SMART TOOLS FOR A SMART RECOVERY:

The development of a motivational training aid to address issues related to athlete adherence to the current injury recovery process.

Arien Hielkema
MCT

2016

SMART TOOLS FOR A SMART RECOVERY:

The development of a motivational training aid to address issues related to athlete adherence to the current injury recovery process.

Arien Hielkema

A thesis submitted to
Auckland University of Technology
in partial fulfilment of the requirements for the degree of
Masters of Creative Technologies (MCT)

2016
AUT COLAB

ABSTRACT

Smart Tools for a Smart Recovery.

How can the use of smart wearable technology motivate a stronger adherence to strengthening exercises as part of an athlete's injury recovery process?

Injury recovery is often perceived by athletes as being totally separate from training. This mind-set can cause mental blocks, often resulting in a slow recovery, with the athlete choosing to go back to regular training instead of the strengthening and rehabilitation exercises prescribed by professionals.

The aim of this project is to understand why adherence rates to prescribed exercises affect the recovery process, with a particular focus on motivational and psychological behaviours throughout injury recovery. The research explores the manipulation of such behaviours, through the investigation of a prototype feedback device in the form of a smart fabric knee brace.

Focusing on one particular knee movement allows the research to concentrate on the connection between motivation and adherence to prescribed exercises. In suggesting that "our behaviours are shaped by the environmental stimuli around us," Chris Lewis implies that technology creates, and thus might be used to explore, ways to enhance the intrinsic motivation of recovering athletes (2014).

By thinking about recovery as training, we can move past psychological barriers to adherence and improve recovery performance on all levels, helping injured athletes to recover faster and return to unimpeded training.

TABLE OF FIGURES

Figure	Description	Source
Figure 18	integrated sensor. Knitted with the Shima Seiki machine	Project progression photos
Figure 19	Shima Seiki program pattern	Project progression photos
Figure 20	Test Swatches, knitted with the Shima Seiki machine.	Project progression photos
Figure 21	Dropped stitch within pocket	Project progression photos
Figure 22	Test swatches, knitted with the Shima Seiki machine.	Project progression photos
Figure 23	Test circuit with integrated flex sensor	Project progression photos
Figure 24	Knee brace schematic	Project progression photos
Figure 25	Circuit layout created with Fritzing	Project progression photos
Figure 26	Final knitted prototype with fold conductive yarn acting as wires	Project progression photos
Figure 27	Componentry housing design	Project progression photos
Figure 28	3D printed componentry housing	Project progression photos
Figure 29	Arduino and Processing code to analyse sensor data.	Project progression photos
Figure 30	Exhibition of outcomes 01	Project progression photos
Figure 31	Exhibition of outcomes 01	Project progression photos
Figure 32	Exhibition of outcomes 02	Project progression photos
Figure 33	Exhibition of outcomes 03	Project progression photos
Figure 34	Exhibition of outcomes 04	Project progression photos
Figure 35	Exhibition of outcomes 05	Project progression photos

ATTESTATION OF AUTHORSHIP

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person (except where explicitly defined in the acknowledgments), nor material which to a substantial extent has been submitted for the award of any other degree or diploma of a university or other institution of higher learning.

Signed by Arien Hielkema, Thursday, May 12, 2016

ACKNOWLEDGMENTS

Firstly, I would like to thank all the interview participants for their input, support and the sharing of their personal experiences throughout injury and the recovery process. Your contributions have helped to inspire and drive the project's direction, ensuring a relevant and useful body of work that will help with those following in your footsteps. Thank you to the AUT ethics committee for allowing approval of ethics for this research. Application number 15/291.

To my two wonderful supervisors (primary James Charlton, Secondary Mandy Smith) as well as AUT technicians, thank you for believing in the vision of this project. Your direction has shaped and pushed the project to achieve far more than the original scope. You give hope and direction where no obvious path exists. You truly are the unwavering motivational force behind this project.

A personal thanks to my Ironman coach and mentor Andrew Mackay from Boost Coaching, as well as Matt Merrick. Without the both of you, the topic or scope of this project would not have been possible. You have opened a door that cannot be closed, resulting in a lifelong passion for triathlon and Ironman. Your guidance and support throughout the darkest moments of training make the light of success that much brighter. I am a better person because of your input, guidance, and friendship.

To Sarah Metcalf from Devonport Peak Pilates & Physiotherapy, your physio skills are equal to none. The knowledge you hold of body mechanics, anatomy, and treatment, as well as the mental states and motivational factors of recovering athletes, has not only helped me overcome my own personal injury but the integrity of this project.

My friends and family. Thank you for letting me do the work that I needed to do, knowing that you are there for me when I need you and giving me space when needed is more important than you will ever know. I am confident you now know more than I do about the topic of injury recovery, after listening to every piece of recounted information in the creation of this thesis.

Lastly but most importantly to my amazing wife, your support, guidance, understanding and keen editing eye has enabled me to realise my potential, your strength and determination is always a source of motivation and it is this that keeps me going on a day to day basis, you see the best in me and guide me from realisation to end goal. Everything we do we do it together, this thesis is a product of our combined efforts. Without you, there would be no recovery.

INTELLECTUAL PROPERTY RIGHTS

Signed by Arien Hielkema, Thursday, May 12, 2016

TABLE OF CONTENTS

1. INTRODUCTION

The concept for this research was born out of my own experience recovering from injuries sustained in a bike accident, during training for Ironman New Zealand, 2014. The injury list included a torn posterior cruciate ligament (PCL), a fractured scaphoid (wrist), a broken elbow and a partially dislocated shoulder. Through undertaking hours of rehabilitation, physiotherapy, strength training, and by sheer determination, I was able to make a full recovery, and within one year of the accident, I was able to finish my first Ironman.

With a background in 3D animation, visual effects and motion graphics in the film and broadcast industry, my skill range offers me the ability to adapt and apply loosely related 3D and programming skills. Once repurposed, these skills, combined with new tools and methods gained from the research, allow a unique combination of knowledge to be used towards enhancing the injury recovery process.

I am interested in understanding how technology might inform and build on the more traditional methods of injury recovery. This research is targeted toward the Triathlon community, supporting physiotherapists, as well as researchers looking to build on motivational theories within the sports rehabilitation sector, and in particular to explore motivational theories and how potential implementation could be used to help assist with adherence rates to prescribed programs and accuracy throughout the strengthening exercises.

The common issues and techniques explored throughout the practical research can provide a framework for future projects looking to build upon the current body of work in this field.

The primary target audience for this research is therefore framed around those supporting practices within the Ironman Triathlon community. However, it has the potential to benefit other groups and areas of study, which include but are not limited to, stroke patients, surgery recovery, injury prevention and movement analysis.

The idea

The proposition presented here is that successful recovery from athletic injury relies on adherence to prescribed treatments, and the level of adherence is affected by motivation. If mismanaged, motivation can work against the rehabilitation process, resulting in poor adherence to prescribed exercises that are vital to the progression of the injury recovery.

Most strengthening exercises can be subjectively interpreted, or are confusing for the athlete due to unclear explanations and misinterpreted demonstrations. As these exercises target specific areas of the body, poor *form*[1] throughout the exercise will result in the targeted area not experiencing the intended effect, thus making the exercise redundant.

The development of a smart training aid is used to explore methods of movement correction, addressing perceived issues related to adherence and recovery times experienced by recovering athletes who are returning to training.

Before such tools can be developed, it is first necessary to obtain an overview of the recovery process. To achieve this, a series of one on one interviews with physiotherapists, coaches and athletes were conducted and used to identify a relevant focus for the targeted community of injured athletes[2]. Surveying not only the injured athlete but also the wider support community allows for individual accounts to be collected and assessed for common issues related to the current recovery process. Once obtained, such issues can be used to drive the purpose and direct the research.

Drawing upon the ideas and feedback from the interviews, a smart knee brace was developed by using electroconductive yarn, which when knitted together creates a completely cohesive and lightweight smart fabric. Once integrated with soft flexible sensors, in place of the bulky circuitry traditionally used for this type of application, the prototype is used to capture and analyse an individual's movement. If developed as a consumer product, the brace will allow for a high-tech, low-weight, wearable device that can be calibrated to an individual athlete's recovery profile.

The aim of the brace is to monitor the *form*, repeatability, and quality of the exercise prescribed by the physiotherapist. To achieve this, the knee brace is fitted to the injured athlete during the initial consultation. The patient then performs the newly prescribed exercise under the supervision and direction of the physiotherapist, while in the background the brace captures a movement profile. Once the correct movement profile has been captured, the brace will then be given to the patient, and used to compare the previous movement profile with the exercise as it is performed.

Real-time feedback from the calibrated movement profile will be used to help visually inform the athlete of any incorrect or improper movement whilst performing the exercise. This will be communicated via Bluetooth to an external computer, analysed and processed into visual feedback. As an example of a potential form of feedback: if an athlete is performing the exercise within 5% of the movement profile, the app could respond with a green light, communicating to the athlete that the exercise is being performed correctly. If the exercise is being performed outside the 5%, but inside 20%, an amber light would urge the athlete to reassess and make corrections to their movement until the light goes green. However, if the exercise is out of the movement profile by more than 20%, a red light would indicate improper *form* and urge the athlete to start again.

---

[1] Within the scope of this thesis, *form* will be referred to as 'proper technique' throughout the movement of a prescribed exercise.

[2] See section 6 page 25 for further details on the interview process

There is, however, a shortcoming to this approach, and as such, it reveals a gap in the research. Although feedback is provided on the previous movement profile, an individual will not be given absolute informed instruction on how to correct the movements. For instance, if they need to bend less or more, or if the lateral deviation is outside the correct range. The device should, therefore, signal the athlete to stop and consult a physiotherapist for correct instructions. This message would address issues relating to health and safety and liability. The device is not intended to replace the role of the physiotherapist, but rather to provide a rehabilitation tool to assist with not only *form* but also with motivation, throughout the injury recovery process. By enhancing engagement and encouraging accuracy through the strengthening exercises, the device will shift the mind-set around recovery, from viewing recovery as a tedious inconvenience to viewing it as a productive challenge, akin to an athletic goal itself.

Research problem

The successful recovery of an injured athlete relies heavily on the adherence to recovery programs prescribed by physiotherapists. Poor adherence can impede successful functional outcomes, resulting in frustratingly slow recovery times.

What is not always understood, or taken into account, is the mental impact the recovery has on an individual athlete, as “In addition to the pain associated with injury, athletes often struggle psychologically to cope and return to their chosen sport” (Cudmore, 2014, p. 50).

An athlete must not only manage their physical recovery but also ensure their psychological and mental state is looked after. It could, therefore, be argued that one of the main causes of low adherence is low motivation.

To encourage a higher level of motivation throughout the recovery process, innovative solutions must be sought. One such solution is presented here, in the form of a training aid that acts as a motivational guide, to help measure the quality, *form*, and progression of prescribed exercises.

This qualitative study explores the motivational factors experienced by athletes, to highlight causes of low adherence to strengthening exercises that are prescribed by physiotherapists.

These factors are used as a basis for the on-going exploration of technology that could be used to improve the mental and motivational state of a triathlete; exploring different data collection techniques through integrated or off the shelf sensors, helping with the on-going struggles and frustrations experienced during the recovery process.

Although the study successfully demonstrates ways of visualizing and processing the collected data, further investigation and experimentation are strongly needed to address the close relationship between motivation and visualisation. While this is an important topic, it is not a key component of the current thesis.

Objectives

1. Identify factors that contribute to poor adherence to strengthening exercises prescribed by physiotherapists as part of an injury recovery plan, and determine potential behavioural impacts that cause poor adherence.

2. Critically analyse current, relevant techniques and technology used to assist with injury prevention and ongoing care from sport related injuries within the physiotherapy field.

3. Utilise new and existing technologies to create useful training aids, which can be used to reduce recovery time and create a positive experience for recovering athletes.

4. Develop a prototype training aid (knee brace) that is informed by factors identified by this research, with the aim of helping improve adherence rates.

5. Explore ways of visually communicating complex rehabilitation strengthening exercises, to improve patient accuracy in their performance.

6. Create a pathway for others to continue research into technology-assisted motivation for recovery.

2. INJURY

This section investigates the relationship between the knee joint and various injuries by exploring the biomechanics, musculoskeletal structure, and limitations of the joint, as well as the physical impacts and stresses that can lead to overuse injury. It is important to note that the purpose of this section is not to provide an in-depth review of the topic, but rather to understand in practical terms how the movement of the knee relates to the questions being asked of the sensors and integrated technology of the training aid.

A physiotherapist has a complex understanding of anatomy, muscles, bones, ligaments, movements, and common injury causes, as well as the ability to correctly diagnose, treat and prescribe exercise programs to patients used in the correct management of an injured athlete.

The training aid created as part of this research is designed to be used as a tool alongside the physiotherapist. It needs to measure movement while addressing all the relevant issues that the physiotherapist identifies. This is particularly important to note in relation to the successful recovery of athletes, as treatment requires in-depth knowledge and understanding of movement and muscle groups.

Every case is unique. Knowing what you need from the technology allows it to be a more relevant and useful tool. As this research field of inquiry is restricted to the injury and treatment of the knee, it is important to explore the anatomy and movement of the knee, which has informed the creation of the training aid. It is also relevant to the methodological approach used in this research: design methodology is being used to understand and assess current recovery systems, to be used to position the training aid as more than just another high-tech training device. This training aid is a way to invoke and encourage a rethink of current recovery systems.

The Knee

Within the medical profession, the structure, movement, and articulation of the knee joint are reasonably well established. Goldblatt and Richmond (2003) suggest that, in relation to the physiotherapy treatment of injured athletes, a "thorough knowledge of the complex anatomy and biomechanical function of the structures of the knee is essential to make accurate clinical diagnoses and decisions regarding the treatment of the multiple-ligament-injured knee" (p. 172).

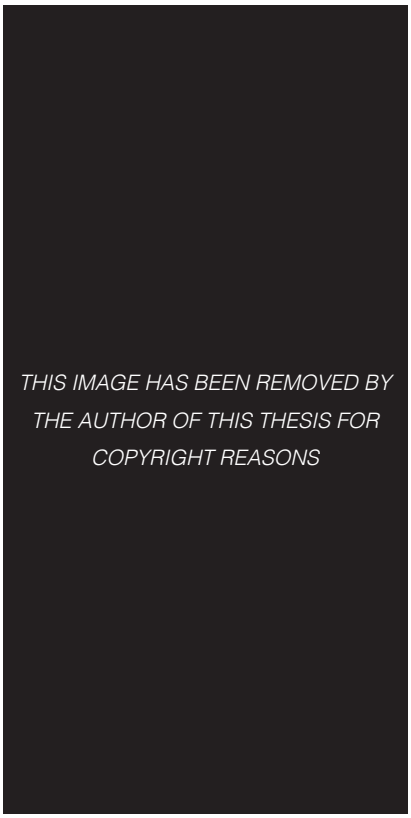


Figure 1
Bone layout of the knee

Comparable knowledge is required when creating a technological tool, as the application is the same and the tool will be used in parallel with the recovery process. The following information provides an outline of the basic anatomical framework, which was used to inform the design process.

The knee is a modified hinge joint between the femur (thigh bone), and the tibia (shin bone), "that must allow flexion and rotation, yet provide complete stability and control under a great range of loading conditions" (Goldblatt & Richmond, 2003, p. 172). The fibula lies parallel to the tibia, while the patella (knee cap) is a small bone that sits in front of the knee joint, which helps improve the "mechanics of the quadriceps muscle over the front of the knee" (Figure 2).

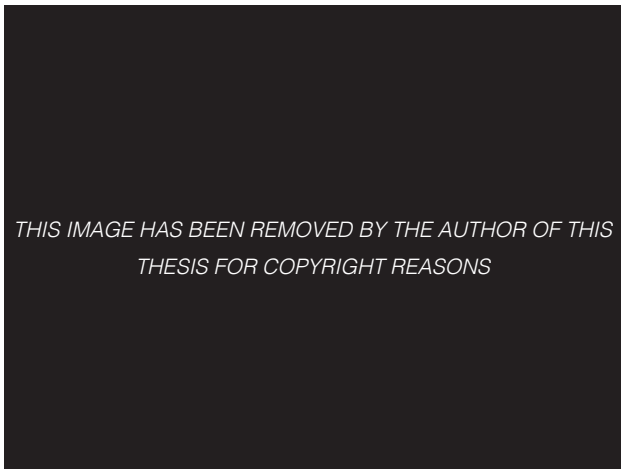


Figure 2
Knee section

There are two cartilage cushions between the femur and tibia called the meniscus; which help to distribute the load of the femur evenly on the tibia. Because the meniscus acts as a shock absorber from the upper leg to the lower leg (Figure 2) (McHale, Park, & Tjoumakaris, 2014), meniscus tears are one of the most common injuries to the knee, often due to sudden twisting, or sustained in conjunction with other acute or overuse knee injuries.

The tendons are connective tissue that attaches muscle to bone. They transfer force from the muscles to the skeletal system, thereby contributing to stabilising the joints (Bahr et al., 2012).

Ligaments are the “primary restraining tissues, and in contrast to muscles that are activated by signals from the brain or reflexes, ligaments are not innervated and serve as passive restraints to joint motion” (Kersh, Ploeg, & Pandy 2015, p. 38). There are three main ligaments that help with the stability of the knee.

1. Anterior cruciate ligament (ACL), which controls the fluid flexion and rotation.

2. Posterior cruciate ligament (PCL) controls posterior (back and forward) translation of the tibia on the femur, and a secondary restraint to varus-valgus (external-internal rotation).

3. Medial collateral ligament (MCL), which is an important restraint to the valgus rotation and a check against external rotation and straight side-to-side translation of the tibia.

Like a rubber band, the ligaments can only withstand so much; “any motion or load that extends the ligaments beyond their normal restraining force can lead to ligament tears, or even rupture, resulting in joint dysfunction and disease” (Kersh, et al, 2013, p. 38). Ligaments are typically only injured due to acute trauma, or sudden impacts, unlike tendon injury, which can result from overuse.

The main muscle structures that surround and control the actual movement of the knee are the quadriceps, hamstrings, iliotibial band, and the muscles of the calf. Signals are sent from the brain to each muscle individually, signalling the muscle to activate or release, “creating internal resistance in the loaded structures (stress) that counteracts deformation (strain) of the tissue” (Bahr et al., 2012).

Sport related injuries

Generally, sport related injuries can be divided into two main categories by their cause: acute injury, which is usually caused by a sudden impact or traumatic event; and overuse injury, where an athlete performs a motion with poor *form* and the same movement is repeated numerous times (Bahr et al., 2012) resulting in muscle imbalance and eventually injury, through overuse of the compromised area.

Sport related injuries can also be classed by injury type. Bahr and Wiley categorise them as “soft tissue injuries (cartilage injuries, muscle injuries, tendon injuries, and ligament injuries) and skeletal injuries (fractures)” (2012, p. 3). Soft tissue injuries can be caused by various different strains and stress commonly brought about by overuse or overtraining. Overuse or chronic injury can occur when an athlete mismanages the injury recovery process, or certain imbalances exist between training and rest, which result in overtraining. Rountree (2011) discusses the challenges posed by overtraining, suggesting a close link with psychological indicators.

