrial design practice.

Table 5 shows most of the current materials used to produce the padding for jockeys' safety vests. It highlights doubts that have been reported in the industry literature regarding suitability of these materials, based on the characteristics of each material.

Table 5. Padding materials used in safety vests

MATERIAL	CHARACTERISTICS		
FOAM RUBBER	This is rubber that has been assembled with a foaming agent to create an air-filled matrix structure. Commercial foam rubbers are generally made of either polyurethane or natural latex, popular for their strengths.	• Lightweight • Impact dampening • Thermally insulating	• Buoyant • Hard to recycle
POLYESTER	This is a category of polymers containing the ester functional group in the main chain: it means the linking of several esters within the fibres. Reaction of alcohol with carboxylic acid results in the formation of esters. The word "polyester" generally refers to a type called polyethylene terephthalate (PET).	• Natural polyesters and few synthetic ones are biodegradable • Polyester fabrics are highly stain resistant • Easy maintenance • Quick drying	• Polyesters include naturally occurring chemicals • Polyesters include synthetic chemicals • Most synthetic polyesters are not biodegradable • Polyester retains its shape
ABSORBING FOAM	This is a visco-elastic polymer and so it can deform under load and address forces in every direction, and then return to its original shape when the weight is removed.	• Dampening material • Controls vibration • Low cost	• It is a visco-elastic polymer • Variable weight
NITRILE RUBBER	This is a synthetic rubber copolymer and its characteristics vary depending on the polymer composition.	• Superior strength and resistance • Its elongation at break is ≥ 300% and it possesses a tensile strength of ≥ 10 N/mm2	• Low flexibility • Can cause more allergic reactions than normal rubber

Table 5 indicates that most of the vests provide safety to jockeys through their thickness, utilising different kinds and/or multiple layers of several materials including types of rubber. The materials used rely on adding thickness to increase safety, but thick layers might not be necessary if advanced materials could be used. Australian approved vests show the following similarities: use of rectangular structural foam sheets that are perforated to allow air flux and ease in fitting the body contour; layers of the material; straps; occasional availability of different colours; and absence of ergonomics.

3.8 Summary

This overview of the international and national standards for safety vests shows that, of revisions made since their introduction, only minor changes are relevant to jockeys' safety vests. This closes the door to innovation, even though safety vests do not incorporate the latest materials or technologies to enhance jockeys' safety or to improve their performance from the viewpoint of medical professionals. The expanded functionality of technology has become central to the contemporary idea of wearable technology but this is currently not applied to safety vests for jockeys. Its consideration could bring significant benefits.

These findings could bring benefits to other equestrian disciplines such as show jumping, three-day eventing, dressage and pony clubs. Analysing the origin of the standards has highlighted that differences in regulations between countries have not been fully addressed, specifically regarding weather conditions and the turf. These factors affect the standards and should constantly be revised so that updates in standards can enable changes in vest design.

After an accurate examination of jockeys' safety vests, its standards and their riding positions, the author presented the methodology of this study in Chapter Four. Along with that, a background is presented about user experience (UX) and user centred design (UCD) models to properly introduce the reader into the methods utilised by this study.

Chapter Four: Field Research: Methodology and Methods

> “Case study is an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident”. (Yin, 2003b, p.13)

Chapter Four sets out the case-based research design and the methods used for data gathering and analysis to arrive at a body of knowledge to support UCD.

An instrumental case study is:

> “The study of a case (e.g., person, specific group, occupation, department, organization) to provide insights into a particular issue, redraw generalizations, or build theory” (Mills, Durepos, Wiebe, 2010, p.2).

According to Coggon, Barker & Geoffrey (2009, Chapter 1), epidemiology is the study of “how often diseases occur in different groups of people and why. Epidemiological information is used to plan and evaluate strategies to prevent illness and as a guide to the management of patients in whom disease has already developed”. While Pearce (2012, p.396) states that there is not one way only to classify the kinds of epidemiological studies and “different classification schemes may be useful for different purposes”. Both these publications associate the word epidemiology with disease and for this reason, the author must state that this study is a case study because only aimed to analyse the intimate insights of the users (jockeys and medical professionals) with a specific product (safety vest). Besides, it only represented a small portion of the whole population (either jockeys and medical professionals) and thus, further research is requested. Due to the fact that no disease was involved, this study won’t be considered epidemiological.

A case study has different applications: it is crucial to identify the case and establish its logic (Yin, 2017). In this study, the case offered the possibility to analyse a product from the users' point of view because the author even took into consideration how this relationship (users – product) was influenced by the context within which it is situated. According to Baxter & Jack (2008, p.556), a case study is “an excellent opportunity to gain tremendous insight into a cae. It enables the researcher to gather data from a variety of sources and to converge the data to illuminate the case”. Applying these concepts, the author acted as the researcher to collect the insights to answer the research questions as mentioned in Chapter One, subsection 1.2.1 of this thesis.

Stake (1994, 1995) subdivides cases into intrinsic, instrumental, and collective: due to the importance of this study, its focus was known in advance and designed around established theory, and thus the author stated it as an instrumental case study. In giving this category to the study, a deep description was offered of a particular group of participant, carefully selected.

Hence, qualitative research methods were perfectly aligned with this instrumental case study, in which the author, adopting an instrumental case-research design, aimed to develop new knowledge regarding safety vests for jockeys. The author utilised specific research questions, which originated after the following stages: (1) the identification of the situation that triggered the case study, (2) the initiating stage, (3) the stage of collective data, and (4) the reaffirming purpose stage. The author’s use of the instrumental case facilitated the development of new knowledge and offered suggestions about its applicability. Understanding such a particular group of people was only possible through the use of an instrumental case study because the author was able to utilise the case as a comparative point across other cases in which the phenomenon might be present. In doing that, the dearth of literature covering jockeys’ safety vests was confirmed.

This chapter itemises the epistemological approach, research design and methods of this study. The main justifications for this approach are:

- Jockeys are still experiencing severe torso injuries.
- Standards permit only minor design revisions, resulting in highly constrained innovation in the product category.
- Medical professionals, who deal with safety vests in providing aid to injured jockeys, have not yet been investigated as possible dependent users of these products.
- The various disciplines of equestrian sports are experiencing strong growth and therefore demand for quality, innovative products.

Using a qualitative research method and, thus, inductive theory building due to the lack of the literature in this field, the author worked from the particular to the propositions of explanatory framework. In addition, the author used a holistic approach in order to understand participants within their social and cultural contexts. An ethnography approach in qualitative research allowed the author to observe participants with the aim of becoming immersed in the participants' culture and view them as active research.

The author became immersed in the lives of those being studied and used the individual semi structured interviews and the focus group to gather data. The information gathered and that from documents were combined and ordered into larger topics. Inductive data analysis generated meaning from the data and built substantive theory from practice (Patton, 2002; Merriam & Tisdell, 2015). This way of theory building was suitable for this study, which aimed to understand practice and to offer practical benefits for the application of design to jockeys' safety vests. Findings are presented as problems, guidelines and propositions.

This chapter presents the research design and components, including tools of data collection and discussion of the case-study method, outlining its benefits and defending its application to this study. The chapter specifies aspects of the case-study design, methods of data gathering and analysis, and limitations of this study. Figure 21 sets out how the research problem was approached.

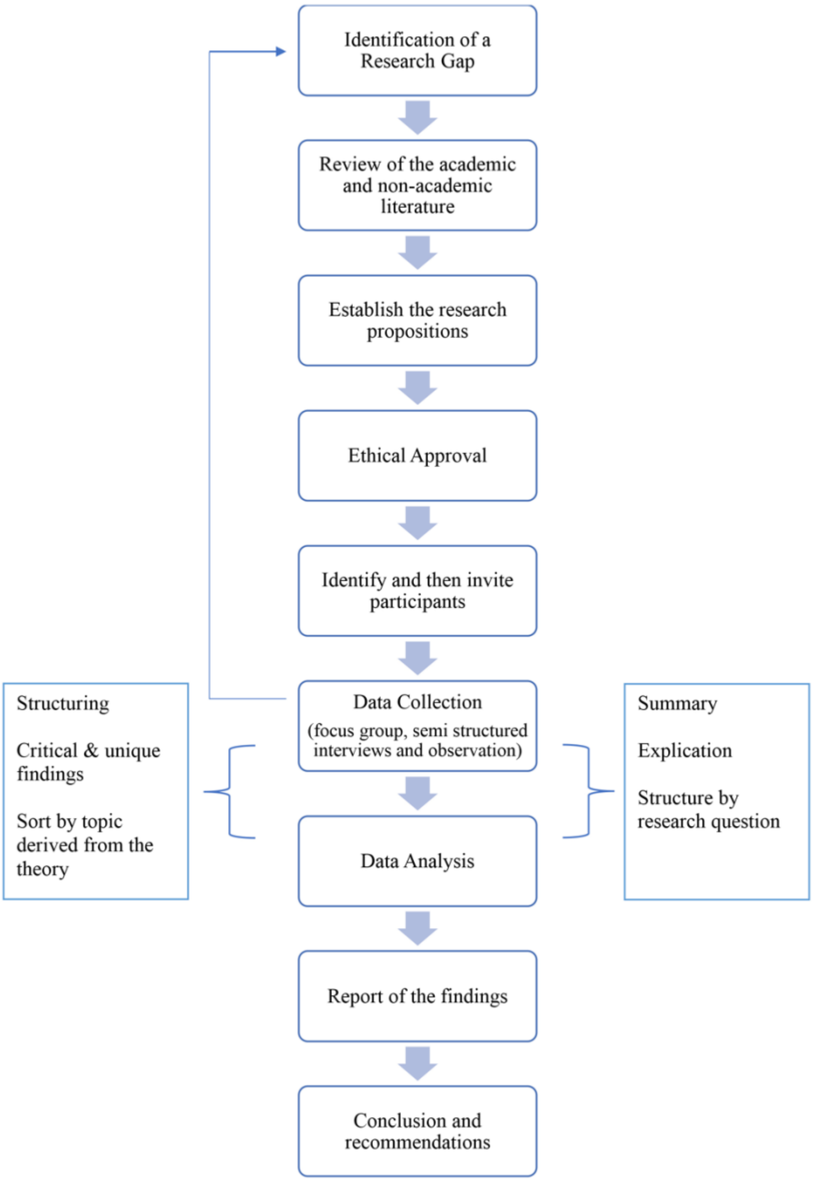

Figure 21. Diagram of research design and methods

Figure 21 provides guidance about all facets of this study from the identification of the research gap to the data collection stages and analysis procedures.

4.1 Research design

Practice and theory are two kinds of knowledge in the fields of design and interpretation. To obtain advanced knowledge, a dynamic relationship between the aforementioned concepts is needed. According to Crouch and Pearce (2012), theory and practice are intertwined, and the lack of published knowledge hinders the development of a dynamic relationship between the two in this field.

To understand jockeys' and medical first-responders' experiences with and perceptions of current safety vests as a basis for proposing enhancements to vest design, the study used a flexible qualitative-research design informed by Forlizzi's (2008) concept of product ecology. Forlizzi argues that:

> "The Product Ecology … articulates all of the factors that evoke social behaviour around products. The factors in the framework can be used in a generative manner to scaffold the selection of design research methods for understanding current experience and generating new products to change that experience….The Product Ecology framework provides an alternative way of understanding the complex physical and social context of use around a product, and a means for suggesting change within the current state of the world…. The Product Ecology framework is useful for broadening the view of what a product is. For example, many products are much more than functional objects of use - they serve important emotional and social functions in people's lives. These uses and meanings of products evolve over time and are often not revealed in single-visit fieldwork." (Forlizzi, 2008, online)

According to Forlizzi (2008), product ecology supports a design researcher in describing how a product evokes social behaviour, offering a path for choosing the adequate research method, expanding the design culture in interaction design that allows for design-centred research. Users are unique, so each one associates different meanings and feelings with the product as a consequence of the everyday use of the same product.

Inspired by Forlizzi (2008), and to have a good understanding of what the safety vests mean and the roles they play in users' lives, the author started by considering the primary users: the jockeys. This main users' group comprised apprentices, professionals and former jockeys. However, the author found that there was another group to be considered: the medical staff who handle the safety vests when jockeys are injured. This second group was important to the aims of this study and they needed to be considered regarding the ways in which they interacted with the product and how the product could help them to save jockeys' lives.

The author adopted a qualitative approach to data collection and a holistic, interpretative sense-making approach to its analysis. It was a core approach, because qualitative research investigates how people build their realities and what meanings they give to their experiences (Merriam & Tisdell, 2015). The research design was conceived to develop a thorough understanding of participants' needs and experiences to drive design innovation.

Knowing the ways in which users interacted with the product was vital because human experiences are influenced by many factors linked to the environment, such as geography or technology, and to the social environment, including culture and institutions. These kind of relationships generate aesthetics, meaning and emotional experiences (Forlizzi, 2008). They play a core role but are currently missing when thinking of the design of the jockeys' safety vests.

According to Brown (2008), to create products that are economically, functionally and technologically superior to that which already exists requires empathic design that considers the whole of the socio-economic and human landscape in which a product sits. This is shown in Figure 22.

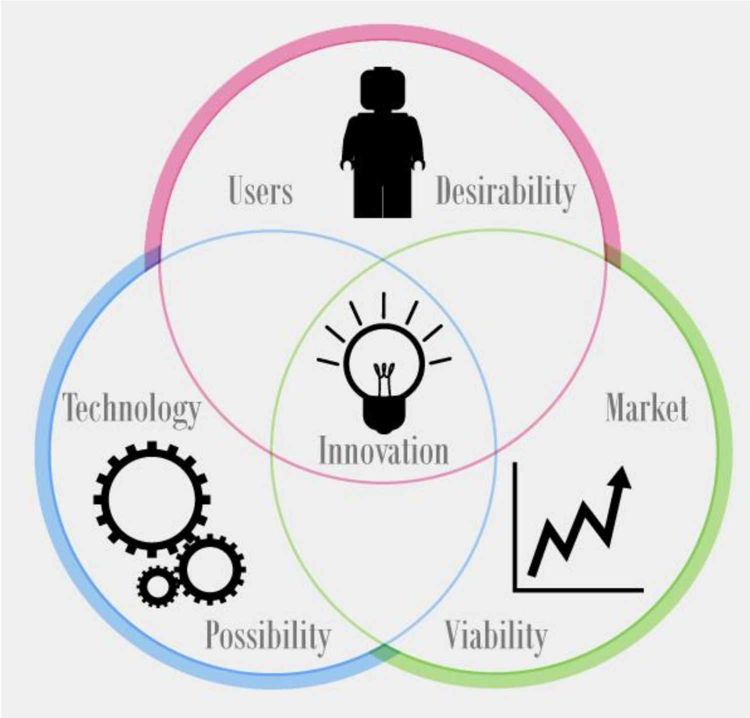

Figure 22. Design thinking process

(Brown, 2008)

Locating the user at the centre of the research is innovative even in the field of equestrian equipment design, indicating the need for a case-based, qualitative approach to understand how to design PPE that is optimised for rider safety and acceptability. The significant contribution of this body of work is the effect that a designer may have on the jockeys' safety, ensuring a level of quality and security that can only be achieved through the innovative use of materials and the users' involvement. Given the dearth of literature regarding medical professionals and the implication for jockeys in analysing vest design and its principal basis in practice, the author discovered the need for a first known comprehensive study of these users' needs to help inform new standards in vest design.

The author then realised the need to apply usability design, and took inspiration from Norman (2004), which can be summarised in 'beauty and brains, pleasure and usability go hand-in-hand in good design' along with the concept that there were three different levels of experiences which might be triggered by three different levels of design.

Norman (2004) recognises the existence of the visceral design, the behavioural design, and the reflective design. The first level of design is the one primed by the initial sensory scan of a certain experience, and the user cannot control it. Behavioural design is the most meaningful level because it encompasses the experience and how the user perceives it. However, it is necessary to sense the visceral prior to reaching the behavioural design. When a user first starts to use a product, they enjoy an experience beyond association and familiarity, so reflective design may be gentler than the other two but is equally significant to design a product with lasting value for its users.

Considering the above and that design research focuses on what ought to be via the disruption of the status quo, the author reflected on the users in this study. The author identified the primary users as those wearing the vests, and recognised the secondary users as primary users undergoing a secondary-use experience, an example of which could be the emotion generated when a primary user experiences the product’s purchase. There are also the tertiary users, for example those responsible for taking care of the vests.

In this study, the author also gave importance to the involvement of an industrial designer in the product development process. Bonsiepe (2007) argues that the main difference between scientists and designers is that scientists produce new knowledge while designers create new experiences for users. Krippendorff (2007) suggests that designers are preoccupied with what will exist and is currently unobservable, which is the opposite position of scientists. Even Bonsiepe (2007) suggests that designers and scientists both can progress experimentally, while Glanville (1999) comments that researchers should act as designers because research is a design activity.

Hence, the author believed that this study represented a good compromise between science and design. The findings of this study might create new knowledge, which could be extended and contribute to enhance the safety of all horse riders, not just jockeys. In addition, the findings could support the creation of a prototype for a new safety vest because the author acted as a designer.

According to Driver, Peralta and Moultrie (2011), the opinions previously reported about the differences and similarities between designers and scientists can be summarised as in Table 6.

Table 6. Differences and similarities between Designers and Scientists

(Driver et al., 2011)

	DESIGNERS	SCIENTISTS
DIFFERENCES	• Concerned with what will exist and is unobservable (1) • Create new experiences (2) • Predilection for images, figurative models and prototypes (3)	• Both proceed experimentally (2) • Both act as designers (3)
SIMILARITIES	• Concerned with that already exists and is observable (1) • Create new knowledge (2) • Preference for abstract mathematical models (3)	

Note: (1) (Krippendorff, 2007), (2) (Bonsiepe, 2007), (3) (Glanville, 1999)

Applying a user-centred process is considered a form of progress because it enables designers to “make things better for people” by considering the functionality and stylistic characteristics of the products in relation to people’s physical and emotional needs (Seymour, 2012). This approach highlighted the importance of taking into consideration not just the jockeys but also the medical professionals and the standards.

According to Giacomin (2014), a human-centred design process asks who, what, when, how and why to supply the requisite knowledge of human factors, functions, semiotics, communication and meaning to establish a deep understanding of the context for use (Harte et al., 2017). There is immature knowledge in this field and the widely cited ‘Double Diamond’ shown in Figure 24, which was developed by the United Kingdom Design Council (2016), may offer inspiration for this study.

The diagram in Figure 23 describes the design process and its four distinct phases - discover, define, develop and deliver - as they relate to problem definition and solution, with the insights provided by user and contextual research driving divergent and convergent stages of a design.

In this qualitative research plan, the first quarter represents examination of published knowledge of race injuries, their consequences and ways to mitigate them. The second quarter matches the field research to understand more clearly the parameters and scope for product innovation. The third quarter represents the application of knowledge to the development of prototype designs. The fourth quarter develops overarching findings from the research process to frame recommendations for product innovation and ways in which these might be supported by revised product standards.

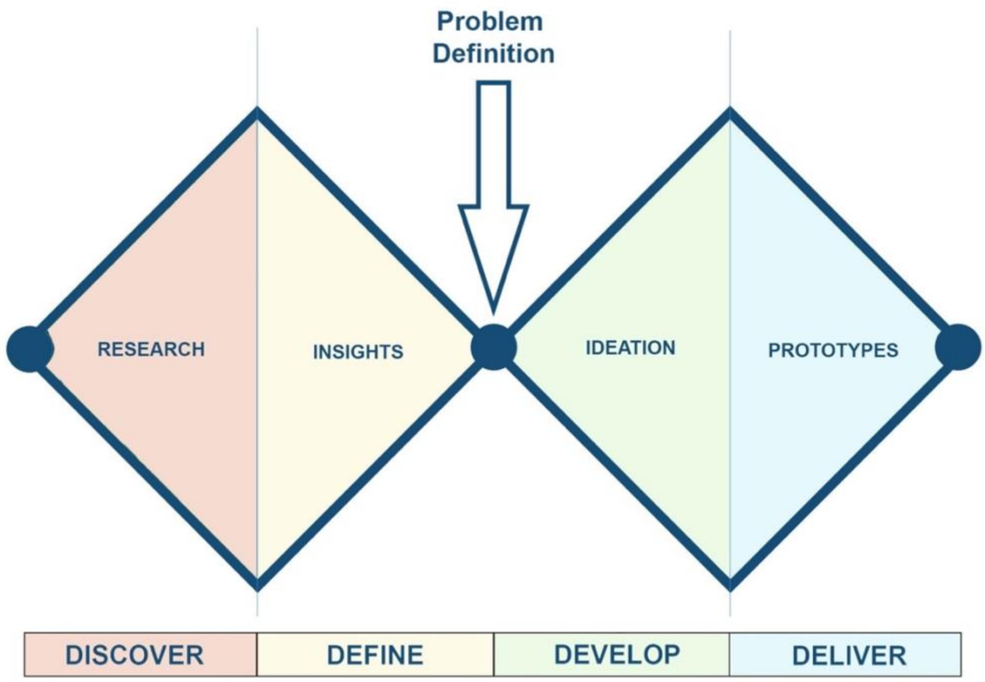

Figure 23. The 'Double Diamond' process

(Design Council, 2016)

Inspired by the diagram shown in Figure 23 and addressing the questions underpinning this study, the author analysed safety vests for jockeys to understand if better protection was possible and the ways in which it could be produced. Using a mixed-method design enabled the author to consider a different perspective: to satisfy the aims of this study, the author utilised an additional and diverse perspective in responding with a second group of participants.

According to Morse (2009, p. 1524), a "QUAL-qual mixed design allows us to examine the pieces that we would otherwise not be able to see, or may overlook". Even in this study, a QUAL-qual mixed design helped the author to consider jockeys and related medical staff: hence, the primary users contributed with their knowledge, but the medical professionals also offered significant data since they interacted with the safety vests as well.

Qualitative research relies on inductive reasoning processes grounded in the interpretation of the research data by the researcher (Thorne, 2000). It is best suited to obtaining a deep understanding of the underlying motivations people have for engaging with products and the experiences that engagement produces: hence, in-depth and non-altered insights into the attitudes, fears, experiences, lives and wishes of both jockeys and medical staff were generated.

Besides, the use of multiple methods sought to produce an overall knowledge of jockeys' safety vests (Patton, 1999). According to Patton (2002), by gathering detailed insights into participants' lives, qualitative research offers the opportunity to understand their day-to-day activities through the eyes of those studied. This approach led the author to identify the need to include medical professionals as participants in this study.

The author also considered the fact that designers usually design for a user, but in this case there were multiple users. The author considered jockeys and medical staff as users of the same product and this led to the conclusion that there could be more than two dependencies: in this study, there were at least three dependencies, as indicated by the review of what was known about safety vests. The author found that the product had a clear main user, the jockey, but also dependencies such as the medical staff and the standards.

Therefore, this study was an example of 'real-world' research, which Robson (2002) defined as research undertaken with, among and for people. For Robson (2002, 2011), real-world research is typically exploratory, descriptive and explanatory while having the aim of improving things for people. In inductive empirical research based on the observation or experience of both the research subjects and the researcher, data triangulation is an important addition to the research design to produce robust research findings, even where research results are convergent, inconsistent and contradictory (Guion, Diehl & McDonald, 2011; Carter, Bryant Lukosius, DiCenso, Blythe & Neville, 2014).

Because data came from different sources in this study, (individual semi-structured interviews, the focus group and observation), the author utilised triangulation to prove its validity. According to Denzin (1978) and Patton (1999), there were various types of triangulation but the author adopted the one called ‘method triangulation’ because this study used three methods of data gathering about the same topic in a qualitative method. Due to the use of multiple methods of data collection, rigorous findings were established because the data triangulation reinforced the validity and the growth of utility of this study (Maxwell, 1992; Trochim, 2001; Corbin & Strauss, 2008; Strauss & Corbin, 1990, 1998; Carter et al., 2014; Save The Children, 2015). Triangulation also increased the credibility of this study’s findings by interweaving, scrutinising and contrasting results against data sources and perspectives (Hayes & Morse, 2010; Guion et al., 2011).

Hence, the author recognised different perspectives about the safety vests for jockeys that previously had been overlooked. Empathic design, like qualitative research, seeks to enable the designer to see a situation from the inside, as users potentially would see it (Laurel, 2003). According to Milton and Rodgers (2013), empathising with users leads designers to produce goods that offer pleasure, satisfaction and desire to users. However, users often are not sure what they want or need: typically, they do not think they need a new solution to satisfy or improve their circumstances because they are too used to their current situation (Leonard & Rayport, 1997; Laurel, 2003).

Chawla (2015), the founder of Fueled (a tech company that utilises user experience process), in one of his post argues that qualitative data gathering with intellectual creativity can lead the designer to create something for users before they know they need it. In this study, some jockeys may imagine a perfect safety vest, but most of them are unsure or unconscious of their real needs. Hence, the author devised an appropriate data collection plan which required that, during the data gathering, seeds be planted into the jockeys’ and medical professionals’ minds, bringing them to consider safety vests in a different light.

4.2 Conceptual Framework: accommodating ‘co-dependent users’ in the UX and UCD models

Design research often adopts a UCD approach and/or UX approach. Both approaches utilise a wide variety of research methods, such as semi-structured interviews and usability evaluations as asserted by Rosson & Carrol (2002). Specifically, human insight, empathy and input are considered to answer a problem, because the user is at the core of these research methods (LUMA Institute, 2012).

The UX process aims to enhance user satisfaction regarding a product by improving the usability, accessibility and even the pleasure offered by the interaction with the product. Both UX and UCD models are critically analysed by the author in Chapter Five, particularly in the subsection 5.2 of this thesis. However, due to the similar focus on the empowerment of users and on their interaction with the product, the author started to investigate safety vests for jockeys while taking into consideration the aforementioned models.

According to Hassenzahl and Tractinsky (2011), knowledge of the user experience involves understanding the ways in which the users interact with technology, and taking into account the users’ moods, the characteristics of the design system (for example, functionality) and the environment. This offers endless design and experience opportunities, as shown in Figure 24.