Such indicators can point to a state of overtraining before any physical injuries occur. McKenzie, Watson & Lindsay, in Treat Your Own Knee (2012), explores treatment plans for chronic or overuse injury and suggests that overuse can also be caused by a premature return to the sport, not allowing the pre-existing injury the time needed to fully heal.

Muscle imbalances, poor *form*, improper equipment, or negative and excessively hard surfaces can also lead to chronic injuries. Ironman triathletes are particularly susceptible to overuse or chronic injury, due to the sheer amount of training and load placed on the body. This is where having a coach or external party to the training process is useful, as the physiological effects related to overtraining are not always apparent to the individual engaged in training.

Support roles

This section evaluates the expectations of all the individual parties related to the injury and describes the roles they hold within the recovery process. This information was gathered and synthesized from interviews conducted as part of the primary research for this project.

Interview data was used to help understand and evaluate the general roles and responsibilities associated with each relevant party, including coaches, athletes, physiotherapists, and medical specialists such as surgeons and doctors (GPs).

An understanding of the roles and responsibilities of all those involved can be used to highlight any motivational gaps within the recovery process. These gaps have then been used to help inform the design and functionality of the training aid.

Figure 3 and 4 highlight the relationships between the different specialties within the recovery process, as well as the main interactions between the injured athlete, physiotherapist, and coach. Family members typically provide motivational support, but this is usually separate from the other support roles. Specialists may communicate with the physiotherapist; however, their main job is to treat the initial problems associated with the injury.

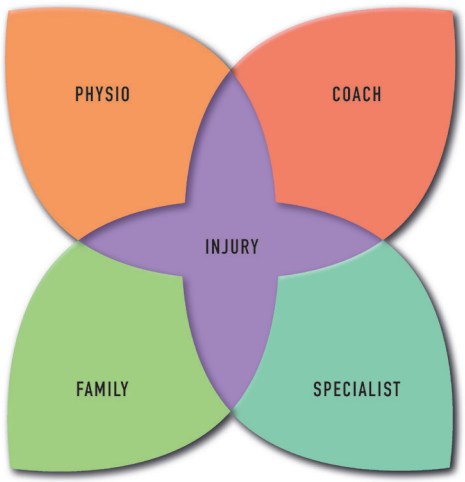


Figure 3
Injury relationship matrix.

Figure 4
Recovery roles and the impact each have at different stages of the rehabilitation

Athletes

The athlete is at the central point in the matrix of recovery, and is synonymous with the injury. It is easy to objectify injury as a mind-body duality, suggesting something foreign has been added to your body when in reality a more holistic approach is needed, as the person and the injury, the thinking self and the body are one and the same.

It is up to the individual to manage and maintain effective communication throughout the recovery process, as well as managing and organising the physical and psychological obligations of adhering to the exercises prescribed by specialists.

Eight Auckland triathletes with previous injuries were interviewed about their recovery process. A common view amongst interviewees was that accountability throughout the recovery process was one of the main issues that challenged motivation.

One athlete suggested that a major cause of their frustration was that they did not feel accountable to the support professionals for performing their exercise program correctly.

Several athletes mentioned that prescribed recovery exercises can be hard to complete correctly. In their experience, the athlete would be given a series of strengthening exercises which would be demonstrated and performed under the watchful eye of the physiotherapist. However, problems began as soon as the athlete attempted to perform the prescribed exercises at home.

According to these athletes, the current process relies on honesty, but if the athlete is unmotivated, there is no accountability to complete the exercises correctly. The current process thus relies on the integrity and motivation of the athlete.

This highlights the issue of accountability, which is an issue because, regardless of the support group around the individual athlete, if they are not adhering to the exercise program they will have difficulty throughout the entire recovery process.

Other interviewees considered that lack of motivation to adhere to the exercises was related to a lack of visible progress. It is important to note that this can occur even when an athlete is correctly completing the exercises prescribed. As physiotherapist B put it, there are “certain recovery times that you just can’t rush” (Physiotherapist B, personal communication September 30, 2015).

When viewing the recovery process as a whole, it is easy to see how an athlete might perceive these periods as a lack of forward momentum, and become discouraged. This highlights the need for effective communication between not only the athlete, but all the support crews involved. These findings provide important insights into why the athlete must maintain close communication as well as effective motivation throughout the recovery period, which includes maintaining a strong but realistic mind-set to promote their own internal motivation.

Physiotherapists

The physiotherapist diagnoses and treats injuries and prescribes programs, calling upon advanced knowledge of anatomy, biomechanics, and treatments to assist with on-going injury recovery. According to the physiotherapists interviewed in this research, this role is vital to the recovery of an injured athlete. Interestingly, the interviews revealed that some of the most common injuries incurred by long-distance triathletes were not acute injuries from sudden impacts or twists, but rather overuse injuries such as "muscle imbalance, weakness, tightness and insufficiencies" (Physiotherapist A, personal communication September 30, 2015).

The knee is the main problem area, often injured from muscle imbalances caused by overtraining, leading to on-going injuries such as friction syndrome[3] and patellofemoral syndrome[4] . The physiotherapist must spend time ensuring that the recovering athlete receives the correct education on what caused the injury, how it could have been prevented, why the prescribed exercises are important, and ways to adhere to correct *form* and accuracy (Physiotherapist A, personal communication September 30, 2015).

Coaches

The role of the coach is to provide support and guidance to the injured athlete. Typically, coaches will have little input in the initial stages of the injury, until mobility starts to be restored. Motivation is not only a factor for the athletes, but for their coaches as well. The coach is directly affected when an athlete is injured, as they are frequently working to a set timeline determined by upcoming events for their athlete.

This is interrupted if an injury occurs. When asked about problems experienced when managing their athletes through injury, Coach C identified the common issue of coaches attempting to diagnose athletes. "There is a trap that a coach can fall into, of prescribing treatment plans instead of referring them to a professional. (Coach C, personal communication September 30, 2015)."

Coaches may feel pressured to ensure that their athletes show positive results at an upcoming event. Such results can have personal benefits, as results can directly affect a coach's reputation and, in turn, create a larger client base for the coach.

For small injuries that are easy to manage, the coach may be able to recommend a suitable form of treatment, however, an incorrect diagnosis could lead to further injury if an athlete pushes their strength beyond what is appropriate. It is, therefore, important that coaches understand the fine line between prescribing basic treatment and referring injured athletes to a professional.

It is now apparent that motivation is an issue for all parties involved and the correct management is dependent on rational thinking and the clear communication of expectations, putting all personal stakes aside and focusing on the recovery process.

Coaches are expected to communicate closely with athletes throughout the recovery process but rely on injured athletes providing them with accurate recovery updates from physiotherapists and specialists throughout the process.

This helps coaches to assess not only when to reintroduce training plans, but also how and when to help with the athlete's mental responses to changes in the normal training regime.

---

[3] ITB Friction syndrome is a common cause of lateral knee pain, particularly experienced by runners and cyclists, due to overuse. ("Patellofemoral pain syndrome May 9, 2016)

[4] Patellofemoral pain syndrome is knee pain experienced, from the back of the kneecap rubbing with the thigh bone. (Karageanes, 2016)

This information can be used to inform and supplement light training and strengthening exercises, which can help the athlete find them more meaningful, contributing to a positive mind-set towards the recovery program. Coach A discussed ways in which good communication can be used to help motivate an individual athlete, suggesting that by treating the recovery stage as an extension of the normal training program, the athlete experiences a higher level of accountability for their own recovery.

This might be achieved by insisting that the athlete completes and uploads recovery data through normal training channels; athletes are therefore monitored and held accountable, just as they would be on the traditional training program. (Coach A, personal communication September 30, 2015).

Family

Though individual circumstances vary, an athlete's family is typically there to support the athlete emotionally throughout the recovery stage. This group can include personal family as well as training partners, fellow coached athletes and other supporters who follow the affected individual.

The relationship between athlete and family can prove to be an important source of motivation, as connecting with an external party who is not directly associated with the recovery can help provide a sense of normality for the athlete, during disruptive stages of recovery.

Cultural differences between support groups surrounding an athlete may affect motivation by providing different types of sympathy and support. Athletes with bigger families may find the recovery process to be smoother, due to a larger support base. While this is purely speculative it is an issue that was brought up by many of the interview participants.

It is, therefore, important to highlight but does fall outside the scope of the research. Similarly, those athletes who are part of a coached group or train in a team may find that fellow athletes share a unique understanding of their situation and demonstrate enhanced empathy. Alternatively, fewer supporters, family or fellow athletes, can lead to more isolating experiences. Apart from motivational support, the family is relatively disconnected from the recovery process itself.

Specialists

Specialists are defined here as skilled practitioners who treat and react to the athlete's injury - specifically, surgeons working in the field of sport related injuries and their treatment.

Recovery Development

Due to practical constraints, this research cannot provide a comprehensive review of the diagnosis, treatment and strengthening exercises required to fully recover from a specific injury, as it is beyond the practical scope of the study. Instead, one exercise has been chosen to test the generic movements required by typical strengthening exercises related to the rehabilitation of the knee. This section provides a rationale for choosing that particular exercise.

Strengthening exercises can be divided into three categories. Each category is relevant at different stages throughout the recovery process, as each focuses on a different aspect of recovery and builds from the previous stage. Walker (2013), identifies the stages as:

1. Movement based exercises, non-weight bearing, and gentle movement.

2. Weight-bearing and a range of motion exercises, starting to build strength focusing on progression week to week.

3. Isometric exercises gentle static stretching, an external force is applied to the injured knee focusing on the strengthening of the muscle, progressive increasing weight loads.

(p. 42)

Based on the three specific stages identified above, this research focuses on the second stage - weight-bearing exercises - as this point in the recovery is typically when an athlete's acute pain starts to dissipate and focus turns to strengthening exercises. This is when the importance of adherence to the program prescribed by the physiotherapist becomes vital.[5]

[5]See section 3 page 24 for further details on Psychological adjustment to injury.

Figure 5
Lunge starting position

Figure 6
Lunge mid position

Figure 7
Lunge end position

A one-leg lunge was chosen as the strengthening exercise that would be evaluated because it demonstrates a full range of movement through the knee joint. This exercise highlights the knee's full range of flexion, as well as interior and exterior rotation and is a commonly prescribed exercise, for both acute or overuse injury.

3. MOTIVATION

Psychological adjustment to injury

Motivation in a broad sense is used to explain why and how people act the way they do. To understand the problems with the disconnect between motivation through the recovery stages of an injury, it is first important to explore what defines motivation, and how it can be used to create a positive effect on an individual athlete throughout the recovery process.

The term “motivation” derives from the Latin word movere meaning ‘to move’. According to Karageorghis and Terry (2011), “it is a powerful inner force” (p. 27) that gravitates an individual toward a desired goal and is considered a psychological power that can reinforce action, allowing individuals to have clear progression, direction, and movement towards desired outcomes.

Given the emotional, physical and financial investment of individuals engaged in training at every level of sports, a large amount of useful research has been conducted to understand key motivational and physiological constraints that create barriers inhibiting optimal performance (Karageorghis & Terry, 2011).

One potential explanation for poor motivation is that “people are generally not motivated toward every possible type of endeavour; rather, they are motivated to perform in specific domains to achieve very specific outcomes” (p. 28). This helps to explain why the amount of assertion and drive that is evident in training is not always transferred to the injury recovery process.

This well-researched field directly parallels the anatomical knowledge of the knee that is at the centre of this research. Combined, they provide a solid and factual grounding for the development of this project. As motivation is a crucial part of the research to be conducted as part of this exegesis, it is important to next look at the potential motivational issues that may arise throughout the recovery process.

There are certain factors that can promote the successful recovery of an athlete. Initially, it was assumed by the researcher that biometric data and technology driven tools, physically attached to the body, could dramatically affect the recovery process. However, key factors relating to the athlete's state of mind were only revealed once the interviews took place. These interviews were conducted with three different types of groups within the triathlon community: individual athletes, coaches, and physiotherapists. The goal of the interviews was to uncover the various factors that influence the recovery process.

When exploring the most common factors that might enhance a patient's full recovery, an overwhelming number of participants interviewed, regardless of type, revealed that motivation was the most important factor for a successful recovery from injury. This was in contrast to my initial assumption about attached biometric tools.

The complication here is that each interviewee identified different tools and processes that helped to motivate them, such as knowledge, education, and goal setting. Another important factor for a successful recovery was highlighted to be adherence to the strengthening exercises typically prescribed as treatment. Physiotherapist A helped to elaborate on the importance of this crucial stage, discussing how the hands-on therapy conducted by physiotherapists amounts to about "20% of the treatment", the other 80% being left to the athlete, to comply with the strengthening exercises at home.

This poses a problem highlighted by Physiotherapist B: if an athlete becomes confused or finds the exercises crucial to recovery to be "mundane, disruptive, or boring", they might consider the exercises prescribed to be a waste of time, as they "don't quite see the benefit" (Physiotherapist B, personal communication September 30, 2015), resulting in a lack of progression and momentum through the injury recovery.

To combat this mind-set, physiotherapists rely on patient education, explaining the reasons for injury, as well as how the exercises are relevant and why they are important to the patient's recovery.

Heaney, Walker, Green, and Rostron, (2015), suggest that "a poorly designed education program with little relevance to its target audience will likely have much less impact than a well-designed program with highly relevant content" (p. 72). This statement is reinforced by Physiotherapist C, who stated that around 50% of clients seen throughout the day in that particular clinic have a "low touch" environment (Physiotherapist C, personal communication September 30, 2015). This means the majority of time spent in a session is education, revising exercises and discussing plans and goals, instead of the traditional hands-on approach, which is commonly expected.

The interviews help to frame key factors and reasons that could attribute to a positive recovery, namely a motivational mind-set, adherence to programs prescribed by physiotherapists, education, and well-designed recovery goals and programs. These factors are essential to eliminating confusion.

By empowering the injured athlete with knowledge and trust, the athlete can take control and become an active shareholder invested in their own recovery. Mind-set thus seems to be a key motivational element that helps to support an individual through to a positive recovery. It is, therefore, important to follow this thread as it runs through every aspect of the recovery stage.

It has been shown that an individual who has the correct mind-set is more equipped to deal with the barriers that arise relating to their injury. So the next logical step is to explore the motivational factors that might impede the recovering triathlete.

Once the initial acute pain of an injury starts to dissipate, mobility and a sense of normality are restored, prompting a desire to return to training. This mind-set, however, is also capable of having a negative motivational impact on an individual athlete, by promoting a premature return to training instead of the strengthening exercises required to achieve optimal functional outcomes. The majority of physiotherapists interviewed as part of the research indicated that a premature return to training was an issue that frequently prevented athletes from a full recovery. Physiotherapist A describes external pressures, such as fear of missing a perceived “key training session”, or expectations of “performing at up and coming events”, as key factors.

The consequence of such a mind-set is shown by Physiotherapist B, who revealed that even though an athlete might feel fully recovered due to a certain amount of mobility being restored, the injury might still be present, as there are “certain healing times that cannot be buffered” (Physiotherapist B, personal communication September 30, 2015).

This issue shows the importance of mind-set and the emotional needs required from an athlete. In an article about managing injured athletes, Mark Cudmore touches upon key factors that potentially impact an athlete’s mental outlook, such as separation from the sport, loneliness or becoming stressed while watching the sport they participated in. It is now apparent that the correct mind-set depends highly on the athlete’s ability to use coping skills, as this “will affect their emotional reaction to the injury” (Cudmore, 2014, p. 54).

Because of these pressures from externally motivated factors, a negative frame of mind towards the recovery process can easily be created. We can now see how an individual athlete could become caught up in a false sense of recovery and why they might choose to ignore the solid advice and guidelines given to them by professionals.

It is, therefore, important for the mind-set of an athlete to be able to adapt to the different pressures put on them internally or externally, and be able to rationally use coping skills to help determine and understand the consequences of each decision or action.

Due to the importance of having the correct mind-set, it is essential to understand and explore the physiological constructs contributing to motivation that promote this positive frame of mind. This is particularly important for the research, as the tools being created will help with adherence to strengthening exercises and will need to promote a positive mind-set in the athlete in order to do so effectively.

The old adage “mind over matter” refers to the importance of willpower to overcome adversity and physical problems. This is particularly relevant to the research, as it refers to issues related to the achievement of physical goals. These might be achieved not by strength or physical ability, but instead by acknowledging the correct mind-set needed to achieve the desired goal. By commanding a powerful desire to achieve the task, a stronger level of investment in the physical activity should follow. With this in mind, it is, therefore, important to explore the physiological constructs that make up motivation.

Intrinsic and Extrinsic motivation

In its purest form, motivation can be broken down into two main types: intrinsic and extrinsic motivation, both of which have been "densely researched with respect to exercise and continue to be a topic of interest" (Ball, Bice, & Parry, 2014, p. 132).

Lewis suggests that "intrinsic motivation comes from within", where it is the joy of doing that is the key driving factor, in contrast to "extrinsic motivation [that] comes from without", which relies on external rewards such winning, money or fame (Lewis, 2014, p. 12). Words such as interesting or fun are symptomatic of intrinsic motivation, whereas incentive, attention, and win are related to extrinsic motivation.

An athlete who is motivated to finish an Ironman race because they enjoy the atmosphere, and love feeling alive on the bike, rather than winning or reaching time oriented goals, is said to be an intrinsically motivated individual. On the other hand, another athlete might be primarily motivated by finishing first, becoming famous or attracting media attention, making them extrinsically motivated.

Individuals are motivated and driven towards the achievement of goals by different factors. Although these factors are not always apparent, an exploration and understanding of them can serve as a vital tool for discovering how a positive drive might be used during injury recovery when motivation is low or non-existent.

Hagger and Chatzisarantis (2007) explore the complex multi-level nature that makes up motivation and suggests that for most athletes the rewards and contingencies that drive motivation are not always clear. Individuals have distinct personalities and may act differently depending on context or situation.

Therefore, the motivators of sport at an individual level don't always include the externally driven factors you would typically associate with the sport, such as ribbons or trophies.

They suggest instead that internally motivated factors are in fact the main driving force for the majority of athletes. Environmental conditions are equally as important and support feelings of competency and autonomy, which can be used to facilitate intrinsic motivation (Hagger & Chatzisarantis, 2007).

Whether it is intrinsic or extrinsic, motivation is a key ingredient to achieving goals. By splitting motivation into its two categories, we can start to explore how the balance between intrinsic and extrinsic factors can highlight reasons for a loss of motivation.