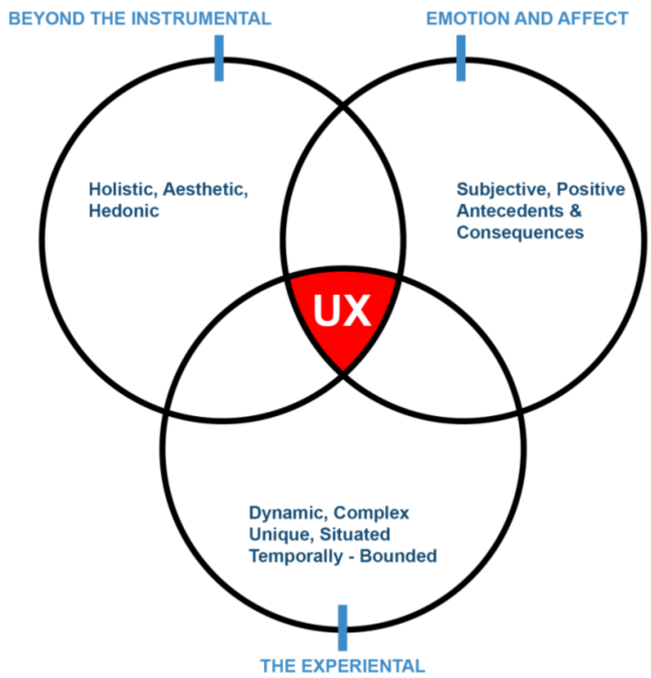

Figure 24. Facets of UX

(Hassenzahl & Tractinsky, 2011)

Figure 24 offers a representation of UX, used as a subjective, situated, complex and dynamic encounter. According to Hassenzahl & Tractinsky (2011), the needs and expectations of the user, along with the functionality and the environment within which the interaction happens are the causes of UX. It is crucial to maintain a positive approach because in this way it is possible to generate exceptional quality experiences (Kahneman et al. 1999; Seligman & Csikszentmihalyi, 2000).

Instead, User Centred Design (UCD) has similarities with agile development and the importance of knowing who the users are and comprehend their needs is often used in software engineering (Chamberlain, Sharp & Maiden, 2006) . The UCD approach aims to deeply involve the users throughout the development of a system or product and the UCD model is often visually represented as in Figure 25.

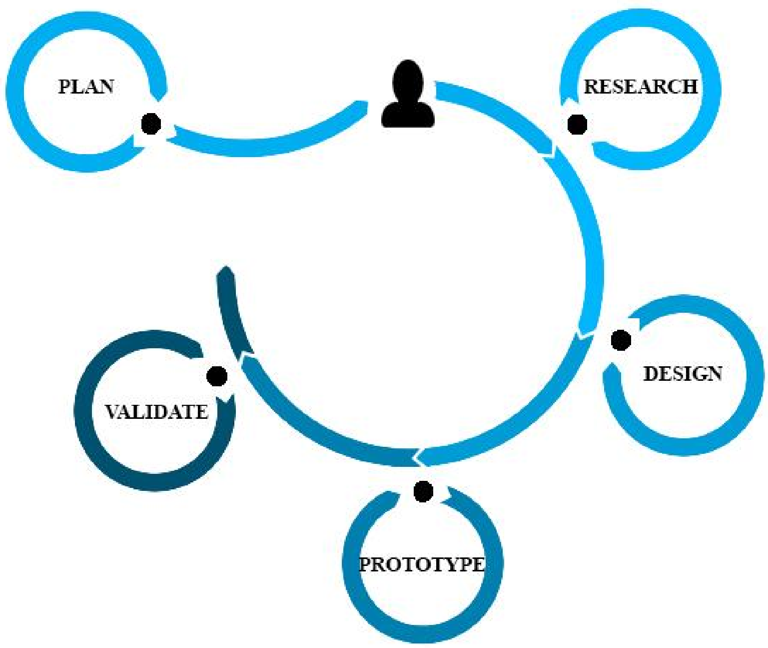

Figure 25. User-centred Design Model

UCD is a creative, multi-stage, problem-solving process that aims to create a product that the users want, rather than forcing the users to modify their behaviour to use a product. However, according to HBS Professor Christensen's research (Nobel, 2011), around 95% of all new products fail every year despite the use of UCD and/or UX. It is recommended to design products for pleasure rather than for solving problems (Hassenzahl et al., 2013; Hekkert, 2006).

However, the application of UX and UCD models in the case of the jockeys' vests led the author to consider whether the products' success required the qualitative insights of those the author named "co-dependent" users, whose experience was also critical to the design's success.

Thus, the author understood the importance of considering co-dependent users on the design solution. In this study, the jockeys were still the primary users while the medical staff were the co-dependent/secondary users. Both user groups relied on the design solutions for the same products, the safety vests. Jockeys rely heavily on health professionals, who are the first to provide them with medical aid in case of a fall. Therefore, not only the safety vests but the helmets and other safety products worn during races are critical elements that can either delay or restrict the medical staff in delivering care on the track.

4.3 Methods of data gathering employed

Each method of data gathering used in this study had its own characteristics, and therefore a variety of appropriate uses. The first step was to choose an adequate method to collect the data. Design research utilises both quantitative and qualitative research methods because they can support each other, but data collection remains at the core of all research (Milton & Rodgers, 2013). If factual material is not found, there is no basis upon which to base rational conclusions.

The author relied on some of the most commonly used qualitative-data collection methods, preferring individual semi-structured interviews, observation and a focus group. It was crucial to produce guidelines for the product that would be well accepted by both the users and the co-dependent users. After this, triangulation of the findings provided strong support as this stage reinforced the validity and the increased use of this study (Maxwell, 1992; Trochim, 2001; Corbin & Strauss, 2008; Save The Children, 2015).

In case study research is well known that gaining access to organisations and appropriate participants can prove to be a difficult and time-consuming challenge in the research process (Yin, 2009). Time constraints and the nature of a doctoral case study restricted the author in accepting the number of 20 participants as enough to reach saturation in this study. The number of participants (overall they were 20) was limited and the author's aim was to gain insights regarding personal experience from locally based jockeys and medical professionals. Therefore the author adopted the case-study methodology that is typically used to focus on a small group or situations and gather information about them on a specific topic, in this case jockeys' safety vests. However, due to a higher number of jockeys and medical professionals present in Australia, the author strongly recommend further research in this field.

The literature offers a good amount of publications (Marshall, Cardon, Poddar & Fontenot, 2013; Mason, 2010; Robinson, 2014; Sandelowski, 1995; Shenton, 2004) that debate about the sample size and saturation in qualitative and also quantitative researches. However, in this case the author had to agree with Strauss and Corbin (1998, p.136) with "saturation is a matter of degree and it should be more concerned with reaching the point where it becomes "counter-productive" and that "the new" is discovered does not necessarily add anything to the overall story, model, theory or framework”.

However, it often happens that authors that conducted qualitative researches received criticism for not being able to justify their sample size decisions utilised (Boddy, 2016). This study adopted a qualitative research method and even Sandelowski (1995, p.179) affirms that is hard to determine adequate sample size in this case of research and is “ultimately a matter of judgment and experience in evaluating the quality of the information collected against the uses to which it will be put, the particular research method and purposeful sampling strategy employed, and the research product intended”.

Instead, Marshall, Cardon, Poddar & Fontenot (2013) conclude that there are three methods to support the sample size utilised in qualitative research: cite recommendations by qualitative methodologists, act on precedent by citing sample sizes used in studies with similar research problems and designs or an internal justification through statistical demonstration of saturation within a dataset. At the end, Marshall et al. (2013, p.21) conclude making these recommendations: “ (a) grounded theory qualitative studies should generally include between 20 and 30 interviews; (b) single case studies should generally contain 15 to 30 interviews; (c) qualitative researchers should examine the expectations of their intended journal outlets based on history and culture; and (d) replication studies should further examine the impacts of culture and study design”.

In this study, the author utilised 20 participants (jockeys and medical staff) and due to the aforementioned points (a), (b), and (c), this sample size is to be considered pertinent to reach saturation. According to Morse (2000, p.3), saturation depends on a “number of factors, including the quality of data, the scope of the study, the nature of the topic, the amount of useful information obtained from each participant, the number of interviews per participant, the use of shadowed data, and the qualitative method and study design used”.

The literature often utilises “qualitative research” as an umbrella term (Bowen, 2008). However, for this study, the author took serious inspiration from Creswell (1998, p.64) that indicates sample sizes’ guidelines for grounded theory methodology in 20 to 30 but in phenomenology 5 to 25, while Morse (1994, p.225) at least 6.

To complete the PhD in the limited time available (3 years), the author decided to focus on jockeys and medical staff available at that time and based around Melbourne to facilitate their availability and then collect the data for the aim of this study in time. Focusing on how the users (jockeys and medical professionals) experience the safety vests, this study examined to set aside biases about human experiences, needs, feelings to a particular product. This number of 20 participants represent only a small portion of jockeys and medical professionals that operate in the Melbourne area: however, they were enough to reach saturation in offering intimate insights to the author.

According to Racing Victoria (2017), during the data collection for this study, there were 291 jockeys who rode in races (metro and country) and about 20 jockeys battling for the premiership. However, it is relevant to remind that the author of this study only considered jockeys riding in the Metro area and in flat races.

The data-collection activities are central to qualitative research, in which the researcher is the primary instrument of both data gathering and analysis. However, research design acknowledges that a researcher's subjectivity can lead to biases. In this case, the use of multiple data-gathering methods led to an acceptance of trustworthiness and validity in the case of data derived from different participants, which were comparable and substantial (Golafshani, 2003). It is significant to note that the author was introduced to people as a subject matter expert in design and as a doctoral candidate second. This was helpful in gaining credibility and access to participants.

During data analysis, the author examined the case data, and clarified and checked for accuracy with respondents. In this way, the author could shape and refine the questions, discarding tentative hypotheses and research directions that were not supported by evidence. The author conducted analysis in conjunction with triangulation of the data collected.

Hence, the emphasis of this study shifted from examining the safety vests to a greater focus on the impact of the design process on the designer role and outcomes as more data became available. Accordingly, the design-process investigation was conducted utilising a qualitative-research methodology with a UCD approach that included the user and the co-dependent user. Thus, the stages were as follows:

- An initial desk research project summarised the history and evolution of safety-vest design from an academic and industry perspective, clarified the end users' needs and highlighted the leading insights from the Australian horse-racing industry. This informed the overall investigation and supported the conversations with the participants that were interviewed.
- A sample of individuals who were familiar with the safety vests was identified as possible participants in this investigation. Qualitative research is based on the sensations of the researcher, so the research needed to be conducted in a systematic way due to the need for transparency.
- Individual semi-structured interviews were conducted between July 2016 and November 2016. The interviewer usually had more awareness than the participants of the main issues surrounding the design project and the necessary questions to ask, which were standardized across interviews. The author referred to prompts to ensure that the specific points to be covered were addressed, while the flexibility offered by semi-structured interviews allowed participants to make unstructured contributions that were still relevant to this investigation. Through this method, the author could explore the participants' beliefs, values, experiences and knowledge regarding the research subject.
- When the semi-structured interviews had been completed, a small group of participants gave the author the opportunity to conduct a focus group. This took place in October 2016 and was conducted with one group only because of prior commitments by other participants that could not be postponed. The focus group offered the opportunity to discuss issues associated with the topic of the safety vests. People participating in a focus group have the opportunity to stabilise the discussion's direction, while the moderator ensures that all the participants are able to voice their opinions (Milton & Rodgers, 2013).
- Between July 2016 and July 2017, the author conducted observations

with the same participants. Design research often begins with observations to discover what users really need. This allows a deeper engagement with users' emotional attachments to their belongings. A critical analysis of the designed product could then support the author to design and develop a better safety vest.

4.4 Ethical approval and participant recruitment

A subcommittee of Swinburne University of Technology's Human Research Ethics Committee (SHESC) granted approval for the study on 18 July 2016. According to the terms of the ethical approval, consent information statements and consent forms were provided to enable the provision of informed consent. The help and support provided by the authorities (such as Racing Victoria, Racing Australia, the National Jockeys' Trust and Wilson Medic One) guaranteed to this study that participants were over the age of 18 and none of them was diagnosed with anxiety, depression or any other emotional disturbance in the previous 12 months.

According to Malterud, Siersma & Guassora (2016), the number of participants should be determined by the purpose of the research, sample specificity, application of established theory, quality of dialogue and analysis strategy. In qualitative research, the sample size is considered sufficient when data saturation is reached. Sargeant (2012) argues that this end point can be achieved when an iterative cycle can be formed of analysis occurring concurrently with data collection (Sargeant, 2012).

A range of writers (for example, Guest, Bunce, & Johnson, 2006; Burmeister & Aitken, 2012 ; O'Reilly & Parker, 2013; Saunders, Sim, Kingstone, Baker, Waterfield, Bartlam, Burroughs, Jinks, 2017) suggest that when using the interview method, saturation is usually achieved in a homogeneous participant group of between 13 and 15 participants. The present study involved a case study group representing male and female jockeys and medical track staff. Consequently, participants differed from each other based on their sex, age and experiences. This number enabled the researcher to build and maintain close relationships with participants. Qualitative research is used in a context of discovery, so the researcher's work is more open-ended, and may take unexpected turns that follow empirical and conceptual findings that emerge unexpectedly (Baker & Edwards, 2012).

The sample of 20 participants enabled the gathering of rich qualitative data (Malterud et al., 2016). Participants were recruited through Racing Victoria, Racing Australia, the National Jockeys' Trust and Wilson Medic One. Table 7 provides details on the 20 participants – 16 males and four females – and how they were coded. Seventeen were jockeys, with a range of experience: six apprentices, nine fully qualified jockeys and two retired jockeys.

The second group of participants was made up of medical professionals, older than 35 years old, with a strong history of dealing with jockeys' injuries. For instance, there was a paramedic with over 25 years' experience who had worked at horse races for almost three years. There were two doctors in the group. One was a racecourse doctor with almost 28 years of experience, and the other had been working with the Victoria Jockeys' Association and Racing Victoria for more than ten years.

All participants reported English as their first language. The privacy of participants was preserved by using codes in the data analysis, as shown in Table 7.

Table 7. Participant codes and categories

Participant Number	Code	Category
1	**AJ01**	Apprentice Jockey
2	**AJ02**	Apprentice Jockey
3	**AJ03**	Apprentice Jockey
4	**AJ04**	Apprentice Jockey
5	**AJ05**	Apprentice Jockey
6	**J01**	Jockey
7	**J02**	Jockey
8	**J03**	Jockey
9	**J04**	Jockey
10	**J05**	Jockey
11	**J06**	Jockey
12	**J07**	Jockey
13	**J08**	Jockey
14	**D01**	Doctor
15	**ICP**	Intensive Care Paramedic
16	**D02**	Doctor
17	**AJ06**	Apprentice Jockey
18	**J09**	Jockey
19	**JR01**	Retired Jockey
20	**JR02**	Retired Jockey

The following criteria were applied to identify suitable participants in the data-collection phases of this project: participants needed to be older than 18 years; they had to have participated as professional jockeys in horse racing; they had to have participated as apprentices in at least three professional races; or they needed to have participated as a doctor, a paramedic or an ambulance officer at racecourses. All participants in both categories were required not to have been diagnosed with anxiety, depression or any other emotional disturbance in the 12 months before data collection.

These criteria enabled the author to select meticulously the most suitable participants who met the scope of the research. They were questioned about safety vests for jockeys and were observed during their regular work activities. This user research could be valuable in identifying how users accessed current products, the areas that could be improved or innovated, and the opportunities for new products and/or services that would address users' needs (Design Council, 2007).

The in-depth interviews, focus group and observation techniques enabled the author to identify profoundly the users' and the co-dependent users' needs. Stimulus materials, such as the current safety vests, riding simulators and helmets, were used to describe present and future user scenarios involving the employment of these products and services. Hence, the need for a good design to keep users happy and confident regarding their safety was confirmed. The single data collection phases are described in detail in the following chapters.

4.5 Interviews with jockeys and medical professionals

The interview sample was purposeful and small, but encompassed the range of jockeys and medical staff. Most of the interviews were undertaken in person at race courses in Melbourne, a location familiar to the participants, although J09's interview was executed over the phone. Due to the potential sensitivity of the topic, care was taken not to press participants in a line of questioning that proved upsetting. Most participants from both groups were happy to discuss their personal experiences and all supported this study.

Sixteen of the 17 jockeys interviewed had experienced at least one fall during their career when wearing a safety vest. Medical first-responder participants confirmed significant experience in treating jockeys' injuries after falls. Semi-structured interviews were chosen to allow the researcher to explore participants' answers more deeply and to allow the interviewees to introduce topics of discussion they saw as relevant, and to enable them to reflect fully on their workaday experience of wearing safety vests.

The semi-structured approach enabled participants to feel comfortable and the author to use discretion in adapting questions as needed to bring benefits to this study. A consistent list of questions provided a framework for discussion to generate comparable material without restricting novel input from each participant. The interview protocol developed for the participating jockeys involved the following questions:

1. At what point on race day or during track work do you put on your safety equipment?

2. Can you describe the experience of wearing a safety vest in the lead-up to a race?
3. Can you describe the experience of wearing a safety vest during a race?
4. Can you describe the experience of wearing a safety vest after a race?
5. What are the main functions and benefits that you expect from a safety vest?
6. What do you think are the main irritants in wearing a safety vest?
7. What should a safety vest look like for you?

The interview protocol developed for the medical first responders asked the following questions:

1. Can you describe how and when you started to provide professional medical help to jockeys?
2. What are the most common injuries you have treated as a consequence of a fall? Please describe this with details.
3. What do you think are the strengths and benefits of wearing a safety vest?
4. What are the main functions and benefits that you expect from a safety vest?
5. What is the main function that you expect from a safety vest that could contribute to your medical services?
6. What could the redesign of a safety vest do to improve the medical staff services at racecourses in case of a fall?
7. What should a safety vest look like to you?

The consistent interview format allowed the author to apply the same interview protocol for both groups of participants in this study. This offered an opportunity to make comparisons that might have been harder if the interviews had been unstructured.

All interviews were conducted in person, digitally recorded and transcribed. When possible, the author also made handwritten notes and took photos during the interviews to record contextual information such as body language, interruptions and intensity of feelings expressed. Each transcription was edited and organised under headings that emerged from the discussion: topics were ordered according to the number of respondents who commented on the subject of the heading and the extent of concern shared. The author adopted this approach, not to report a rigorous statistical analysis of the relevant importance of each topic but rather to identify common themes and issues that originated from participants’ experiences.

Ordering the data by topic and respondent type proved the most effective means of retaining the meaning and degree of emphasis in the original text. The same approach was adopted for data obtained from the focus group.

4.6 Focus group

Once individual semi-structured interviews had been completed, as argued by Attride-Stirling (2001) a preliminary analysis of the interview data was undertaken using thematic network analysis with the assistance of NVivo software (NVivo qualitative data analysis software; QSR International Pty Ltd. Version 12, 2018). The findings were used as the basis of the focus group so that the interaction between participants on the research topics could offer an efficient and effective way to check the interview results (Waller et al., 2016).

Participants in a focus group often feel more confident to express their opinions than in individual interviews (Kitzinger, 1995, 2005). This stage was the hardest one to organise due to the multiple commitments of jockeys and medical professionals, which meant that their available time was scarce. One focus group was successfully conducted but participants were only jockeys. Time constraints, the nature of a doctoral study and lack of opportunity prevented the inclusion of medical professionals in the focus group activity.

In qualitative research, focus groups represent a form of in-depth interviews performed in groups with precise characteristics: the aim is the interaction between the participants (Jacob, 1988; Mishra, 2016). The focus group is also a powerful tool because it offers the opportunity to observe interaction of the participants during a process, and it is pleasant for the researcher and participants because they can discuss something that interests them all (Waller et al., 2016).

Thanks to the support and collaboration of Racing Victoria, the focus group was held at one of their premises in the Melbourne, Victoria, metropolitan area.

The focus group consisted of the author, five apprentices and two former jockeys. Such a particular group of participants offered an insight into their language, concepts and opinions about the topic. Participants gained confidence to speak in a group rather than alone with the interviewer and a free way to discuss their joint experiences, and some were passionate in discussing the safety vests. According to Waller et al. (2016), the data collected should be rich and meticulous: participants conversed about the topic in their own language, in their own environment, and in their spare time. Being in a group gave participants the courage to take part even if they felt insecure about what to say on the topic: thus, this activity especially utilised the set of participants as part of the way to collect data (Kitzinger, 1995, 2005).

The focus group was a part of the research strategy to collect qualitative data, and the author had a range of open-ended questions to gather relevant information. In this way, the participants felt able and encouraged to analyse the topic, but using their own words and in a perspective that took account of their order of importance. Due to the medical professionals' busy schedules and therefore the impossibility of jockeys and medical professionals being available at the same time, plus the skills in time management required to conduct this data collection stage, the focus group comprised some of the jockeys and no medical professionals.

As with the semi-structured interviews, the author provided a consent information statement letter in addition to a project consent form that each participant needed to sign before taking part in the activity. Participants again were recruited through Racing Victoria (in collaboration with Racing Australia and the National Jockeys' Trust) and this aided the author in not causing interference with the participants' activities. In compliance with the ethics guidelines for this research, anonymity and confidentiality in respect of participants' identities were assured. Hence, participants have been given codes bearing no relation to their real names.

The seven jockey participants in the focus group were male. Most of them were born in Australia and all of them reported English as their first language. Five participants were apprentice jockeys who graduated at the end of 2016, so all the apprentices who were involved in this study have now entered into the senior jockey ranks. Again, time constraints, the nature of a doctoral study and lack of opportunity prevented the author in organising another focus group with female jockeys.

The author was the moderator of the focus group, but extra support was given by participants JR01 and JR02 as former jockeys and as well-known trustable mentors to most of the group. This was helpful and a useful tool to reinforce the relationship established with the participants. All of them had similar backgrounds and experiences, which facilitated the data gathering and discussion of the topic (Mishra, 2016; Waller et al., 2016).

The participants in the focus group came from a pre-existing group of jockeys already involved in this study (they participated in the data gathering phases of observation and individual semi-structured interview): this offered easier recruitment for this activity, along with comfort and familiarity in discussing the topic. However, due to the fact that most of them were apprentices and thus less experienced than professional jockeys in an activity like this, to guarantee a free-flowing conversation in which they would feel free to express their opinions, the location chosen was familiar to these participants. During this group discussion, the people involved demonstrated a sense of confidence and security. The only issue was experienced by the author, and this was the limited time available to the participants for activity outside their work time. Despite that, the collaboration between the author and the participants led to the successful running of a focus group.

The majority of participants in the focus group were still apprentices at that time hence, they needed objects to support their ideas and to be sure that the author/moderator had completely understood their points of view. Thus, two safety vests were used to support the focus group conversation. Most of the participants had experienced at least one fall and all showed genuine interest in the topic, so the opportunity to show the researcher extra details about the vests, or how they experienced a vest during the falls, added high-quality data.

Overall, the atmosphere was friendly and relaxed, so this stage generated a conversation about the safety vests but it also offered insights into the jockeys' world. The author could learn the participants' language and camaraderie. Although they compete against each other almost every day of the year, they are simultaneously conscious that something can go wrong, so during races they look after each other with the hope of avoiding that.

Being in a group provided support to the shyer participants. It was crucial for the purpose of this study to have at least one person able to break the ice to discuss such a sensitive and significant topic for all the participants. It is relevant to remember that generally, they need to show how good they are to keep them engaged in relevant races and, hence, earn money.

The participants used two safety vests to motivate and illustrate their remarks, with indications of dissatisfaction about the products. Eventually, this stimulated them to open up about the taboo topic of jockey safety. During this data collection stage, participants felt safe and comfortable to open up about their problems. The author/moderator was already known to them, and feelings of comfort were reinforced by the participation of two well-known former jockeys who could provide extra support to the youngest participants.

The focus group provided the author with plentiful and useful data. It was easy to gather interesting data, but analysis was harder when compared with that obtained from the individual interviews because the data was obtained in a social atmosphere, so required interpretation inside the context (Mishra, 2016).

The whole group appreciated the time offered to discuss such an important product (safety vest) for their careers and what eventually experienced with it in case of falls. The occasion made them feel valued because their opinions were considered integral to finding a solution to the shortcomings of the vests. This pre-existing group of participants registered consistency because most of them also participated in the semi-structured interviews and they were subjects of the observation phase. As mentioned in Chapter Two of this thesis, the author has found no papers that have utilised participants in this way. The focus group was audio-recorded, and then the recordings were transcribed to facilitate the data analysis. All the people who participated in this activity demonstrated good interaction and support for this study.

4.7 Observation phase

To develop a holistic understanding of jockeys' and medical first responders' experiences of safety vests, the author believed that observation was useful in this study, since observing people in their natural settings would enable the design researcher to acquire a rich understanding of the design context (Kurz, 1983).

The two main methods of observation are non-participatory and participatory observation. The author adopted a non-participatory method of watching the participants directly without any involvement. The benefits of this approach to the research aims were that keeping a distance from the participants, while demonstrating no involvement in their activities, would prevent any influence on their activities and allow the researcher to record notes and facts. The risks faced by the author during this process were time management and its consumption, and the eventuality of observer bias.

According to Flick (2014), it is not possible to define the preferred amount of time that should be dedicated to observing participants in a study, but the more time employed, the better. Therefore, to collect more secure data, the author used every occasion possible to observe participants. This also enabled the author to establish a trusting relationship useful to conduct the interviews and focus group.

This data-collection phase took place as a supplementary data-gathering technique. Discretion was employed when observing the participants. The observation was conducted mainly at the Flemington, Caulfield and Ladbrokes Park racecourses, which are all near Melbourne, Victoria. The author was able to watch the participants in familiar environments, such as around the track, in the jockeys' room, the press room, the main community room and the weights room. More observation was performed at the Apprentices School, which is close to the headquarters of Racing Victoria, and at the Exercise Research Australia (ERA) fitness sessions. Observations were recorded with notes and some photographs.

This activity enabled the author to understand participants' behaviours and feelings. Particularly, jockeys were observed handling their safety vests both during and outside races. The author saw that each jockey meticulously selected the best safety vest for their races with the aim of respecting the weight limits but remaining light in weight. Jockeys sometimes took care of the vest during breaks between races to maintain it. The vests play a core role in their professional lives and they spend most of their time with a vest.

The medical staff offered another point of view on their interactions with safety vests and jockeys. They have good knowledge of these products and the approved brands. Jockeys shared their thoughts with the medical professionals, who felt responsible for the jockeys' wellbeing and put effort into helping as much as they could. This group of participants shared their deep knowledge and enthusiasm regarding the safety vests with the author.

4.8 Data analysis

The qualitative data collected during the interviews, the focus group and the observations were recorded using an audio recorder, and the author took notes. The goal in analysing these data was to produce an accurate representation of participants' thoughts and responses, which were combined during analysis to build a picture of users' and co-dependent users' needs regarding safety vests for jockeys. This analysis could group data into consistent topics.

This part of the study utilised NVivo Version 12 software as a support tool to identify and collate discrepancies in the data and prepare those for thematic analysis. The use of NVivo Version 12 software assisted the author in organising and breaking down the interviews and focus group data by assigning codes to words and phrases within the data, these codes being actively identified by the author as having meaning in relation to the research questions.

Following this phase, most of the qualitative research handbooks underline that data analysis should concern on interpreting meaning rather than aggregating, describing the categorised and coded data. According to Geertz (1983) the main aim of the researcher is to produce a "thick description" of the research context. To achieve this, the coding process utilises narrative forms, e.g. snapshots and quotations, along with formal analysis to seize the variety of meanings of concepts for the participants. Glynis (2006) argues that the data should first be organised by themes, then the researcher can initiate to determine how the research data are related to the questions and problems being analysed.

The author of this study focused on going beyond the immediate meanings of the participants' comments to establish a deeper understanding of the data gathered to better address the research questions. Collecting data as audio-recordings offered the benefit that their retention as recorded documents enabled access to them at any time to reconstruct detailed transcripts. The author could analyse the recordings by listening to small parts at a time, and could repeat the most significant and interesting parts to gain a better understanding.

Interviews and focus group data were divided into two types: audio and text. The audio data were then transcribed into text. Subsequently, interview questions and transcriptions were reviewed to obtain a general sense of the data gathered. The text was analysed as a proxy for experience, while the transcripts as text were analysed using thematic analysis. This process generated generic themes, which were classified systematically into sub-themes according to Chapter One, section 2.1 of this thesis. To improve the accuracy of the data interpretation, the author frequently referred to the audio data collected and its transcriptions.

Content analysis is a common data analysis approach, and it was used to obtain results from the semi-structured interviews, the focus group and observation data (Cavanagh, 1997; Hsieh & Shannon, 2005; Scott, 2006). According to Hsieh and Shannon (2005), there are three methods of content analysis: conventional, directed and summative.

"Directed content analysis could be described as being deductive in nature"(Humble, 2009, p.37). In this case, the author started with a directed approach, beginning with analysis of safety vests for jockeys and their standards, and then using those data as guidance for initial coding. This choice aimed to reach the goal to "validate or extend conceptually a theoretical framework or theory" (Hsieh & Shannon, 2005, p.1281). Each method implies coding, which begins with a close reading of the data. This first phase is often referred to as "open coding", which Saldaña (2009, p.4) defines as "the transitional process between data collection and more extensive analysis". "Axial coding" is then undertaken to understand the interconnections and ratios between codes and themes.

To develop themes from the data gathered, the major research questions were answered and then followed up until an in-depth understanding of the main issue emerged through thematic development (Creswell, 1999). At the beginning of the data analysis, the author identified a large volume of codes, which subsequently could be reduced according to the identification of a few major themes through the elimination process.

Case study research is often criticised because associated with bias and weak construct validity: however, manifold sources of evidence are used in and across investigations to supply multiple perspectives about the case (Miles & Huberman, 1984). From a holistic perspective, the convergence of data from a variety of sources and sites offers many measures of the same case (Yin, 1994) and provides stronger substantiation of ideas (Eisenhardt, 2007; Leonard-Barton, 1990).

The subjectivity of ethnographic methods and the nature of case study research often brought to think that biases introduced by the researcher during the data collection and its analysis may occur. In this case, particularly in participant observation and semi-structured interviews phases, effects arising from the author being on site were somewhat unavoidable. As per Walsham (1996), being on site and share concepts and interpretations with participants, brings the researcher to influence what is happening. These limitations are also recognized by Hammersley & Atkinson (2007), that state that the awareness of these limitations helps the researcher in reducing and controlling the reactivity.

Each research method intrinsically has certain inbuilt biases and perspectives: however, the author utilized in this study multiple methods and sources of data to reduce possible bias to construct a more holistic, objective and credible picture of a case study of primary and dependent-secondary users in practice. Hence, in this study, by involving diverse participants and including multiple methods of data collection, the biases and uncertainties of convenience sampling were reduced.

The framework for data analysis drew on theories from the NPD literature and, following Moultrie, Clarkson and Probert (2007), was particularly based on six stages of activities:

- market learning

- setting design targets
- product specification
- prototyping to reduce technical risks
- maintaining the design vision
- a structured development process.

According to Moultrie et al. (2007), these six stages allow new sets of questions to be asked during data collection, which unfolds as an iterative approach that moves between the data and existing definitions and categorisations of NPD to enable concept formation and causal inference. Thus, the iterative approach effects a systematic, repetitive and circular process in research, and therefore enables an analysis of rich data, which are focused on the collection of specific rather than general information, as the basis of reliable and accurate qualitative research (Mills, 2010).

Braun and Clark (2006, 2014) recommend the use of thematic analysis (TA) to help further with the framework and coding of the data gathered. TA is particularly useful when qualitative research is utilised to develop applied research, as it offers a 'toolkit' for researchers who aim for strong, sophisticated analysis of qualitative data so that they can present them to be readily understood by lay audiences (Braun & Clarke, 2014).

TA was particularly applicable to support this research due to the nature of the study and the non-academic participants involved. Focusing on the users, the author agreed with Creswell and Plano Clark (2007, p.23) that a qualitative researcher acts from the "bottom-up, using the participants' views to build broader themes and generate theory interconnecting the themes". In this study, the two dependencies (jockeys and medical professionals) guided the author in the depth analysis of safety vest design. The analysis drew on the interpretation design knowledge in the literature and in industry, communications and propositions arising from the interviews and the focus group and participants' observation.

4.9 Addressing the limitations of case study research

Stake (2005) regards case-study research as a scarce method, lacking in rigour. However, Flyvbjerg (2006) rebuffs criticism, stating that case-study research is not lacking in rigour, nor does it have more bias than other research methods. Yin argues that the aim of case-study research is not to provide absolute truths, but the proof depends inevitably on the context while bias can be found in any type of research (Yin, 2003a).

However, both Flyvbjerg (2006) and Yin (2003a) recognise that case studies can rely strongly on previous experience acquired by researchers along with the worth of things, even if this has value. Stake (2005) reports that, in qualitative research, the researcher can be affected by many factors. Nevertheless, to establish the rigour and reliability of research, sufficient proof of its findings should be provided along with interpretations and reasons for them in case some interpretations are rejected (Darke, Shanks & Broadbent, 1998).

Hence, to establish rigour in this study, the author used the technique of informal reviews to cross-check the findings across all the data gathering stages. This method allowed the author to review the findings in their formative stages, rather than utilise an external review process at the end when the analysis was finalised. Thus, the author constantly checked the findings to avoid biases about participants. To be successful with this process, the author relied on people inside this research process (supervisors) and on people from the racing industry.

The author recognises that case studies as a research method are context specific; thus, findings are of less significance because they are not generalisable, and this is a limitation. However, analysing the design of safety vests for jockeys is a practical endeavour. Hence, the author particularly considered how transferable the findings of this study were to horse riders, medical professionals and researchers.

4.10 Summary

As an early study in the field, this thesis has argued for the composition of the qualitative-research design based on its relevance to a UCD process grounded in understanding participants' experiences with and perceptions of safety vests.

The use of qualitative research in this study enabled the author to act as an instrument to gather the data required from a natural setting, but still as a way to obtain answers to research questions. Qualitative research focuses on meaning in context, employing data-gathering instruments that are sensitive to hidden meaning, both for collecting and interpreting data. This chapter has explained that research design is based on a constructivist epistemology and takes a qualitative, interpretive sense-making approach to guideline-building. It has set out the mixed methods of data collection and analysis utilised in this study.

Chapter Four has established that this study did not seek to present generalised advice from one case for application to the rest of the industry, but rather to develop a deeper, richer understanding of the process, issues and suggestions at play within the subject of safety vests for jockeys. However, this study is among the first to be undertaken in the field of interpretation of safety-vest design. As such, it examined the overarching aspect of these products and developed some preliminary explanatory frameworks as a grounding for further research into the role of a UCD product innovation.

This chapter has provided an overview of the data collection stages, the reasons why these methods were appropriate for this study and how the data gathered were analysed. Interviews, the focus group, observation and analysis were activities central to the qualitative research, the researcher being the primary instrument of data collection and analysis. Hence, the use of a predominant inductive approach to this study allowed the author to start with specific observations of safety vests for jockeys, and then to move to the detection of related topics and models in the data (Zhang & Wildemuth, 2009).

The following chapters will provide further details about the results and findings, along with chapters dedicated to UXD and the relationship between user and product. Specifically, Chapter Five offers a critical analysis of the user’s role because an accurate understanding of user needs is essential in developing commercially successful products.

Chapter Five: Critical Analysis of the User's Role in Product Innovation

> "The 'Design Thinking' label is not a myth. It is a description of the application of well-tried design process to new challenges and opportunities, used by people from both design and non-design backgrounds. I welcome the recognition of the term and hope that its use continues to expand and be more universally understood, so that eventually every leader knows how to use design and design thinking for innovation and better results" (Moggridge, 2010)

The world is changing fast and is characterised by strong competition, and complexity of products and process. The market success of a product depends on criteria such as strong process development, fast production and good timing of market entrance (Žargi, Kušar, Berlec & Starbek, 2009). To achieve this success, it is necessary to take into account the user, in terms of needs, during the product-innovation process. Acquiring knowledge about user needs is key to designing a successful product.

Considering the scarce knowledge in this field discovered during the review of the literature and the absence of UCD in creating safety vests for jockeys, this chapter set outs the main characteristics of UCD and UXD. The user and the co-dependent user have core roles in product innovation, so the author has justified their inclusion at the centre of this process and the importance of enhancing the safety vests' features of sustainability and wearability. Jockeys' safety vests and their standards are due for reform and innovation. For all these reasons, this study investigated the product designs as a balance of the ability of the vests to withstand force, technology, aesthetics, ergonomics and innovation to achieve a good design (Martin et al., 2011).

5.1 Overview

A product innovation is often related to the introduction of a product or service that can be new or can show improvements over a previous product or service in terms of characteristics or intended uses. Evidence from firms that use product innovation varies across countries. However, companies often adopt mixed methods of innovation that combine product and process innovations. Product innovation also means different things to different people, but, since the 1970s and throughout the industrial world, companies have invested increasingly in product improvement (White, Braczyk, Ghobadian & Niebuhr, 1988).

Technology is constantly advancing and this constantly reshapes the work: according to the World Bank's report (2019, p.72) "advances in technology call for new skills seemingly overnight". Technology brings opportunity and applying it to safety vests might ease the users' lives and thus generate innovation. However, the review of the literature in this field demonstrated lack of information regarding innovation in the design of safety vests for jockeys. Hence, the author examined two crucial design methods, UCD and UXD, prior to considering a product innovation of safety vests.

5.2 A brief analysis of user-centred design and user-experience design

Good design means more than an attractive product. The product's aspect is actually the last phase of the UCD process. This process comprises strategy, research, analysis, design and production phases, and its employment enables consideration of users' needs and ways to satisfy those needs (Magain, 2013). The process is successful because it contains the opportunity to understand fully the users of the product. Whether people will experience the product is likely to be affected by how it has been designed, rather than who has designed it.

The understanding of users, their needs, duties and habitats represents the basis of a design: it is process driven and affected by user-centred evaluation, which involves the users' experience. The first step is the analysis and planning phase, followed by development of concept during which information about the users' requirements is gathered, preferably from different sources. This enables specification of the context of use and the requirements that the product needs to address. Then, in the design phase, rough and unpolished sketches come alive. Aesthetics is important since users prefer a beautiful appearance and this persuades users of its ease of use.

Good design shows a balance between aesthetics and accessibility. The design phase usually concludes with the prototyping of the product and is followed by the implementation phase. The final step is the launch of the product. Hence, the UCD process is an iterative cycle, in which each phase is considered against the identification of the users' needs at the beginning of the process (Garrett, 2002).

UCD is used to indicate approaches and positions in design that originated in debates during the early 1960s. UCD characterises both a design philosophy and a set of methods that endeavour to design while taking into consideration people's needs, preferences and abilities and the context of the product's use, rather than forcing users to conform to a certain design. The users are involved from the analysis phase to help with the development of goals and with task analysis (Harte et al., 2017).

UCD is at the core of designer-dictated design that considers people as an extension of the designed artefact. Some authors (Hanington, 2003; Siu, 2003; Krippendorff, 2005; Redström, 2006) argue that UCD does not concentrate on the general end-user notion implicit in the approach to design experienced in the computer industry, in which people need to operate efficiently to suit technology, but rather on the human complexity of design. The UCD literature, in contrast, is mainly focused on the areas of human-computer interaction, giving importance to legibility, accessibility and navigation.

UXD focuses on the experience of what is designed. According to Garrett, user experience relates to the way in which a product works on the outside, hence, where the users create a connection with it and have to work with it (Garrett, 2002). Therefore, the direct involvement of the users in this study generated valuable data to sustain the aim of the research. UXD indicates how the users feel, and what they expect when thinking about the product. However, every person is an individual and therefore every user interacts with the product and situation in a different way. The users are required to be protagonists, and designers need to listen to them to produce an innovative and winning design.

Users have different requirements based on their conditions and skills. Satisfying these needs and providing access to the product for as many users as possible represent the aims of inclusive design. In the present case, the jockeys interact daily with safety vests in a personal way. However, because the vests are mandatory, jockeys are only required to purchase them thus, they ignore the products' meanings. Purchases are largely cost driven and users may not be persuaded that innovative features provide benefits to justify these costs and enhance their experiences (Anttonen, Halme, Houtbeckers & Nurkka, 2013). As discussed until now and with the aim to help the reader, the author created Table 8 to show the main equalities and inequalities that UCD and UXD possess.

Table 8. User Centred Design & User Experience Design features

USER CENTRED DESIGN	USER EXPERIENCE DESIGN
The focus is on the user (user experience & user satisfaction)	The focus in on the user
Driven by user input	Driven by the need for creating products that provide meaningful and relevant experiences to users
A considerable user involvement • User studies • Participatory design • User feedback • User testing	A considerable user involvement. The design of a product should focus on: • offer a great user experience • create for the entire process of acquiring • own and troubleshoot it • provide pleasure
Design by iterative prototyping	Design by emotional design, creative thinking and prototyping.
Highly varied, informal or unspecified process	The process encompasses the entire user journey, it's a multidisciplinary field
A continuous approach of discovering, design, evaluate what users' needs	A continuous approach of user research, design and evaluate against requirements

According with Table 8, UXD is a process of intensifying user satisfaction with a product through its accessibility, usability and the pleasure generated by the interaction of the user with the product. Hence, the author chose to study the users, both jockeys and medical staff, interacting with the safety vests in their natural environments to support the aims of this study (Kurvinen, Koskinen & Battarbee, 2008).

Importance was also given to adopting multiple perspectives in respecting the time that users made available or shared with the author: it was crucial to differentiate problem solving (achieving the design in the right way) from problem setting (achieving the right design) (Buxton, 2007). This approach supported the aim that the user should develop and obtain a great experience with the product, while the use of a holistic approach enabled focus on the design.

The design process also demands verifiable data. Thus, this study checked first how jockeys experienced safety vests in the context of races and track work, including the particular meanings attached to their use, and secondly, the events that unfolded in the case of a fall. The features attributed to a product according to the product ecology helped the author to understand the ways in which users built social relationships with safety vests. These features encompass the products' aesthetic, emotional, functional, social and symbolic dimensions (Desmet & Hekkert, 2007). A similar verification affected the medical users. Therefore, the approach was to understand the safety vest as part of continual activities and experiences, especially in the event of a fall, at which point the jockey became part of a medical process to which the vest could contribute.

User research should reveal users' needs and preferences. To meet this requirement, the author used qualitative exploratory methods, including participant and non-participant observation, a focus group of users in their natural environments, and individual semi-structured interviews to develop and solve the research problem.

During the last 10 years, UX has become crucial in the fields of human computer interaction (HCI) and interaction design. Interactive products have become usable and functional, but also fashionable and desired objects (Hassenzahl & Tractinsky, 2011). The effective system increases its importance because the user experience acts via a human perspective, focused on positive emotions to prevent users' dissatisfaction.

Determining users' needs is crucial because companies need to develop products that will last in the marketplace. The UX research focuses on positive users' emotions, such as delight, pride and enjoyment. These are feelings not associated with jockeys' safety vests. Listening is an important skill for a designer to demonstrate empathy, and because all people/users are different: hence, an anthropometric analysis gave support to 'fit' the users, and with the observation of the study participants in a ‘day in the life’ process, deeper insights were provided (Curedale, 2013).

Anthropometry plays a core role in modern industrial design, clothing design, ergonomics and architecture to optimise products. Through the application of ergonomics, it is possible to understand human factors in the design of equipment to improve comfort, safety and health (Environmental Ergonomics, 2012; International Ergonomics Association, 2013). These design research methods allow the creation of design solutions based on experienced human needs, in a field where these approaches are unexplored.

Users may have different goals when they use the product. These goals reveal the information requirements that need to be addressed in order to reach a high level of usability. Even in the case of this study, users may try to satisfy different needs when using the safety vests: better comfort while riding, a higher level of safety, a feeling of freedom, or a tool on which to rely for a quick safety response.

Hence, the author preferred a qualitative research method to justify the aims of this study. Inspired by the UCD process as a dynamic and multi-dimensional cycle that involved research, defining, creating and testing, the author began the research by identifying the people who primarily used the product (jockeys and related medical staff). Then, the reasons for using it (it is a safety tool) and under what circumstances it was used (horse racing) were considered.

According to the UCD cycle, the defining stage is the establishment of the user needs and goals that the product must meet. This is based on user research. After this the iterative design can begin in successive stages to arrive at a viable test design. A consideration is needed of how users perceive products on many levels. These perceptions could move potential test designs to the centre of any design developments (Cohen, Withgott & Piernot, 1999; Green & Jordan, 2002; Gibson, 2014). The users’ involvement in every step of the design process generates the most successful results. In addition, the meanings are integral to products even in excess of their functions. These notions have been lacking in the development of safety vests (Ewen, 1999).

Jockeys rely on safety vests as a primary source of protection because vests are compulsory safety gear, but they should also experience ease and comfort.

Even the medical staff providing help to jockeys could benefit from well-designed safety vests, in that the product should provide critical assistance in the case of a fall. Jockeys should wish to wear a safety vest because of the protection provided and not see it as an encumbrance or imposition, because the meanings and emotions attached to a product are an important supplement to its functionality. Products can be viewed in terms of their appeal, with product emotions arising from users' feelings or previous negative experiences related to a particular product. To date, this approach has not been considered when considering the role of design in this field.

Evaluating the design of safety vests leads to the possibility of applying the latest technologies to the product. The safety vest could become part of the new range of protective smart wearables, with the aim of designing an advanced product ecology. Taking into consideration that evaluation of aesthetic quality is based on the context, aesthetic appreciation of innovation is dependent on dynamics and framework. The present study has remarked that this aspect is lacking in consideration of safety vests, but that it is important for user experiences.

5.3 Analysis of Radical Product Innovation versus Incremental Product Innovation

Innovation is trendy but important. It seems noticeably lacking in this field. The word 'innovation' derives from the Latin noun *innovatus*, which means renewal or change. The first known appearance in print was early in the 15th century, and it is therefore not a new word (Kwoh, 2012). In the productive sector, it is ordinarily defined as the creation of novelty of economic value. Hence, innovation can be translated into the creation of new products and services: indeed, both invention and creativity can be found in innovation (Marceau, 2011).

Designers choose to innovate products radically or incrementally. This means that industrial design plays an essential role in the development of innovative products. Jockeys' safety vests need to become an innovative product because they show a very basic and unsatisfying design, which is demonstrated by the lack of innovation.

The primary obstacle to this are the standards, which have been in use since 1998 but maintain a classic approach in this field. Hence, to obtain a balance between safety and comfort in terms of safety vests, a designer faces two options: use existing technology to improve an existing product by enhancing everyday design, or employ a radical approach.

Each of these choices has its advantages and disadvantages (Fullagar, 2015). In the safety vest market, the opportunities for improvement are represented by:

- basic and rigid design
- paucity of ergonomics
- lack of advanced materials and technologies
- spinal area not adequately protected
- absence of UCD approach
- the rules and sub-rules in the standards regarding safety vests are not updated regularly, so they limit innovation and use of ergonomics.

To respond to these issues, an incremental innovation approach may offer the following advantages: the product remains competitive; the new idea is easy to sell because it is added to an already recognisable product; it can be a reasonably priced development; and there is a huge market. Besides, the main opportunity in this process of innovation is that design starts with needs and not solutions: a great idea that starts from needs enables incremental innovation to follow.

However, a radical innovation approach offers a bigger win, the opportunity to create a whole new brand and market, and to open the door to new companies. These characteristics perfectly complement the safety vest market. Eventually, innovation may be the answer to most of the issues that jockeys attribute to safety vests.

Successful innovation relies on creative people because, to introduce a new product, thinking outside the box, or thinking as if there is no box, is required. However, invention is a mindset while innovation is a thing. Product design plays a core role in easing the introduction strategy for a new product. “Design thinking” is a human approach to innovation that places the findings and observation of human needs at the forefront of the innovation process. It contributes to a cognitive elaboration by humans to appreciate an innovative design, and it offers the right approach to the aims of this research (Carbon et al., 2013; Mugge & Dahl, 2013; Gruber, De Leon, George & Thompson, 2015).

Jockeys' needs are not adequately satisfied by safety vests because are still perceived uncomfortable to wear during races and yet not good support in minimizing falls' injuries. An innovative product is required that is appreciated because of its aesthetics, and that is dynamic and context-dependent, and therefore highly adjustable to the changes occurring in the world.

Jockeys are also dissatisfied with the vests due to the lack of ergonomics they experience when wearing them. These safety vests show a lack of appreciation for the users' needs because according to Crawford and Di Benedetto (2014, p.314), a "deep understanding of customer needs is required in order for the firm to translate a high-potential technology into a product that provides meaningful benefits to the customer. Collaboration with end users and capturing the voice of the customer are important ways to get this depth of understanding, now sometimes referred to as user-oriented design". This determines design as the sum of technology and human needs translated into manufacturing products. This contrasts with the view of some designers who seem to perceive materials and use of technologies as the only means to translate design into products.

To summarise: an original and provocative design can arouse emotions, stimulate the users in purchasing it and generating positive experiences for them (Micheli, Jaina, Goffin, Lemke & Verganti, 2012). These characteristics are lacking in current safety vests for jockeys. The failure of design-driven innovation to improve them is probably a result of what the New Product Development (NPD) literature identifies as manufacturer-driven design.

In regard to design-driven innovation, it is pertinent to mention Verganti (2008) who appraises international manufacturers such as Alessi or Apple. In the case of Alessi, Kartell, Apple and Bang & Olufsen, design-driven innovation is the radical innovation to a product's meaning. This is why design-driven innovation may not represent the perfect answer in the case of safety vests for jockeys, but rather a case of a "conversation with the market", as argued by Verganti (2008).

Radical innovation of uses and meanings can be achieved only when a design-driven innovation approach is employed. The author aimed to be the interpreter of both jockeys' and medical staff's needs, to generate guidelines for a new design to be applied to safety vests. The often-cited example of Swatch can be followed to develop jockeys' safety vests, bringing new meanings for both groups of users. Verganti offers a deeper analysis of the Swatch. Verganti argues that the brand radically revised product meanings so that the product, known originally as an ordinary watch, came to epitomise fashion and emotion (fun) (Verganti, 2008).

The idea to convert the well-known Swatch brand from watch manufacturer to trendy product maker can be used as inspiration in the safety vests' field. Studies in cultural anthropology and cultural branding have shown that a product's meaning concentrates around archetypes. Thus, some products can attain the status of icons, having a longer life than those of normal competitors (Holt, 2003).

Dumas argues that, where design is central to the concept phase of the development of technological products, iconic design can be the result (Dumas, 1994). Hence, the relation between design research and technological research, which was also utilised during this study, allows the targeting of the users' needs to develop the best product, as illustrated in Figure 26.

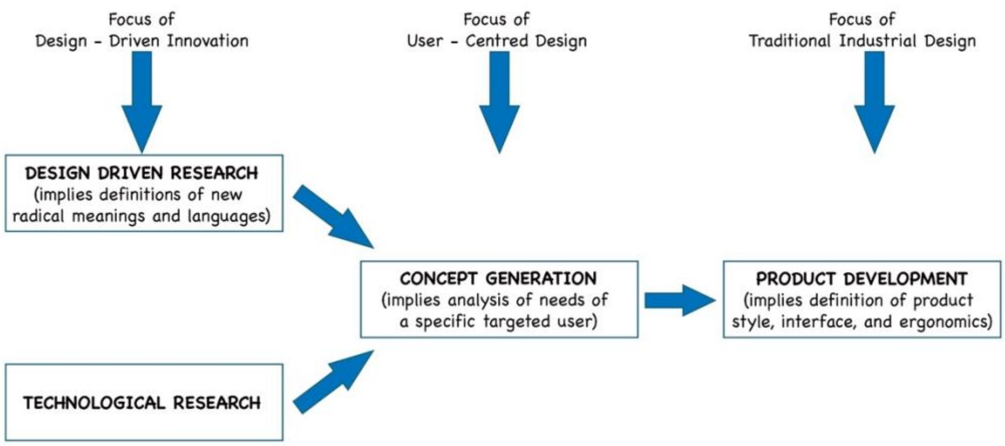

Figure 26. Design-driven innovation as research

(McCartan, Thompson, Verheijden & Morgan, 2015)

The design research phase represented in Figure 26 shows the exploration of users and meanings in NPD in the context of advanced materials and new technologies. UCD requires deep analysis of the needs of a specific targeted user, so the scope of NPD can only be reached through design thinking to creatively produce new product concepts (Verganti, 2008).

The role of design is the centre of this thesis. Therefore, it was significant to consider the qualitative research approach chosen for this study. Indeed, research has two forms in design: the first form is research as exploration and experimentation, while the second is research as any activity that collects and analyses data.

Another relevant distinction to make is between quantitative research, which is statistics-based and involves questions to which the answers are numbers, and qualitative research, which utilises observations of people and/or events to analyse the data gathered through a qualitative method and which searches for trends.

In 1942, the term ‘creative destruction’ was first introduced into the literature by Schumpeter, who stated that focusing only on old technology tended to enable radical product innovation to jeopardise the market position. Therefore, a product needed to incorporate new technologies if it was to survive in the market (Cunningham, 2010). Although technology is part of our lives, many applications are not yet developed because old knowledge often settles and becomes isolated within a particular domain. New knowledge then has difficulty in gaining exposure. This was the case in this study. This is a good explanation of the vicious circle created between the paucity of innovation and the safety standards for safety vests.

Radical product innovation has not been involved in the design of jockeys’ safety vests, so the UCD method becomes ignored. The review of the literature that discussed radical product innovation (Porter, 1985; Porter, 1997; Herrmann, Tomczak & Befurt, 2006) produced four explanatory stages regarding radical product innovation, which were considered in this study. These stages are:

- abandon existing knowledge
- acquire fresh knowledge

- translate the knowledge into core competencies
- develop new products

Thus, incremental product innovation is the dominant form of innovation. It upgrades the performance of existing products. Hence, to create a radical product innovation successfully, even in the design field, knowledge is crucial. According to Garud (1997) and Herrmann et al. (2006), knowledge can be subdivided into three categories, which are shown in Table 9.