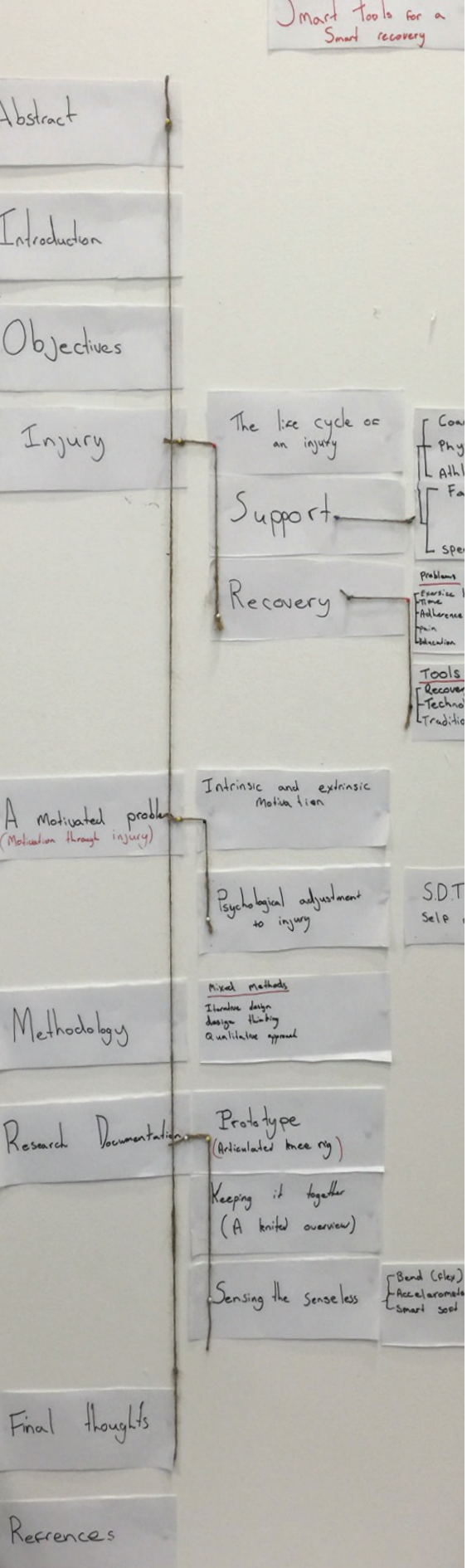
Karageorghis and Terry (2011) expand on such issues and explore the different qualities related to motivational balances, suggesting that "athletes who demonstrate the best motivational qualities, such as persistence, a positive attitude, and determined concentration, tend to be both extrinsically and intrinsically motivated.

Athletes who are predominantly extrinsically motivated tend to become discouraged when they do not perform to expectations and can experience a downturn in *form*" (p. 33). Based on Karageorghis and Terry's work, we can start to understand where the compliance problems identified by Physiotherapist B arise. Injured athletes often perceive rehabilitation exercises as an extrinsically motivated task.

Still concentrating on the two types of motivation, we can see that an extrinsically motivated athlete is more likely to respond to the instructions from the physiotherapist and to the external goal of returning to competition. On the other hand, the intrinsically motivated athlete who is given the same instructions would be less likely to comply with an exercise regime, as exercises are forced on individuals without their internal buy in, and if mismanaged or delivered incorrectly could cause discouragement and loss of enthusiasm, resulting in low adherence to the program. The only way an individual can overcome this is if they internalise the purpose as a personally rewarding goal.

In reality, different combinations of both intrinsic and extrinsic factors motivate most athletes, depending on personality, autonomy, experiences, and environmental surroundings. The core of their recovery needs to incorporate a strong intrinsic motivational base, as external factors alone will not be enough to get most athletes through recovery. It is the personal drive towards recovery, regardless of motivation, that is the goal.

Ultimately the onus is on an individual athlete to find the best combination of the two types of motivation that works for them. The recovery phase must, therefore, exploit both intrinsic and extrinsic incentives to enhance engagement and enjoyment through the strengthening exercises, shifting the recovery mind-set from a tedious inconvenience to a productive challenge akin to the athletic goal itself.



4. METHODOLOGY

Motivational methods

In the early stages of this research, a new and exciting methodological issue presented itself, whilst exploring possible reasons why athletes become demotivated within the recovery stages of an injury. It was hard for the research to ignore the certain correlations between an athlete's motivation and the motivation of the researcher himself.

This correlation has, in turn, became an important tool for determining the direction and drive of the project. As the topic chosen was intrinsically motivated, by personal interest, extrinsic goals were not always present. This had a negative impact at times, resulting in a sense of loss and confusion in relation to the project's direction. By adding extrinsic motivational factors such as daily word counts and micro-goals, and focusing on individual tasks instead of the overall picture, it became apparent that a stronger drive was possible.

Once such methods were adopted and implemented, the motivational successes of completing the micro-goals resulted in higher personal motivational levels that allowed the project to move forward, by increasing the overall scope of the project. This was all possible due to the use of motivational methods explored throughout this project and replicated within the research itself.

Although outside of the scope of this project an interesting question now arises: to what extent does the notion of a motivational recovery aid, such as the knee brace for injured athletes, find a parallel in academic research? Can the motivational issues, which often hinder the recovering athlete, also affect, in parallel, the adherence to academic constructs of research? If this is the case, then further research could be used to help identify tools and methods for addressing factors such as internal and external motivation, and determine whether training systems could be used to maximise individual research aims and productivity.

Iterative design

An iterative design approach was adopted in the creation of prototypes throughout this project. Its inclusion has helped to create and inform the relevant prototypes and identify the next steps needed to motivate and drive the project forward. This was achieved by using rapid prototyping tools and techniques such as 3D printing, allowing for quick and affordable prototypes to be placed, assessed and evaluated. This workflow was used to test new concepts, as well as to react to any design flaws or changes dictated by the previous iteration.

One example, of how this worked well, was in the creation of housing for the electronic componentry of the knitted training aid. It was initially designed to be separate from the knitted sensor. However, when the 3D printed housing prototype was placed in the desired position on the knee brace, it felt foreign and awkward, prompting a rethink and design of not only the componentry but of the design and structure of the knee brace itself - with a new focus on integration between soft material and hard surface.

These revelations would not have been possible if a feedback process had been excluded from the methodology. The iterative design of the project was also a great way to explain and demonstrate ideas and concepts to external parties. These professionals included physiotherapists, athletes, and technologists, who provided vital feedback and critiques of each iteration. This feedback loop not only assisted the redesign of prototypes but also informed the design thinking process, which was used for on-going support and integration within the targeted community.

Design thinking

To correctly address the creation of a relevant and informed training aid, design thinking was chosen as a key methodology.

This method was used to help understand why previous forms of recovery tools and technologies were not adopted and applied to the issue of poor adherence to prescribed strengthening programmes throughout the rehabilitation phase. Brown and Kātz (2009) examine how design thinkers transform organisations and inspire innovation, and identify three key design constraints:

1. Feasibility (what is possible within the foreseeable future)
2. Viability (how can it be sustainable business model)
3. Desirability (what makes sense to people and for people)

Brown and Kātz (2009) compare a traditional designer with a design thinker, suggesting that a competent designer will resolve all three constraints, whereas “a design thinker will bring them into a harmonious balance.” (p. 47). Design thinking therefore requires a larger scale perspective, with community at the forefront, and has a major emphasis on overall impact and usefulness, relevant for the desired industry.

Rather than just satisfying a need, this methodology addresses the wider issues at play and doesn’t just look at the “fire” (perceived problem), but instead at “fire prevention” (why the problem happens in the first place). Such solutions commonly address the seemingly unrelated issue of the wider community.

As designing a practical product to assist with the recovery of injured athletes is one of the main project aims, the inclusion of this methodology has helped ensure that the project is inspired, informed and influenced by not only the end user but also the wider triathlon community. Because of this, feedback could be collected and used to inspire relevant design features relating to the three key design constraints. This enables the product to be relevant and to help with adherence, and also address where the training aid fits within the recovery process as a whole.

Qualitative

Edwards and Skinner (2009) discuss the reasons why a qualitative approach encourages a systematic exploration of new and old information. They suggest that by focusing on evaluating, analysing, implementing and understanding how each researcher has reached their conclusions, a more robust and informed project can be achieved.

This research has used similar explorative methods, without fixed expectations or outcomes, in order to allow room for growth and development throughout the project. As suggested by Edwards and Skinner (2009), this approach also allowed for the project to be informed and directed by previous research.

The information was gathered from academic papers, interviews conducted with relevant industry stakeholders (mentioned above), as well as from the investigation of related and unrelated technologies, which encouraged new solutions for old problems, by using systems that worked and redeveloping those that did not. By not limiting the research to the field of enquiry, and considering the use of unrelated technologies, previously unexplored creative responses to the research questions were identified. “There is no one best research approach, rather the approach most effective for the resolution” (Edwards & Skinner, 2009, p. 5).

Summary

The methods used in this research have worked in conjunction to ensure the direction and drive of the project to be relevant and useful towards the field of injury recovery. The important role played by motivation in the design of the recovery training aid is also a key factor in determining the direction of project structure and methodology.

Although certain questions remain unanswered regarding production, due to the necessarily limited scope of the project, the use of iterative design methodology has helped to provide the groundwork for future production of the training aid.

The research has revealed many issues related to motivation that is not commonly considered by those involved in athletic injury recovery. It is interesting to note that even though the participants of the qualitative interviews collectively provided the necessary details that led to the basis of this thesis, it wasn’t until key questions were asked, analysed and resolved, that potential solutions could be identified.

5. DESIGN PROCESS

Communication is a major design hurdle when working on a multidisciplinary project, as lack of communication can result in missed opportunities between specialists in different domains, who traditionally don't work together. The designer needs to know exactly what to ask of the project, and who to communicate with when knowledge is beyond the scope of their expertise. This makes effective communication vital to the success of collaborative projects.

With this in mind, certain parallels can now be drawn between the methods employed in this thesis, and the interdisciplinary nature of the injury recovery process, as both the individual and the project team must find the relevant motivational mind-set to overcome hurdles that obstruct the path to the end goal.

The identification and analysis of a particular community's requirements enable a project to draw upon a comprehensive body of knowledge. Salcedo (2010) demonstrates this fact through the vast amount of research on foot anatomy, articulation and characteristics that were undertaken before the need for accurate 3D motion monitoring within the field was identified.

It was only due to Salcedo's inclusion of effective communication between the targeted groups that such a need could be identified. The inclusion of multi-disciplinary areas allows each domain to have their own input and contribution.

This helps to accurately assess and analyse the needs of the project and scope of the technology required. Salcedo successfully understood not only what was currently available, but also used the research to highlight how utilising e-technology could be effective in creating accurate 3D motion analysis tools.

This also accords with earlier observations from Goldblatt and Richmond (2003), in relation to how anatomical knowledge informs physiotherapists, to accurately diagnose patients. Each injury is unique, and as such, the physiotherapist is required to manage their anatomical knowledge to obtain an accurate diagnosis.

Once a diagnosis is identified, the probable causes of the injury are used to establish a correct treatment plan that works alongside the diagnosis.

Such anatomical knowledge is key to identify both how and why the injury happened in the first place, and to determining what treatment processes should be used during recovery.

Some injuries require a more specialized approach. As a physiotherapist is typically a generalist they rely on input from specialists within the community to develop plans for treatment of complex areas such as hands and feet, thus mirroring the requirements of the multidisciplinary project.

In view of all that has been discussed so far, one may suppose that collaboration and effective communication is a vital stage in the creation of a successful multidisciplinary project and that such communication helps to avoid the limitations of traditional disciplinary-based research.

This insight is one reason for the inclusion of the anatomy and motivation sections as part of this exegesis, allowing clear communication from the research to flow down to influence and motivate the design process.

Interview process

The following overview is intended to highlight the process and methods used in the interview stages of this project, and to clarify how these processes were used to inform the research.

Identify

Preliminary discussions with active members of the triathlon community, as well as the researcher's personal involvement in, and observations of, Ironman triathlons, resulted in the identification of three distinct interview groups: athletes, coaches, and physiotherapists. Although other groups, such as surgeons, psychologists, and medical specialists, operate in connection to the recovery process, it was decided to focus on those involved throughout the entire recovery, instead of professionals who have more limited input.

Invite

Once these groups were identified, a series of flyers were created to invite interested individuals - targeting closed Facebook groups, physiotherapist waiting rooms and triathlon events. Initial emails were sent out to interested parties and attached with information sheets outlining the purpose and scope of the research. Once each individual agreed to participate, a confidentiality agreement was signed to ensure ethical issues such as privacy and confidentiality were addressed and agreed to. Each candidate was then matched with the specific group they belong to, on the basis of expertise and number balance.

Interview

After establishing balanced group numbers, a series of individual interviews were conducted. The interview questions were designed as qualitative allowing the results to be framed by personal experiences both positive and negative. The participant's role was to provide information and they were encouraged to share personal expertise. The feedback from the interviews helped to inform and influence certain aspects of the research, prototype development, direction and design. By working together as equals with each participant, a mutual respect was encouraged and created.

The questions asked were approached as indicative questioning, and designed to encourage the sharing of knowledge and experiences of each individual. This allowed for unbiased outcomes regardless of group dynamics such as coaches, athletes, and physiotherapists. Discussions were led via personal experience and expertise and not driven by the researcher's personal opinion as it was found to have an adverse effect of dictating the interview direction.

The questions differed slightly for each group, yet followed similar lines of enquiry aimed at exploring the connections and relationships between individuals actively involved in the recovery process.

The interviewees were invited to pass and move onto the next question or stop the interview altogether if any of the questions were too difficult or uncomfortable to answer. This approach was used to ensure genuine and honest data was collected which was invaluable ensuring relevance to the project aims and outcomes.

The intention of the interviews was to single out any underlying re-occurring themes and issues found within the recovery process. This approach helped to ensure that no particular participant was singled out, yet relevant data was collected and used to inform the project. It was important to keep the privacy of each interview confidential, as it was stated as part of the ethics application that each participant would be kept anonymous, and would only be directly quoted with Physiotherapist #, coach #, or athlete# .

All the interviews were recorded to be later transcribed and analysed, ensuring no thread of enquiry was missed. Once recorded, the interviews were individually transcribed, reviewed and analysed to look for patterns, common trends, as well as relevant experiences, or frustrations with the current recovery process.

Transcription

The single most striking observation that materialised from the transcription process was how certain threads and recurrent themes emerged. Such themes were not necessarily apparent to the researcher during the interviews themselves, and would have been missed had the interview not been transcribed. For example, the themes of motivation and mind-set would not have been identified as important contributing factors to poor adherence, if this stage had been skipped. The audio files of the interviews were individually transcribed using dictation software. This was found to be the most effective and quickest way to accurately process all the interview data. It was also found to be helpful as a first pass analysis of common themes started to form.

Analysis

Pre-analysis of the interview data during the transcribing stage enabled the researcher to quickly identify key areas and issues commonly raised by individual participants. By being actively engaged in the interviews and transcribing each audio file, it was a relatively easy task to evaluate the qualitative data and to identify key issues across the three different groups. This helped to paint a picture of current processes and stages that can at times impede a successful recovery. The interview data proved to be an invaluable resource for this project, as it helped to highlight issues and frustrations to the recovery process on all sides.

At an individual level, although similar in content, each combined group of interviews didn't pinpoint direct issues within the current recovery process. It was not until the data was combined, analysed and cross-referenced at a holistic level against the other groups, that a poor adherence towards strengthening exercises was found to be interconnected with motivational issues. It is interesting to note that each group held a piece of the puzzle and it was not until each piece was collected and the whole put together, that the bigger picture was revealed.

This helps to highlight the inclusion of interviews within the design methods, and it was important to the overall methodology of the project for them to be used as a main data collecting method. By including all stakeholders within the recovery process, a more relevant and worthwhile theme was found.

	Athletes	Physios	Coaches	SUM					
Motivation	5	6	8	19	**Adherence**	0	6	0	6
Mind-set	9	6	3	18	**Personalised**	2	1	0	3
Education	2	10	1	13	**Pressures**	1	1	1	3
Time	4	3	5	12	**Quality**	1	0	2	3
Injuries	3	6	2	11	**Misinformation**	0	2	0	2
Technology	2	5	3	10	**healing times**	0	2	0	2
Wrong priorities	5	1	3	9	**Prevention**	1	0	1	2
Communication	4	3	1	8	**Premature return**	0	1	0	1
Form	0	5	3	8	**Pain**	0	1	0	1
Solutions	4	2	1	7	**Accountability**	1	0	0	1
Expertise	1	0	6	7	**Knowledge**	0	0	1	1
Expectation	3	1	3	7	**Relationships**	0	0	1	1

Figure 8
Raw interview analysis of three participants per group

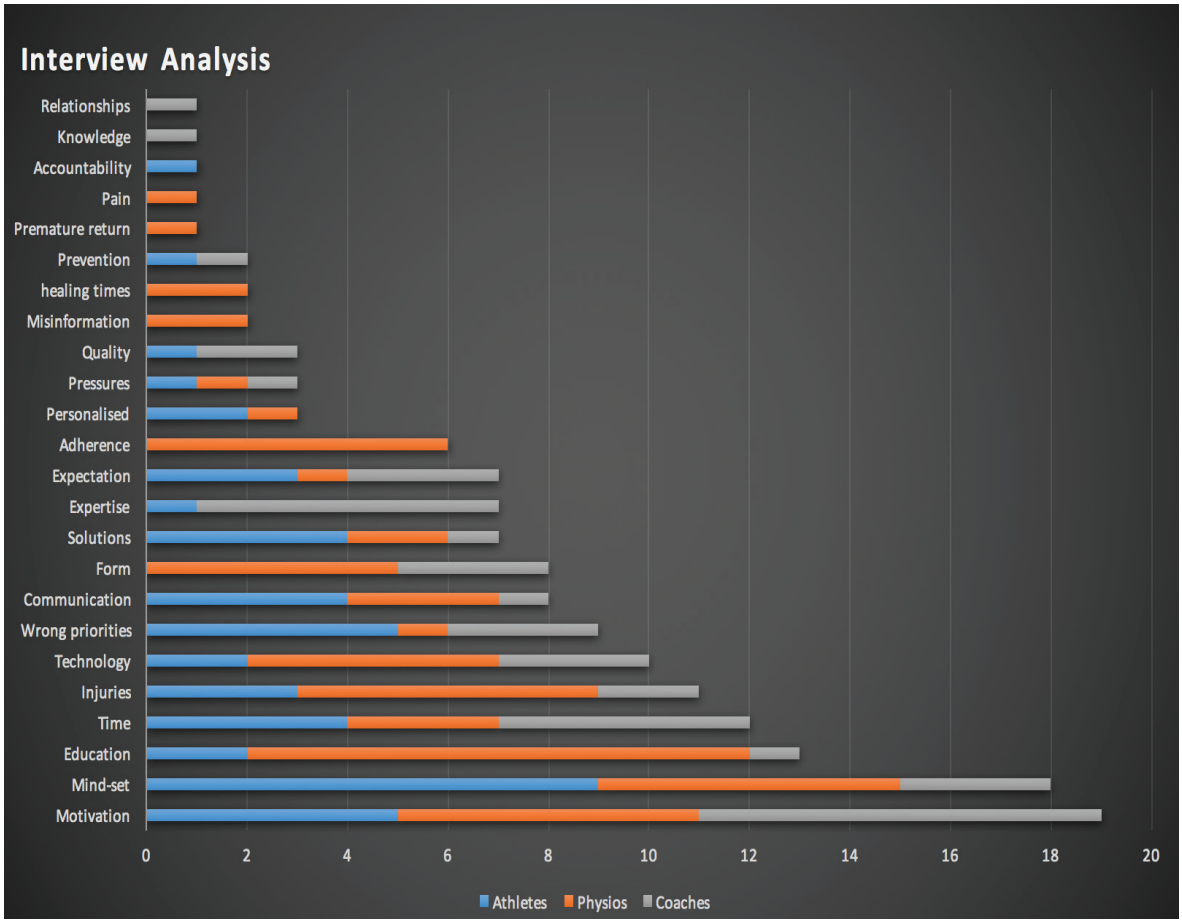


Figure 9
Visualization of sample data from interviews

Justification

Many researchers have studied smart fabric for use in sporting and injury recovery. The appeal is largely due to the intimate nature of the fabric and the body. The recovery process is closely entwined with specific fabrics, as they are used for applications such as compression tights, bandages, and slings, and because of connectivity with ease of movement and supportive properties. The fabric is able to move and distort over contours of moving joints, yet create isolation and support as well as stability for injured areas.