Table 9. Categories and competencies of knowledge

(Garud, 1997; Herrmann et al., 2006)

CONCEPT	CATEGORY	COMPETENCIES	MEANS	KIND
KNOWLEDGE	Description = Know How	Information about products, process and markets gained from experience. It represents the key success factor in stable market.	Through a process of learning by doing	Tacit Knowledge
KNOWLEDGE	Explanation = Know Why	It represents an understanding of the principles underlying phenomena.	Through a process of learning by studying	
KNOWLEDGE	Design Knowledge = Know What	This perspective allows a differentiated interpretation as a dynamic system of generating and applying knowledge.	Through a process of learning by using	Explicit Knowledge

Table 9 indicates that 'know how', 'know why' and 'know what' components of the intellectual capital are involved in the design, manufacture and use of technological systems. Jockeys' safety vests represent an unmet market need in which radical product innovation can improve the role of design, possibly with the involvement of incremental innovation to enhance or upgrade the vests' design.

Hence, the safety vest is a good example of a product for which UCD is ideally suited to incremental product innovation, due to its emphasis on the existing needs, wants and interests of the user. Therefore, the main difference between radical product innovation (RPI) and incremental product innovation (IPI) is the starting point.

NPD literature highlights that success depends on several factors: accurate market forecasting, prediction of user needs and specifications; technical resources and skills; concept and product development; planning quality; and identification of users' needs or wants (De Brentani, 1989; Parry & Song, 1994; Mishra, Kim & Lee, 1996; Workman Jr, Homburg & Gruner, 1998; Balbontin, Yazdani, Cooper & Souder, 2000). These success factors should be applied to the design of and standards for safety vests for jockeys.

5.4 Why transform safety vests into sustainable wearables?

This section aims to understand why safety vests have not been converted into technologically smart protective garments to enhance jockeys' safety.

Sustainable wearables are currently debated in the context of improving the quality of individual lives, social impact and social public interest. These wearables have applications in areas such as wellness, healthcare and public safety (Lee, Kim, Ryoo & Shin, 2016). Wearables are important because, in the future, they will track data and collect extended objectives and meanings that are vital for users: this should be applied to safety vests as well.

The ultimate wearables are considered to be smart pieces of clothing that incorporate body sensors, or trackers, which can be integrated into everyday life by being discreetly hidden in a garment or footwear. The sensors can track specific physiological or biometric data (Report Buyer, 2017). According to Ed Gillespies, founder of Futerra, wearables should not be just beautiful, useful and sustainable but should address a specific human need (Kapfunde, 2017). The smart textile industry is experiencing a lot of experimentation and innovation, growing in complexity, form and function while facing issues related to cost and durability. However, its potential is clear. Sustainable wearables are created to solve real problems or improve lives, incorporate recyclability and look to the future: a triple purpose that should be applied to jockeys' safety vests.

Current applications of smart clothing and body sensors include sports, consumer goods, healthcare and industrial settings. Although trackers are very popular among sports players, it has been estimated that the sports market for these products will not represent the largest portion because of the huge potential in the health market: the population of athletes is much smaller than the population of patients (Report Buyer, 2017).

Tractica (2017) forecasts growth in the number of shipments of smart clothing from 968,000 units in 2015 to 24.75 million units in 2021, indicating a compound annual growth rate (CAGR) of 71.6%. It also foresees growth in the body sensors market from 2.7 million units in 2015 to 68.0 million units in 2021 (Tractica, 2016). Jockeys belong in this niche market as the benefits they could enjoy from wearing body sensors are huge and could enhance their safety.

Examples of electrified technologies embedded in garments (such as large battery-powered heating systems) existed in the early part of the 20th century. The technology was more commonly embedded through mechanically produced or reproduced textile designs, whose aesthetics were derived considerably from machines made of moving parts. Nowadays, conductive metallic thread discreetly enmeshed in a fabric weave can enable a “live” garment to send an impulse to innumerable electronic devices either embedded in or external to the garment.

Wearable products had their most important explosion in late 2014, when the private consumer market started to feature items such as smart glasses, smart watches and health trackers. Following this boom, other experts forecast that the global wearables market would reach a value of US$19 billion in 2018 (Statista, 2016), which was more than ten times its value five years prior, when only military forces and medical professionals were the beneficiaries of wearable technology.

In 2017, the analysts revised their forecasts due to high demand: 411 million smart wearable devices are expected to be sold in 2020, with a value around US$34 million. Instead, in 2017 the industry was “only” expected to reach a value of US$14 million (Lamkin, 2017). However, with all the smart technologies available (smart wearable products, smart application and textiles), the market is forecast to grow from US$15.74 billion in 2015, to US$51.60 billion by 2022 (Markets And Markets, 2017). Smart wearable products need a balance between design, technology, comfort, human-computer interaction and their social context. If all these constraints are satisfied, without forgetting the business and marketing aspect, a real product is achieved (Martin et al., 2011).

Nowadays, the most popular and best-known wearables are smart watches and health fitness trackers such as the Fitbit, Garmin Vivosmart HR and Jawbone UP2 (Materia, 2008; Stables, 2016). According to forecasters, the fitness and activity trackers will account for more than 50% of the unit sales in 2019, with 245 million wearable devices sold in 2019, up from 84 million in 2015 (CCS Insight, 2016). A pioneer sportswear brand, Colmar, has already started to use graphene to produce a new collection of smart fabrics tailor-made to the users' comfort while still ensuring their performance (Kapfunde, 2016). These data represent a positive scenario in which safety vests for jockeys might be inserted. Use of the latest technologies and advanced materials could enable these products to transmit information on the location and severity of injuries, perhaps to become a vital part of the post-fall treatment process.

Luxury wearable technologies for horse riders have become popular: a good example is represented by the Swarovski bracelets (Charara, 2015). With a simple app to track body movements, this range offers different models to choose from in many colours and all have Swarovski crystals inserted.

While wearable technologies have become well spread in sports (Wareable, 2016;), only a few, however, have been considered applicable to the horse racing sector. The majority of smart gadgets available are designed for the horses rather than the riders. Equine monitoring devices and sensors are able to track the wellbeing of horses (Nguyen, 2016a, 2016b). The welfare of horses influences the safety of riders. Hence, another smart device, an example of which is the Equimètre, monitors the wellbeing of horses during races or track work, with the intention of reducing fatalities because early detection of problems should improve diagnosis (Marcellin, 2016).

A recent investigation by Gandy, Bondi, Hogg and Pigott (2014) utilised an inertial sensing technology capable of registering rider hip rotation asymmetry. In this case, horse riders are the principal users of a wearable sensing technology. This technology requires further advanced analysis, but it is just one of a few available for horse riders rather than horses (Gandy et al., 2014; Lyte UK, 2017). The fast evolution of smart devices is affecting the horse racing field, but at the time of this study, such specific gadgets are not yet applied to jockeys' safety vests.

The current lifestyle wearables on the market are now well spread into our lives, and are still increasing in popularity. However, their functions remain elementary in terms of data provided for practical and usable applications towards health improvement, showing a considerable need for biomechanical analysis during activities within professional sports, physical therapy programmes and the fitness industry. Biomechanical analysis utilises the laws of mechanics and physics applied to human movements in order to gain a deeper knowledge of performance and to decrease injuries (Simi, 2016; Biomechanics, 2016).

Because biomechanics is the study of the muscular, joint and skeletal actions of a human body while exercising or performing a sports discipline, it is relevant to consider it application to safety vests for jockeys. The option of tracking the movements of jockeys while they race can support medical staff in preventing injuries, and reduce the time of medical intervention when required. Besides, jockeys can securely store their medical histories to increase their performances and effectively increase their wellbeing.

Smart clothing originated in 2015 and many companies have started to use these garments. The author has considered the most popular and furthest-developed smart sports clothing to compare the possibilities for thoroughbred horse racing with those offered in other sports.

One example is the Polar Team Pro shirt. This is a smart compression shirt that contains a GPS sensor to capture heart rates, enabling users to collect and broadcast live training data (Polar, 2017).

Similarly, there is a shirt laced with sensors that can monitor heart rate, breathing and movement in real time. This is useful in sports such as cycling (Hexoskin, 2017). There are many products dedicated to women (Athos, 2017; OM Signal, 2017; SUPA, 2017) or to activities such as yoga (Wearable, 2017), swimming (Spinali Design, 2017) or tennis (Sole Impact, 2017).

Jockeys need garments for protection against impact: its consequences can be severe because the energy of the impact is transferred from the safety vest to the jockey's body. Thus, a more advanced material could absorb the energy by decreasing the strength of the energy's shockwave. The most popular shock-absorption products on the market are those made with Sorbothane (2017) or

Nitrex (2017), or developed by the United Kingdom-based company, D3O (2018). However, Nitrex is the only one that meets the standard EN 13158:2009 for equestrian body protectors because it is a visco-elastic polymer in a structure that can be temporarily compressed, with composite body-armour technology and shock absorption ability that has been certified. It is produced in a diverse range that can be applied to various design purposes (Nitrex, 2017). Instead, the private equity backed company named D30 makes shock absorbing solutions for its global partners: it has developed a chest protector but for two-wheel racers that claims type A coverage, and is soft, flexible and breathable for improved comfort and fit with a 2mm thick polycarbonate shell (D30, 2019).

This is another indication that current standards applied to the development of jockeys' safety vests represent an obstacle to the use of advanced materials and sensors. Nitrex meets the EN 13158:2009 standard, but this standard applies to all people interacting with horses, whereas jockeys require specific standards applicable to their unique situation. Air mesh and Nitrex are used in the Vipa vests (Velocity Impact Protection Apparel, 2018).

5.5 Summary

The review of the academic and industry literature found requests from the experts and of course from the jockeys for better designs of jockeys' clothing, such as Moss et al. (2002), Yim et al. (2007) and Gibson (2008). However, scientific studies have been performed in parallel with work in the design business, rather than the two working together to resolve this issue. This has led to a lack of innovation applied to safety vests.

Hence, this study aimed to investigate why and how design could be used as an aid to provide safety to professional jockeys and medical staff. In this case, the product design and development process needs to be considered as interaction between the scientific or engineering field and design (De Vere & Melles, 2011). According to Grasso and Martinelli (2007), a new kind of engineer is required who can consider human needs while working across subjects. In this way, importance is given to users' feelings and morale. Empathic design is a deficiency in the safety vests' field.

UCD requires design to be a participatory and iterative process, through which the framework is sensitive to what users bring into the design context (Dunsire, 2010). According to Cato (2001), the framework must be able to acknowledge that what a designer expects users to do and what the users actually do are often different, so the framework can be used to understand how good or bad the final product may be. Hence, focusing only on users' everyday life experiences and their desires and emotions, a human-centred design is able to interpret users' moods and become a problem-solving tool (Mattelmaki, Vaajakallio & Koskien, 2013). These criteria were adopted during this study. However, as explained in the conceptual framework described in Chapter Four, subsection 4.2 of this thesis, the author needed to consider the users and co-dependent users because they both relied on the same product's design.

The author observed the users through the designer's eyes but also utilising the empathic design as the key to enter into their world. This approach represented the closing of a big gap that had been discovered during the review of the literature**.** According to Ali (1994), a product innovation can be qualified as a novel product, completely different from previous ones, which has been a missing aspect when considering safety vests for jockeys.

The main weakness in the design-research literature suggested that a user-centred and an experience design approach was not enough for this study: there was a third party, the medical professionals, with specific needs that needed to be considered. The vests' performances as fall- and impact-protection devices were not sufficient, as the design also depended upon the co-dependent users, the medical staff, who had to engage with the vests to provide aid quickly to the jockeys.

The design literature also shows a weakly tied synergy with the technological innovation literature: design is still considered a wild land that continuously evolves, but human-centred design is needed to lead radical product development, which is linked to variations in technology or meanings (Cautela, Deserti, Rizzo & Zurlo, 2014). Therefore, this study proposed the need for researchers to examine the basis of user-centred/human-experience dependency design to satisfy the users' (jockeys) and the co-dependent users' (medical professionals) needs.

The following chapter sets out the details and criteria regarding the main protagonists of this study, jockeys and their safety vests, but with minor references to the co-dependent medical users.

Chapter Six: The Interaction between Primary and Secondary Users and a Product

The previous chapters have introduced Australia’s thoroughbred racing industry and the risk of falls to jockeys, to highlight the importance of wearing safety vests while riding. While critically examining the user-centred approach to product innovation, the author was encouraged to understand fully the role of both the user and the co-dependent user in the context of designing safety vests for jockeys, in order to consider who should be included in the definition of a product’s ‘user’. The author found that the majority of literature which considered the user was in fields such as medicine (Ray, 2003) and mobile communication and information services (DeLone & McLean, 1992; Nurmi, Lau, Suomela, Sutterer, Millerat, Martin & Lagerspetz, 2006; Sutterer, Drögehorn, & David, 2008).

Design and industrial ecology is an evolving field. Product ecology takes inspiration from the connection between human and environmental interactions, with the aim of obscuring the boundaries (Tansey, Dale & C t , 2006). Taking this into consideration, the author found that, to design safety vests for jockeys innovatively, a design-dependent situation should be considered in this study.

Medical professionals are the co-dependent users of safety vests because their quick and successful aid to injured jockeys relies on the vests’ design. This chapter focuses more deeply on the interaction between users and the product because the literature contains little information regarding the consideration of dependent users in product innovation.

6.1 Overview

Chapter Six focuses on the two main groups (jockeys and medical professionals) and their interactions with safety vests, and on the factors that affect these interactions. The chapter provides a product ecology, which is considered as a mix of explicit knowledge and intuitive opinion (Forlizzi, 2008).

The International Organization for Standardization (ISO) supports UCD principles, specifically, user-centred design processes for interactive systems (ISO/DIS 13407 Model, 1999). This standard stimulates designers in all fields to consider end-user participation as a characteristic of progressive design practice. Hence, an original contribution of this thesis is the move to break out of the typical approach to user/product interaction, which focuses on the interplay between the individual user and the product (Postma & Stappers, 2007).

For this research, a unique framework was required to reflect the product's two key user groups and their dissimilar interaction with the safety vest. This was in light of Forlizzi's (2008) argument that product ecology is based on social ecology theory because it seeks to understand how products evoke social behaviour. Each product experience has its own individual ecology and mediated dynamic factors. Users bring prior experiences and expectations to product interaction (Nurkka, Kujala & Kemppainen, 2009). The meanings that a product transmits can be varied for a range of people, at different times, and in disparate contexts (Sharma & Jamal, 2013).

Users' emotions help them to act in certain ways rather than in other ways (Norman, 2004). Thus, it was crucial to consider and understand the emotions and values of both jockeys and medical staff in relation to safety vests. The design of the vests not only creates a defined relationship with the jockeys but also with the medical staff.

The better the design, the more effective the help of medical staff will be. Thus, the author analysed the jockeys' feelings about the vests and the factors that might affect this interaction, and employed a similar approach to the health professionals, who were considered to be co-dependent users.

6.2 Factors influencing the product ecology of safety vests

In this study, jockeys represent the main users of safety vests and are unique in using the product as part of a horse and rider team. To be successful in this, jockeys have evolved their riding style to that of a crouched posture. Understanding jockeys' riding posture and their interaction with the mandatory safety gear, which comprised helmets and safety vests, allowed to deepen the author's knowledge regarding the product-ecology framework as an approach for comprehending jockeys' behaviours with the vests (Forlizzi, 2008).

The author took into consideration the functional, aesthetic, symbolic, emotional and social dimensions of safety vests to focus on these products. This reinforced the need to consider the users (jockeys) and the co-dependent users (health professionals). Usually, human behaviour is considered as an adaptive adjustment to an external environment. This relationship between human and environmental factors is complicated and dynamic, affected by factors such as social, cultural, institutional and historical contexts (Forlizzi, 2008).

The author then used the product ecology framework to understand the social relationship with the safety vests, because each product has its own ecology which generates subjective and individual experiences for each user. Observation of the subjective experience of safety vest use from a range of perspectives, particularly jockeys and health professionals, was useful for the author to discover knowledge for the vests' re-design.

To understand the social implications of the vests, the author delved briefly into the deep, old roots that the thoroughbred horse racing industry has in the fashion industry, as described in Chapter Six, section 6.3. Horse racing has always been a means of showing social status, and horse racing and fashion continue to have a strong connection. Flat horse-racing is the equine category that registers the least innovation and fashion in terms of jockeys' attire. The design of the compulsory safety vests has been stated to be conservative and not compliant with users' needs.

Jockeys are superstitious. During some races, they prefer to wear certain colours because racers who wore those colours in those races previously have won more often than those who did not. On other occasions, such as when jockeys purchase or are given a new uniform, they often throw the silk on the ground, trample on it and soil it so as to ward off any similar misfortune during their next race. These aspects of jockey life contribute to the creation of a unique environment that the author had to consider when approaching and observing the jockeys, but also to understand the symbolic meanings that safety vests generate for these unique professionals. There is a range of symbolic meanings that may be part of each user's experience: aesthetic pleasure, emotional pleasure and symbolic meaning. This last is based on memory retrieval and association, support for identity (self-expression of status), beliefs about the kinds of people who use the product, support for user values and social relatedness.

Along with that, it was relevant to comprehend the bond between horses and jockeys. The animals also are subject to fashion trends, which extend to riding tack and products such as equine glitter gel (Sabella, 2016; Twinkle Glitter Products, 2016). All these factors, and the evolution of jockeys' riding style as previously described in Chapter Three, section 3.4, influence the environment and relationship between user and product.

The horse-racing industry is viewed as a social activity, a profitable business, a gambling issue, a group of fashion events and as an animal rights concern. However, the author paid attention to the bond between horse racing and the fashion industry because "across the globe there are premier horse-racing events that attract major punters and 'fashionistas' - these include: the Dubai Cup; Melbourne Spring Racing Carnival; Royal Ascot; Randwick, Saratoga, the Kentucky Derby; Happy Valley in Hong Kong and the Japan Cup" (Williams & Laing, 2013, p.930). The Sydney Autumn Carnival has been described as "racing at its best and where the worlds of fashion and sport collide for six weekends of thoroughbred racing, fashion, entertainment and hospitality" (Lulham, 2016, online). Similarly, the Melbourne Cup 2016 produced AU$44.3 million from fashion and retail spending, with AU$23.6 million spent on food and beverage (Winter & Frew, 2018).

The equestrian world has a strong bond with the luxury fashion industry. Luxury implies something unnecessary but a pleasure to have or to experience. The fact that something is not essential, but is desirable and possibly expensive or difficult to obtain, is synonymous with success, especially in the riding industry. Safety vests are the antithesis of this, being essential but unfashionable, and therefore they do not represent a good experience or a desirable product for their users.

The author as a product and industrial designer needed to take into consideration the product-ecology framework for these special horse-racing participants, their needs, which are always changing within a situation, and how their relationships with safety vests alter over time. Hence, it was relevant to spend a good amount of time with participants to observe how they interacted with the products, to understand the environment in which the products were used and to observe ways in which participants interacted with the product and with each other around these products. The above concepts were relevant to an analysis of the thoroughbred horse-racing industry throughout the world and more specifically in Australia. Subsequently, these considerations produced the need to explore the jockeys' world. This led to the need to introduce medical staff to this investigation.

Observing and listening to the jockeys increased the author's understanding of the safety vests, which justified the use of product ecology in defining a special framework for this study and the employment of a qualitative research method. This reinforced the recommendation that future research be conducted in this field, because the use and meanings attributed to safety vests evolve over time and must be taken into consideration during revision of the standards and in terms of product innovation in addressing users' needs. Designers should defy new challenges that build on existing skills and practice to solve users' problems (Buxton, 2007).

6.3 The culture of equestrian gear: fashion versus function

Horse riding gear has a strong fashion dimension beyond racing. Kujala and Nurkka (2012) argue that products hold symbolic meanings for users and communicate meanings to others regarding status, identity and personal taste. People assign personality and other expressive characteristics to material objects through cognitive processes of association, interpretation and memory retrieval. External social influences also drive people's product choices and interactions with the physicality and look of a product. Users select products, not only because they provide benefits of usability but also for a good experience (Thuring & Mahlke, 2007). In contrast, safety vests do not evoke hedonic and symbolic responses in users that lead to purchase or use of the product. The role of design in radical product innovation, as investigated in this study, should satisfy the users' needs but also their feelings, such as joy, contentment or pleasure. The incorporation of emotional value into products is an essential strategy for increasing their competitive edge in the consumer market.

The design of safety vests for jockeys needs to be not simple problem-solving but should start from the concept that a product carries meaning. Users can experience the safety vests through aesthetic pleasure, attribution of meaning and emotional response (Krippendorff & Butter, 1984; Desmet & Hekkert, 2007; Mielach, 2012). People have a stronger bond with a product where they use it to show their personal identity and their social relations with others (McDonagh, Denton & Chapman, 2009).

Hence, the author considered different horse riders to gain a deeper understanding of external social influences that might affect them in product choices. For instance, amateur horse riders represent a social elite. This idea mainly results from the discipline of dressage which evolved from military training of the horses for battle, but has become one of the most fashion- and tradition-orientated sectors of horse riding. Fashion brands such as Chanel and Moncler create exclusive collections for and inspired by dressage riders (Koob, 2014). Female dressage riders customise their look through sportswear and equipment adorned with crystals, pearls and special leathers, while manufacturers use these glamorous additions to differentiate their products, especially the helmets (Group 1 Glamour, 2018). Female jockeys even wear make-up and nail polish that matches the owner's colours (Daily Liberal, 2010; Exelby, 2014).

In line with this trend, jockeys feature in fashion and TV campaigns: a good example is the father-and-son duo, Dylan and Dwayne Dunn. Dylan, the son of Dwayne, was recognised as the 2016 Apprentice Jockey of the Year while his father was the 2016 Scobie Breasley Medallist. Together, they became the protagonists of the 2016 Spring Racing Carnival marketing campaign (Spring Racing Carnival, 2016).

Horses have also become the stars of photo shoots, complete with mane stylists. Some of them have been photographed by world-renowned photographers such as Annie Leibovitz, who took photos of horses posing with former soccer player David Beckham (Skernman, 2016).

However, the author found that safety vests were rarely shown on TV, in magazines or at photo shoots unless there was a marketing reason or because a jockey's bad fall was reported. More generally, horse riders usually invest insufficient money in their safety equipment. According to the Australian Horse Industry Council, in statements regarding the AHIC survey of 3,054 horse owners, in 2014/15 79% of them spent money on clothing and safety equipment and AU$40.2 million annually across categories such as horse feed, professional assistance, clothing and safety equipment and fuel/vehicles (Australian Horse Industry Council, 2015).

Consequently, the author compared sports safety gear on the market and presented it in Appendix 1 – Visual Review (Helmets): this visual review was undertaken to help inform the reader of the different aesthetics and design of a small range of helmets in sport. The comparison included children and adults helmets, with the youngest users as a luxury version of adult helmets developed for the market. Common elements discovered among the categories analysed were visual design, the customisation possibilities and the product's sense of luxury.

These concepts were also applied to children's head protectors. There was a vast range of colours from which to choose, mainly based on the gender and age of the young athletes, with luxury and fancy models available, as for adults. The horse-riders' helmets were the most trendy and glamorous, especially those used in dressage, with helmets made of python skin, pearls or Swarovski diamonds and with custom logos available. The more basic design and features were found in those helmets dedicated to jockeys.

A visual review of a small range of body protectors used in sport was undertaken as well to further illustrate those points. Appendix II – Visual Review (Body Protectors) demonstrates the visual disparity between body protectors designed for motocross, ski, hockey and dressage riders. Once again, children body protectors are a luxury version of the adult ones created for the market. The body protectors offered many colours, materials and matching outfits as shown in Appendix II. However, jockeys' vests did not satisfy these criteria.

Some sports, such as motorcycle racing, cycling and skiing, offered more options than sports such as hockey or horse riding. In horse riding, the most popular brands participated to advance the visual design of helmets, jackets, jodhpurs and other accessories rather than the horse riders' safety (Ticino Moda, 2015; Michaels, 2015; Equestrian Life, 2016). The most conservative products were the safety vests for jockeys. For dressage only, brands such as Hermes, Gucci and Miasuki offered special collections that represented luxury and elegance.

This visual review of protective equipment in sport was undertaken as a "first step" in identifying the problems and then understanding those surrounding the aesthetics and design of safety vests for jockeys. A web search for protective equipment in sport was performed and many items were displayed. A small selection of these items is included in Appendix I and Appendix II. Thanks to this visual review, a few points became noticeable: the typology of a modern helmet and body protector is relatively consistent, while some sports have a number of different designs, the products specifically dedicated to jockeys herein demonstrated to be conservative in design within a common use of old materials.

Nevertheless, big fashion brands have introduced attractive outfits that integrate technology into sports such as skiing or cycling (Dainese, 2018b; Head, 2018). The link between luxury and sports has facilitated the introduction of VIP athletes who act as brand and product ambassadors. For instance, the American show-jumping champion, Jessica Springsteen, and the German equestrian champion, Dirk Schrade, feature in fashion campaigns. Instead, jockeys are becoming ambassadors for not-for-profit organisations (Little Heroes Foundation, 2017) or for industry suppliers (Horobin, 2016).

For more than a century, two major fashion brands, Gucci and Hermes, have been involved in the equestrian products industry. In European culture, especially in French and Italian society, the horse has an enduring social and cultural presence. It has strong connections with the identity of socially dominant groups: it symbolises wealth and power. Horseback riding is a very old sport, seen as beautiful, noble, elegant and expensive. These characteristics generate an easy connection with the fashion industry.

Horse riders have long worn special clothes and accessories to practise equestrian sports, so wealthy participants wish to ride in style, dressing the part and using only the best equipment. Spectators also dress stylishly at these events. Equally, equestrian attire has become a general inspiration for fashion. Hence, Gucci and Hermes are considered two pioneer brands born of the demand for high-quality riding accessories, and they have instituted the strong bond between equestrian sport and the fashion industry.

The saddler, Thierry Hermes, opened his saddler workshop in Paris, France, in 1837, with the aim of producing saddles and harnesses for horses. In 1927, Hermes launched a line of jewellery inspired by the equestrian world. In 1929 the French house released its first collection of women's clothes, and then in 1935 Hermes created the still famous 'Kelly' bag, which was inspired by the shape of a saddle. The current version of the Kelly bag and many silk scarves associated with the equestrian world are still part of the Hermes brand, and the company claims to define "s for saddle-maker" (Hermes, 2018). Meanwhile, Guccio Gucci founded the House of Gucci in Florence, Italy, in 1921, manufacturing luggage and saddle gear. The symbols of the business still include stirrups.

Hermes and Gucci branched out into luxury fashion from their base in horse equipment and they still leverage their equestrian heritage, sponsor horse shows and sell riding clothes and accessories (Equestrian Lifestyle, 2016b).

Gucci made its comeback to the equestrian world in December 2009 after 20 years of absence, using aristocrats and elite riders as part of its communications campaign. For this important comeback, Charlotte Casiraghi of Monaco, a talented show jumper and daughter of Caroline, Princess of Hanover, was appointed as the official equestrian 'ambassador' of the Gucci label.