The inclusion of integrated sensors opens the further potential for recording and capturing a true and accurate measurement of movement. This representation of the natural unimpeded movement during prescribed exercises is achieved, due to a lack of traditional bulky components usually associated with data collecting applications. Others have experimented with 'smart' knee sleeves to monitor biomechanical performance and prevent injury such as The Intelligent Knee Sleeve (IKS): A wearable biofeedback device to provide an auditory feedback during landing movements. Munro, Campbell, Wallace, Steele (2008).

The purpose of the device is to help prevent injury through feedback of incorrect *form*. “It was concluded that although the IKS provides valid and reliable feedback on knee flexion angle, consistent feedback is dependent upon the use of sensors unaffected by environmental conditions.” Munro, et al (2008).

This insight helps address the questions asked at the beginning of the exegesis “How can the use of smart wearable technology motivate a stronger adherence to strengthening exercises as part of an athlete’s injury recovery process” Although the device provides some potential solutions, there are areas that could be improved. There is a major reliance on preprogrammed knee angles to provide the feedback needed to correct improper movement.

This out of the box approach causes a one size fits all method, which has the potential to cause more harm than good. If the individual’s correct movement is outside the preprogrammed angles, what might be correct for one person could be incorrect for another. It is, therefore, appropriate for the device being developed as part of this exegesis to be calibrated to the specific athlete’s movements and the subsequent feedback to be used as the comparison.

The issue of environmental situation addressed by Munro et al (2008) is also a consideration that is highlighted by Metcalf, Collie, Cranny, Hallett, James, Adams, Chappell, White and Burridge (2009). In the paper Metcalf et al highlight issues relating to data stability such as variation in sensor positions and changes in sensor output over time. (2009) This is a big factor when working with yarn as highlighted in the sensor development section bellow.

The resting position of the yarn changes each time the fabric is manipulated by movement, this causes variations in data accuracy resulting in instability of the sensor. Metcalf et al address this by testing different knit structures and sensor placement. Their findings show that the most accurate results were achieved when the yarns were knitted running down the leg (lengthways) as they produce more repeatable and stable results than a sensor constructed side to side (2009).

Data variation is not a big problem with the device created for this research, the accuracy of the movement although important, is not the key goal of the knee brace. The importance instead is placed on the motivation of the athlete, achieved by providing loose feedback via visual representation. Any drift or blips in the data can be smoothed out at a programming level. This helps to compensate for a small margin of error that exists in the data captured from the knitted sensors.

These examples of smart fabric applications help to highlight the pros and cons of working with these mediums. Because fabric is already closely tied to the recovery process, the addition of conductive yarns as a sensor is an unobtrusive way to quickly and effortlessly capture movement data, and provides real-time feedback to the injured athlete. It is for these reasons that it was decided to develop a device that utilises the technology of smart fabric.

6. PROTOTYPE (ARTICULATED KNEE RIG)

It was decided early in the project that it would be necessary to construct an articulated knee in order to accurately test and compare the different types of sensors in the training aid. This was important, as the capacity to capture the movement data from the exercise being performed provided the ability to test, visualise and troubleshoot any data collected.

This rig allows a mechanical baseline to be established, which helps to compare and evaluate the reliability of different sensors against the consistent repeatable mechanical movement. If a human was used for the testing stages, slight deviations would occur which would directly affect the comparison. The creation of such tools to aid in the recovery process required similar knowledge to that of the physiotherapist, who must have solid foundational knowledge of anatomy and movement.

This became most apparent when creating the articulated silicone knee, which simulates the movement required of the chosen exercise for this study. The model knee was cast in a soft flexible silicone around a 3D printed modified artificial knee rig - originally download from GrabCad and created by Jose Luis Martin Medina (Medina, 2015).

The prosthetic knee rig acts like bones and is driven by a servo motor which moves the silicon knee and simulates the hinged movement between the femur and tibia. The result enables a fully programmable articulated knee. The creation of this fully articulated rig makes it possible to repeatedly test the sensors from a movement profile of an individual. Because the programming is not limited to computer generated sequential numbers, the rig can successfully simulate different users, with differing speeds and movement ranges.

Figure 10
Articulated bone structure for programmable knee rig.

Figure 11
3D printed articulated knee rig and silicone knee.

7. KNEE BRACE

Sensors

The research described in section 4 (Injury) revealed that the knee has limited movement in two directions: varus-valgus, which is a limited side-to-side movement; and flexion, which controls the up-and-down motion and is constrained like a hinge from the centre of the joint. In order to correctly measure the different types of movements required by the chosen exercise, different sensors were evaluated and tested for accuracy and usability, as well as the ability to be integrated into the training aid.

For the side-to-side movement, a six-axis accelerometer was used. The sensor also has a built in gyroscope that helps to stabilize the accelerometer data. The gyroscope has internal vibration sensors that are used to measure the initial forces applied to the vibrating element. The vibration is then converted and emitted as an electrical signal which translates to either the X, Y, Z axis. This is called an orientation sensor. The sensor is an off the shelf product which is compact and easy to program. Initial tests revealed promising results and displayed the ability to be able to accurately track rotation.
The only issue with the six-axis accelerometer is that a certain amount of data drift does occur over time. This was identified during the testing stages of the sensor. However, this is only experienced after some time, and with the number of repetitions encountered, the drift will be minimal or at least programmable to be taken into account. The size of the circuit board for the six-axis accelerometer is manageable and easy to incorporate into the design. For reasons of accuracy and size, it enhances the capture of side-to-side movement data.

The sensor used to measure the flexion of the knee has been developed with the use of smart fabric technology. This decision allowed for minimal componentry, as the sensor is seamlessly integrated into the knit structure. The development of this sensor began by purchasing an off-the-shelf flexible sensor[6] to explore its limitations and develop the circuit for capturing the desired data. Once the reliability of the circuit was established, a stand-alone neoprene sensor was fabricated and the output data compared to the flex sensor[7].

[6] Flex Sensor 2.2” A simple flex sensor 2.2" in length. As the sensor is flexed, the resistance across the sensor increases. Patented technology by Spectra Symbol.

[7] The neoprene sensor was developed using the by the step by step guide on the website Koba Kant (Satomi & Perner-Wilson, 2010) which explores how to create a soft flexible sensor.

Figure 12
Flexion test of off the shelf sensor.

Figure 13
Hand made neoprene flexable sensor.

The neoprene sensor is made up of three separate layers as shown below in figure 3. This technique utilises electroconductive yarn knitted in a zigzag pattern for each layer, separated by a piezoresistive material called Velostat.

This middle layer acts as a resistor between the electrical current of the two layers. The setup of the sensor is actually a pressure sensor; however, due to the flexible nature of the neoprene, the pressure is exerted when the sensor is bent.

Comparisons between the two sets of data show that the flexible sensors evaluated are both relatively stable. However, the neoprene flex sensor has more data range, which is helpful when remapping values, as there are more data points to map from.

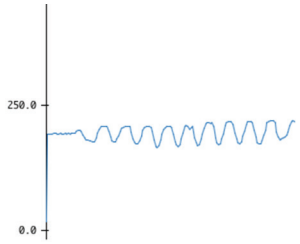


Figure 15
Off the shelf flex sensor data.

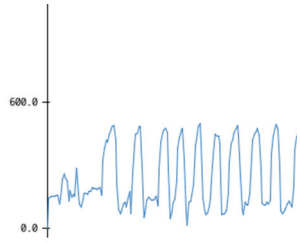


Figure 16
Neoprene flex sensor data.

Success in creating a soft flexible sensor has made it possible to design the sensor into the knee brace, instead of using the off the shelf sensor, and this allows fuller integration of the technology with the garment. While developing the design of the neoprene flexible sensor, a pocket with a zigzag pattern of conductive yarn, running through the length, was built into the brace. The problem with this method is that the piezoresistive Velostat, which acts as a resistive barrier to give the range of readings of flexion, had to be added after the fact. This meant that the pocket could not be fully closed until the brace had been knitted. Once the Velostat was inserted a hand stitch was used to seal the pocket.

Figure 17
Neoprene flex sensor

The biggest issue faced, when knitting sensors on the Shima Seiki knitting machine, is that when knitting the pocket, using a jersey fabric stitch structure, the control lines used to measure the changes in electric current were picked up by the wrong bed, resulting in the conductive yarn knitted in the zigzag pattern switching from the front side of the pocket to the back side.

This causes the threads to become tangled between the two layers of the pocket and required the threads to be cut before inserting the Velostat. It was determined that this was caused by incorporating a ‘missed stitch’ technique: where a missed stitch is used between each second line of the zigzag, as shown in figure 10, with the dotted line representing this missed stitch.

Figure 18
Integrated sensor. Knitted with the Shima Seiki machiene

The tangles had to be cut free throughout the pocket, which caused the electronic connection to be broken. This made the sensor unstable and in most cases unusable.

Removing the missed stitch and redesigning the pattern overcame this issue; in order to incorporate the conductive yarn knitted the whole way up the pocket as a solid stitch. Combined, these sensors allow the knee brace to track movement and provide feedback on progress through the chosen exercise regime.

Once the sensors were selected and tested, the task of finding a smart way of integrating the normally foreign components together was the next phase of the project.

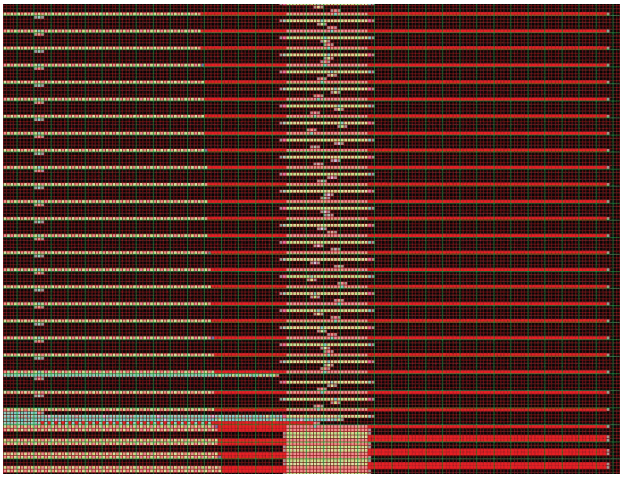


Figure 19
Shima Seiki program pattern.

Knitting

Fabrics are considered to be soft and comfortable whereas technology is often seen as hard and cold. In order for these two juxtaposed mediums to amalgamate, major consideration is required, not only to develop a new aesthetic, but also to seamlessly integrate the hard and soft componentry required to create a harmonious balance between design and technology. Genevieve Dion (2013) explored such considerations are in an article regarding the challenges of fabrication for wearable technology.

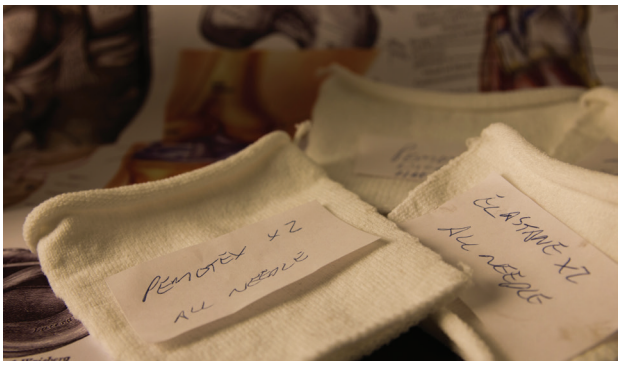


Figure 20
Test Swatches, knitted with the Shima Seiki machine.

Suggesting that the successful design of a smart garment must meet all requirements related to textile, design and the technology industries. Dion (2013) also touches on the importance of design considerations in creating a balance between comfort, wearability, style and ease of use. These considerations are particularly important in designing the knee brace as part of this thesis. Each iteration within the development phase demands a different combination of design, wearability or integration.

The first is the exploration of the fabric needed to incorporate comfort, look and feel, and also to help with structure and the ability to support any hard surface componentry. There are two main considerations when designing a knitted garment: the combination of different knit structures creating support or design features and the different types of yarn and its properties needed to support the project.

The combination of these two factors not only dictates the garment's overall aesthetic, but also the material's functional attributes, such as how it moves, recovers and supports the integrated technology.

All prototypes were knitted by the AUT technicians within TDL (Textile Design Lab), using the rapid prototyping tools at hand, namely on a flatbed knitting machine, model number SIG123SV, which is a 14 gauge, intarsia knitting machine manufactured by Shima Seiki in Japan.

This rapid prototyping technology enables multiple iterations to be quickly produced in order to determine the most effective structures and yarns. Initially, test swatches were created, containing a combination of Permotex, Elastine, and polyester. Each was then assessed for the following qualities; look, feel, stretch and recovery.

It was found that Permotex swatches produced a strong and secure structure, yet they were stiff to the touch and didn't bend or stretch as the Elastine did.

Figure 21
Dropped stitch within pocket

The research findings, as well as the experience gathered from creating and testing the nylon flexible sensor, indicated that a reliance on the recovery of the original resting position of the fabric allows for more stable results when recording the data.

The yarn used, therefore, needs to possess the same or similar qualities to the neoprene used during the testing stages of the flexible sensor, in order to help with the stability of data feedback from the sensor.

Figure 22
Test swatches, knitted with the Shima Seiki machine.

Traditionally yarns such as Lycra and Elastine are used in sporting applications, due to their material properties: support, comfort, elasticity and durability. Based on the researcher's personal experience and observation from training and racing, as well as other athletes' input, sports clothing must have the ability to be light and unrestrictive and also to maintain its position on the body whilst under the stresses and strains of physical exercise. Using the knee rig to recreate the typical movement profile of a knee simulated these physical limitations.

When evaluating the material qualities of each swatch, a system was developed, utilising the articulated knee rig. This was used to simulate the flexion of the knee and helped to test the fabric's properties, as well as each iteration of the sensor.

The material was tightly pinned to the silicone knee, which allowed for a measurable test between each swatch and test sensor created by TDL. This was achieved by connecting each knitted iteration to a flexible sensor circuit, which was then compared with a working control test captured from an off the shelf sensor. It was found that while Elastine and Polyester yielded the best result, the Elastine had better recovery and the Polyester superior aesthetic qualities.

The choice of knit structure is vital to the recovery of stretched fabric. An all needle structure produces a tightly knitted row, resulting in a stiffer surface that holds its shape and form. The benefits of this stitch are that it creates stability and strength, providing a good recovery in resting position, however, a tighter structure compromises the stretch and softness properties of the fabric. A one-needle stitch has the opposite effect, producing elasticity, but is more susceptible to a poor recovery. Combining the two different structures provides variation, allowing solid structure and support for the sensor and hard circuit casing when required, as well as flexibility and shaping in areas where the structure is not necessary.

Figure 23
Test circuit with integrated flex sensor.

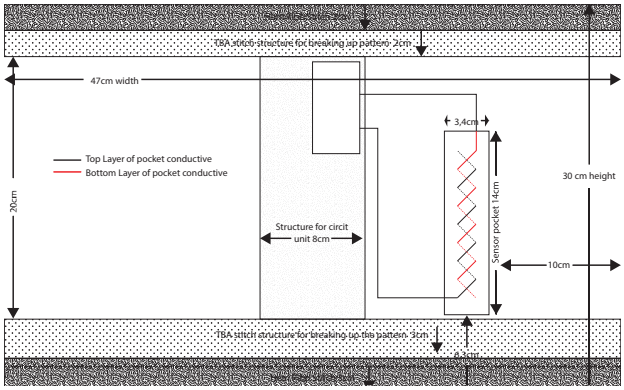


Figure 24
Knee brace schematic.

These choices were dictated by placement, however, as a by-product of different structures, design features result that adds to the overall aesthetics of the brace.

The design is largely dictated by the placement of the integrated sensor and hard surface technologies. The approach for the design of the garment borrowed from a more traditional circuit schematic, as the placement of electro conductive yarn and sensors need to follow the same rules as an electronic circuit (Figure 24, 25).

A flexible sensor works by measuring the variation of resistance, here caused by the flexing and bending and straightening of the knee. It was found that the best results were captured by placing the sensor in the middle of the kneecap and running it some way down the Tibia (shin), as it is the major hinge point of the knee. Control lines of conductive yarn run from the top and bottom of the sensor and provide the power and grounding required to capture the data. They also add to the overall aesthetic as a design feature, due to the patterns produced by the gold wires on the sensor.

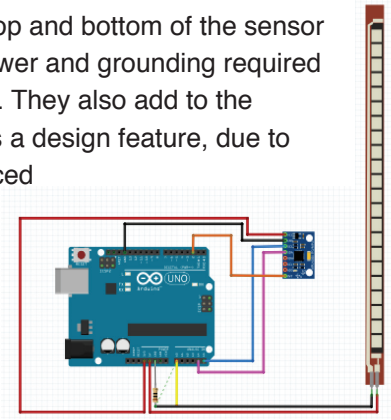


Figure 25
Circuit layout created with Fritzing.

These control lines act as the traditional wire and must follow the same rules as the circuit, meaning that the control lines cannot be cut. Otherwise, if the wires crossed over, a short circuit would be created. One of the major issues when creating an integrated sensor is the problem of connecting the conductive yarn with hard componentry.

Figure 26
Final knitted prototype with gold conductive yarn acting as wires.

This arises due to the yarn being fragile and snapping easily, as well as the inability to solder wires in the traditional manner. Many solutions exist for this problem; however, each seems to be unique to each individual device.

The approach used for this project drew upon inspiration from a ball socket connection, much like a ball lock, often found in kitchen cupboard doors. On one side, a slightly exposed ball on a spring sits and is pushed in by a baseplate on the doorframe when closed. These balls click into an indent on the baseplate, caused by the pressure of the compression spring pushing back. This compression prevents the door from opening until it is pulled out of position by opening the door.

Componentry Housing

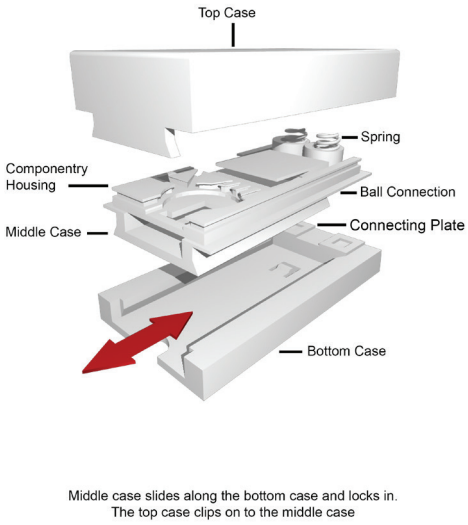


Figure 27
Componentry housing design.

By using this mechanism as inspiration, a simple three case design was created to address the connection issues. The base plate is sewn onto the brace with traditional thread, and the ends of conductive yarn, left by the knitting process, are sewn at one end. A base plate is placed securely over the top of the yarn, which creates a connection between the conductive yarn and the metal plate. On the middle case, wire is soldered to the end of the spring and ball and connected to the microcontroller used to process the captured data. The connection happens when the ball and spring click into the indent, held by the compression of the spring.

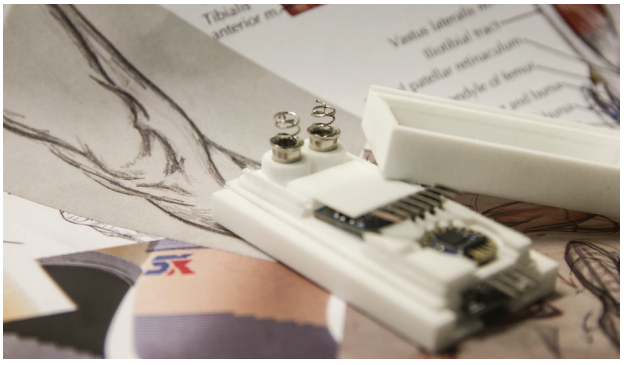


Figure 28
3D printed componentry housing design.

Motivated Software

Motivation cannot be programmed, and will absolutely adhere to the programme constructs. Unlike an athlete who is intrinsically driven or motivated to complete a task, a computer reacts to a set of external programmable logic. At a stretch, one could say that programming is an externally motivated tool, as it relies on rules and conditions to dictate its action and the next logical step.

It may, therefore, seem strange that a series of externally motivated ones and zeroes could be used as a tool to help motivate injured athletes, as we have already found that most athletes are internally motivated. In considering the interconnected, dualistic nature of motivation, we can see that this is also in accord with earlier observations as highlighted by Karageorghis and Terry (2011), which asserts that the best motivational outcomes arise from a combination of both internal and external factors.

Programming adheres to its function absolutely and therefore can be useful as an external motivator. The software acts as a standalone or impartial tool, that allows for the unbiased comparison of previous and current movements. Thus the software plays its part as an uncompromising external motivator.

This may explain the relatively close correlation between programming and external motivation theory and therefore we can see that the software can play an active positive role in helping with adherence, by providing accountability, feedback and progression throughout the injury, acting as a necessary externally motivated agent. It is therefore up to the designer to ensure that the conditions and tools provided by the program are useful and relevant, to promote positive behaviour within the recovery stages.

A recurrent theme that emerged from interview data was that useful technological devices are often cast aside.

Some interviewees argued that this is the rapid pace of changing treatment techniques, resulting in the constant proving and disproving of theories and treatment modalities.

This goes some way to explaining a consistent attitude of interviewees, who were united in suggesting that regardless of the latest treatment trend, if you don't actually do the exercises then you won't progress through the injury.

To avoid the technology being cast aside, special attention must be paid to its design. With tech getting smaller and smarter it is easier to build in more technology to the assessment tool on the assumption that this will produce better tools. This approach can be a trap, which results in a focus on technology instead of user needs.

Developers neglect to consider where and how the tool might support the industry and resist the temptation of being dictated by current trends and available technology.

By focusing on the core methods of treatment, a more relevant useful tool will be the result. Although it has been argued that programming is an extrinsic source of motivation, the software can provide certain functions that support intrinsic drives.

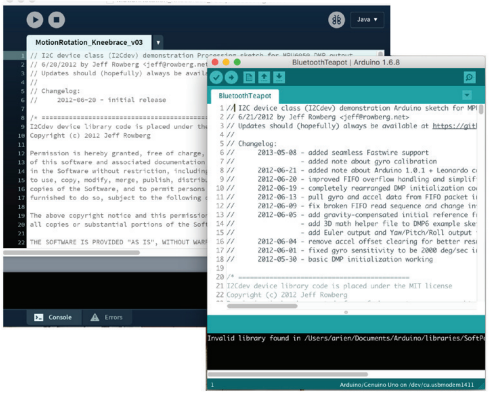


Figure 29
Arduino and Processing code to analyse sensor data.

Figure 30
Motivational program design
sensor data.

This is only possible if the user is given freedom to personalise the software and make it their own.

To explore this idea further, systems such as the Garmin, Fitbit and Wishbone, track and record various data sets such as heart rate, speed, and steps per day. Data is then uploaded to a website or app for the viewer to track and analyse the day's progress.

The success of these tools is not that they capture all the data available, but rather that they provide a certain amount of customisation and personalization, to occur. In order for the software to achieve this, the programmer must understand the core concepts that make up motivation.

Such concepts can be used to take advantage of the same motivational tools an athlete must use to achieve a positive recovery. Lewis (2014) explores

Decci & Ryan's self-determination theory (SDT), suggesting a close association between programming and the psychology of motivation.

SDT describes three core concepts that a task needs to address in order for it to be intrinsically motivating:

- Autonomy: Make choices that suit the situation and allow them to be made as they see fit.
- Competence: Make the task challenging but achievable.
- (Relatedness.) Provide a feeling of connectedness to others.

By using the SDT theory, it is possible to program these core building blocks into the software. It is, therefore, the job of the programmer to determine how the traditional methods used by the industry could be adapted.

In the case of the knee brace, it is the inclusion of feedback and accountability - traditionally given by the physiotherapists - which are used to try and produce a stronger adherence rate. It is hoped that a recovery aid which implements both intrinsic and extrinsic motivational tools will allow for the shift in motivation needed to successfully navigate the recovery process.

8. FURTHER RESEARCH

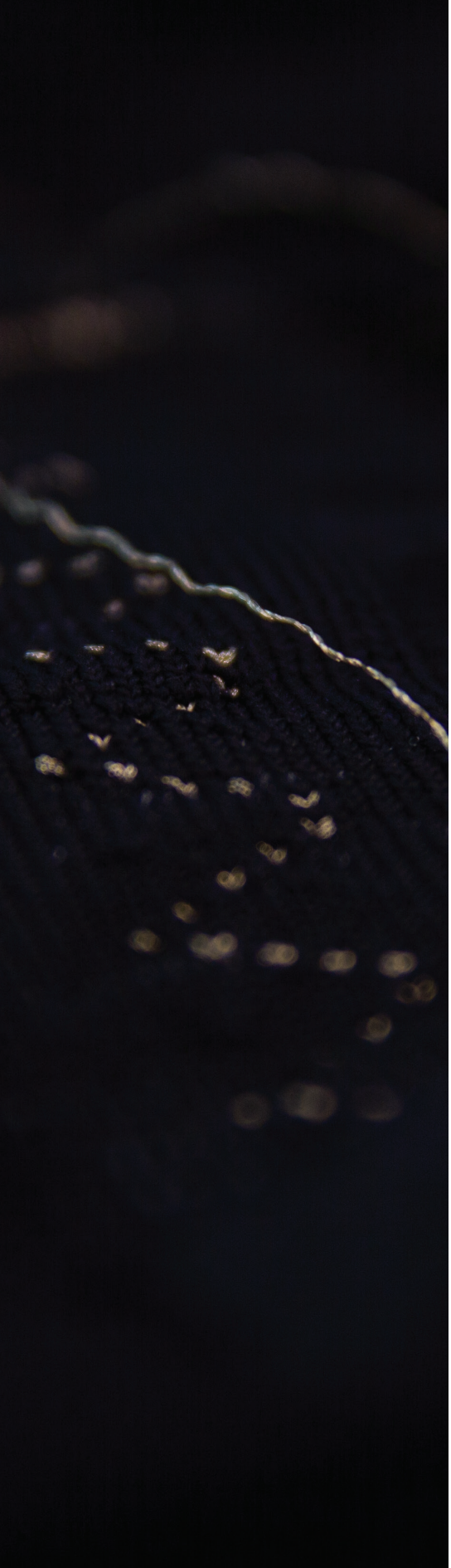
This research has gone some way towards enhancing the researcher's understanding of issues related to adherence and motivation, as well as the design and creation of technological tools. However, with technology advancing quicker than ever it is becoming increasingly harder to maintain an individual body of knowledge that will cover the entire scope of the project. The lines between different disciplines, which once were once solid and easy to define, are now blurred and indefinable.

This can be a positive situation if managed correctly. However, if mismanaged, it can lead to unrealistic project scope and unnecessary tension, due to miscommunication or unknown limitations related to a particular field. More research must be conducted to address the common issues found when creating a multidisciplinary project.

As a result of this limitation, this project was restricted to the researcher's disciplinary knowledge set, as well as tools and resources at hand. This has resulted in the project scope only being able to create a proof of concept, although further developments are possible. The scope of this project is limited to the exploration of issues related to adherence and possible solutions that could help combat the problem. As a result, a prototype has been created, but the efficacy of the device still needs to be tested to prove the project's hypothesis, outlined in the objectives of this exegesis.

The potential exists for greater collaboration on the development and creation of the smart training aid created as part of this research. Such developments could include the adaptation of other common injury areas: joints such as the wrist, ankle, elbow or shoulder, as well as further development of integrated sensors, coding and app integration.

Further research in this field will help conquer the physical and physiological pressures experienced by recovering athletes, and remove the guesswork, allowing the athlete to progress faster through the recovery process, and ultimately returning them to unimpeded training and racing sooner.



9. CONCLUSION

The aim of this study was, to identify factors that contribute towards poor adherence to strengthening exercises prescribed by physiotherapists as part of an injury recovery plan. Influential data and facts were obtained by conducting one on one interviews, with the purpose of exploring issues relating to behavioural impacts that cause poor adherence to injury recovery.

It has been found that factors include incorrect mind-set, external pressures, unrealistic expectations and a lack of education towards recovery methods. Individually, or combined, these issues directly affect an athlete's motivation to adhere to the prescribed strengthening exercises. If the interviews had been omitted from the research, significance of motivation factors would not have become apparent. Communicating and listening to the industry obtained essential feedback that productively informed this research project.

Relevant techniques and technologies relating to the injury recovery process have been critically analysed and assessed to identify the pros and cons of methods currently being used by professionals to aid with the successful recovery of an injured athlete.

By understanding problems relating to the injury recovery process, this research was able to identify how and where new or existing technologies could be used to develop this research result, that of a prototype to be used as a training aid; the knee brace.

Visual feedback has been used to highlight solutions to patient accuracy throughout the strengthening exercises. This helps with the motivational mind-set of an individual by providing real-time feedback on quality and *form*, removing the guesswork often associated with these exercises, and adding a layer of accountability where previously none existed. By addressing the objectives outlined at the start of this research, it has created a pathway for others to continue researching into technology-assisted motivation for injury recovery.

The single most important finding of this research is that no matter what technological tools are used, injury recovery is dependent on an individual's drive and ability to self-motivate throughout the recovery process.

It has been shown throughout this exegesis that to be successfully motivated, a balance of both intrinsic and extrinsic motivation is required, in order to positively affect the mind-set of a struggling individual, ultimately enhancing engagement and enjoyment. Such a mind-set will result in a change in the athlete's attitude to recovery exercises transforming them from being perceived as a 'tedious inconvenience' to appreciating them as a 'productive challenge' akin to the athletic goal itself.

Whilst this study did not definitively confirm that a technological training aid could be used to help with adherence, the inclusion of the test rig and prototype create grounds to help support the theory. The knee rig has allowed for a mechanical baseline of movement to be established, thus helping to ensure that each iteration of the sensor was accurately tested and compared to the previous results. This accuracy has helped to ensure a stable base to program with and has enabled the focus to be on programming software, including the motivational qualities required within the prototype.

10. EXHIBITION OF OUTCOMES

Figure 31
Exhibition outcomes 01.

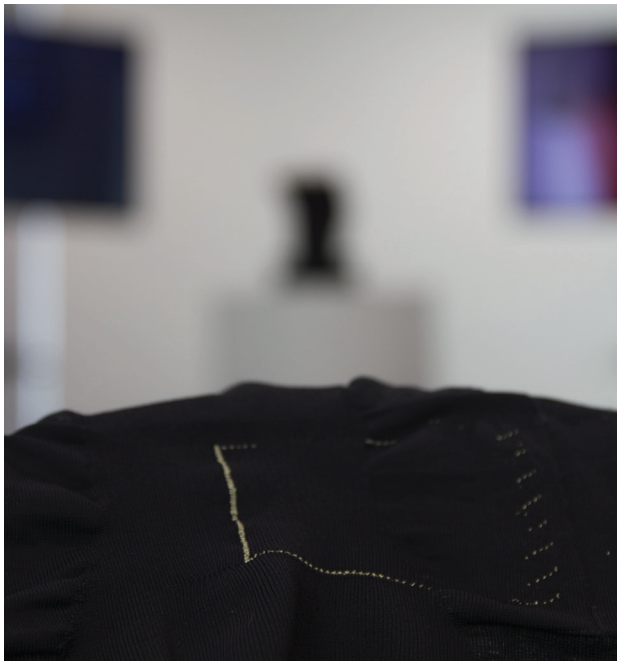


Figure 32
Exhibition outcomes 02.

Figure 33
Exhibition outcomes 03.

Figure 34
Exhibition outcomes.

Figure 35
Exhibition outcomes

Figure 36
Exhibition outcomes.

11. REFERENCES

Bahr, R., McCrory, P., & Bolic, T. (2012). The IOC manual of sports injuries : an illustrated guide to the management of injuries in physical activity. Chichester, West Sussex, UK ; Hoboken, NJ : Wiley-Blackwell, 2012.

Ball, J. W., Bice, M. R., & Parry, T. (2014). Adults' motivation for physical activity: Differentiating motives for exercise, sport, and recreation. Recreational Sports Journal, 38(2), 130-142. doi:10.1123/rsj.2014-0048

Brown, T., & Kātz, B. (2009). Change by design: How design thinking transforms organizations and inspires innovation. New York: Harper Business.

Cudmore, M. (2014). Managing injured athletes – a psychological perspective for the strength & conditioning coach. Journal Of Australian strength & conditioning, 22(4), 50-57.

Dion, G. (2013). Garment device: challenges to fabrication of wearable technology. presented at the meeting of the Proceedings of the 8th International Conference on Body Area Networks, Boston, Massachusetts. doi:10.4108/icst.bodynets.2013.253707

Edwards, A., & Skinner, J. (2009). Qualitative research in sport management. Oxford : Butterworth-Heinemann, 2009.

Goldblatt, J. P., & Richmond, J. C. (2003). Anatomy and biomechanics of the knee. Operative Techniques in Sports Medicine, 11(3), 172-186. doi:10.1053/otsm.2003.35911

Hagger, M., & Chatzisarantis, N. (2007). Intrinsic motivation and self-determination in exercise and sport. Champaign, IL: Human Kinetics.

Heaney, C. A., Walker, N. C., Green, A. J., & Rostron, C. L. (2015). Sport psychology education for sport injury rehabilitation professionals: A systematic review. Physical Therapy in Sport, 16(1), 72-79. Retrieved from http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3445177/figure/fig1-1941738109343156/

Karageanes, S. J. (2016, April 11). Iliotibial band friction syndrome: Background, anatomy, pathophysiology. Retrieved from http://emedicine.medscape.com/article/1250716-overview#a4

Karageorghis, C. I., & Terry, P. C. (2011). Inside sport psychology. Champaign, IL: Human Kinetics.

Kersh, M. E., Ploeg, H., & Pandy, M. G. (2015). The dependence of knee joint stability on the cruciate and collateral ligaments. / Contribution des ligaments croisés et latéraux à la stabilité de l'articulation du genou. Movement & Sport Sciences / Science & Motricité, (90), 37-54.

Lewis, C. (2014). Irresistible Apps: Motivational Design Patterns for Apps, Games, and Web-based Communities: Apress. Retrieved from https://books.google.co.nz/books?id=wpiJAwAAQBAJ

McHale, K. J., Park, M. J., & Tjoumakaris, F. P. (2014). Physical examination for meniscus tears. Meniscal Injuries, 9-20. doi:10.1007/978-1-4614-8486-8_2

McKenzie, R., Watson, G., & Lindsay, R. (2012). Treat your own knee. Raumati Beach, NZ: Spinal Publications New Zealand.

Medina, J. L. (2015, May 29). GrabCAD - CAD library. Retrieved April 19, 2016, from https://grabcad.com/library/otto-block-artificial-knee-3r20-1

Metcalf,C.D., Collie, S.R., Cranny, A.W., Hallett, G., James, C., Adams, J., Chappell, P.H., White, N.M., Burridge, Fabric-based strain sensors for measuring movement in wearable telemonitoring applications, J.H. IET Seminar Digest, 2009, 12725

Munro, B.J., Campbell T.E., Wallace G.G., Steele J.R.,
The Intelligent Knee Sleeve: A wearable biofeedback device, Sensors and Actuators B 131 (2008) 541-547

Patellofemoral pain syndrome - Wikipedia, the free encyclopedia. (2016, May 9). Retrieved May 12, 2016, from https://en.m.wikipedia.org/wiki/Patellofemoral_pain_syndrom
Rountree, S. H. (2011). The athlete's guide to recovery: Rest, relax, and restore for peak performance. Boulder, CO: VeloPress.

Salcedo, M. C. (2010). Smart fabric sensors for foot motion monitoring (Master's thesis, University of Maryland). Retrieved from http://drum.lib.umd.edu/handle/1903/11314

Satomi, M., & Perner-Wilson, H. (n.d.). NEOPRENE BEND SENSOR. Retrieved August 07, 2016, from http://www.kobakant.at/DIY/?p=20
Walker, B. (2013). The anatomy of sports injuries: Your illustrated guide to prevention, diagnosis and treatment. Chichester, England: Lotus Pub.

APPENDIX A: ETHICS APPLICATION

Participant flyer

Calling all Triathletes, Physio's & Coaches!

HOW CAN YOU HELP?

We are conducting a study on injury recovery and looking for participants to share their experences in a short 20 minutes one on one interview.

Aiming to investigate smart fabrics and the potential benefits to Triathletes injury management.