The Gucci creative director at that time, Frida Giannini, designed clothes that were made only for Casiraghi and were never retailed to the general public. During this collaboration with Gucci, Casiraghi introduced her friend and Australian professional show-jumping champion, Edwina Alexander, to the firm. Since 2010, Alexander has established a long-term agreement with the Italian brand.

Alexander and Casiraghi compete wearing exclusive Gucci equestrian wardrobes, including clothing and accessories designed for them and their horses by Gucci's creative director. A few years ago, Alexander commented of her long-term relationship with Gucci:

> "I am particularly proud to be starting this new collaboration with Gucci in its 90th anniversary year. I have been riding since I was eight years old and now, after years of hard work, what was once a childhood aspiration has become a reality. Gucci embodies the excellence that I strive to achieve in my own endeavours and I would like to express my gratitude to Frida Giannini for her personal support as I prepare for my biggest challenge: the 2012 Olympics". (Long, 2011, online)

Since its beginnings, equestrian style has displayed a specific fashion look and is associated with aristocracy and wealth, so consumers who wish to feel part of, or close to, the elite equestrian class seek apparel styled after equestrian attire or merchandise imprinted with the images of horses and riding equipment. Gucci and Hermes use the horse as the main symbol in their branding, because for them the horse represents tradition, luxury and ultimate power.

During 2016, the fashion industry launched new products that emphasised the use of horse logos to support their brands. For instance, Italian brand Miasuki, which is exclusively dedicated to female horse riders, has integrated the horse shape into its logo which is often visible on its products, as shown in Figure 27. The Miasuki-KEP helmet, which displays a horse logo on the back, took inspiration from historical female equestrian heroines, aiming to incorporate femininity and elegance into the design.

Figure 27. Miasuki-KEP helmet
(Miasuki, 2016)

Figure 27 shows that horses have been incorporated boldly into the logo on the helmet, but the use of fine leather on its front and back panels preserves grace and style to attract female riders (Miasuki, 2016).

Other famous brands have used this strategy to emanate luxury while reminding customers of the equestrian world. MiddynMe has used fabrics that display horses and riders for its latest collection, offering also a custom fit, design and fabric service (MiddynMe, 2016). Gucci, Hermes and Carolina Herrera have created unique collections that contain few accessories. Figure 28 shows the incorporation of equestrian references into the logos and products of international brands.

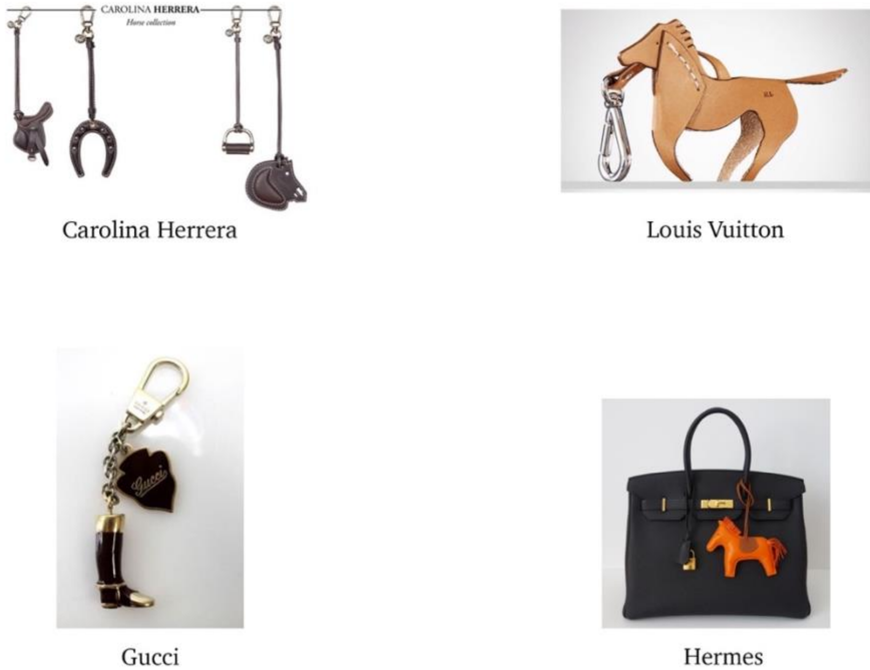

Figure 28. Brand collections of accessories that display horses

Celebrities and fashion are now an established part of the equestrian world: varied fashion brands routinely take inspiration from jockeys' attire and equipment for their collections, such as Salvatore Ferragamo, Bottega Veneta, Ralph Lauren and Tommy Hilfiger (Adams Achara, 2012; Ralph Lauren, 2016; Bauer, 2018; Buffetti, 2018; Vestrum, 2018).

Retired American jockey John Hundley has produced custom racing saddles and helmets since 1992. The ability to use avant-garde materials such as clarino and calf allowed him to be successful. Hundley once stated that he was dreaming of seeing Paris Hilton wear one of his creations (Bartholomy, 2006).

The latest equestrian outfits for horse riders, and occasionally for horses, are shown at the Spoga Horse (Spoga Horse, 2014; So Horse, 2015), which is the major international trade fair for equestrian sports, held each year in Cologne, Germany. Each year, the Spoga Horse trade fair shows that equestrian attire and equipment is big business and a standalone fashion industry. Affluent horse riders expect outfits in the latest colours styled to the height of fashion, and perfectly coordinated with saddlery for both competition and training.

The German event showcases products from international manufacturers, ranging from equestrian fashion to helmets, shoes, boots, saddles and bridles, and through to care and feed products, accessories and services. It styles itself as “a catwalk for equestrian sports” (Spoga Horse, 2014, 2017/2018).

Equitana is a similar event dedicated to the equestrian world, also hosted in Germany. It is a show but also a trade fair, with about 860 exhibitors showing 1,600 different varieties of feedstuffs, 700 saddles and 100 horse trailers (Equestrian Lifestyle, 2017; Niehues, 2017b). Equitana 2018 was focused on creative riding lessons for children, modern jumping, safe cross-country riding, safety in driving, riding-style comparison and dressage. Fashion, luxury and style were apparent throughout the event.

Equitana also organises a similar but smaller event in Melbourne, Australia (Equitana Melbourne, 2018), billed as the “equestrian sports world fair”. These events are marketed as an opportunity to be part of an elite group of people. The website advertises the fair with the phrase “if you are not in, you are out” (Niehues, 2017a).

Safety vests for horse riders and jockeys represent only a small portion of the products on show at these events. Horse riders are increasingly choosing to wear helmets over traditional headwear such as top hats or Stetsons in recognition of the risks involved in riding. However, this is encouraged by the glamour options available, and appearance is more important than safety. During dressage competitions, many competitors wear the traditional top hat even though the Fédération Equestre Internationale (FEI), the international governing body of equestrian sports, encourages riders to use safety gear when competing and training.

World champion dressage riders Charlotte Dujarding and Karl Hester and the world champion barrel racer Nicole Aichele wear helmets during competitions. At 16, Nicole Aichele learned about accidents and head injuries: consequently, since then, Aichele started to wear the helmet. Aichele then started a campaign urging that helmets be made with improved fit, style, comfort and weight in order to encourage more riders to wear them (Be #Helmet Tough, 2015).

Dressage riders do not wear body protectors: unlike other equestrian events, dressage aesthetics plays a core role, and how the rider and horse appear is crucial as it may influence the judges scoring and therefore the outcome. The only protection approved to be worn at any dressage level is the helmet, but the FEI's dressage rules leave the choice of whether to wear a helmet to the riders (Equestrian Australia, 2015; Fédération Equestre Internationale, 2019). Any helmet worn must be in a dark colour or the same colour as their coats.

In dressage, it is crucial to preserve a beautiful appearance. The *Dressage Rules Book (2019)* of the Fédération Equestre Internationale highlights the importance of the horse riders' poise and outfits. Only helmets are mentioned as official safety gear, with the safety vest omitted because looks and elegance are predominant. This is despite many examples in dressage of horses falling or rolling on their prone rider, or riders being slammed into the ground causing devastating injuries and fatalities. Jumping follows similar rules, with senior riders allowed to remove their headgear for ceremonial protocol, while more strict rules are applied for para-dressage, endurance and eventing. Prestigious events throughout the world also showcase the equestrian world to the elite. The Longines Global Champions Tour was created in 2006, when Jan Topps and his wife Edwina Alexander attended a show in Malaysia that was aimed to promote show jumping to a wider audience. The tour is the world's premier five-star professional show jumping circuit, which underscores the intimate connections between the equestrian industry, luxury global brands and the international social and economic elite.

These shows are organised in some of the world's most impressive locations, such as Cannes (France), Madrid (Spain), Rome (Italy), and Shanghai (China), with substantial prize money on offer. The series is accessible from around the world through live broadcasts and attracts major sponsors such as Massimo Dutti, Gucci, Hermes and Longines (Ticino Moda, 2015; Equestrian Life, 2016; Massimo Dutti, 2016; Longines Global Champions Tour, 2018). This event hosts Olympic, world and continental champions in 15 international spectacular destinations, with rich prizes and prestige hospitality events.

Race horses and their jockeys are celebrated during special events such as the Melbourne Cup (Australia), the Kentucky Derby (United States), the Epsom Derby (United Kingdom) and the Prix de L'Arc de Triomphe (France). During these events, fashion brands advertise themselves, while celebrities, high society and social aspirants participate by showing their outfits. The Australian Spring Racing Carnival has a special fashion category on its website, where everyone can admire the latest trends or the dress codes dictated by the celebrities (Carnival, 2016).

However, jockeys are less attractive than other riders to the fashion industry, and this may influence the design of safety vests and helmets, and their meanings. These findings reinforce the statement that every user is different and has various needs.

6.4 Luxury as emotional comfort

The present market offers a huge variety of luxury products and services, highlighting the latest trends in automobiles, clothing, accessories, home furnishings, consumer electronics, food, sports equipment and toys. According to Silverstein and Fiske (2003), such brands achieved levels of profitability and growth beyond the reach of their lesser competitors. Consumers have been influenced to seek luxury by this market revolution. In the past, they tended to purchase the best product in their most important category, or low-cost brands.

Luxury is predominant in affirming the status quo and it affects jockeys' lifestyles. The charm of the equestrian world attracts many people who show off their success and flaunt their wealth, thereby creating many followers ready to imitate them, just to be part of this special universe. The horse-racing industry internationally also generates a huge volume of money, as sponsors, manufacturers and fashion brands support this business and contribute to its elitist profile. Being involved in horse racing as an owner or attendee is a way to show social status.

Luxury is also a state of mind and a sensory experience. People choose luxury brands to indicate their social status, symbolising achievement, wealth and prestige (Page, 2015). People purchase above their income level to feel part of a glittering social sphere such as the equestrian world, in which elitism is deeply ingrained.

Horse riding is a passion, so creates community and a sense of belonging. Each person who belongs to this world develops a propensity for wealth and an innate ability to understand and appreciate design. Humans who experience positive moods seem to be more willing to take risks to gain pleasure, while:

> "people in a negative affective state will indulge more when their affect is associated with uncertainty because indulging can help repair the negative state." (Petersen, 2012, p.6)

Attitudes have also changed in the last few years. People do not feel guilty about spending, and they openly look for goods that show who they are or how they wish to be viewed. Consumers have more money, a greater desire to express their emotional side and a vast variety of choices in goods and services (Silverstein & Fiske, 2003). For all these reasons, users expect products that engage their curiosity and confirm their lifestyles. Equestrian disciplines are involved in this cycle because the bond between the fashion industry and the equestrian world is already firmly established (Daily Mail, 2012; *Fame and fillies*, 2015; Show Chic Dressage, 2015; Equestrian Lifestyle, 2016b).

A regal equestrian style is usually appreciated and requested by horse riders, both female and male. Jockeys are also affected by these fashion changes.

The availability of a special-edition product allows equestrian consumers to feel special and wealthy, often beyond their social position. For instance, Longines has created a 2015 limited edition of a classically styled pocket watch. It has a decorated case backed by a trio of horses, it is in 18-carat rose-gold, and it has limited availability, so it is very desirable (Luxuo, 2015). Starting from a similar concept, Gucci offers a limited edition foulard to celebrate the Gucci Paris Masters (AFP Relax news, 2014; FashionOne, 2014). Luxury, authenticity and limited availability can be considered synonymous with most equestrian pursuits.

Fashion is a profound part of the equestrian industry, but technology and its design are now also entrenched in the fashion system, contributing to the desirability of products and driving consumption. For example, witness the success of Apple products. With a good application of new materials and technologies available on the market, and through the use of the special link between equestrian and fashion industries, real innovation may be introduced into this field with benefits for users.

6.5 Summary

Horse riders are exposed to different kinds of injuries, which vary based on the disciplines practised by them. Falls and other injuries are common and the possibilities of prevention are often limited because of deficient knowledge about the causes and mechanisms, so wearing adequate protective equipment is crucial (Carmichael et al., 2014; Institute of Medicine and National Research Council, 2014; Hessler et al., 2014; University of California, 2015). Hence, in 1998, Australia introduced mandatory use of safety vests to reduce the severity of injuries sustained, yet jockeys still suffer major injuries when they fall. The product review showed that equestrian equipment is pulled in several directions, towards fashion, comfort and safety while competing with each other to dominate design. Jockeys still need a safety vest able to satisfy their needs and guarantee an appropriate level of safety. Specifically, Australian jockeys may represent a niche market; however, the findings of this study may be extended to worldwide jockeys and to other equestrian disciplines in which riders experience similar injuries.

A safety vest that suits a jockey may not accommodate another rider since the product experience is unique for users. Therefore, the author identified the need to link safety vests and their functional performances with users' needs and desires. The deep roots of the fashion industry in the equestrian world have led to intricacies around the safety vests. Fashion is constantly changing and re-inventing trends, whereas the standards applied to Australian safety vests have been little revised since their formulation.

According to Hanington (2003), knowledge of design allows the interpretation of research information in a context, while a full immersion in the research process and direct engagement with users forges a sense of empathy between designers and users. Hence, this study mainly focused on the role of design in safety vests for jockeys, with the aim that the findings regarding protection of the torso would be further applied to all the equestrian disciplines.

In order to help determine whether this case of primary and dependent-secondary users affect the evolution of jockeys' safety vests in Australia, the author conducted a series of individual semi-structured interviews, a focus group, and observation in a sub-sample of the original population of jockeys and of medical professionals. Hence, the author introduced and critiqued the principal outcomes of this study in the following chapter.

Chapter Seven: Findings and Analysis

This chapter collates and critiques the key findings of the study. The chapter is written in two parts: part one presents the overall case study in which jockeys and health professionals as end-users developed information to promote innovation applicable to safety vests. It describes the specific data gathered directly from participants during semi-structured interviews, the focus group and observation. The second part analyses the influence of product innovation on safety vests for jockeys and shows a series of significant effects. The need to develop a holistic understanding of the user and the co-dependent user of a product is reinforced and the author discusses the involvement of product ecology to improve the jockeys' safety-vest design. This holistic understanding starts with the development of knowledge regarding the ways in which users and co-dependent users influence the relationship and design direction between them and the target product. The two parts offer a basis for analysis of the potential redesign of safety vests for jockeys that incorporates a holistic approach and takes into consideration a set of users and co-dependent users. This analysis enabled the author to produce a set of concept designs for new safety vests that aimed to address users' requirements more effectively than the designs currently available.

7.1. General development goals underpinned by participants' responses

The study of safety vests aimed to investigate the broad context of a UCD approach, specifically in the Australian thoroughbred racing industry. The goal was to understand how and why to consider product innovation in this field. Thus, a qualitative approach was used to explore and seek to explain the need for further research regarding safety vests for jockeys. The definitions of the design role, UCD and UXD, and empathic design employed during the collection of data ensured the accuracy and integrity of the process.

The search for knowledge can be defined through research and particularly design research. It continuously challenges the status quo, while it is concerned with what ought to be rather than what already subsists (Milton & Rodgers, 2013). Choosing the right research method was fundamental for this study as designers need dependable, strong and rigorous evaluation methods discovered through a convergent process.

The qualitative research method selected required focus on a restricted number of respondents who were chosen to participate because of their in-depth knowledge about this topic. The participants had experienced the product and therefore had developed a specific knowledge about it. The integrity and purity of the data gathered was provided, and the information was analysed to achieve the results of the research.

Due to the nature of this investigation, all the activities executed to collect data were focused on the safety clothing that jockeys are mandated to wear during races, specifically safety vests. As discovered during the review of the literature, the initial inspection of the data gathered reveals that Australian jockeys receive good training, which includes knowledge of falling techniques, so they are able and confident to use these skills if required. However, the most common cause of their falls during races is catastrophic injury to, or sudden death of, the horse (Collar et al., 2015; Hitchens, Hill & Stover, 2013, 2016). Accidents are bound to happen given that there is at least one race each day in Australia (Racing Australia, 2019a) and this heavy workload pushes the jockeys to their limits of performance.

7.1.1 The participants and the products: thoughts and experiences

This study offered jockeys the opportunity to express their feelings, opinions and beliefs through the three stages of data collection. The health professionals also participated in the semi-structured interview phase and observations, which added validity to the study. Jockeys were able to discuss their issues related to a product (safety vests) that should be able to save their lives in an everyday activity.

Relevant data was produced for the aims of this study as the jockeys were given the spotlight to talk about such an important matter for them. Participants were surprised that they were being questioned about such a topic because they reported that they had often tried to say something but had been ignored. Therefore, they were enthusiastic to share their stories with the author about their falls, injuries and uncomfortable feelings while wearing the vests, and discussed the limits that current vests had. The participants strongly supported this study and often demonstrated excitement regarding the possibility of trying a new safety vest, if a prototype were to be made available in the future, based on this investigation.

The data collected confirmed the risks that jockeys faced every day and their awareness that their lives could change after a fall. Most of the jockeys said that they needed to have a bit of faith in the safety vests on the market and in the people involved in making sure that standards were respected. However, the most experienced expressed doubts about the way in which standards were developed and/or revised because they were not involved in this procedure. The female participants also reported many problems in wearing the vests because ergonomics had not been applied to the vests' design.

Jockeys work hard to achieve results and this pushes them to complete daily strenuous training, which exposes them to a higher chance of falls. Jockeys often fall because the horses become sick unexpectedly during the race or they accidentally clip the heels of others (Bartley, 2002; Racing And Sports, 2010; Cormick, 2012; Hitchens, Hill & Stover, 2013, 2016; Fawkes, 2015; Navarra, 2015; Scadden, 2016b; Winter & Frew, 2018).

Like the jockeys, the medical staff showed their surprise and curiosity about this study: they rarely had the opportunity to discuss these products, especially from a medical point of view. The medical professionals reported the severity of injuries that they treated in jockeys and the ways in which they experienced the safety vests. After a fall, the time that a jockey spends lying on the turf is crucial: the medical attendants need to act fast and with accuracy. Unfortunately, the vests represent an impediment to the fast supply of aid because they are hard to remove. The medical participants showed interest and respect for the author because, finally, someone was trying to investigate such an important product and they hoped this could bring improvements to help them improve the execution of their jobs.

People not employed and fan often see the thoroughbred horse racing industry only as a glittering world but the professionals who participated in this study offered intimate and different insights, starting with their experiences with safety vests. They found time to spend with the author to provide benefits for this study, despite their workloads and any personal issues, and the author felt safe, respected and privileged to be introduced to the backstage events of the 'sport of kings'.

Leading Australian jockeys often race overseas in prestigious meetings in Asia, Europe and North America, where they wear the safety vests approved by overseas authorities. This has led them to realise the shortcomings of equipment and standards used in Australia.

Most jockeys offered positive feedback regarding the Racelite vest, so the author decided to use it during the focus group to compare it with the Descente vest. Specifically, the author had concerns regarding the tags attached to new Racelite vests, which carried the following wording labelled as warnings:

- This body protector will provide limited impact protection to the areas it is designed to protect when worn correctly.
- Your body protector should cover the following areas of your body: the whole circumference of the torso, the rib cage at the front, the coccyx at the back.
- Body protectors offer some protection from impacts suffered as a consequence of falling from a horse. They do not guarantee the wearer's safety as they cannot protect the wearer against all foreseeable impacts. Body protectors provide limited protection for injury severity reduction.
- Inspect body protector before each use for signs of damage or wear. The body protector should be replaced if damage or wear has occurred.

Despite these caveats, the participating jockeys liked the Racelite because it was very light in weight and offered better comfort than others during the races. Therefore, 15 out of the 17 participant jockeys expressed their discontent that the often-mentioned Japanese vest, the Descente, was not yet approved to be used in Australia. They were conscious that their profession was risky, and thus they seemed to accept the products on the market, even if these products did not guarantee their safety.

Almost all the jockeys involved in this study found strange that the Descente vest had failed the tests to become usable in Australia due to the composition of its stretchy materials that created gaps between the padding. Participants expressed concerns regarding the criteria applied to exclude from or include a vest in the approved list, particularly the Descente vest.

AJ06 expressed frustration during the focus group: “What is the issue with the gaps?! Maybe the grass can go between the gaps!” This phrase indicated the participants’ doubts regarding the knowledge of the people who revised the standards and, at the same time, it confirmed bonding between jockeys. All the participants in the focus group laughed and agreed with AJ06, while the author perceived a strong sense of camaraderie among the jockeys.

The testing methods used for vests have been queried in the past. Users of the safety vests have shown experts the standards applied in Australia and the experts selected showed concerns about the methods used to test the vests (Agtrans Research, 2015). During the focus group discussion for this study there was a common feeling of dissatisfaction, mainly among jockeys, that the team of experts dedicated to investigating the standards did not include jockeys. The three-quarter of jockeys participating in this study strongly felt excluded from a process that affected and was important for them. This was confirmation of the problems caused by omitting UCD from the development and testing of the vests.

Users demonstrated knowledge about the products and were conscious of the lack of innovation applied to them. They were aware of the drive towards production of more compact, portable technologies that had led to the embedding of technological hardware into garments such as those utilised in winten sport (Dainese, 2018d) or by motorbike riders (Alpinestars, 2017). This could be incorporated into jockeys’ safety vests and contribute to the aim of the medical professionals to provide aid quickly to jockeys, and help the riders as the technology might be capable of tracking their injuries.

7.1.2 Key features and Insides of the findings

Inspired by Burnard, Gill, Stewart, Treasure and Chadwick (2008, p. 432), the author utilised a “pragmatic process of thematic content analysis as a method of analysing qualitative data” gathered in this study. This method provided a way of generating categories under which similar themes (e.g. injuries, falls, safety vests' brand) was collated.

Overall, the participation of such a specific group of people (jockeys and medical staff) generated data consistency and offered deep knowledge of the subject. All the participants confirmed the particular characteristics of the thoroughbred horse-racing world, the unique features of the job for professional jockeys and the risks associated with it. The jockeys were aware that their occupation was dangerous, as participant J02 explained:

> "For what we do there is always no guarantee…. And again, the perception is not that we expect the vest to save our lives…. All we want it to do is to help us, not hinder us in a racing incident."

Some of the participants described in detail their feelings of restriction when wearing the vests, including J02, J03, J04, J06, J08, D02 and ICP. The jockeys attributed their discomfort when wearing the vests during riding to a system that had not paid attention to their concerns or involved them in the vests' design or in development of standards that could improve their conditions. This problem highlighted the vicious circle that existed between standards applied in Australia and the lack of innovation that had been applied to safety vests and was criticised by the users.

Limited movement is a serious problem for jockeys, who need to bend their heads, turn to look around for other runners, talk to each other during races, and be able to roll into a ball in the case of a nosedive fall, which is a common form of tumble. In this study, 13 out of the 17 participant jockeys specifically reported that the vests were uncomfortable or rigid, restricted them during races and were even heavy to wear. This reinforced the legitimacy of the research.

The literature review showed that injuries to jockeys were often similar to those reported among motorcyclists, cyclists and skiers. However, these sports report that the number of catastrophic injuries has fallen over the last few years, due to the use of improved protection and the latest technologies. Many of the jockeys shared their knowledge about this topic with the author, as some of them have practised sports such as motocross or motorcycling during their leisure time. What is was initially collected as evidence anecdotal, it then became evidence-based because the jockeys reported their stories, showed their safety gear to the author and offered other similar proofs of their stories. These jockeys were unhappy that they did not see the same technology or innovation applied to safety vests as had been applied to the body protectors used in different sports activities. Particularly, female jockeys complained because sports such as motorcycling offered a choice between a male and female body protector while jockeys' safety vests did not offer this form of ergonomics.

Most jockeys are slight and of small stature, but they differ from each other based on gender, height, weight and age. These characteristics require serious consideration when designing safety vests. Female jockeys involved in this investigation were particularly aware that the safety vests worn during track work were more comfortable than those worn for racing. This is simply explained by the fact that, for track work, they can wear heavier and softer vests than they can during races. This increases their comfort because these vests mould more efficiently to their body shapes.

Female jockeys brought attention to the need for a safety vest designed for the female body shape, in the same way that many other sports offer this option (Competitive Cyclist, 2017; Dainese, 2018). This problem was explained by participant AJ02:

> "From a female's point of view or perspective, I think definitely they need to have a male and a female vest. That's my opinion. They do it with all the motorbike gear and all that sort of stuff. The only reason I know is because I used to ride a lot of dirt bikes when I was younger. There's a big difference with the female body suits compared to the male's body suit. Obviously, we've got our breasts and our hips and stuff – our curves. It was all fitted, it was completely different. I just think, as a female, they definitely need to work on that a little bit. Just to make it a little bit more comfortable for us. Also, you want that light vest but you also want the stability in it as well and the comfort, material-wise, too. So, it's probably saying the impossible, really…"

Many of the participants (more than 50%) had taken part in several sports from a very young age, so they used their knowledge based on their experiences to prove that users were not all the same but had different needs. This reinforced the need for UCD, as claimed by this study. They were conscious of their variance in terms of body shapes, but current jockeys' vests did not offer them options to solve their difficulties.

Most of the jockeys (75%) reported that they found the vests worn for track work to be the most comfortable. However, these were the heaviest vests, so they explained that it was not possible to wear them during the races, as confirmed by participant J01:

> "I've had the Vipa vest, which I really like because it moulds to your body and I just feel like it's, you know, you can move around in it and it doesn't annoy you, but it's much heavier for race day. So, that's why I have the Racelite vest, which I don't mind, sometimes, like, to move around in. I've ridden just over 200 winners and it's a little bit uncomfortable, you could say. It doesn't restrict you too much, although I have it pretty loose on my body. Yeah, but the weight issue – I mean, I don't really have to worry about it anymore, but that's why I have it, because of weight."

The majority of the participants (75%) favoured a Vipa vest for track work. This vest was reported as more comfortable and suited to the needs of a female body, but it was still too heavy to meet race-day criteria, as explained by participant J07:

> "I wear a vest called Vipa. My track-work vest is a heavier version of this, but it's a lot more comfortable. This is a lighter version. It's good because it is light, but it's not very comfortable; it's quite bulky and stiff to ride in. It's good because it has worn in a little bit, but it's still quite stiff and it can restrict your movement a little bit. I much prefer the heavier version, only that when you've got to ride a certain weight, you can't really [wear the heavier one]. So, weight is the issue."