If you are interested or for more information, please contact me below.

Contact Details
arien.hielkema@gmail.com
021 8t57753

Initial Email

Hello (name)

My name is Arien Hielkema.
Thank you for your initial interest in participating in my research as part of my Master's thesis project for AUT.

You have been invited to participate in this research, due to your commitment and dedication to triathlon/ Ironman as an athlete, coach or physiotherapist.

This project aims to explore different types of sensors, how they are constructed and integrated to create smart aids or clothing, as well as the advantages and disadvantages of gathering essential data for analysis and visualisation through the synergy of different techniques and technologies. The purpose of this study is to investigate how technologies can promote quicker recovery from injury with the hope of getting injured athletes back on the racecourse faster, stronger and quicker than before.

As part of the research you will be required to fill out a 15min questionnaire and take part in a 20 min one on one interview with myself. The interview will be approached with a unique angle of enquiry, promoting informal and honest answers. Your interview will be used to help inform potentially unexplored creative solutions for the projects design and research areas.

For your convenience an information sheet has been attached to this email, as well as a consent form. Please feel free to ask if there is anything that you are not clear on, or if you require more information. Take your time to decide whether or not you wish to take part.

If you decide that you would like to be a part of this research, please answer the questions below, complete the consent form and send it to arien.hielkema@aut.ac.nz within one week of receiving this email.

Questions to answer

1) Are you an:
    a. Athlete
    b. Physiotherapist
    c. Coach
2) How many years experience in your chosen field
    a. 0 – 1
    b. 1 – 2
    c. 2 – 3
    d. 3 – or more

Thank you for your time,
Arien Hielkema
Primary researcher.

Physio Questions

1. What are the most common factors or issues that might prevent a patient from recovering fully?

2. What are the most common injuries you come across in patients who are athletes?

3. What information, tools and processes do you use to manage a patient's injury and does this differ based on the type of injury or area?

4. Do you feel that traditional recovery methods and exercises are more or less effective than technological developments such as programmes, apps and computer assistance?

5. In your opinion what changes or improvements could be made to current technologies to better aid injury recovery or prevention?

Patient/Athlete Questions

1. Have you had experience with a sports related injury and if so please explain the process of your recovery.

2. What measures do you take to prevent injury in your sport and or training? This could include anything from a coach's advice, nutrition, products, apps, exercises and/or after race care.

3. Do you feel that traditional recovery methods and exercises are more or less effective than technological developments such as programmes, apps and computer assistance?

4. In your opinion what changes or improvements could be made to current technologies to better aid injury recovery or prevention?

Coaches Questions

1. What are the most common factors or issues that might prevent an athlete from recovering fully?

2. What are the most common injuries you come across when managing athletes?

3. What information, tools and processes do you use to manage an athletes injury and does this differ based on the type of injury or area?

4. Do you feel that traditional recovery methods and exercises are more or less effective than technological developments such as programmes, apps and computer assistance?

5. In your opinion what changes or improvements could be made to current technologies to better aid injury recovery or prevention?

Participant Information Sheet

Date Information Sheet Produced:

12/8/2015

Project Title

Smarter tools for Smart Recovery

An Invitation

You are being invited to take part in a research study as part of my Masters thesis project for AUT. This information sheet has been created to help you make an informed decision before agreeing to participate in the research. Please take your time to read the following information carefully, and discuss it with others if you wish. Participation is voluntarily and you may withdraw at any time prior to the completion of data collection. Please feel free to ask if there is anything that is not clear or if you require more information. Take your time to decide whether or not you wish to take part. Thank you for your time.

What is the purpose of this research?

The project aims to explore different types of sensors, how they are constructed and integrated to create smart aids or clothing, as well as the advantaged and disadvantages of gathering essential data for analysis and visualisation through the synergy of different techniques and technologies.

How was I identified and why am I being invited to participate in this research?

You have been invited to participate in this research, due to your commitment and dedication to triathlon/Ironman as an athlete, coach or physiotherapist. Your contact details have been obtained via social media, local coaching groups, clubs or friends.

What will happen in this research?

The research will involve a written questionnaire that will take 15mins of your time. This will need to be completed before the informal interview.

A 20 minute interview will be scheduled and conducted once the questionnaire is completed. Audio recording will be taken and used to transcribe the interviews, to ensure robust information. The data collected will only be used for this research project.

The interview will be approached with a unique angle of inquiry promoting informal and honest answers. A combination of personal and professional experience will be discussed. Your interview will be used to help inform potentially unexplored creative solutions for the projects design and research areas. You will also have the opportunity to review the design options in the final stage of the research.

What are the discomforts and risks?

There are no foreseeable discomforts or risks involved with this research.

How will these discomforts and risks be alleviated?

If at anytime you are feeling uncomfortable you are more than welcome to decline to answer the questions, or withdraw from the research.

What are the benefits?

You will not only be assisting me to obtain my Masters, but you will also be assisting in the development in new potential technologies that could help fellow athletes to recover faster.

How will my privacy be protected?

The information collected from your interviews will be used as a broad statement and will not to single out you as a participant. A copy of the research dissertation will be provided for you to read before the work is published. There will then be a consultation period and you will be invited to provide input if you feel that you have been misrepresented in any way.

What are the costs of participating in this research?

The cost to the participants will be only in time. If traveling to AUT city campus is not an option the interviews will be conducted at a convenient location and time.

What opportunity do I have to consider this invitation?

One week will be given from the sending of this email, for you to consider the invitation.

How do I agree to participate in this research?

If you agree to participate in the research you will need to complete the attached consent form and sent back to arien.hielkema@gmail.com. Once received, the preliminary questioner will be sent out to be completed before the first interview.

Will I receive feedback on the results of this research?

There will then be a consultation period before the publication of research. You will be invited to provide input if you feel that you have been misrepresented in any way.

What do I do if I have concerns about this research?

Any concerns regarding the nature of this project should be notified in the first instance to the Project Supervisor, James Charlton, james.charlton@aut.ac.nz, 09 921 9999 ext 9793.

Concerns regarding the conduct of the research should be notified to the Executive Secretary of AUTEC, Kate O'Connor, ethics@aut.ac.nz , 09 921 9999 ext 6038.

Whom do I contact for further information about this research?

Researcher Contact Details:

Arien Hielkema

arien.hielkema@gmail.com

Project Supervisor Contact Details:

James Charlton

james.charlton@aut.ac.nz

Approved by the Auckland University of Technology Ethics Committee on *type the date final ethics approval was granted*, AUTEC Reference number *type the reference number*.

Ethics application form

Please do not staple your application

AUCKLAND UNIVERSITY OF TECHNOLOGY ETHICS COMMITTEE (AUTEC)

EA1

APPLICATION FOR ETHICS APPROVAL BY AUTEC

For AUTEC Secretariat Use only

_____/_____

Once this application has been completed and signed, please read the notes at the end of the form for information about submission of the application for review.

NOTES ABOUT COMPLETION

- Ethics review is a community review of the ethical aspects of a research proposal. Responses should use clear everyday language with appropriate definitions being provided should the use of technical or academic jargon be necessary.
- The AUTEC Secretariat and your AUTEC Faculty Representative are able to provide you with assistance and guidance with the completion of this application which may help expedite the granting of ethics approval.
- The information in this application needs to be clearly stated and to contain sufficient details to enable AUTEC to make an informed decision about the ethical quality of the research. Responses that do not provide sufficient information may delay approval because further information will be sought. Overly long responses may also delay approval when unnecessary information hinders clarity. In general each response should not exceed 100 words.
- AUTEC reserves the right not to consider applications that are incomplete or inadequate.
- Comprehensive information about ethics approval and what may be required is available online at http://aut.ac.nz/researchethics
- The information provided in this application will be used for the purposes of granting ethics approval. It may also be provided to the University Postgraduate Centre, the University Research Office, or the University's insurers for purposes relating to AUT's interests.
- The Form is focussed around AUTEC's ethical principles, which are in accordance with the *Guidelines for the approval of ethics committees* in New Zealand.

To respond to a question, please place your cursor in the space following the question and its notes and begin typing.

A. *Project Information*

A.1. **What is the title of the research?**

If you will be using a different title in documents to that being used as your working title, please provide both, clearly indicating which title will be used for what purpose.

Smarter Tools for Smarter Recovery

A.2. **Is this application for research that is being undertaken in stages?** ☑ **Yes** ☐ **No**

If the answer is 'Yes' please answer A.2.1 and the following sections, otherwise please answer A.3 and continue from there.

A.2.1. Does this application cover all the stages of the research? ☑ **Yes** ☐ **No**

If the answer is 'No' please provide details here of which stages are being covered by this application, otherwise please answer A.3 and continue from there.

A.3. **Who is the applicant?**

When the research is part of the requirements for a qualification at AUT, then the applicant is always the primary supervisor. Otherwise, the applicant is the researcher primarily responsible for the research, to whom all enquiries and correspondence relating to this application will be addressed.

James Charlton (Primary Supervisor)

A.4. **Further information about the applicant.**

A.4.1. In which faculty, directorate, or research centre is the applicant located?

AUT, Colab

A.4.2. What are the applicant's qualifications?

BFA from Elam School of Fine Arts

MFA at the State University of New York

A.4.3. What is the applicant's email address?

An email address at which the applicant can be contacted is essential.

james.charlton@aut.ac.nz

A.4.4. At which telephone numbers can the applicant be contacted during the day?

09 921 9999 ext 9793

A.5. Research Instruments

A.5.1. Which of the following does the research use:

☑ ***a written or electronic questionnaire or survey*** ☐ ***focus groups*** ☑ ***interviews***
☐ ***observation*** ☐ ***participant observation*** ☐ ***ethnography*** ☐ ***photographs***
☐ ***videos*** ☐ ***other visual recordings*** ☑ ***a creative, artistic, or design process***
☐ ***performance tests***
☑ ***some other research instrument (please specify)***

Interviews will use indicative questioning, inviting participants to answer from personal and informed experiences. All interviews will be digitally recorded on an iPhone. The audio recording will be transcribed, and tools such as note pad, pen, paper, iPhone, iPad and a computer will be used to gather and collate notes/data. A written questionnaire will be given to the participants one week prior to conducting the interview.

Please attach to this application form all the relevant research protocols. These may include: Indicative questions (for interviews or focus groups); a copy of the finalised questionnaire or survey in the format that it will be presented to participants (for a written or electronic questionnaire or survey); a protocol indicating how the data will be recorded (e.g. audiotape, videotape, note-taking) for focus groups or interviews (Note: when focus groups are being recorded, you will need to make sure there is provision for explicit consent on the Consent Form and attach to this Application Form examples of indicative questions or the full focus group schedule. Please note that there are specific confidentiality issues associated with focus groups that need to be addressed); a copy of the observation protocol that will be used (for observations); full information about the use of visual recordings of any sort, including appropriate protocols and consent processes; protocols for any creative, artistic, or design process; a copy of the protocols for the instruments and the instruments that will be used to record results if you will use some other research instrument.

A.5.2. Who will be transcribing or recording the data?

If someone other than the applicant or primary researcher will be transcribing the interview or focus group records or taking the notes, you will need to provide a confidentiality agreement with this Application Form.

Arien Hielkema will be transcribing and recording the data. As he is the primary researcher on the project a confidentiality agreement will not be needed.

B. *The Ethical Principle of Research Adequacy*

AUTEC recognises that different research paradigms may inform the conception and design of projects. It adopts the following minimal criteria of adequacy: the project must have clear research goals; its design must make it possible to meet those goals; and the project should not be trivial but should potentially contribute to the advancement of knowledge to an extent that warrants any cost or risk to participants.

B.1. Please provide a brief plain English summary of the research (300 words maximum).

This research aims to investigate and explore the possible uses and implementation of smart fabric technologies in the field of multi-discipline athletics, particularly Ironman, to help with ongoing recovery and injury prevention for individual athletes. This investigation will adopt a practice based research methodology and will look at how injury recovery can be enhanced by the use of smart training aids.

By conducting a series of interviews with physiotherapists, coaches and athletes, experiences and potential future wants and/or needs will be analysed and assessed. This information will be used to shape a series of iterative prototypes, such as small, strategically placed, smart wearable sensors, that gather and monitor key data.

Once captured, the data could be used to visually aid and assist individual athletes to analyse and critique performance, and optimise results during strengthening exercises given by coaches/professionals.

B.2. Is the applicant the person doing most of the research (the primary researcher)? ☐ Yes ☑ No

If the answer is 'No' please answer B.2.1 and the following sections, otherwise please answer B.3 and continue from there.

B.2.1. What is the name of the primary researcher if it is someone other than the applicant?

Arien Roel Hielkema

B.2.2. What are the primary researcher's completed qualifications?

Diploma in Visual Effects and Motion Graphics (Media Design School)

Diploma in 3D Animation (Media Design School)

Graduate Diploma in Advanced 3D Animation (Media Design School)

B.2.3. What is the primary researcher's email address?

An email address at which the applicant can be contacted is essential.

arien.hielkema@gmail.com

B.2.4. At which telephone numbers can the primary researcher be contacted during the day?

021857753

B.3. **Is the primary researcher** ☐ **an AUT staff member** ☑ **an AUT student**

If the primary researcher is an AUT staff member, please answer B.3.1 and the following sections, otherwise please answer B.4 and continue from there.

B.3.1. In which Research Institute or Faculty and school or department is the primary researcher employed?

B.4. **If the primary researcher is a student:**

B.4.1. What is their Student ID Number?

14875703

B.4.2. In which faculty school, department, or Research Centre are they enrolled?

AUT, Colab

B.5. **What is the primary researcher's experience or expertise in this area of research?**

Where the primary researcher is a student at AUT, please identify the applicant's experience or expertise in this area of research as well.

The area of smart textiles or wearable tech is relatively new to the researcher. Personal experience as a semi professional athlete will be used to help inform design and research needs, as well as an educational background and expertise in 3D animation and modelling. This has led to a wider understanding of emerging technologies, creative and technical problem solving skills.

B.6. **Who is in charge of data collection?**

The primary researcher will be in charge of data collection.

B.7. **Who will interact with the participants?**

Arien Hielkema, the primary researcher, will interact and communicate with participants.

B.8. **Is this research being undertaken as part of a qualification?** ☑ **Yes** ☐ **No**

If the answer is 'Yes' please answer B.8.1 and the following sections, otherwise please answer B.9 and continue from there.

B.8.1. What is the name of the qualification?

Master of creative technologies.

B.8.2. In which institution will the qualification be undertaken?

AUT

B.9. **Details of Other Researchers or Investigators**

B.9.1. Will any other people be involved as researchers, co- investigators, or supervisors? ☑ **Yes** ☐ **No**

If the answer is 'Yes' please answer B.9.1.1 and the following sections, otherwise please answer B.9.2 and continue from there.

B.9.1.1 What are the names of any other people involved as researchers, investigators, or supervisors?

Mandy Smith

B.9.1.2 Where do they work?

Fashion & Textiles

B.9.1.3 What will their roles be in the research?

Secondary Supervisor

B.9.1.4 What are their completed qualifications?

PhD, MA, BA (Hons).

B.9.2. Will any research organisation or other organisation be involved in the research? ☐ **Yes** ☑ **No**

If the answer is 'Yes' please answer B.9.2.1 and the following sections, otherwise please answer B.10 and continue from there.

B.9.2.1 What are the names of the organisations?

B.9.2.2 Where are they located?

B.9.2.3 What will their roles be in the research?

B.10. Why are you doing this research and what is the aim and background?

Please provide the key outcomes or research questions and an academic rationale with sufficient information, including relevant references, to place the project in perspective and to allow the project's significance to be assessed.

This study examines and compares the implementation of e-textile technologies. "E-textiles usually entail the use of adapted conventional electronics with certain mechanical modifications to match the flexibility of fabrics" (Castano et al 2014, p5) this synergy allows an opportunity to adapt and repurpose existing technologies to take on a new and meaningful opportunity for collaboration on many different levels.

The research looks to explore different types of sensors, how they are constructed and integrated to create wearable smart aids or clothing, as well as the advantages and disadvantages of gathering essential data for analysis with an emphasis on injury prevention and recovery.

B.11. What are the potential benefits of this research to the participants, the researcher, and the wider community?

The research conducted will look at the possibilities of using e-textile technology, with a focus on potential uses in sport and the rehabilitation sector. By combining traditionally different fields of practices together, exciting and previously uncharted opportunities could be revealed.

B.12. What are the theoretical frameworks or methodological approaches being used?

The proposed methodology will take a mixed methods approach by blending practice-based and iterative design. The inclusion of practice-based methods will help in the creation of prototypes informed by a key focus on exploratory outcomes ensuring robustness through flexibility and room to grow. The iterative methodology will be used to design, evaluate, and prototype: "Iterative design facilitates working with the user and involving the user in the design" (Bailey, 1992).

B.13. How will data be gathered and processed?

Data will be gathered from the participants in the form of a questionnaire and a 20min interview which will be recorded in either written or audio form. The project will approach the research from a unique angle of enquiry with a combination of personal and professional experience.

B.14. How will the data be analysed?

Please provide the statistical (for quantitative research) or methodological (for qualitative or other research) justification for analysing the data in this way.

The interviews will be approached as qualitative allowing the results to be framed by personal experiences both positive and negative. The interviews will be conducted informally. This approach will be used to insure genuine and honest data is collected which will be invaluable to ensure relevance to the project aims and outcomes. The data will be used to help inform potentially unexplored creative solutions for the projects design and research areas.

B.15. Has any peer review taken place? ☑ Yes ☐ No

If your answer is 'Yes', please specify and provide evidence e.g. a letter of confirmation.

☐ *AUT Competitive Grant* ☐ *External Competitive Research Grant* ☒ *PGR1* ☐ *PGR2* ☐ *PGR9* ☐ *Independent Peer Review**

Optional exemplars for evidencing peer review are available from the Ministry of Health (HDEC) website (http://ethics.health.govt.nz/) or from the Forms section of the Research Ethics website (http://aut.ac.nz/researchethics)

As part of the Research methods paper in the first semester a draft proposal of the PGR1 was marked and moderated. The PGR1 was also signed off by primary and secondary supervisor.

C. *General Project Details*

C.1. Likely Research Output

C.1.1. Will the research result in one or more of the following

☐ ***a thesis*** ☑ ***a dissertation*** ☐ ***a research paper*** ☐ ***a journal article***
☐ ***a book*** ☐ ***conference paper*** ☑ ***other academic publications or presentations***
☐ ***an exhibition*** ☐ ***a film*** ☐ ***a documentary*** ☐ ***some other artwork***
☑***Some other output, please specify =*** **Artifact**

C.2. Research Location and Duration

C.2.1. In which countries and cities/localities will the data collection occur?

Auckland

C.2.1.1 Exactly where will any face to face data collection occur

If face to face data collection will occur in participants' homes or similarly private spaces, then a Researcher Safety Protocol needs to be provided with this application.

All face to face data will be conducted onsite at one of the following three convenient AUT campuses closest to the participant.

- City campus
- North Campus
- AUT Millennium

If the participant is unable to conduct the interview onsite then an alternative public location will be used i.e. coffee shop.

C.2.2. In which countries and cities/localities will the data analysis occur?

Auckland, New Zealand

C.2.3. When is the data collection scheduled to commence?

As soon as Ethics approval is given

C.3. Research Participants

C.3.1. Who are the participants?

Physiotherapists, coaches and athletes aged between 20 – 80 years old

C.3.2. How many participants are being recruited for this research?

If you are unsure, please provide an indicative range.

The minimum number of participants will be 15 and the maximum will be 30.

C.3.3. What criteria will be used to choose who to invite as participants?

Only Participants from the bellow groups within Auckland will be selected. There will be no prerequisite of ability, level of competency or relevance will be required, as every level of expertise will be valuable.

- Physiotherapists
- Athletes
- Coaches

C.3.3.1 How will you select participants from those recruited if more people than you need for the study agree to participate?

If more than 30 people agree to participate, the potential candidate's initial questionnaires will be reviewed by the researcher. Criteria of longevity, and involvement within the sport will be used to select the final 30 participants.

C.3.4. Will any people be excluded from participating in the study? ☐**Yes** ☑ **No**

Exclusion criteria apply only to potential participants who meet the inclusion criteria. An exclusion criterion is any characteristic that ought to disqualify any potential participant from recruitment into the study. Consider exclusion criteria when there are heightened risks due to power differences in the relationship, recent injury, or other characteristics that might place potential participants at unreasonable risk of harms.

If the answer to this question is 'Yes' please answer C.3.4.1 and the following sections, otherwise please answer C.3.5 and continue from there.

C.3.4.1 What criteria will be used to exclude people from the study?

C.3.4.2 Why is this exclusion necessary for this study?

C.3.5. How will participants be recruited?

Please describe in detail the recruitment processes that will be used. If you will be recruiting by advertisement or email, please attach a copy to this Application Form

C.3.5.1 How will the initial contact with potential participants occur?

A flyer will be sent out via public Facebook pages and groups, coaching groups and at triathlon events. This will serve as the initial contact for potential candidates. The flyers will have basic information advertising the research and inviting candidates to partake in the research. The potential participants will have 2 weeks from the first flyer to consider participating in the research.

C.3.5.2 How will the contact details of potential participants be collected and by whom?

The primary researcher will collect the contact details of potential participants, via email reply from the flyers. An independent database will be temporarily created to monitor potential applicants. Once the two-week recruitment phase is over, the database will be deleted and only the agreed participant's emails will be retained.

C.3.5.3 How will potential participants be invited to participate?

Once the initial email has been received from the candidates to the researcher indicating interest in the research, a reply will be sent back which will have basic information about the research and ask the candidate their involvement in the sport, as well as how long they have been involved in triathlon. An information sheet and consent form will also be attached to this email.

C.3.5.4 How much time will potential participants have to consider the invitation?

The participants will have one week from the time the information sheet is sent out to consider the invitation.

C.3.5.5 How will potential participants respond to the invitation?

The potential participants will respond with their answers to the two questions as well as written confirmation that they would like to participate in the research.

C.3.5.6 How will potential participants give consent?

An email will be sent out with a consent form attached to it. The applicant will have one week to decide whether or not they would like to participate. Once the consent form is received and signed the applicant will be coincided a participant.

C.3.5.7 How and when will the inclusion criteria and exclusion criteria given in sections C.3.3 and C.3.4 be applied?

If there are more than 30 applicants then the questions asked in the invitation email will be used to select the final 30 participants. A thank you email will be sent out to any unsuccessful applicants. All successful applicants will be notified immediately.

C.3.5.8 Will there be any follow up invitations for potential participants?

There will be an invitation for optional participation to review design options that will be developed in the final stages of the project.

D. *Partnership, Participation and Protection*

D.1. How does the design and practice of this research implement the principle of Partnership in the interaction between the researcher and other participants?

How will your research design and practice encourage a mutual respect and benefit and participant autonomy and ownership? How will you ensure that participants and researchers will act honourably and with good faith towards each other? Are the outcomes designed to benefit the participants and/or their social or cultural group? How will the information and knowledge provided by the participants be acknowledged?

By working together as an equal with each participant, a mutual respect will be created and encouraged. The questions asked will be open for interpretation. This will encourage personal experience and expertise to lead the way and ensure that the researcher's personal opinion is not overpowering the interviews. This approach will be used to insure genuine and honest data is collected that will build a foundation of good faith. If at any time the participant is uncomfortable they will be invited to skip the question and go onto the next one. All information and knowledge provided by the participants will be used as it is, it will not be misconstrued or altered in any way that would bring shame or embarrassment to any individual.

Once the interview stage is over, a thank you email will be sent out along with general information on findings from the interview research. This will help to acknowledge and thank everyone for giving their time.

D.2. How does the design and practice of this research implement the principle of Participation in the interaction between the researcher and other participants?

What is the actual role of participants in your research project? Will participants be asked to inform or influence the nature of the research, its aims, or its methodology? Will participants be involved in conducting the research or is their principal involvement one of sharing information or data? Do participants have a formal role as stakeholders e.g. as the funders and/or beneficiaries of the research? What role will participants have in the research outputs (e.g. will they be asked to approve transcripts or drafts)?

The participant's role is to provide information and their expertise to inform the design development. The participants will not be involved in collecting the data. The feedback from the interviews will help inform and influence certain aspects of the research and prototype development, direction and design. All the participants in this research are stakeholders, they will be asked, as part of the consent form, if they would be interested in helping with the development design phase of this project.

D.3. How does the design and practice of this research implement the principle of Protection in the interaction between the researcher and other participants?

How will you actively protect participants from deceit, harm and coercion through the design and practice of your research? How will the privacy of participants and researchers be protected? How will any power imbalances inherent in the relationships between the participants and researchers be managed? How will any cultural or other diversity be respected?

Each participant will be treated as an equal. This has been built into the design practise of the research to ensure that there is no wrong doing or malicious intent to any of the participants. It will be made very clear to everyone that if any issues arise as a direct response to the research, the interviewee is invited to pass and go onto the next question or stop the interview altogether. If the participants have any questions or queries regarding the information or research project, both the researcher and supervisors will be available to discuss their concerns.

E. *Social and Cultural Sensitivity (including the obligations of the Treaty of Waitangi)*

E.1. What familiarity does the researcher have with the social and cultural context of the participants?

The researcher has personal experience with the target research group having been a two time Ironman athlete himself. He understands the potential cultural and social context within the sport and all research questions are well informed and relevant based on personal experience and research.

E.2. What consultation has occurred?

Research procedures should be appropriate to the participants. Researchers have a responsibility to inform themselves of, and take the steps necessary to respect, the values, practices and beliefs of the cultures and social groups of all participants. This usually requires consultation or discussion with appropriate people or groups to ensure that the language and research approaches being used are relevant and effective. Consultation should begin as early as possible in the project and should continue throughout its duration.

All researchers are encouraged to make themselves familiar with Te Ara Tika: Guidelines for Maori Research Ethics: A framework for researchers and ethics committee members (This is able to be accessed through the Research Ethics website). Researchers may also find Te Kaahui Maangai a directory of Iwi and Maaori organisations to be helpful. This may be accessed via the Te Puni Kookiri website (http://www.tkm.govt.nz/). As well as these documents, the Health Research Council has published Pacific Health Research Guidelines, and Guidelines on research involving children. (see http://www.hrc.govt.nz). There are also guidelines by various organisations about researching with other populations that researchers will find helpful.

Prior to this stage the researcher has undergone an extensive literature review to inform current development in the sports health, and e-textile area. Personal experience of recovering from bad injuries combined with ongoing advice from both supervisors throughout the project so far. Based on previous experience and connections within the sporting industry, preliminary discussions with physios, athletes and coaches have also taken place.

E.2.1. With whom has the consultation occurred?

Please provide written evidence that the consultation has occurred.

The consultation has occurred with Matt Merrick from Urban Athlete, and Andrew Mackay from Boost Coaching

E.2.2. How has this consultation affected the design and practice of this research?

This consultation provided has raised important information and potential risks involved with this project. This consultation period has helped to inform scope and direction towards the project.

E.3. Does this research target Maori participants? ☐ Yes ☑ No

All researchers are encouraged to make themselves familiar with Te Ara Tika: Guidelines for Maori Research Ethics: A framework for researchers and ethics committee members

If your answer is 'No', please go to section E.4 and continue from there. If you answered 'Yes', please answer the next question.

E.3.1. Which iwi or hapu are involved?

E.4. Does this research target participants of particular cultures or social groups? ☑ Yes ☐ No

AUTEC defines the phrase 'specific cultures or social groups' broadly. In section 2.5 of Applying for Ethics Approval: Guidelines and Procedures it uses the examples of Chinese mothers and paraplegics. This is to identify their distinctiveness, the first as a cultural group, the second as a social group. Other examples of cultural groups may be Korean students, Samoan husbands, Cook Islanders etc., while other examples of social groups may be nurse aides, accountants, rugby players, rough sleepers (homeless people who sleep in public places) etc. Please refer to Section 2.5 of AUTEC's Applying for Ethics Approval: Guidelines and Procedures (accessible in the Ethics Knowledge Base online via http://www.aut.ac.nz/about/ethics) and to the relevant Frequently Asked Questions section in the Ethics Knowledge Base.

If your answer is 'No', please go to section E.5 and continue from there. If you answered 'Yes', please answer the next question.

E.4.1. Which cultures or social groups are involved?

- Long distance athletes active in training for Ironman events
- Ironman coaches
- Physios working on Ironman athletes with common repetitive injuries.

E.5. **Does this research focus on an area of research that involves Treaty obligations?** ☐ **Yes** ☑ **No**

All researchers are encouraged to make themselves familiar with Te Ara Tika: Guidelines for Maori Research Ethics: A framework for researchers and ethics committee members.

If your answer is 'No', please go to section E.6 and continue from there. If you answered 'Yes', please answer the next question.

E.5.1. Which treaty obligations are involved?

E.6. **Will the findings of this study be of particular interest to specific cultures or social groups?** ☑ **Yes** ☐ **No**

If the answer is 'Yes' please answer E.5.1 and the following sections, otherwise please answer F.1 and continue from there.

E.6.1. To which iwi, hapuu, culture or social groups will the findings be of interest?

Ironman athletes, physiotherapists, coaches

E.6.2. How will the findings be made available to these groups?

F. *Respect for the Vulnerability of Some Participants*

F.1. **Will your research involve any of the following groups of participants?** ☐ **Yes** ☑ **No**

If your research involves any of these groups of participants, please clearly indicate which ones and then answer F.2 and the following sections, otherwise please answer G.1 and continue from there.

☐ ***unable to give informed consent?*** ☐ ***your (or your supervisor's) own students?***
☐ ***preschool children?*** ☐ ***children aged between five and sixteen years?***
☐ ***legal minors aged between sixteen and twenty years*** ☐ ***aged over seventy years?***
☐ ***in a dependent situation, such as people with a disability, or residents of a hospital, nursing home or prison or patients highly dependent on medical care?***
☐ ***vulnerable for some other reason (e.g. the elderly, prisoners, persons who have suffered abuse, persons who are not competent in English, new immigrants) – please specify***

F.2. **How is respect for the vulnerability of these participants reflected in the design and practice of your research?**

F.3. **What consultation has occurred to ensure that this will be effective?**

Please provide evidence of the consultation that has occurred.

G. *Informed and Voluntary Consent*

G.1. **How will information about the project be given to potential participants?**

A copy of all information that will be given to prospective participants is to be attached to this Application Form. If written information is to be provided to participants, you are advised to use the Information Sheet exemplar. The language in which the information is provided is to be appropriate to the potential participants and translations need to be provided when necessary.

A written information sheet will be sent out by email to potential participants with the application form. The information will include an easy to understand explanation of the project scope as well as a basic introduction to the research being undertaken.

G.2. **How will consent of participants be obtained and evidenced?**

AUTEC requires consent to be obtained and usually evidenced in writing. A copy of the Consent Form which will be used is to be attached to this application. If this will not be the case, please provide a justification for the alternative approach and details of the alternative consent process. Please note that consent must be obtained from any participant aged 16 years or older. Participants under 16 years of age are unable to give consent, which needs to be given by their parent or legal guardian. AUTEC requires that participants under the age of 16 assent to their participation. When the nature of the research requires it, AUTEC may also require that consent be sought from parents or legal guardians for participants aged between 16 and twenty years. For further information please refer to AUTEC's Applying for Ethics Approval: Guidelines and Procedures.

Consent of participants will be obtained in the form of email by an attached written consent form. The email will also include an information sheet with contact details of the researcher. The consent form will be signed and completed before the interviews commence. All participants will be between 20 and 80 years old.

G.3. Will any of the participants have difficulty giving informed consent on their own behalf?

☐ Yes ☑ No

Please consider physical or mental condition, age, language, legal status, or other barriers.

If the answer is 'Yes' please answer G.3.1 and the following sections, otherwise please answer G.4 and continue from there.

G.3.1. If participants are not competent to give fully informed consent, who will consent on their behalf?

Researchers are advised that the circumstances in which consent is legally able to be given by a person on behalf of another are very constrained. Generally speaking, only parents or legal guardians may give consent on behalf of a legal minor and only a person with an enduring power of attorney may give consent on behalf of an adult who lacks capacity.

G.3.2. Will these participants be asked to provide assent to participation?

Whenever consent by another person is possible and legally acceptable, it is still necessary to take the wishes of the participant into account, taking into consideration any limitations they may have in understanding or communicating them.

G.4. Is there a need for translation or interpreting?

☐ Yes ☑ No

If your answer is 'Yes', please provide copies of any translations with this application and any Confidentiality Agreement required for translators or interpreters.

H. *Respect for Rights of Privacy and Confidentiality*

H.1. How will the privacy and confidentiality of participants be protected?

Please note that anonymity and confidentiality are different. For AUTEC's purposes, 'Anonymity' means that the researcher is unable to identify who the participant is in any given case. If the participants will be anonymous, please state how, otherwise, if the researcher will know who the participants are, please describe how participant privacy issues and confidentiality of information will be managed.

The researcher will hold all data conducted and received by the questioner and interviews. The participant will not be identified by name throughout the dissertation and confidentiality will be upheld by referring to participants as athlete 1, coach 1, physiotherapist 1 etc.

H.2. How will individuals or groups be identified in the final report?

If participants or groups will be identified, please state how this will happen, why, and how the participants will give consent.

The information of each particular group will be used as a broad statement ensuring no particular participant is singled out. A copy of the research dissertation will be provided to each participant to read. There will then be a consultation period where they are invited to provide input if they have been misrepresented in any way.

H.3. What information on the participants will be obtained from third parties?

This includes use of third parties, such as employers or professional organisations, in recruitment.

No information, other than referrals to other relevant experts, will be obtained by a third party.

H.4. How will potential participants' contact details be obtained for the purposes of recruitment?

The potential participants contact details will be obtained through public information and records.

H.5. What identifiable information on the participants will be given to third parties?

No identifiable information on the participants will be given to third parties.

H.6. Who will have access to the data during the data collection and analysis stages?

Only the researcher and the supervisors will have access to the data during the data collection and analysis stages.

H.7. Who will have access to the data after the findings have been produced?

Only the researcher and supervisors will have access to this data until the final written report is released. The data is only going to be used to inform the design development and used within the written report, it will not be stored in a database.

H.8. **Are there any plans for the future use of the data beyond those already described?** ☐ **Yes** ☑ **No**

The applicant's attention is drawn to the requirements of the Privacy Act 1993 (see Appendix I of AUTEC's Applying for Ethics Approval: Guidelines and Procedures). Information may only be used for the purpose for which it was collected so if there are future plans for the use of the data, then this needs to be explained in the Information Sheets for participants. If you have answered 'Yes' to this question, please answer section H.8.1.1 and continue from there. If you answered 'No' to this question, please go to section H.9 and proceed from there.

H.8.1.1 If data will be stored in a database, who will have access to that data and how will it be used and for what?

H.8.1.2 Will any contact details be stored for future use and if so, who will have access to that data and how will it be used and for what?

H.9. **Where will the data be stored once the analysis is complete?**

Please provide the exact storage location. AUTEC normally requires that the data be stored securely on AUT premises in a location separate from the consent forms. Electronic data should be downloaded to an external storage device (e.g. an external hard drive, a memory stick etc.) and securely stored. If you are proposing an alternative arrangement, please explain why.

Once the analysis is compete, the data will be stored in Mandy Smith's (secondary supervisor) office in the AUT Art and Design building (WM). The data will be downloaded onto her computer and securely stored. Any printed data will be scanned and shredded after being digitized.

H.9.1. For how long will the data be stored after completion of analysis?

AUTEC normally requires that the data be stored securely for a minimum of six years, or ten years for health related research. If you are proposing an alternative arrangement, please explain why.

The data will be kept for six years after the projects end to keep with AUTEC requirements and regulations.

H.9.2. How will the data be destroyed?

If the data will not be destroyed, please explain why, identify how it will be safely maintained, and provide appropriate informed consent protocols.

Once the data is no longer needed, it will be destroyed, by wiping any remaining data from the computer.

H.10. **Who will have access to the Consent Forms?**

Both the supervisors and the researcher will have access to the consent forms.

H.11. **Where will the completed Consent Forms be stored?**

Please provide the exact storage location. AUTEC normally requires that the Consent Forms be stored securely on AUT premises in a location separate from the data. If you are proposing an alternative arrangement, please explain why.

The completed consent forms will be stored securely in James Charlton's AUT campus office in WG1001.

H.11.1. For how long will the completed Consent Forms be stored?

AUTEC normally requires that the Consent Forms be stored securely for a minimum of six years, or ten years in the case of health related research. If you are proposing an alternative arrangement, please explain why.

The data will be kept for six years after the projects end to keep with AUTEC requirements and regulations.

H.11.2. How will the Consent Forms be destroyed?

If the Consent Forms will not be destroyed, please explain why.

Once the data is no longer needed, it will be destroyed, by wiping any remaining data from the computer.

H.12. **Does your project involve the use of previously collected information or biological samples for which there was no explicit consent for this research?** ☐ **Yes** ☑ **No**

If the answer is 'Yes' please answer H.12.1 and the following sections, otherwise please answer H.13 and continue from there.

H.12.1. What previously collected data will be involved?

H.12.2. Who collected the data originally?

H.12.2.1 Why was the data originally collected?

H.12.2.2 For what purposes was consent originally given when the data was collected?

H.12.3. How will the data be accessed?

H.13. **Does your project involve any research about organisational practices where information of a personal or sensitive nature may be collected and / or where participants may be identified?** ☐ **Yes** ☑ **No**

If the answer is 'Yes' please answer H.13.1 and the following sections, otherwise please answer I.1 and continue from there.

H.13.1. How will organisational permission be obtained and recorded?

H.13.2. Will the organisation know who the participants are?

H.13.3. How will the identity of the participants be kept confidential?