The application of ergonomics depends on the standards, which vests have to meet to be deemed suitable to be placed on the market. The official approval of a product confers trustworthiness, and participants said they believed that the approved products they had bought satisfied their needs. However, this was perceived as partially true because they still complained about the safety vests and the lack of involvement by jockeys in the development of the standards or the vest, while declaring their faith in the available vests. This feeling was described by participant AJ02: “but I thought, obviously, too, you have a bit of faith in everyone that does make the vests and so forth and stuff, that they wouldn’t have it on the market if it wasn’t [trustworthy]”.

The findings of this study indicated that the mandatory use of safety vests brought benefits in protecting the jockeys, but also introduced problems such as the restrictions of movement, the lack of protection in areas such as the spine and abdomen, and a lack of innovation in terms of design and materials which affected even ergonomics. These concerns were significant for both participant groups. Most of the participants commented and discussed these, including the medical staff, while participant J06 even expressed some doubt regarding the vests’ benefit: “I think, some vests, they can be very restrictive with their [in]flexibility…It’s just a little bit rigid. Anything that’s too rigid on you, I find it probably detrimental to your safety.”

Overall, the participants agreed that the mandated use of safety vests was sensible to improve safety. However, the lack of updates in products and standards meant that the available vests failed the scope. Stiffness and restriction of movement were common themes, confirmed by J07, whose vest was “still quite stiff and it can restrict your movement a little bit”, and by J08, who declared: “I actually really don’t like the fact that they restrict you.”

Most of the participants also highlighted the problems they encountered as the vests came into contact with the helmets, and this issue depended on the kind of helmet worn. This is relevant and unique: most helmet manufacturers have no connection with those producing safety vests, and the standards to which helmets must adhere are different to and do not take account of those used for safety vests.

The lack of innovation and the absence of ergonomics in the vests increase the risk that, during a race in a crouched posture, the safety vests bump into the jockeys' helmets at the back of their necks. Most participants stated that the vests interfered with their helmets, and that this shortcoming led to bigger problems, such as their vision being impaired while riding, as explained by J06:

> "I am not watching where I am going because I have to look with my eyes up instead of my head up…. I can feel it pinching on the back of the vest, so it is just half an inch, so it is stopping me from extending my neck forward."

Jockeys cannot extend forward properly because vest and helmet bump together. This becomes a bigger issue during the last 400 metres of a race when the jockeys speed up their horses to try to win. This discovery highlighted the importance of further investigations. However, the unhappy interaction between helmets and safety vests was considered relevant to the aim of this study from one particular angle: helmets are evolving and they show a bit more innovation (Forero Rueda et al., 2011; Fuernschuss et al., 2016; GPA, 2017; KEP Italia, 2017).

Jockeys very often brought the standards and the methods used to test the vests into the conversations during all the data collection phases. Participants AJ01, AJ02 and J02 frequently expressed their faith in the people charged with revising the standards or approving the vests. Yet at the same time, doubts related to the standards emerged during most of the conversations with both jockeys and health professionals. Jockeys of both genders with more years of experience shared the view stated simply by J04: "I don't know how they do the standards." J03 said: "I am not convinced the standards are right," while participant J02 stated:

> "The people doing the test might be engineers and experts in testing equipment, but they are not experts in riding, racing, or dealing with the animals or what we deal with. They are only dealing with numbers, facts and obviously video footage, but they are not the people actually riding, or the ones actually falling in it."

Almost all the participants (90%), at some stage of the data collection phase, mentioned doubts or criticisms regarding the standards for jockeys' safety vests. The author recorded and observed the importance of that for both the users and the co-dependent users.

Another relevant finding regarded the jockeys' riding style, previously mentioned in Chapter Three, section 3.4 of this thesis. Both jockeys and health professionals reported awareness that, if a fall occurred, the consequences could be more serious because current vests were not produced to complement the present riding style, and thus did not adequately protect areas such as the spine, neck and lower back. This awareness showed that participants were concerned with safety and feeling safe. Jockeys' safety was paramount for themselves and the medical staff.

Apart from comfort and the need for vest models that suited both genders, weight was a major concern among the participants. Many remarked on the importance of wearing vests that were "as light as possible" to help them meet the weight requirements of each race. As the safety equipment is designed to protect jockeys forms part of their weight allowance: therefore, if a safety vest was heavy it would require jockeys to ride at even lighter weights. This is crucial because jockeys apply a hard regime to be fit and light in weight, but as often reported in this thesis (e.g. Chapter One, Two and Three), they can utilize extreme measures to quickly lose weight. Those rapid weight loss measures impact their mental conditions to properly ride a race and also on their general wellbeing. Hence, a safety vest should be extremely light in weight to avoid those extreme measures that jockeys use to fast reduce their weights prior to a race and thus, even support their wellbeing. This reinforced the need for asking further research in this field: a new vest may reduce the severity of jockeys' injuries and also take the pressure off them in losing weight.

Along with that, the pieces used and the methods of assembly of the safety vests were problems that were discussed with some of the participants, especially those who had experienced falls or the medical participants. For instance, participant ICP said:

> "A better-functioning, better-performing vest will be good
> and providing better protection, easy to use, comfortable for

> the jockeys and easy removal by other people, because you have to remember that, oftentimes, we are trying to remove the vests and the jockeys are lying on the ground and often we have to roll them so they're flat on their back…So, the weight of their bodies is lying on the vests and so it can be very hard to get them off."

Most of the participant jockeys in this study had experienced falls, and they shared with the medical staff their observation that the most dangerous place to fall was at the starting barriers as well as falling at full gallop while raised in the saddle. The majority of participants (75%) said that the vests' design was not exactly right for their needs. In addition, during a fall, a jockey's chin often comes forward and catches in the top of the vest. This causes bruises and cuts, as reported by participant D02:

> "The injuries vary a lot and any part of the body can be injured, from simple things like soft-tissue injuries and bruising, through to fractures, minor and major fractures, head injury, chest injury, abdominal injury…I have seen injuries in all parts of the body."

Throughout the interviews, participants discussed positives and negatives that they had experienced due to the wearing of safety vests. All of them accepted compulsory use of the vests because they acknowledged that the vests offered some improvement in their protection. However, some of them (60%) still feared that the use of the safety vests might be linked to the number of spinal injuries currently registered and as previously discussed in Chapter Two of this thesis.

7.1.3 Major findings of how safety vests impact on jockeys' lives

The research presented herein has demonstrated the importance of building innovative design into safety vests for jockeys. Background research into the thoroughbred racing industry, internationally and in Australia, and the culture that has been formed among jockeys, highlighted the importance of safety vests for safety. The qualitative research method helped to reduce observer bias in the selection and interpretation of data. This study also discovered the importance of engaging with the user (jockeys) and the co-dependent user (medical staff) to inform the design of personal protective equipment (PPE), focusing on safety vests because they were failing to meet the needs of jockeys and medical staff.

Medical participants in the study confirmed that among all the injuries treated, bruises and soft-tissue injuries were seen most often among jockeys: however, these were the minor injuries observed. Flat jockeys are exposed to daily risks since, in Australia, there is at least one race each day and daily track work in which they are involved. Thus, there is almost one insurance claim every day as a consequence of a horse-related injury. Fractures and soft-tissue injuries are the most common, but head injuries represent the highest mean cost per claim (Hitchens, 2011).

In addition, despite the mandatory wearing by jockeys of the safety vests, medical participants in this study confirmed that they often needed to treat serious injuries when jockeys fell or were kicked or trampled between horses' hooves. In this case, medical staff frequently needed to treat injuries to the jockey's spine, head, neck or ribs: these kinds of injuries were the most dangerous of the injuries they treated. This was relevant to this study because they have to deal with the safety vests in providing the first aid to jockeys when one or more of those injuries occur. That is why the medical staff have been considered as depend/secondary users.

The review of the literature reporting on the Australian industry revealed that, in the years between 1955 and 2005, there had been 20 deaths recorded on racetracks in the state of Victoria alone, due to the above-mentioned injuries (Australian Associated Press, 2005). New South Wales registered 200 jockeys in 2017; every week one is taken to hospital by ambulance due to the intense injuries reported (Eddy, 2017). The United States industry reported in 1997 that, of 30 million participants in horse riding, more than 100,000 emergency room visits were recorded due to injuries caused by the sport (Doty, 1997).

Hence, each country experiences consequences caused by the relationship between people and horses, particularly in the case of thoroughbred horse racing. The jockeys and horses are more subject to risk because their work involves many interactive activities, such as training, riding or racing, and travelling. The jockey can be injured during any of these activities (Turner et al., 2012).

However, none of the jockeys who participated in this study blamed or criticised horses when talking about the falls experienced during their careers. This was also observed in the literature. Instead, participants questioned the role of the safety vests. They confirmed that the wearing of the vests brought some benefit but they considered the benefit to be limited because the vests also caused difficulties. For instance, it was stated that wearing a safety vest in case of a fall might reduce some injuries but still hindered jockeys as they sought to roll. The jockeys experienced safety vests as compulsory products rather than essential and desired clothing to guarantee their wellbeing. Many negatives were reported in terms of insufficient protection provided for areas such as the spine or the ribs, and the problems often experienced by the riders as their helmets interacted with the vests.

An academic study in 1973 made the first move to consider the importance of wearing helmets during horse-riding activities. Then there was less knowledge available regarding the nature and incidence of riding injuries (Danielsson & Westlin, 1973). Since then, head protection has been considered the main wearable aid for horse riders and, according to Danielsson and Westlin (1973 p.601):

> "the use of a helmet ought to be a good precaution, but, remarkably enough, as many as one out of every three riders do not use one. On the other hand, it might be questioned whether the conventional helmet with a rubber chin strap does not fall off far too easily."

Jockeys must wear helmets and safety vests during races. However, in this study the jockeys shared with the author their dissatisfaction with these products. The origin of these complaints may be found in the fact that there are different standards for the two products and, in the specific case of safety vests, users are not involved in their development. Consequently, because different rules guide the design of helmets and safety vests, the products interact poorly and interfere with each other, which has a negative impact on the users.

The safety of jockeys has paramount importance in the horse-riding industry but improvements are always possible (Australian Associated Press, 2009 & 2014a; Foote et al., 2011; Australian Racing Board, 2013; Foote et al., 2014; Bowman, 2017). It was significant for the aim of this research to consider a unique approach to the development of one product to improve safety. It has been stated that unforeseeable falls can happen during both track work and races. Therefore, wearing adequate safety equipment is crucial for the safety of jockeys, as confirmed by participants and by Lowry (2009 p.8), who states: “Weighing less than 115 pounds, jockeys have virtually no protection as they hurtle down the track atop a 1,200 pound thoroughbred.”

Often falls are caused by injuries or falls of the jockeys’ horses (Australian Associated Press, 2017a, 2017b; Hitchens, Hill & Stover, 2013, 2016; Msenhelder, 2017; Wood, 2017). According to Hitchens et al. (2013, 2016), jockeys' falls can happen prior, during and after a race. It has been reported that manufacturers struggle to meet the approved standards for helmets as well (Australian Associated Press, 2014a). Jockeys who participated in this study were not satisfied with the standards and therefore the products. They demonstrated a good knowledge of possible innovative solutions that were on the market for other sports (for instance, motorcycling, cycling and show jumping) and they hoped that something similar would be developed for jockeys' safety vests.

The majority of the jockeys (90%) had experienced severe injuries and most of these were described by the health professionals involved in this study. The author registered a real need for intervention. The participants were conscious of the risks they faced but they were asking why something serious in terms of innovation had not been applied to their main safety tool (safety vests).
The author perceived a sense of calling for help so that a product could be delivered that would help to increase their enjoyment of their chosen profession. Table 10 offers a recap of the major findings of this study, implications and possible limitations.

Table 10. Major findings, implications and limitations of the study

FINDINGS	IMPLICATIONS	LIMITATIONS
Safety vests worn are rigid, stiff, and restrict movements	If a fall occurs, jockeys are not able to apply their falling techniques and this may expose them to a higher level of injuries	This study is based on the data collected from participants, thus investigation of riding style represents a limitation
Safety vests may bump into jockeys' helmets while racing	Jockeys may have restricted vision and this exposes them to more risks	This study is based on the data collected from participants, thus investigation of riding style represents a limitation which may affect other safety gear
There is a necessity to have faith in those people in charge to revise the standards or to approve the vests	Jockeys are conscious of their skills and risks. However, they need to believe that if something has been approved it is good for sure	Despite the analysis of the knowledge in this field, some data about the process to approve a vest are not completely available to the public
There is uncertainty regarding how standards are made and developed	Jockeys are not involved in the revision and development of standards for their safety vests, thus their needs cannot be totally satisfied	The life cycle of standards is partly hidden or not well explained to the public
There is a need for a better performing vest that is easier to remove	Severe injuries are still registered (e.g. to spine and ribs) thus the vests need to be produced with a better design	Each manufacturer protects the patent of its safety vest, which is linked to the standards and thus not totally accessible to the public
There is a need to have a male and a female safety vest	Males and females have different body shapes; thus, one vest cannot fit everybody	Manufacturers and standards have not specified yet why one safety vest should fit all the jockeys. Revision is missing
A vest should be as light in weight as possible	Jockeys fight all their lives to keep a light body weight to meet the race criteria. Hence, a lighter vest may reduce this pressure	The unclear data offered by the standards and manufacturers neglected the research for innovative materials to be applied

The findings shown in Table 10 confirm the legitimacy of the research: there is a scarcity of data available regarding jockeys' falls, so no urgency has been observed regarding the need to alter designs of safety vests; any qualitative data previously gathered regarding jockeys' post-fall experiences has not been considered linked to the users' dissatisfaction with safety vests; and aligned with this, no innovation has been applied to improve the designs or update the standards regarding safety vests. At today, jockeys' data are preserved in the Australian Racing Incident Database: however, there is a need for better recording of PPE used during races and not just recording the jockeys injured. All the data belonging to fallen or not fallen and injured or not injured jockeys should be collected. For this reason, the standards used in Australia should be revised to allow the use of the latest technologies into safety vests and properly collect those data, which may be easily shared among the primary and secondary-dependent users.

Design and science have not worked together to solve the problems, and this influences the use of the latest technologies and materials. Minor revisions applied to the standards may have hindered the introduction of innovatory technologies or materials to safety vests. Significantly, most of the findings that this study has generated are new or contrary to those contained in the literature, such as the need for at least two different styles of vest to suit male and female users, the need to apply jockeys' knowledge and experiences to innovate the design of safety vests and the fact that current vests are not designed for medical professionals to attend quickly to injured jockeys.

A different significant improvement should the fact that the weight of the jockeys safety equipment should be independent of their riding weight. This simple change would certainly help with compliance and well as allowing greater innovation in terms of safety vests' design while letting the jockeys with less pressure for applying extreme weight loss measures prior to races.

Another consideration that needs more attention is the possibility that safety vests and helmets could be designed together to ensure their suitability to be worn together. These two sets of protective clothing have different standards, so diverse teams design and approve the products without consultation and without consideration of jockeys' postures. This issue was often discussed and confirmed by the participants in this study. Figure 29 clarifies the concern.

Figure 29. Interaction between safety vests and helmets
(Racing Zone, 2018)

Figure 29 shows just one situation in which the safety vest negatively interacts with the helmet (two black arrows are used by the author to clarify the problem). The way in which the safety vest rolls up and eventually bumps into the helmet is visible on the jockeys' backs. It is particularly clear in the case of the leading jockey in this race. This absence of complementarity between safety vest and helmet was often mentioned and confirmed by most of the participants.

This problem is more accentuated in the case of female jockeys. The current safety vests do not use ergonomics and one vest fits all: both female and male jockeys. However, despite the fact that jockeys are fit and conserve a lightweight, female jockeys may preserve their feminine shapes. Hence, the actual vests result not so comfortable for them in perfectly accommodating their bodies' silhouettes. This is another indication of the lack of updates to the standards for safety vests to accommodate female users' needs. This concern suggests the need for future research, in which the co-development of a helmet and a safety vest may be performed through the use of common standards and a shared team of professionals.

The findings of this study suggest that, through employment of new designs and the use of innovative materials, safety vests could be produced that solved most of the users' and co-dependent users' issues. However, many factors must be considered. For instance, jockeys' riding posture has evolved over the years, so jockeys alter their postures as they approach the finish line in a race, but the vests are too bulky to conform to the jockeys' positions.

7.2 Empirical analysis

The empirical analysis was conducted on data derived from the individual semi-structured interviews, participants observation and one focus group. This qualitative research method targeted jockeys (professionals, apprentices and former jockeys) and related medical professionals, as they were judged in the preliminary research to be the most reliable and accessible sources available to respond to the research aims. However, data analysis was limited to the concepts considered most relevant to the theoretical framework and research questions of this study.

Inspired by Visser, Van Der Lugt and Stappers (2007), the author researched situations in which designers and end-users demonstrated transfer between being insiders and outsiders. This investigation aimed to study the qualities of engagement between end-user and designer participants during the phase of ideas generation in a design project, specifically safety vests for jockeys. The importance of identifying the correct problem and not jumping to design outcomes that are irrelevant is acknowledged by Freidman (2003) who argues that the designer becomes “a critic whose post-solution analysis considers whether the right problem has been solved” (p.511).

Significantly, face-to-face discussions with participants regarding their falls and injuries seemed difficult for most of them because they perceived such events as failures and discussion of them showed a fragility in their professional lives. This was especially the case among the younger and less experienced jockeys. However, the author expressed empathy and this approach, which gave importance to the user, won over their trust.

In similar vein, the author noted that the younger jockeys, such as apprentices, were ashamed to talk about their falls or injuries. However, thanks to the apprentice programme that Racing Victoria offers to young riders to develop their culture, and the encouragement offered by a positive atmosphere in familiar locations, they slowly opened up regarding their negative experiences and issues with safety vests. Besides, as they understood this study and its potential benefits, they became the protagonists and thus more keen to discuss their problems. Indeed, their embarrassment, which was mainly perceived at the start of the focus group activity, slowly disappeared under the influence of the group and its friendship.

7.2.1 Grouping and understanding results

The author found that jockeys were not satisfied with the safety vests in use and were experiencing nasty injuries following falls. Considering this, the medical staff who assisted them at the racecourses recognised that introducing the mandatory requirement for safety vests brought some benefits to the jockeys. However, the severity of jockeys’ injuries reinforced the need for future research.

Firstly, those jockeys who had enjoyed the opportunity to race in different countries borrowed features from other brands that influenced the users’ ideas to expand the products’ uses to meet their needs. Jockeys demonstrated a strong camaraderie, so opinions regarding what they called “foreign” vests worn when racing overseas were shared with the others. It was noticed that the less experienced and younger jockeys were curious about or influenced by them.

All but one of the jockeys who took part in this study has experienced at least one fall in their whole career, as shown in Table 11. At that time, only 6 out of the 17 participant jockeys in this study did not have ever experienced a race outside Australia.

Table 11. Participants' racing and fall experiences

Participant Number	Code	Category	Gender	Years of Experience	Falls	National Races	International Races
1	AJ01	Apprentice Jockey	Male	5	•	•	
2	AJ02	Apprentice Jockey	Female	4		•	
3	AJ03	Apprentice Jockey	Male	2	•	•	
4	AJ04	Apprentice Jockey	Male	3	•	•	
5	AJ05	Apprentice Jockey	Male	3	•	•	
6	J01	Jockey	Female	6	•	•	
7	J02	Jockey	Male	21	•	•	•
8	J03	Jockey	Male	24	•	•	•
9	J04	Jockey	Female	28	•	•	•
10	J05	Jockey	Male	30	•	•	•
11	J06	Jockey	Male	18	•	•	•
12	J07	Jockey	Female	5	•	•	•
13	J08	Jockey	Female	18	•	•	•
14	D01	Doctor	Male	28			
15	ICP	Intensive Care Paramedic	Male	3			
16	D02	Doctor	Male	10			
17	AJ06	Apprentice Jockey	Male	3	•	•	
18	J09	Jockey	Male	16	•	•	•
19	JR01	Retired Jockey	Male	28	•	•	•
20	JR02	Retired Jockey	Male	12	•	•	•

The involvement of medical staff in this study offered special inside views. They could offer details regarding an important design limitation with the vests that they had experienced when attending jockeys during critical moments for their wellbeing. Health professionals currently waste time as they try to find the best way to remove the vests from injured jockeys. The time available to provide aid is limited and using as little time as possible is crucial. In addition, however carefully the medical professionals try to remove the vest, there is still a risk of increasing the severity of the injury during removal.

It is relevant to note that both jockeys and medical staff who participated in this study felt comfortable when talking with the author: nobody requested to leave or was in tears. Within the three phases of data collection, the author experienced a professional and friendly atmosphere due to the choice of safe environments for both the participants and the author.

About 30% of them clearly expressed concerns and provided negative feedback regarding the system for drawing up the standards and the consequences of this system for the users. Instead, the remain 70% did make comments about the standards but in a more informal way and thus, the author did not report these opinions in the table below. A comfortable feeling allowed the 60% of participants of this study capable of manifesting with the author their issues and unsatisfying feelings experienced while wearing the vests.

Fifty percent of participants expressed concerns and doubts regarding the safety of the neck and spine, which is one of the most sensitive topics in the horse-racing industry. Flexibility and freedom of movement were crucial for the jockeys but they experienced movement restriction during races; thus, dissatisfaction was recorded and represented in Figure 30.

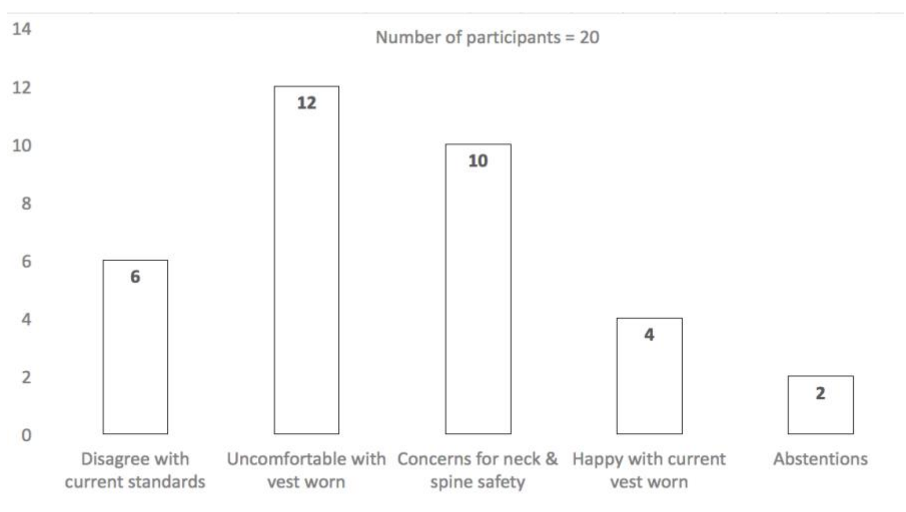

Figure 30. Chart representing the main opinions of participants

The results shown in Figure 30 demonstrate that innovation, ergonomics and an accurate design are missing in the field of safety vests for jockeys. Innovation seems to have been prevented by the use of standards ARB 1.1198 and EN 13158 (Racing Australia, 2019a).

Therefore, to perform a hypothetical redesign of safety vests, a designer should proceed with the following stages:

- consider the users and the co-dependent users;
- considering the findings offered by the users, the design of the vest is rethought;
- designers then consider the joint development of safety vests and helmets, since one influences the other during riding due to jockeys' riding posture;
- a new or different method may challenge the standards, since these are the main obstacles to the application of innovation to safety vests and the resolution of users' dissatisfaction;
- consider the latest materials and technologies applicable to the vests; and,
- consider the opportunity as vest design evolves to convert safety vests into first-aid tools for jockeys and related medical staff.

Participants confirmed that, as users, they had sound knowledge of the product, mainly due to everyday use and their experiences with it. Particularly, all the female jockeys who took part in this study reported issues with the safety vests due to their body shapes. The designs of current vests did not take this into consideration and wearing the safety vests was perceived as a discomfort while racing. Most of them were forced to wear the safety vests differently, for instance a bit looser on the sides or backwards. This alteration of the recommended way to wear the garments might badly affect female riders in case of a fall because areas such as the spine and the torso are not protected.

The review of the literature showed that the number of female jockeys was increasing, while many studies indicated that only female jockeys were reporting more injuries. However, there is a paucity of information due to the under-consideration that as the number of female jockeys increases and is now higher than the number of male jockeys in some jurisdictions, the number of injuries reported by female jockeys will also increase. Significantly, the jockeys who participated in this study had seen four females involved in accidents. This created a gender-based product effect.

Ergonomics must be incorporated into designs of safety vests. The different needs of each gender validated the observation that there is a vicious circle relationship between the standards in use and the product. Without innovation in terms of the latest materials and technologies applied to safety vests, ergonomics cannot be used, and the designs therefore take poor account of human factors and of post-fall features.

Innovation is required in the field of safety vests, even if its use might be risky. However, through design research, it is possible to understand why change justifies the risk. Along with that, design research marks the user as a source of inspiration for innovation and, if focused on satisfying users' needs, an approach to a problem from the outside can be effective. However, the final product will not work without the use of technology, as it will not evoke without design.

7.2.2 Limitations

This study adopted a qualitative research method, which generated results that met the study aims. However, this method had some limitations, including:

- the skills of the researcher formed the base of the research quality; however, they may have easily been influenced by the researcher's bias.
- the researcher's presence during the data collection phases possibly influenced participants' responses.
- maintaining and demonstrating rigour was challenging.
- the scientific community may not understand or accept the study as quantitative research.
- the data collection and its analysis took a long time.
- in some qualititative research studies, it may be difficult to present findings and results in a visual way.
- protecting the privacy of participants may be difficult during the presentation of the findings or in publications.

Despite these limitations, this study has succeeded in exploring safety vests for jockeys and their design in terms of product innovation. The same participants were involved in all the three stages of data collection, so consistency was provided. Participants involved themselves with enthusiasm in this study and they developed a clear and respectful relationship with the author.

The individual semi-structured interviews, the focus group and the observations offered proof that the research was necessary, as they showed that users of jockeys' safety vests urgently need innovation to enhance their safety during races. Regarding the observation phase, following the author's introduction and the study's explanation, participants appreciated the empathic design approach as a source of innovation in data gathering, along with the user-centred design method. The advantages and disadvantages of each data gathering method that were experienced by the author are summarised in Table 12.

Table 12. Advantages and disadvantages of data-gathering methods

	Advantages	Disadvantages
Individual semi structured interviews	• Detailed questions can be asked • Non-verbal data can be collected through observation • Complicated and/or unfamiliar data can be explored	• Good time management is required • Sensitive topics may be challenging • Interviewer's bias needs to be avoided or reduced
Focus Group	• Valid to investigate how and why people think in a particular way about a topic or product • Suitable to investigate people's behaviours and beliefs • Participants do not need good literacy skills	• Particular effort is needed in organising a well-balanced group • Potential risk that the group is influenced or dominated by one person • Good time management is required
Observation	• Access to people and situations in real life • Certain kinds of data can be collected only by observation • An in-depth understanding is produced • It is hard for a participant to lie or mislead	• Risk that the observer's bias may affect what they see • Ability to record the information is needed • Possible ethical dilemmas inherent in observing real-life situations for research purposes

7.2.3 Summary

This study confirmed the exclusion of users (jockeys) and co-dependent users (health professionals) from the design process for a product (safety vest) that played a core role in their lives. User-centred design had never been used and this had generated what nowadays would be regarded as a meaningless product, with scarce attention to ergonomics.

Accordingly, the findings produced by this study enabled consideration of a concept design of one safety outfit able to provide the required safety to the head, neck and torso areas of jockeys, representing the best hypothetical solution to the problem that current safety vests did not meet users' requirements. This confirmed the need for future research because the present vests showed a lack of innovation, which might influence the level of safety offered to jockeys.

Jockeys need to feel safe and confident during their races. The vests should be a tool that is highly admired by the users, both jockeys and medical staff. Particularly, current vests do not link the safety of jockeys with medical professionals because technology and the latest materials are not used. This produces a medical support that is not innovative and does not keep in step with the times.

Participants confirmed that each user was different, with needs dictated by body shape and experiences. Ergonomics is a key component of every good product design, yet the study showed it was missing from the present safety vests. This problem, which was often highlighted during the data collection stages, was attributed to the way in which and by whom the standards were prescribed. This generated feelings of uncertainty and exclusion that were generally diffused among the participants, leading to the absence of what is better known as user-design experience (Krippendorff, 2004; Nurkka et al., 2009; Magain, 2013; Mugge & Dahl, 2013; Samit, 2014).

The next chapter reflects on the main findings of this study in terms of its contributions to the research questions raised from the review of the literature, the key issues of this case study, the methodology of including users and dependent/secondary users applied to this study, and the medical staff participatory approach. The latter two are relevant aspects of the contribution to knowledge in as much they shall be the focus of attention in Chapter Eight.

Chapter Eight: Discussion

This chapter discusses the general inferences that may be drawn from the study findings, which confirmed the need to introduce contemporary technological innovation into the design of jockeys' safety vests and to revise the current standards applied to safety vests. Particularly, the study identified the need to introduce a correct use of ergonomics to enable female and younger jockeys to feel greater comfort in wearing safety vests, since comfort affected rider focus and thus was a factor in rider safety. The author produced a set of prototype designs (refer to subsection 8.3 of this thesis' chapter) that reconceived the safety vest for jockeys as part of a safety service system. In such a system, vests equipped with the latest sensor technology could provide first-responder medical staff on the site with information regarding the severity of injuries, and incorporate an improved method to open and close the vest to afford medical staff quicker access in providing help to injured jockeys. The chapter concludes with a holistic overview of the relevant factors found in the study to influence the product innovation of safety vests for jockeys. Proposals for improved design development and a standards review are discussed.

8.1 Overview and general goals

There was sufficient evidence to suggest that a lack of ergonomics was a basic factor that negatively influenced the jockeys' experience of the safety vests. Poor ergonomics was shown to have affected at least two key aspects of contemporary racing safety. These were the satisfaction of female jockeys with the vests, and input by track-side health professionals to the evolution of vest designs. Track-side health professionals are currently involved in injury recording into the Australian Racing Incident/Injury Database. Information on the safety vests used should be recorded on these forms. Additionally, the Single National System should have a record of each jockeys' safety vests and accordingly, of the safety equipment used thus, this can be used as denominator data at each race ride and used as the basis for further research.

Further, the standards currently in use in Australia were perceived as suppressing the application of modern contemporary materials and health-based sensor technology to these products. Consequently, the research found that both ergonomics and the input of track-side medical professionals remained excluded from jockey vest designs and standards.

The review of academic literature identified several investigations into jockey injuries, riding techniques, horse riders' injuries and therapy. Horse riders and race-track jockeys were often investigated because of their injuries, and this produced an abundance of medical publication, as described in Chapter Two, section 2.1 of this thesis. The findings highlighted a pattern of exclusion of jockey experiences to help improve vest design standards.

The UCD approach was at the base of this study and helped the author to consider more than one user. Specifically, the author proposed that a special class of 'user' should be considered in this product context, upon which the safety vests' design critically depended for them to achieve their functional purpose. The author asserted that the role of the track-side health professional was not identified by any of the classes of user discussed in the research literature for UCD and UX design. This special class of user was not adequately explained as a lesser secondary or tertiary user relative to the jockey. The track-side health profession also could not be clearly classed as a stakeholder under the conventional definition, since this user neither risked losing a financial benefit, nor did the members of this user class risk their personal health or safety. Yet their role in the future improvement of the vest design was likely to be critical and co-dependent, possibly co-primary, to the successful evolution of the vest. Track-side health professionals would be the primary users of injury-sensing technology and an innovative method for removal of the vest, since there was potential for critical-health fall-data to be transmitted to the attending medical officer on track thereby permitting faster and more informed medical assistance on site, in situ.

It is usually possible to identify the following kinds of users: primary, secondary, and tertiary (Eason, 1987). Primary users are frequently those who actually utilise the product while the secondary users are occasionally persons that use a product via an intermediary; instead, tertiary users are those that may make decisions or have a say in the product's purchase (Abras, Maloney-Krichmar, & Preece, 2004; Bergvall-Kåreborn & Ståhlbrost, 2008). In 1979, Mumford provided other three types of users participation: consultative, representative, and consensus (Mumford, 1979). Other disciplines such as product development, marketing, and innovation management have alternative categories but often focus on "customer integration rather than user participation" (Bergvall-Kåreborn & Ståhlbrost, 2008, p.105), which was not the case of this study.

Still starting from the UX and UCD models, the author took into consideration the fact that jockeys are the primary users of the safety vest in such directly utilizing the product. However, the related medical staff can't be categorised like the secondary users because they directly deal with the safety vests but even can't be named tertiary users because they are not the decision maker in purchasing the product. Hence, the author named the medical staff as dependent-secondary users per those reasons. The author therefore proposed that an extension to the conventional UX and UCD models was worthy of further research since, in cases such as the design of jockey vests, a class of user might exist that was neither clearly a secondary or tertiary user, nor a stakeholder, but rather a co-dependent user.

The author suggests that there may be a case to examine a special class of user experience that may be summarised as a dependent class. This design approach is nominally suggested in this study as a Dependency-based User Experience (D-UX) approach, as shown in Figure 31. Use of D-UX and D-UCD models has enabled the author to identify the needs and preferences of co-dependent users, and this model supplements the conventional UX or UCD model.

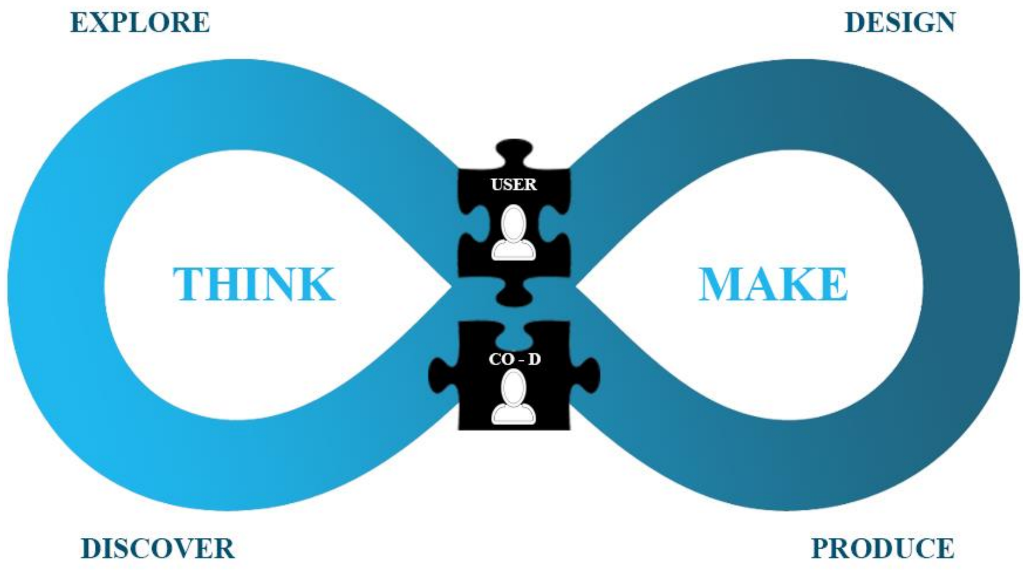

Figure 31. D-UX: Conceptual framework diagram of this study

Figure 31 shows that there are situations in which the success of a product design depends not only on qualitative engagement with a target user or user persona (the UX model), or with a particular human user at the centre, (the UCD model), but is co-dependent on the equal engagement of a critical co-dependent user. Thus, the author argues for further research in future to test the notion of a co-dependent class of users within the general UX model for special product contexts of the type studied in this thesis.

As has been stated, many injuries to jockeys are still reported that affect those body areas that should be protected by the safety vests (Masenhelder, 2016; Thomas, 2016b; Sheehan, 2017a). Previous studies have provided quantitative data in connection with equine-related injuries and have investigated horses' wellbeing, yet no research has been found that, instead, considered the design ecology of jockeys' safety vests.

Most of the published studies are epidemiological kinds: epidemiology is defined as the study of "how often diseases occur in different groups of people and why". (House, B.M.A. & Square, 1986, Chapter 1). Instead, Pearce (2012, p.393) argues that "all epidemiological studies are (or should be) based on a particular population (the "source population") followed over a particular period of time (the "risk period")". Somewhat, the author referred to Munnagi & Boktor (2019) because an experimental study design in some cases may be not suitable thus, the researchers conduct observational studies as this study's author did as well. As per their name, observational studies involve "merely observing the patients in a non-controlled environment without actually interfering or manipulating with other aspects of the study and therefore are non-experimental" Munnagi & Boktor (2019). Hence, this study did not want to be an epidemiological kind of investigation and the author only referred to those already published to create the basis to better investigate the design of jockeys' safety vests from the users' intimate point of views gathered during this doctoral's time. This study brings originality to this field, due to the use of multiple methods of data gathering and different kinds of participants to obtain various opinions about one topic.

Validity was crucial to this study. The etymological root of the word 'valid' originates from the Latin word *valere*, but it has various meanings in different cases. Angen (2000, p392) argues:

> "Validity does not need to be about attaining positivist objective truth, it lies more in a subjective, human estimation of what it means to have done something well, having made an effort that is worthy of trust and written up convincingly."

Accordingly, a debate of these findings needs meaningful discussion to support readers within the thesis and to stimulate further research for a wider dialogue. Participants held different perceptions of safety vests due to their ages, experiences, cultures and roles, yet the analysis undertaken has identified a gender effect regarding the perception of ergonomics. However, the validity of the study was supported by the fact that all the participants were happy to establish connections with the author and be placed under the spotlight to discuss something important for their careers.

8.2 Case summary

The premise of this study was to investigate whether user-centred or user experience design was not sufficient as a conceptual framework in situations where the users' wellbeing was dependent on the design solution, such as when the solution was increased safety.

Although successful overall, there is room for improvement in the proposition of D-UX design. The concept presented in this thesis is universal across all fields of design research and practice, not just applicable to jockeys' safety vests. This study has considered only a restricted group of users, but the industry literature offers many other potential participants to stimulate future research, since the 2015/16 Australian thoroughbred racing industry fact book (Racing Australia, 2017) shows 873 riders. This number comprises 523 jockeys, 270 apprentice jockeys and 80 amateur jockeys.

According to the National Jockeys' Trust, (2017b), there are currently 840 jockeys registered in Australia, while 557 race meetings were scheduled to take place in the state of Victoria alone over 353 days at 67 racetracks during the 2017/18 season (TROA, 2017).

These figures indicate that the author required strong time-management skills during the participant recruitment. As a result of a compressed timeline, the author enrolled 20 participants. The author had previously been able to establish the required focus of the questions while reviewing the literature, so that the small number of participants could nevertheless provide rich data in their answers. This number of participants could be considered not well representative of the whole Australian jockeys population. However, the review of the literature shown no studies citing "qualitative methodologists for an appropriate sample size" Marshall et al. (2013, p.15). Still, according to Marshall et al. (2013), there are some single case studies that utilised a single case based on Yin's citation (2017) but not providing more details to justify the number of interviews they conducted. However, the majority of the studies mention the importance of saturation but not provide a "defence of the size of their sample" (Marshall et al., 2013, p.15).

In this case, the author focused on the users (jockeys and medical professionals) because the direct contact with them offered a valuable resource. As an industrial and product designer, the author was investigating the use of a product which was outside her own experience. This is a qualitative study that used non-quantitative methods to contribute new knowledge about safety vests for jockeys. Hence, to respect the PhD deadline, the author recruited participants based in Melbourne and available at that time: this reduced the

Australian jockeys' population availability as either the medical staff. Besides, the author did not want to interfere with the professionals' activities performed by the users: again, the users' limited time available reduced the overall population. The rigorous attempts to recruit participants is stated by the fact that the available time was limited: this reduced the likelihood of making unsupported statements and allowed to accept such a small number of participants in this study (Altheide, Johnson, Denzin & Lincoln, 1994). Therefore, the author strongly recommended further research to include a wider population of jockeys and medical staff.

The questions targeted the scarce involvement of jockeys and especially health professionals in the design of safety vests for jockeys, which was highlighted by the lack of research literature regarding the use of user-centred/user-experience design as the conceptual framework in which the user was dependent on a successful design solution.

Hence, this study asserts that, for some items such as safety vests, products for a user might rely on meeting the needs of co-dependent users, whose contribution to the fulfilment of the design is key. Thus, the participation in this study of both jockeys and health professionals helped to validate the thesis proposal.

Despite their commitments, participants overall showed sincere and voluntary willingness to be involved in this study. Particularly, jockeys demonstrated the desire to be involved in any further development because they wanted to contribute to something that was important for their lives and ensure that their needs were finally understood. Some other participants decided to talk with the author, but they refused to be recorded, even though anonymity was guaranteed in this study. The author did not include the data provided by these people, but their wish to give their opinions demonstrated that the topic was important for many.

To understand the importance of wearing safety vests, it was necessary to discuss with participants the falls and injuries they had experienced, and this could have affected their sensitivity to this topic. The older and former jockeys, due to their experience of riding before safety vests were made compulsory and then once vests had become mandatory, contributed important data. Younger riders, for whom safety vests had always been mandatory wear, showed curiosity regarding and desire for a new product that could better address their needs. Female jockeys particularly directed the author's attention to the current approved safety vests' designs because they failed to take account of body shapes.

The medical professionals recognised that the mandatory use of safety vests brought benefits to jockeys, for example in mitigating the effects of some torso injuries, but they remained concerned about the dramatic neck and spine injuries that some jockeys had experienced because of falls. The difficulties in managing the vests when injured jockeys lay on the track were reported to the author as a way to ask for a better design to facilitate their job. Medical professionals reported struggles to open or remove safety vests when treating injured jockeys, and that this could also increase the severity of the injuries. None of these issues were discussed in academic or industry literature that the author observed.

Participants took part voluntarily and they were free to withdraw at any stage during or after the study. However, no one withdrawn from any data collection activity. Overall, the author received abundant and precious data through a huge collaborative effort from participants. In their own ways and styles, the participants were asking simply for help to ride in better, safer conditions.

8.3 Synthesis and proposals

Safety is paramount for jockeys, but there is a need for improvements to their safety vests to satisfy the needs of both users and co-dependent users. Jockeys continue to suffer after-effects such as paraplegia following severe thoracic injuries, yet these consequences should be avoided by the wearing of an appropriate safety vest (Young, 2005; Lynch, 2012; Sinclair, 2012; Pengilly, 2015; GaSport, 2016; Eddy, 2016b; Jones, 2019). This study did not introduce specific design attributes. However, it should be the basis of future research to develop a prototype. Future research is posited to explore design attributes and smart materials that create many possibilities to satisfy the needs of users of an everyday product. This study has however introduced a set of concept designs.

This paragraph delineates the core criteria to be assessed in order to produce a concept of a jockey's safety outfit. The criteria are based on the findings discussed in the previous sections. However, this part should be used as a guide to the translation of the research findings into a possible prototype. These key criteria are listed below:

1. Design for need is required to satisfy the user and the co-dependent user.
    a. This can be achieved by applying a dependency-based user experience (D - UX) design approach.
    b. An integration of knowledge is necessary from the engineer/scientific and industrial design fields.
    c. The product should employ advanced technology and the latest materials, which are uncommon in current safety vests.
    d. The product must consider ergonomics to suit the different users' needs, especially based on their gender.
2. The user and co-dependent user must desire the product and its features. A safety vest should be perceived as essential to guarantee the user's wellbeing.
    a. The safety vest needs to communicate special meanings to the wearer; a good interaction is required.
    b. Tailor-made options are necessary.
    c. The user and the co-dependent user need to be able to rely on the product.
    d. Elevating the product to a smart wearable outfit will contribute to reaching the scope and to addressing the co-dependent user's needs.

Taking into consideration the above criteria, the author realised a set of concept designs to indicate the early stages of improvements to safety vests for jockeys to achieve product innovation. In biologically inspired design, the use of a design method has core importance because it needs a very systematic approach (Singh et al., 2012). The methods available are the problem-driven and the solution-driven: in this case, the author utilised a problem-driven design method to create the base for further investigate the design of safety vests for jockeys. Despite most of the published studies inspired by nature are scientifically oriented (Ahmad & Mark, 1998; Carlson et al., 2005; Sanchez, Arribart & Guille, 2005; Gibson & Castaldi, 2006; Helms, Vattam & Goel, 2009; Parness et al., 2009; Shu, 2011), some of these (Benyus, 1997; Kicinger, 2004 Ahmed, 2009; Singh et al., 2012) offered concepts that the author considered to propose patterns that may satisfy the jockeys and medical staff needs which were gathered during this study. Specifically, the need to wear a product super light in weight but still flexible, that at the same time offers protection: for instance, spiders must be taken into consideration to obtain a durable fabric design while the camouflage of chameleons may be helpful in creating fabrics able to communicate the injury's location to the medical professionals.

Firstly, Figure 32 shows a proposed pattern shape, in which two colours are used to explain the use of a combination of materials.

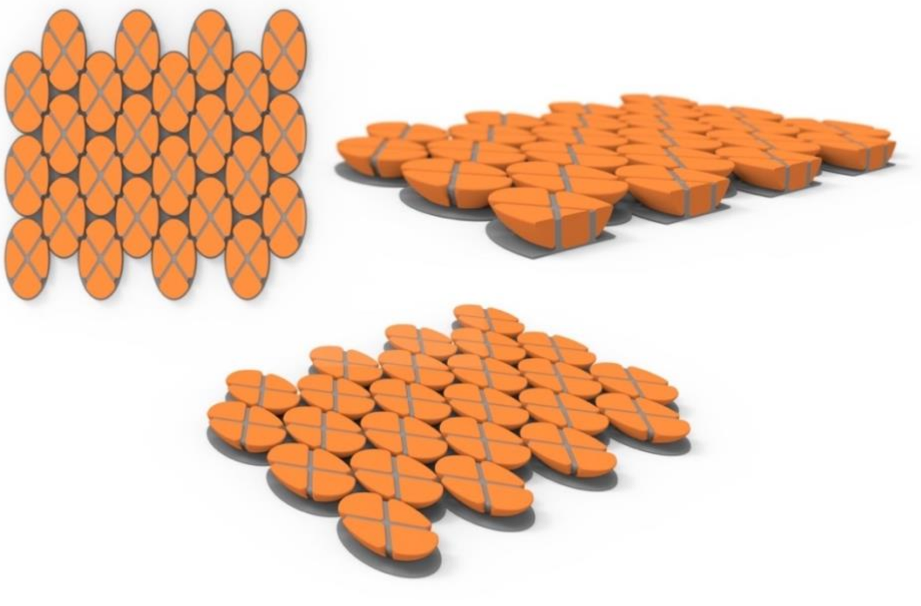

Figure 32. Proposed pattern of a concept vest design

The new shape option developed by the author is designed to improve protection of the jockeys. This new shape, represented in Figure 32, takes inspiration from nature, and specifically from spiders' webs, eggs and flowers. The jockeys' needs that emerged from the data collection were for a product that was able to follow and accommodate their movements, rather than forming an obstacle in their profession.

Hence, the author considered two materials integrated into an innovative shape to achieve a product able to follow jockeys' movements but still light and breathable. This was in line with jockeys' wishes. The shape suggests the use of a stretchy material to support the aim: however, the current standards would not support this concept design and this indicates the need to review the standards. Manufacturers should be able to use stretchable materials that can result in creating small gaps (around 5mm) to better satisfy users' movements.

Figure 33. Proposed pattern variations, option 1

Figure 33 shows how the proposed pattern could fit into the Racelite vest, which at the time of this study was the favourite among jockeys for race days. This proposed pattern employs smaller shapes than the current vest. These shapes could be made using one of the latest materials on the market but integrated with a stretchy material. This design would allow improved performance through freedom of movement, breathability and greater comfort.

Tailor-made variations could be provided that employed different colours or different shape sizes within the pattern. This would enable vests to be produced that satisfied male and female jockeys' different needs.

These simple steps represents the application of a D-UX design approach, which this thesis proposed. The approach places users and co-dependent users as the core of innovation, and listening to their needs leads to a resolution of issues through a useful and functional design. Offering customised solutions introduces ergonomics into the field of safety vests. Future research is needed to understand which materials offer the impact performance necessary to provide the highest safety level for jockeys.

Figure 34 applies the new concept pattern shape to the existing safety vest template, again using the Racelite vest as an example. A smaller dimension of the pattern allows free movement for the users and the vest might show improved moulding to their bodies.

Figure 34. Proposed pattern variations, option 2

The concept proposed in Figure 34 is particularly suitable for smaller and/or female jockeys. The pattern shown in blue indicates how the pattern can be integrated into a stretchy material instead of being covered by it, as displayed on the right side of the actual Racelite vest. More investigation is needed to understand which option fulfils users' needs and eventually to modify the standards to make such a change possible.

Figure 33 and 34 mainly differ in the design proposed to compose the vests while still respecting the current standards but suggesting the introduction of latest materials to obtain more shapes and flexibility to accomplish the users' needs. In the proposed designs, technologies may be applied to help the medical professional in collecting jockeys' injuries data or to judge the severity of an injury by a material's colour changing. Therefore, more research in this field is strongly required.

To address the concerns of the medical staff regarding removal of the vests, the author considered as a starting point the idea of embroidering small and hence light-weight magnets into the vests. Of course, more tests are needed to identify the best solution for both jockeys and medical professionals. If these were used to fit the vests to the body, they would enable medical staff to remove the safety vests promptly from fallen jockeys when required without interfering with their injuries. An example is offered in Figure 35.

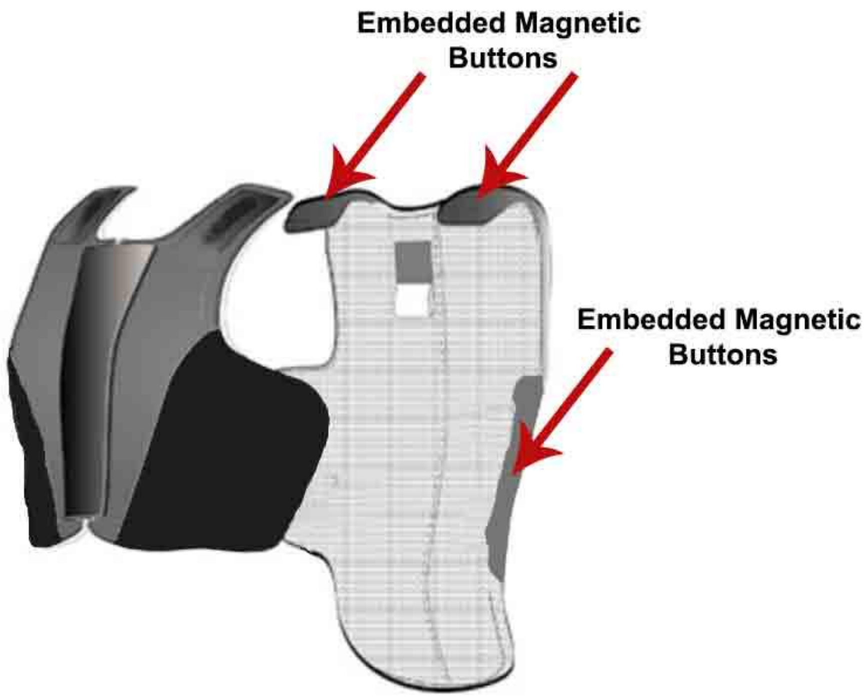

Figure 35. Proposal for an opening mechanismfor safety vests

To prepare Figure 35, the author used the template of a currently worn safety vest, without altering its front zip, which is utilised during day-to-day wear of the vest. However, the author removed all the Velcro® strips used on the shoulder and side areas. Other designs employ ties in place of the Velcro®. The proposal was to embed into the vest's shoulder and side areas small magnetic buttons to facilitate the medical staff in pulling the vest open easily to provide fast medical aid. The inspiration came from examination of clothes that contain magnets to facilitate people with health conditions (Serrie, 2013), and from those sports clothes that use magnets to bring benefits to athletes' lives (Apex, 2017; Trionz, 2017). Future research would be needed to consider the most suitable "buttons" to meet both jockeys' and medical staffs' needs. Safety is paramount for both the users, this is why the author strongly suggests conducting more research in this field.

Another vest design might provide a higher level of safety and comfort. Revision of the neck cut at both the front and back of the safety vests offered a new scenario in which the standards would be reinterpreted to lead to the development of an outfit made of vest and helmet. Simultaneous consideration of the safety vest and the helmet designs would produce a design that responded to the users' and the co-dependent users' needs: this concept represented one of the most relevant findings of the study and should be the basis of future research, which would be needed to improve safety equipment for any type of horse rider.

The review of the academic and industry literature was compared with the data collected to produce knowledge and reflection. Based on this, the author suggested six main areas for future research in which the findings could be developed:

1. This case requires the application of a D-UX design method to address the needs of users and co-dependent users, who all depend on the success of the safety vests' design.
2. The medical staff should be considered as co-dependent users of safety vests, since they deal with these products for the jockeys' wellbeing. The introduction of innovative technologies and advanced materials may help medical professionals to treat jockeys' injuries more quickly on site and the information regarding the best technologies and materials could be stored in a database for further reference.
3. Innovation is currently lacking in this field. Its use would open new

frontiers in the development of safety vests through the application of the latest materials. This could help the jockeys to experience the vests in a different way, while feeling safer during their activities.