I. *Minimisation of risk*

I.1. Risks to Participants

Please consider the possibility of moral, physical, psychological or emotional risks to participants, including issues of confidentiality and privacy, from the perspective of the participants, and not only from the perspective of someone familiar with the subject matter and research practices involved. Please clearly state what is likely to be an issue, how probable it is, and how this will be minimised or mitigated (e.g. participants do not need to answer a question that they find embarrassing, or they may terminate an interview, or there may be a qualified counsellor present in the interview, or the findings will be reported in a way that ensures that participants cannot be individually identified, etc.) Possible risks and their mitigation should be fully described in the Information Sheets for participants.

I.1.1. How much time will participants be required to give to the project?

The participants will be required to put aside time to conduct one 20 minute interview and one 15 minute questionnaire.

I.1.2. What level of discomfort or embarrassment may participants be likely to experience?

As the research will be looking at injury prevention and recovery, there is a chance that some questions may bring past emotions from previous accidents or uncomfortable moments. This will be maintained and watched carefully. If at anytime participants are feeling uncomfortable they will be encouraged to decline to answer the question, or in extreme cases given the option to withdraw from the research, as stated in the consent form.

I.1.3. In what ways might participants be at risk in this research?

Participants may not be comfortable talking about personal details and specific information relating to injuries and recovery.

I.1.4. In what ways are the participants likely to experience risk or discomfort as a result of cultural, employment, financial or similar pressures?

Participants may not be comfortable talking about details or be embarrassed that they did not follow instructions to recovery due to financial position and/or circumstance.

I.1.5. Will your project involve processes that are potentially disadvantageous to a person or group, such as the collection of information, images etc. which may expose that person/group to discrimination, criticism, or loss of privacy? ☐ **Yes** ☑ **No**

If your answer is 'Yes', please detail how these risks will be managed and how participants will be informed about them.

I.1.6. Will your project involve collection of information of illegal behaviour(s) gained during the research which could place the participants at current or future risk of criminal or civil liability or be damaging to their financial standing, employability, professional or personal relationships? ☐ **Yes** ☑ **No**

If your answer is 'Yes', please detail how these risks will be managed and how participants will be informed about them.

I.1.7. If the participants are likely to experience any significant discomfort, embarrassment, incapacity, or psychological disturbance, please state what consideration you have given to the provision of counselling or post-interview support, at no cost to the participants, should it be required.

Research participants in Auckland may be able to utilise counselling support from the AUT Counselling Team, otherwise you may have to consider local providers for participants who are located nationwide, or in some particular geographical area. You can discuss the potential for participant psychological impact or harm with the Head of AUT Counselling, if you require.

I.1.8. Will any use of human remains, tissue or body fluids which does not require submission to a Health and Disability Ethics Committee occur in the research? ☐ Yes ☑ No

e.g. finger pricks, urine samples, etc. (please refer to section 13 of AUTEC's Applying for Ethics Approval: Guidelines and Procedures). If your answer is yes, please provide full details of all arrangements, including details of agreements for treatment, how participants will be able to request return of their samples in accordance with right 7 (9) of the Code of Health and Disability Services Consumers' Rights, etc.

I.1.9. Will this research involve potentially hazardous substances? ☐ Yes ☑ No

e.g. radioactive material, biological substances (please refer to section 15 of AUTEC's Applying for Ethics Approval: Guidelines and Procedures and the Hazardous Substances and New Organisms Act 1996).

If the answer is 'Yes', please provide full details, including hazardous substance management plan.

I.2. Risks to Researchers

If this project will involve interviewing participants in private homes, undertaking research overseas, in unfamiliar cultural contexts, or going into similarly vulnerable situations, then a Researcher Safety protocol should be designed and appended to this application. This should identify simple and effective processes for keeping someone informed of the researcher's whereabouts and provide for appropriate levels of assistance.

I.2.1. Are the researchers likely to be at risk? ☐ Yes ☑ No

If the answer is 'Yes' please answer I.2.1.1 and then continue, otherwise please answer I.3 and continue from there.

I.2.1.1 In what ways might the researchers be at risk and how will this be managed?

I.3. Risks to AUT

I.3.1. Is AUT or its reputation likely to be at risk because of this research? ☐ Yes ☑ No

If the answer is 'Yes' please answer I.3.1.1 and then continue, otherwise please answer I.3.2 and continue from there.

I.3.1.1 In what ways might AUT be at risk in this research?

Please identify how and detail the processes that will be put in place to minimise any harm.

I.3.2. Are AUT staff and/or students likely to encounter physical hazards during this project? ☐ Yes ☑ No

If yes, please provide a hazard management protocol identifying how harm from these hazards will be eliminated or minimised.

J. *Truthfulness and limitation of deception*

J.1. How will feedback on or a summary of the research findings be disseminated to participants (individuals or groups)?

Please ensure that this information is included in the Information Sheet.

J.2. Does your research include any deception of the participants, such as non-disclosure of aims or use of control groups, concealment, or covert observations? ☐ Yes ☑ No

Deception of participants in research may involve deception, concealment or covert observation. Deception of participants conflicts with the principle of informed consent, but in some areas of research it may sometimes be justified to withhold information about the purposes and procedures of the research. Researchers must make clear the precise nature and extent of any deception and why it is thought necessary. Emphasis on the need for consent does not mean that covert research can never be approved. Any departure from the standard of properly informed consent must be acceptable when measured against possible benefit to the participants and the importance of the knowledge to be gained as a result of the project or teaching session. This must be addressed in all applications. Please refer to Section 2.4 of AUTEC's Applying for Ethics Approval: Guidelines and Procedures when considering this question.

If the answer is 'Yes' please answer J.2.1 and the following sections, otherwise please answer J.3 and continue from there.

J.2.1. Is deception involved?

J.2.2. Why is this deception necessary?

J.2.3. How will disclosure and informed consent be managed?

J.3. **Will this research involve use of a control group?** ☐ **Yes** ☑ **No**

If the answer is 'Yes' please answer J.3.1 and the following sections, otherwise please answer K.1 and continue from there.

J.3.1. How will the Control Group be managed?

J.3.2. What percentage of participants will be involved in the control group?

J.3.3. What information about the use of a control group will be given to the participants and when?

K. *Avoidance of Conflict of Interest*

Researchers have a responsibility to ensure that any conflict between their responsibilities as a researcher and other duties or responsibilities they have towards participants or others is adequately managed. For example, academic staff members who propose to involve their students as participants in research need to ensure that no conflict arises between their roles as teacher and researcher, particularly in view of the dependent relationship between student and teacher, and of the need to preserve integrity in assessment processes. Likewise researchers have a responsibility to ensure that any conflict of interest between participants is adequately managed for example, managers participating in the same research as their staff.

K.1. **What conflicts of interest are likely to arise as a consequence of the researcher's professional, social, financial, or cultural relationships?**

No conflict of interests are likely to arise, however because of the researchers involvement in the sport and personal injury recovery experience, careful attention will have to be taken to ensure friendships with coached athletes are managed and kept on a professional level. The researcher has no coaching experience and to ensure that the information is accurate and unbiased, participants will be selected from a variety of different coaching groups, teams and organisations.

K.2. **What possibly coercive influences or power imbalances in the professional, social, financial, or cultural relationships between the researcher and the participants or between participants (e.g. dependent relationships such as teacher/student; parent/child; employer/employee; pastor/congregation etc.) are there?**

There is very minimal chance of data or information being influenced by power imbalances. Most participants will be independent athletes or self-employed individuals.

K.3. **How will these conflicts of interest, coercive influences or power imbalances be managed through the research's design and practice to mitigate any adverse affects that may arise from them?**

Interviews will be organised and managed to ensure if a conflict of interest with coercive influence exists, then the identified groups or individuals will be scheduled on different days.

K.4. **Does your project involve payments or other financial inducements (including koha, reasonable reimbursement of travel expenses or time, or entry into a modest prize draw) to participants?** ☐ **Yes** ☑ **No**

If the answer is 'Yes' please answer K.4.1 and the following sections, otherwise please answer K.5 and continue from there.

K.4.1. What form will the payment, inducement, or koha take?

K.4.2. Of what value will any payment, gift or koha be?

K.4.3. Will potential participants be informed about any payment, gift or koha as part of the recruitment process, and if so, why and how?

K.5. **Have any applications for financial support for this project been (or will be) made to a source external to AUT?** ☐ **Yes** ☑ **No**

If the answer is 'Yes' please answer K.5.1 and the following sections, otherwise please answer K.6 and continue from there.

K.5.1. What financial support for this project is being provided (or will be provided) by a source external to AUT?

K.5.2. Who is the external funder?

K.5.3. What is the amount of financial support involved?

K.5.4. How is/are the funder/s involved in the design and management of the research?

K.6. **Have any applications been (or will be) submitted to an AUT Faculty Research Grants Committee or other AUT funding entity?** ☐ **Yes** ☑ **No**

If the answer is 'Yes' please answer K.6.1 and the following sections, otherwise please answer K.7 and continue from there.

K.6.1. What financial support for this project is being provided (or will be provided) by an AUT Faculty Research Grants Committee or other AUT funding entity?

K.6.2. What is the amount of financial support involved?

K.6.3. How is/are the funder/s involved in the design and management of the research?

K.7. **Is funding already available, or is it awaiting decision?**

K.8. **What is the financial interest in the outcome of the project of the researchers, investigators or research organisations mentioned in Part B of this application.**

L. *Respect for Property*

Researchers must ensure that processes do not violate or infringe legal or culturally determined property rights. These may include factors such as land and goods, works of art and craft, spiritual treasures and information.

L.1. **Will this research impact upon property owned by someone other than the researcher?** ☐ **Yes** ☑ **No**

If the answer is 'Yes' please answer L.1.1 and the following sections, otherwise please answer L.2 and continue from there.

L.1.1. How will this be managed?

L.2. **How do contexts to which copyright or Intellectual Property applies (e.g. virtual worlds etc.) affect this research and how will this be managed?**

Particular attention should be paid to the legal and ethical dimensions of intellectual property. Care must be taken to acknowledge and reference the ideas of all contributors and others and to obtain any necessary permissions to use the intellectual property of others. Teachers and researchers are referred to AUT's Intellectual Property Policy for further guidance.

As the researcher the student owns the copyright to their thesis. Any creation of artefacts during this research will remain the students property.

M. *References*

Please include any references relating to your responses in this application in the standard format used in your discipline.

N. *Checklist*

Please ensure all applicable sections of this form have been completed and all appropriate documentation is attached as incomplete applications will not be considered by AUTEC.

Have you discussed this application with your AUTEC Faculty Representative, the Executive Secretary, or the Ethics Coordinator?	☑ *Yes* ☐ *No*
Is this application related to an earlier ethics application? If yes, please provide the application number of the earlier application.	☐ *Yes* ☑ *No*
Are you seeking ethics approval from another ethics committee for this research? If yes, please identify the other committee.	☐ *Yes* ☑ *No*

Section A	*Project information provided*	✔
Section B	*Research Adequacy information provided*	✔
Section C	*Project details provided*	✔
Section D	*Three Principles information provided*	✔
Section E	*Social and Cultural Sensitivity information provided*	✔
Section F	*Vulnerability information provided*	✔
Section G	*Consent information provided*	✔
Section H	*Privacy information provided*	✔
Section I	*Risk information provided*	✔
Section J	*Truthfulness information provided*	✔
Section K	*Conflict of Interest information provided*	✔
Section L	*Respect for Property information provided*	✔
Section M	*References provided*	✔
Section N	*Checklists completed*	✔
Section O.1 and 2	*Applicant and student declarations signed and dated*	✔
Section O.3	*Authorising signature provided*	✔

Spelling and Grammar Check (please note that a high standard of spelling and grammar is required in documents that are issued with AUTEC approval)

Attached Documents (where applicable)

Participant Information Sheet(s)	✔
Consent Form(s)	✔
Questionnaire(s)	✔
Indicative Questions for Interviews or Focus Groups	✔
Observation Protocols	✗
Recording Protocols for Tests	✗
Advertisement(s)	✔
Researcher Safety Protocol	✗
Hazardous Substance Management Plan	✗
Any Confidentiality Agreement(s)	✔
Any translations that are needed	✗
Other Documentation	✔

O. *Declarations*

O.1. Declaration by Applicant

Please tick the boxes below.

☐ ***The information in this application is complete and accurate to the best of my knowledge and belief. I take full responsibility for it.***

☐ ***In conducting this study, I agree to abide by established ethical standards, contained in AUTEC's Applying for Ethics Approval: Guidelines and Procedures and internationally recognised codes of ethics.***

☐ ***I will continue to comply with AUTEC's Applying for Ethics Approval: Guidelines and Procedures, including its requirements for the submission of annual progress reports, amendments to the research protocols before they are used, and completion reports.***

☐ ***I understand that brief details of this application may be made publicly available and may also be provided to the University Postgraduate Centre, the University Research Office, or the University's insurers for purposes relating to AUT's interests.***

Signature ***Date***

O.2. Declaration by Student Researcher

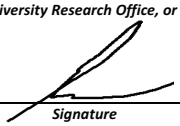
Please tick the boxes below.

☑ ***The information in this application is complete and accurate to the best of my knowledge and belief.***

☑ ***In conducting this study, I agree to abide by established ethical standards, contained in AUTEC's Applying for Ethics Approval: Guidelines and Procedures and internationally recognised codes of ethics.***

☑ ***I will continue to comply with AUTEC's Applying for Ethics Approval: Guidelines and Procedures, including its requirements for the submission of annual progress reports, amendments to the research protocols before they are used, and completion reports.***

☑ ***I understand that brief details of this application may be made publicly available and may also be provided to the University Postgraduate Centre, the University Research Office, or the University's insurers for purposes relating to AUT's interests.***



Signature ***12/8/2015*** ***Date***

O.3. Authorisation by Head of Faculty/School/Programme/Centre

Please tick the boxes below.

☐ ***The information in this application is complete and accurate to the best of my knowledge and belief.***

☐ ***In authorising this study, I declare that the applicant is adequately qualified to undertake or supervise this research and that to the best of my knowledge and belief adequate resources are available for this research.***

☐ ***I understand that brief details of this application may be made publicly available and may also be provided to the University Postgraduate Centre, the University Research Office, or the University's insurers for purposes relating to AUT's interests.***

Signature ***Date***

Notes for submitting the completed application for review by AUTEC

Please ensure that you are using the current version of this form before submitting your application.

Please ensure that all questions on the form have been answered and that none have been deleted.

Please provide ***one*** printed, single sided, A4, and signed copy of the application and all related documents.

Please deliver or post to the AUTEC Secretariat, room WA 505F, fifth floor, WA Building, City Campus. The internal mail code is D-89. The courier address is 55 Wellesley Street East, Auckland 1010.

The application needs to have been received in the AUTEC Secretariat by 4 pm on the relevant agenda closing day [AUTEC's meeting dates are listed in the website at http://aut.ac.nz/researchethics]

If sending applications by internal mail, please post them at least two days earlier to allow for any delay that may occur.

Late applications will be placed on the agenda for the following meeting.

MINIMAL RISK CHECKLIST

Your application may be appropriate for an expedited review if it poses no more than minimal risk of harm to participants. To assist AUTEC's Secretariat to screen the application for assignment to the correct review pathway, complete the following checklist:

Does the research involve any of the following?

NEGLIGIBLE RISK ASSESSMENT

		Yes	No
1	The collection of anonymous and non-sensitive survey/questionnaire data from adults that poses no foreseeable risks to participants OR any foreseeable risk is no more than inconvenience? *(If YES is checked, the application may receive an expedited review – no further questions on this checklist need be answered.)*	✔	

MINIMAL RISK ASSESSMENT[1]

		Yes	No
2	Participants who are unable to give informed consent (including children under 16 years old), or who are particularly vulnerable or in a dependent situation, (e.g. people with learning difficulties, over-researched groups, people in care facilities, or patients highly dependent on medical care)?		
3	A reasonable expectation of causing participants physical pain beyond mild discomfort, or that experienced by the participants on an every-day basis, or any emotional discomfort, embarrassment, or psychological or spiritual harm, (e.g. asking participants to recall upsetting events)?		
4	Research processes which may elicit information about any participant's involvement in illegal activities, or activities that represent a risk to themselves or others, (e.g. drug use or professional misconduct)?		
5	Collection of any human tissue, blood or other samples, or invasive or intrusive physical examination or testing?		
6	The administration of any drugs, medicines, supplements, placebo or non-food substances?		
7	An intervention of any form of exercise, or other physical regime that is different to the participants' normal activities (e.g. dietary, sleep)?		
8	Participants who are being asked to give information of a personal nature about their colleagues, employers, teachers, or coaches (or any other person who is in a power relationship with them), and where the identity of participants or their organisation may be inferred?		
9	Any situation which may put the researcher at risk of harm? (E.g. gathering data in private homes)?		
10	The use of previously collected biological samples or identifiable personal information for which there was no explicit consent for this research?		
11	Any matters of commercially sensitive information?		
12	Any financial interest in the outcome of the research by any member(s) of the research team?		
13	People who are not giving consent to be part of the study, or the use of any deception, concealment or covert observations in non-public places, including social media?		
14	Participants who are in a dependent or unequal relationship with any member(s) of the research team (e.g. where the researcher is a lecturer/ teacher/ health care provider/ coach/ employer/ manager/ or relative etc.) of any of the participants?		

[1] If "No" is checked to all items 2-14, the application's status as Minimal Risk will be checked by the Secretariat, and may be forwarded to expedited review. Applications with more than Minimal Risk (any one "yes" to questions 2-14 above), and applications where the checklist is not completed will appear on AUTEC's next agenda.

Confidentiality Agreement

For someone transcribing data, e.g. audio-tapes of interviews.

Project title: Smarter Tools for Smarter Recovery

Project Supervisor: James Charlton

Researcher: Arien Hielkema

- ○ I understand that all the material I will be asked to transcribe is confidential.
- ○ I understand that the contents of the tapes or recordings can only be discussed with the researchers.
- ○ I will not keep any copies of the transcripts nor allow third parties access to them.

Transcriber's signature: .....

Transcriber's name: .....

Transcriber's Contact Details (if appropriate):

.....

.....

.....

.....

Date:

Project Supervisor's Contact Details (if appropriate):

.....

.....

.....

.....

Approved by the Auckland University of Technology Ethics Committee on type the date on which the final approval was granted AUTEC Reference number type the AUTEC reference number

Note: The Transcriber should retain a copy of this form.

Name Date

Phone Number Email

Initial Research Questionnaire

1. What is your involvement in the sport of triathlon / Ironman? (Tick one)

   Athlete Physiotherapist Coach

2. How long have you been involved in the sport of triathlon / Ironman?

   0 - 1 years 1 - 2 years 2 - 3 years 3 - or more

3. Have you ever had, or treated a training related injury?

   Yes No

4. If yes how did you manage this injury?

In your opinion what are the most common injuries that you see within triathletes?

Do you use technology to help monitor your health and training?

Does this technology help with injury prevention or recovery?