4. Technologies now available on the market are seen as an integral part of innovation. Innovation and technology are two parts of a whole method that needs to be applied to the vest, with the aim of creating a wearable tech product.
5. The use of technology and innovative materials would require revision of the existing standards, or the creation of new ones, perhaps applicable to track-work sessions for an initial test period. The options above are only possible with revision of the standards. In addition, updating the standards could lead to revision of the vests' template, therefore enabling the introduction of ergonomics to satisfy the needs of male and female jockeys.
6. The use of the findings generated by this study during future research offers the opportunity to apply this knowledge to other equestrian disciplines, such as three-day eventing, show jumping and pony club activities, and to other sports in which participants often suffer similar injuries, such as cycling, BMX riding, snowboarding and motorcycling.

In summary, these fundamental principles must be followed to enhance the development of jockeys' safety vests: product innovation through the application of technology and use of the latest materials; a review of the standards that the safety vests are required to meet; and the application of co-dependent user-experience design. The application of co-dependent user-experience design is universal: this adds significance to this thesis and supports the case for future research not only in this but in many areas. Often the UX and UCD literature refers to stakeholders who are typically not users of the product undergoing design, but people with a direct stake in the outcome. However, this is not the case in the situation studied because the health professionals who treat injured jockeys form a class of user that does not fit neatly within these conventional definitions.

The author strongly recommends for further research the need to augment the UX model in design research terms, to accommodate inputs from those in situations similar to that of the medical professionals in this study: people whose experience and input to safety vests' design is critically dependent for the vest's primary purpose for the primary user and yet they have no direct stake in its success or failure as a product.

Co-creation and co-design can draw in anyone to help design anything for a primary user: however, the vest is of concern to specific track medical staff and the vest is subject to very tight design regulations. The author found that there was a need to facilitate a role for the medical staff in future changes to vest design standards.

Based on the findings introduced in this thesis, a new vest prototype represents a guide to future research. The use of advanced materials in a prototype may provide jockeys with greater freedom of movement while maintaining superior energy absorption properties. The design of a new vest must also consider the medical professionals' needs.

By including the users and co-dependent users throughout this process, it is hoped that the usability of safety vests will satisfy their needs. The application of qualitative content analysis offered positive findings because the author was able to work "in an interpretive paradigm" (Zhang & Wildemuth, 2009) to identify significant data from a unique group of participants and in a particular setting. Due to accurate data collection, its coding and then its interpretation, the author elaborated the above outcomes with the aim to support further research in this field, as well as validating the importance of bringing innovation into approved standards.

The next chapter sights to provide conclusions to the research contained within this thesis. Hence, Chapter Nine will discuss the interpretation of research findings and their contribution to knowledge, the limitations of the research design, and will highlight the importance of requesting further research in this field.

Chapter Nine: Summary, Conclusions & Recommendations

This chapter aims to present conclusions to the research encased within this thesis. It will discuss the summary and conclusions of research findings and their contribution to knowledge, the limitations of the research design, and will offer reasons to demand further research. This study has examined the inclusion of primary and co-dependent users to affect the evolution of jockeys' safety vests, specifically within the Australian thoroughbred horse-racing industry. A review of the relevant literature regarding UX, UCD, medical injuries affecting horse riders and particularly jockeys, new product development and wearable technologies was presented. A short but deep analysis of the industry was also presented, along with the standards that affect the design of the safety vests. Vests currently on the market were examined prior to the selection of participants for the research study and then the collection of the data.

The number of female apprentices and professional jockeys is increasing but the current standards (ARB 1.1998 and EN 13158) do not take into consideration the need for ergonomics to accommodate female jockeys' needs. Moreover, these standards do not consider the possibility of using the latest technologies and smart materials to manufacture "smart" safety vests. Thus, UCD is not applied to the creation process of a safety vest, and no account is taken of the co-dependent user. Due to the participation in this study of jockeys (apprentices, professionals and retired) along with related medical professionals, the author was able to understand the need for future research that would enhance the UCD and/or UX methods to include the co-dependent user, not only in this field but in research design. The involvement of the health professionals was vital for the author to obtain unique data to generate these outcomes. Without their involvement, these outcomes would not have been possible with the strict use of UCD and/or UX models.

This study offered meaningful contributions to the design research episteme, with the proposal of a user-dependent design approach, and to knowledge of the product. However, application of facets of D-UX design produced valid findings which confirmed that transforming the user and the co-dependent user into the key to evaluate the safety vests brought benefits that reinforced the need for further research in this field. Both jockeys and medical professionals positively received the results of the design process, demonstrating the value of a D-UX method rather than the conventional UX or UCD model. The research presented herein indicated the effects that innovation and use of the latest technologies could have on safety vests for jockeys, while the background research into smart wearable safety clothes in other sports highlighted the long use for the vests of the same standards, which had decelerated application of innovation and product ecology in this field.

The findings confirmed that the design of jockeys' safety vests and their standards required innovation and reform. They also showed that this particular product had more than one user reliant on its success: the jockeys (user) and the medical staff (the co-dependent user). This thesis posited therefore that UX and UCD models required adaptation and it examined ways in which adding a co-dependent user would work in design research. Due to the application of the conceptual framework named D-UX (refer to Chapter Eight, subsection 8.1 of this thesis), the author revealed new design insights regarding the safety vests that would not have been obvious or discovered if the author had adhered only to the UX and/or UCD models.

Use of an instrumental case research design to develop new knowledge and application of a qualitative research approach that emphasised richness rather than the ability to generalise the results, as explained by Stake (1994 & 1995), has facilitated this study. Thus, the author learned of a few key issues that concerned jockeys and health professionals, which led to the need to revise the standards also to accommodate innovation in the field. These are described in the following subsections.

9.1 Overview

The aim of this research was to understand the ways in which primary and dependent secondary users affected the evolution of jockeys' safety vests. This study is the first exploration of user and co-dependent user, where both depend on the successful design of a product, and it leads academic research in this area. It is also unique because it has involved such a particular group of participants comprising jockeys and health professionals, and has discussed innovation of jockeys' safety vests for the first time. The documentation built during a variety of data-gathering stages provides significant insights into the importance of selecting the correct conceptual framework in situations where user and co-dependent user are dependants of product design.

The review of the literature showed that, since the early 1990s, discussion of the designer's role has become predominant over the value of user participation. This study then considered the use of user-centred design in product innovation in the case of safety vests for jockeys. The author stated that UCD/UXD models were not satisfactory as a conceptual framework in cases in which the user depended on the design solution being successful .This thesis demonstrates that, in some design situations, an alternative to the popular UCD/UX framework is required for such third- situations such as that of the co-dependent user.

The study has contributed to understanding ways in which technology and product innovation may assist in the enhancement of safety vests for jockeys. There is potential for this study's framework to be implemented in developing safety equipment for sports such as horse-racing, horse-riding and others which experience similar injuries. The concept designs developed and the findings of this study are original and should make a significant contribution to the improvement of safety vests for jockeys. The D-UX model proposed by this study should make a significant and universal contribution across all fields of design research and practice. This concept offers foundations for future directions in design research.

9.2 Summary and Conclusions

Chapter One concluded that a core problem in improving the safety features of jockeys' vests was the lack of innovation, along with an inappropriate theoretical framework to guide the formulation of standards and product enhancement properly. In the past, the emphasis was often placed on the use of UCD or/and UXD and, in this field, on the injuries experienced by horse riders without an adequate consideration and understanding of the user.

Asserting that the achievement of high quality in products for a user can rely heavily on meeting co-dependent users' needs led the author to apply this assertion in the context of safety vests for jockeys. There was sufficient evidence that being a jockey involved risks and sacrifices (Fernie & Metcalf, 1999; Domino & Fagan, 2014; Curry et al., 2015 & 2016; Hitchens, 2015; Hitchens et al., 2009 & 2010; Hitchens, Hill, & Stover, 2016; O'Connor et al., 2018) and that currently worn safety vests did not provide sufficient protection, or accommodate all the jockeys' needs.

Chapter One discussed the concerns associated with safety vests for jockeys, and the author proposed an original theoretical framework to evaluate these products and the possibility of new designs offering greater protection. The chapter concluded with three research questions. The methodology required to answer and the answers to these questions highlighted what was needed to improve current user-centred design methods and understanding of the factors that influence innovation in safety vests for jockeys. The main research question was:

> What are the relevant factors that, by themselves and in combination with each other, substantially influence the use of user-centred product innovation in the specific case of safety vests for jockeys?

The research sub-questions were:

1. What are the main historical and regulatory factors that influence the design of jockeys' safety vests?
2. Why has a user-centred design method not been applied to enhance safety vests for jockeys and what benefits might such an application offer?
3. In such a fast-changing world where the pace of technological change constantly accelerates, is it possible to integrate technology and advanced materials into a safety vest?

Chapter Two presented knowledge from the academic and industry literature. It was argued that jockeys were elite athletes who had been proven to place their lives on the line every time they were in the saddle. Although there was extensive scientific knowledge about horse riders' injuries and even relating to the consequences and severity of jockeys' falls, there was a paucity of data about jockeys (how they experienced the product) and the design of their safety vests. Since these professionals aimed to ride in the best safety conditions, yet they reported injuries similar to those experienced in other sports such as mountain biking, skiing and motorcycling, part of the chapter reviewed the body protection available in such sports. Inspired by the innovation and technology already available to many other sports, the author focused on ways in which this study could bring benefits in this field. Influenced by the use in previous research of user-centred design (Garrett, 2002; Knight, 2011) and user-experience design (Garrett, 2002; Buxton, 2007), the author found that case studies such as these were not sufficient because there was the need to consider the co-dependent users, and both user groups were an auxiliary upon product design. This study for the first time placed users and co-dependent users at the centre of an investigation. To proceed successfully with that, the author analysed the industry, with a focus on the Australian thoroughbred horse -racing industry.

Chapter Three offered an overview of the industry while outlining the main issues generated by safety vests. This motivated the author to understand the jockeys (users) and the health professionals (co-dependent users), how they interacted with safety vests and the rules that guided the realisation of these products.

Chapter Four discussed the theoretical framework and model of this study, which identified the needs of the users and co-dependent users as the central focus of this investigation. The author argued that safety vests for jockeys were limited in their capacity to provide reliable safety to these professionals and, to gather valid data, it was important to apply empathic design. However, the author found that the user-centred and user-experience design methods were insufficient for this study, as discussed in Chapters Five and Six.

Chapter Seven of this thesis showed that the evolution of safety vests should lead not only to improved safety for jockeys, but also to a quicker and more efficient medical response to their injuries in an accident. The performance of these products as fall and impact-protection devices was shown to be insufficient to satisfy essential demands for improved recovery from injury. Future research is needed to disentangle the presumed effects of innovation on the vests. If the vests are not altered, jockeys' lives will remain at risk and medical professionals will continue their hard work in a "conventional" way that cannot take advantage of modern materials or technology.

The methodology proposed a model that combined the needs of both users and co-dependent users as the centre of this study. The application of this choice then concluded with the creation of the D-UX model, enabling both to be considered in relation to the performance and success of the safety vest design. The benefits of the D-UX model applied in this study may be summarised with the following points:

- It provided a variation of the commonly applied user-centred/human-experience design framework while including dependent secondary users.
- It supplied a mixed-method research framework that integrated qualitative and industry information.
- It focused on selected target outcomes while preserving an overview of the issues addressed.

The consideration of the users in product innovation and their interaction with products, as discussed in Chapters Five and Six of this thesis, enabled the author to start to understand how users felt regarding safety vests and their and experiences with them.

9.3 Summary of Key Findings

This section has summarised the research findings in order to demonstrate the extent to which the research question and its sub-questions have or have not been answered by the research findings discussed. This study found that the main factors affecting user-centred product innovation in this field included:

- the difficulty that the design development of current safety vests had not involved users (jockeys) or co-dependent users (health professionals); and

- both users and co-dependent users were not satisfied with the current vests because their needs are not contended by these products' design.

The standard applied in Australia to protective clothing such as jackets and body and shoulder protectors was the EN 13158, which was amended in 2009 and is now known as EN 13158:2009 (British Standards, 2009). This European standard can be defined as generic because it applies to all horse riders and people working with horses, with only some sections dedicated to jockeys.

This study also found that:

- The safety-vest standards in use (EN 13158 2009 and ARB 1.1998) should be revised to facilitate product innovation. Regarding this issue, it was found that:
    - the standards represented an obstacle to the use of new materials and technologies to satisfy user and co-dependent user needs;
    - the standards did not take into consideration the use of ergonomics, which would help in improving wearability for female and/or particularly skinny jockeys;
    - the standards for safety vests were different to those stipulated for helmets, and this lack of cohesion created interference between the two products for the user because often helmets and safety vests bumped together during the race;
    - the conditions of the track could influence the consequences of a fall but did not prevent injuries; however, the standards did not take this into full consideration in sections that affected the vests' development.
- The present riding style (known as the Martini glass) should be taken into consideration during the design of safety vests because it affected jockeys' needs. Jockeys' body needs to be extremely flexible to accommodate their riding style and even in case of falls: the safety vests should satisfy these requirements while protecting the jockeys from severe injuries. The front side of the safety vests should be short enough to let them ride in the crouched posture but still able to protect jockeys' ribs and other vital organs. Instead, the neckline on the back side should be deep enough to not bounce into jockeys' helmets while

riding but still able to safeguard their spine and neck areas from catastrophic injuries.

- If jockeys fell, they needed to be able to roll without hindrance, yet the current vests were bulky and hampered this movement.
- The number of female jockeys in the industry was increasing.
- The current design and materials applied to the manufacture of safety vests adversely affected the work of the medical staff. The specific concerns were:
    - a quick medical response was crucial, yet time was wasted while the medical staff found a way to carefully remove the safety vest from an injured and often unconscious jockey;
    - without knowledge of the injury suffered by a jockey, the medical staff needed to pay extra attention to the removal of the safety vest, and because this could be difficult, there was a danger of increasing the severity of the injuries;
    - because the current vests did not integrate any smart devices or materials, the medical staff could not rely on any electronic database other than a mobile app. Thus, paper books were still used as the database but these could be lost, were not always available on the track and were not always updated; and
    - during a fall, the jockey's chin was often harmed by the vest's zip, which forced the medical staff to pay attention to this injury and spend time opening the zip carefully.

Throughout this study, the standards represented a salient topic among users, particularly jockeys, because the revision process of standards did not involve professional horse riders. The author considered this to be another impediment to understanding the requirements of users and co-dependent users. It is known that the team of professionals delegated to review the standards has no experience as jockeys, and sometimes it is not directly associated with the industry. The author contended the research contained within this thesis has answered the original research question and its subquestions.

9.4 Recommendations for future research

In the process of conducting this case study investigation, the need for further research has been recognised. During the development and conduct of this study, the overall aim was to develop an understanding of how primary and dependent-secondary users affect the evolution of jockeys' safety vest designs in the Australian horse racing industry. This has been achieved.

The Australian thoroughbred industry is wealthy, and it has many users who interact with safety vests. Horse riders in other fields such as show jumping, eventing and pony clubs are also potential users of the vests. Therefore the market would receive an innovative product positively. The findings of this study reinforced the discoveries made during the review of the academic and industry literature; that horse riding was a dangerous occupation, yet safety vests were still inadequate to prevent severe injuries to jockeys. They endured a high injury rate due to the nature of their profession.

Future research should investigate the chances of revising the standards and the introduction of a new one. It should also consider the possible use of innovation and the latest materials to enable revision of the whole design of safety vests, or to use different shapes in the design, or to create a new vest template, as the author suggested in Chapter Eight of this thesis.

The user-centred/user-experience design models offered useful methods to conceptualise this case study in product innovation. However, there remain a number of areas in which the proposed D-UX model could be improved through further research. It is meaningful that the D-UX model has a universal application across all fields of design and practice, and therefore this study is significant.

In the thoroughbred horse-racing industry, steps should be taken to include users and co-dependent users in the design of safety vests and the development of related standards. This study proposed some concept designs without production of any prototype and, thus, this requires further research. The author required a deep understanding of the needs of the users and co-dependent users, and because no precedent had been set, this demanded a lot of time to investigate the racing industry. In future this time could be reduced as the result of further research. The key findings of this study can inform directly the framework for further research in this field, which is highly recommended.

This study produced a vision for jockeys' safety equipment with the following characteristics:

- Interactive design methods should be applied to the safety vest, helmet, saddle and ride dynamics to understand ways in which these all work best together for jockeys' safety, light weight and comfort.
- Falls are very hard to prevent, but their effects can be mitigated through the development of smart wearable gear that can inform health professionals of the injuries sustained by the fallen jockey.
- Credible research to inform the next generation of standards is highly recommended.

Since this study for the first time engaged users and co-dependent users by seeking their input and using their knowledge, it may start a process of data conversion into applicable information to create a safety-vest prototype. The key findings that have emerged from this study could inform directly a design for future development. This should include the following steps:

- Apply the most suitable materials and latest technology to a prototype, which should be developed with users and co-dependent users.
- Commence discussions regarding the revision of standards to abolish the vicious loop created between standards and paucity of innovation.
- Introduce ergonomics as a core feature of every safety vest.
- Revise the measurements of the safety-vest template to mitigate issues with the neck hole and zip and therefore to offer benefits to jockeys and to medical professionals.
- Improve the performance of the vest as a fall- and impact-protection device. Its design should support the medical professionals to provide aid to injured jockeys.
- When a prototype is completed, conduct usability testing with both users and co-dependent users.

Professionals such as industrial designers could produce a new safety-vest design with an altered frequency at which it should be replaced. Safety vests that employ innovation could elevate the safety level of the users while encouraging the more frequent replacement of these products.

This study filled a gap in existing knowledge by increasing the importance attributed to the needs of users and co-dependent users, and discussing the exigency of revising the standards. Research findings demonstrate the design-led innovation is the linchpin for primary and dependent-secondary users design, specifically for jockeys' safety vests. Users seek safety while performing in a career they love, but the standards represent an obstacle to the meeting of users' needs. This is demonstrated in the paucity of ergonomics that results in lack of attention to female jockeys' needs, and the limit that the standards produce regarding the use of advanced materials and technologies such as sensors, and application of innovation to the vest template.

What achieved in this thesis may appear as a hybrid solution because the findings are a mixture of design and science (refer to Table 6, p.132 of this thesis). However, the role of industrial design is growing, and the researcher's role to seek new processes that inform the design of future developments will also grow, with the aim of meeting the final users' needs. The link between research and industrial design enjoys mutual benefits to produce positive achievements, even in this research field.

The findings and contributions of this study created an opportunity for future research. If the recommendations are achieved, further research could involve the whole jockeys and medical staff population in Australia prior to considering other countries as well. Along with that, future research could investigate the possibility to create a new standard for jockeys' safety vests and thus let the researcher explore the best materials and technologies could be applied to create a "smart" safety vest. It could examine the simultaneous integration of user and secondary-dependent user to elevate the safety and design of jockeys' safety vests. Future research could explore the influence the use of the latest technologies and materials over future products to drive innovation in this field. In the process of conducting this study, the author recognised the need for further research: future tests are required to create a vest's prototype.

This study has explained clearly the risks involved in the jockeys' profession and what can be done to mitigate the dangers faced by these professionals. Time constraints and the nature of a doctoral study prevented to extend the study to wider jockeys and medical staff populations: hence, additional research is desirable to progress findings of this study further. Primarily, it is hoped that the outcome of the thesis will be innovative for the product design of a new jockeys' safety vest. It is now time to act to provide jockeys with a brighter and safer future, which is not possible without further research.

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Copy of ethics approval

From: Sally Fried **On Behalf Of** RES Ethics
Sent: Monday, 18 July 2016 4:11 PM
To: Kurt Seemann
Cc: RES Ethics; Carolyn Barnes; Lisa Giusti Gestri; Nicole Aimers
Subject: SHR Project 2016/125 - Ethics Clearance

To: A/Prof. Kurt Seemann, FHAD

Dear Kurt,

SHR Project 2016/125 – Safety vests for jockeys: an intrinsic case study in the role of design in radical product innovation
A/Prof. Kurt Seemann, Ms Lisa Giusti Gestri (Student), A/Prof Carolyn Barnes, Dr Nicole Aimers - FHAD
Approved duration: 18-07-2016 to 16-09-2017 [Adjusted]

I refer to the ethical review of the above project by a Subcommittee (SHESC-Other) of Swinburne's Human Research Ethics Committee (SUHREC). Your responses to the review as e-mailed on 9 June and 12 July 2016 were put to the Subcommittee delegates for consideration.

I am pleased to advise that, as submitted to date, ethics clearance has been given for the above project to proceed in line with standard on-going ethics clearance conditions outlined below.

- All human research activity undertaken under Swinburne auspices must conform to Swinburne and external regulatory standards, including the *National Statement on Ethical Conduct in Human Research* and with respect to secure data use, retention and disposal.

- The named Swinburne Chief Investigator/Supervisor remains responsible for any personnel appointed to or associated with the project being made aware of ethics clearance conditions, including research and consent procedures or instruments approved. Any change in chief investigator/supervisor requires timely notification and SUHREC endorsement.

- The above project has been approved as submitted for ethical review by or on behalf of SUHREC. Amendments to approved procedures or instruments ordinarily require prior ethical appraisal/clearance. SUHREC must be notified immediately or as soon as possible thereafter of (a) any serious or unexpected adverse effects on participants and any redress measures; (b) proposed changes in protocols; and (c) unforeseen events which might affect continued ethical acceptability of the project.

- At a minimum, an annual report on the progress of the project is required as well as at the conclusion (or abandonment) of the project. Information on project monitoring and variations/additions, self-audits and progress reports can be found on the Research Internet pages.

- A duly authorised external or internal audit of the project may be undertaken at any time.

Please contact the Research Ethics Office if you have any queries about on-going ethics clearance, citing the Swinburne project number. A copy of this e-mail should be retained as part of project record-keeping.

Best wishes for the project.

Yours sincerely,

Sally Fried

Secretary, SHESCs

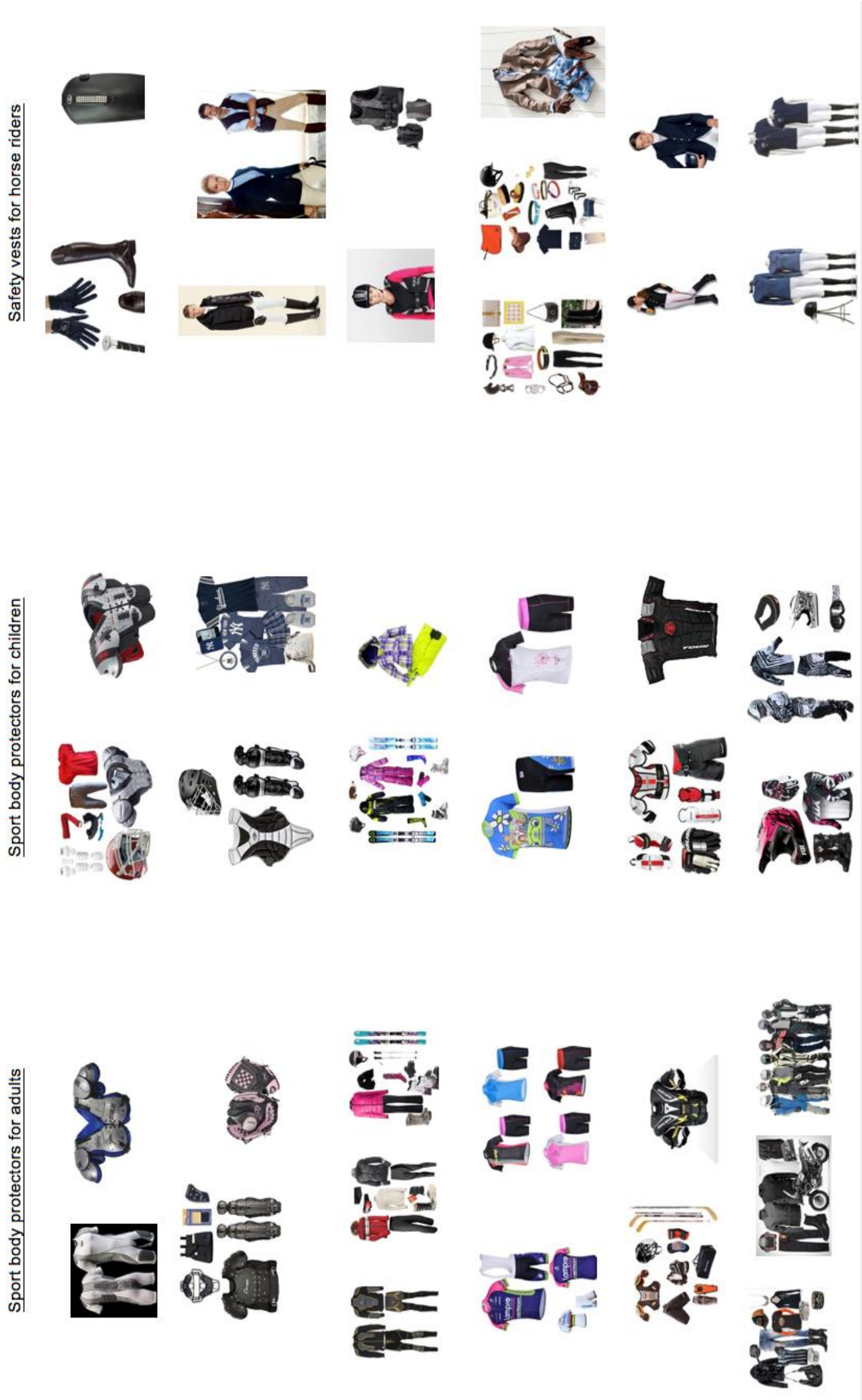
Appendix I - Visual Review (Helmets)

Helmets for horse riders

Sport Helmets for children

Sport Helmets for adults

Appendix II - Visual Review (Body Protectors)



Appendix III - Prompt questions for semi-structured interviews (Jockeys)

The interview protocol developed for the participating jockeys involved the following questions:

1. At what point on race day or during track work do you put on your safety equipment?
2. Can you describe the experience of wearing a safety vest in the lead-up to a race?
3. Can you describe the experience of wearing a safety vest during a race?
4. Can you describe the experience of wearing a safety vest after a race?
5. Have you ever experienced a fall while wearing a safety vest?
6. What are the main functions and benefits that you expect from a safety vest?
7. What do you think are the main irritants in wearing a safety vest?
8. What should a safety vest look like for you?

Appendix IV - Prompt questions for semi-structured interviews (Medical Staff)

The interview protocol developed for the medical first responders asked the following questions:

1. Can you describe how and when you started to provide professional medical help to jockeys?
2. What are the most common injuries you have treated as a consequence of a fall? Please describe this with details.
3. What do you think are the strengths and benefits of wearing a safety vest?
4. What are the main functions and benefits that you expect from a safety vest?
5. What is the main function that you expect from a safety vest that could contribute to your medical services?
6. What could the redesign of a safety vest do to improve the medical staff services at racecourses in case of a fall?
7. What should a safety vest look like to you?